

University of Tennessee at Chattanooga

UTC Scholar

Honors Theses

Student Research, Creative Works, and
Publications

5-2017

Systematic review of patellar luxation in dogs

Alexandria D. Holt

University of Tennessee at Chattanooga, jhd116@mocs.utc.edu

Follow this and additional works at: <https://scholar.utc.edu/honors-theses>



Part of the [Kinesiology Commons](#)

Recommended Citation

Holt, Alexandria D., "Systematic review of patellar luxation in dogs" (2017). *Honors Theses*.

This Theses is brought to you for free and open access by the Student Research, Creative Works, and Publications at UTC Scholar. It has been accepted for inclusion in Honors Theses by an authorized administrator of UTC Scholar. For more information, please contact scholar@utc.edu.

Systematic Review of Patellar Luxation in Dogs

Alexandria Danielle Holt

Departmental Honors Thesis

The University of Tennessee at Chattanooga

Health and Human Performance

Examination Date: April 3, 2017

Jamie Harvey

Associate Professor of Health
and Physical Education

Thesis Director

David Levine

Professor of Physical Therapy
Department Examiner

Nicholas Boer

Associate Professor of Exercise Science
Department Examiner

Systematic Review of Patellar Luxation in Dogs

Alexandria D. Holt, David Levine, PT, PhD, Denis J. Marcellin-Little, DEDV

From the Department of Health and Human Performance and Physical Therapy, The University of Tennessee at Chattanooga (Holt, Levine) and the Department of Clinical Sciences, College of Veterinary Medicine, North Carolina State University (Marcellin-Little).

Funding

No outside funding was received.

Acknowledgements

I would like to thank Dr. Levine for his constant, patient guidance and advice throughout this challenging project. My sincere thanks also goes to Dr. Marcellin-Little as well for providing his expertise in the veterinary field and inviting me to sit in on a dissection lab summer of 2015. To Beverly Kutz: your assistance setting up Endnote on my computer and recovering everything after an unfortunate crash was invaluable to this review. I would like to thank the rest of my research committee: Dr. Harvey and Dr. Boer for their unique perspectives on the subject and constant support throughout this process. To my roommates: as we all went through this process in varying forms, I would like to thank you all for your support and inspiration to succeed in this project. Last but not least, I would like to thank my family: you all constantly motivate and encourage me to succeed in everything I do. I would not be who I am today without each and every one of you.

ABSTRACT

Objective: To systematically review the literature reporting on the development of patella luxation (PL) and to identify areas in need of research.

Study Design: Systematic Literature Review

Animals: Dogs with PL.

Methods: A computer-based search was conducted through July 2016 using the following databases: PubMed, Agricola, and Web of Science. Studies were graded using the Oxford Centre of Evidence chart and categorized into one or more of the following categories: etiology and/or pathophysiology. Studies were excluded if they were not peer-reviewed, were not in the English or French language, dealt with a species other than dogs, were focused on surgical management, and/or were irrelevant to patella luxation.

Results: Twenty-five out of 301 studies were included and reviewed. Breeds at greatest risk for PL are: Great Pyrenees, Pomeranian, Silky Terrier, Miniature Pincher, Chinese Shar-Pei Yorkshire Terriers, Chihuahuas, Miniature and Toy Poodles, and Boston Terriers. PL prevalence has recently increased in Labrador Retrievers. All studies reporting on more than one breed found that MPL is more common than LPL. Smaller dogs have an increased incidence than larger breeds. Even though medial PL is the most common directional luxation across all dog sizes, lateral PL prevalence increases as dog weight increases. Genetic research looks promising in a link between Chromosome 7 and PL in dogs. The relationship between PL and CCLR is still controversial along with results for unilateral and bilateral luxation.

Discussion: When considering the owners, genetic studies that benefit breeding programs and research into the specific causes of PL will aid in preventing dogs bred with musculoskeletal abnormalities.

INTRODUCTION

Patella luxation (PL) is one of the most common orthopedic problems in dogs, occurring most often as a consequence of a developmental orthopedic disease but also after trauma.¹ Medial PL is more common than lateral PL, but there is an increasing incidence of lateral PL in large breed dogs.^{1,2} Little is known about the chain of events leading to patellar luxation and the genetic factors influencing these events. Patella luxation can be treated conservatively, or with surgical management. Despite patella luxation being one of the most common orthopedic problems in dogs,³ a systematic literature review has not been conducted over the last two decades, to our knowledge.⁴

The purpose of this study was to systematically review the scientific information relating to the development of PL in dogs, to summarize the scientific knowledge and identify areas in need of research. Studies were graded based on content using the Oxford Centre of Evidence-based Medicine scale.

Background:

The patella is the largest sesamoid bone in the dog and functions to alter the direction of pull of the quadriceps muscle group (see Figure 1).⁴ The patella maintains uniform tension of the extensor mechanism during the stifle extension that is produced by quadriceps femoris muscle, which is comprised of the rectus femoris, vastus lateralis, vastus medialis, and vastus intermedius muscles. The femoral trochlear groove is where the patella articulates and has a thicker medial ridge in clinically normal dogs. The

quadriceps muscle continues across the patella as the patellar ligament that inserts on the tibial tuberosity and tibial crest. For proper patellar stability and extensor mechanism efficiency, anatomic alignment should be a straight line of force.^{4,5}

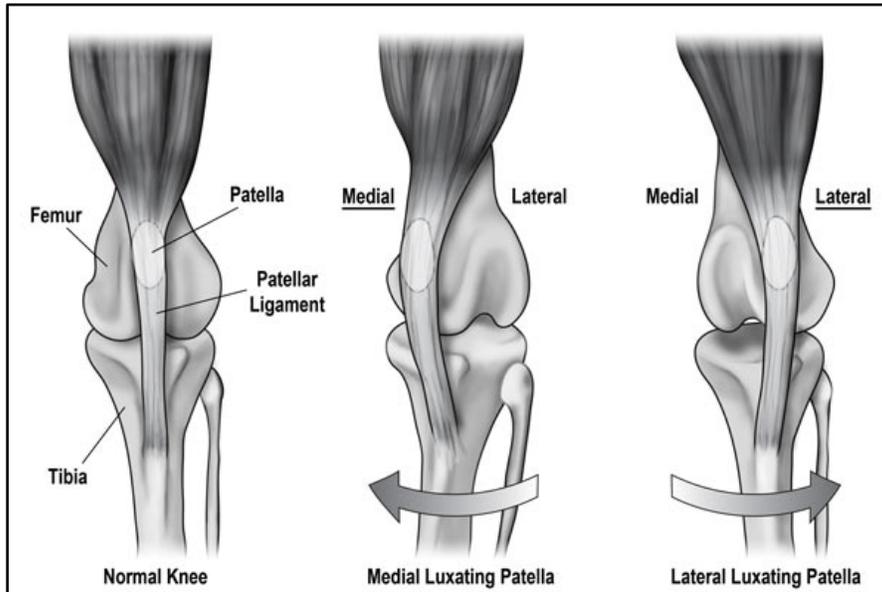


Figure 1: Medial and Lateral PL

Patella luxation is classified into one of five grades (see Table 1) based on severity of the condition.^{4,5} A grade 0 patella luxation is normal and the patella will not luxate during the physical examination. A grade 1 patellar luxation is one in which the patella will luxate when digital pressure is applied, usually with the stifle in extension, but will immediately return to its normal position when the pressure is removed. A grade 2 patellar luxation is one in which the patella will readily luxate with digital pressure and tends to remain luxated. However, it can be returned to the trochlear groove and will remain in place most of the time. A grade 3 patellar luxation is one where the patella is in the luxated position most of the time, although it can be returned temporarily to the trochlear groove with digital pressure. A grade 4 patellar luxation is one where the patella is in a luxated position at all times and cannot be returned to the trochlear groove. Patella

Luxation can be described as medial or lateral, congenital or acquired, and bilateral or unilateral.

METHODS

Search strategy

A systematic literature review was performed through July 2016 using the following online databases: PubMed, Agricola, and Web of Science. Search terms included canine, dog, knee, stifle, dislocation, luxation, injuries, patella, patellar, patella and patellar dislocation, and patella and patellar luxation. In addition to online searches, we identified one article through a web browser using the following words: patella, dog, and Salvati. Articles were limited to the English or French language. Studies were excluded if they were not peer-reviewed, dealt with species other than dogs, focused on surgical management, or did not include patella luxation.

Data analysis

The twenty-five studies included in the review were categorized based on their content and levels of evidence. Levels of evidence were graded using the Oxford Centre for Evidence-based Medicine scale.⁶ Articles could fall under one or more of the following categories: etiology, pathophysiology, diagnosis, nonsurgical management, surgical management, and/or prognosis. Each category was graded on a scale of one through five with one representing the highest quality studies, such as systematic reviews, and five representing expert opinion. Grades 1 and 2 have subcategories a, b, and c, and Grade 3 have subcategories a and b. Grades 4 and 5 are without subcategories. Included studies fit into the following grades: 2b, 3b, 4, and 5. By organizing the peer-reviewed articles based on their levels of evidence, the most reliable and influential sources can be

focused on.

RESULTS

Three-hundred and one studies were identified based on the search criteria. Two-hundred and seventy-six studies were excluded based on the exclusion criteria as follows: Three studies were excluded because they were not peer-reviewed. Ten studies were excluded because they dealt with a species other than dogs. Eleven studies were excluded because they were not in the English or French language. Sixty-two studies were excluded because they focused on surgical management. One hundred and ninety were excluded because they were irrelevant to patella luxation. Twenty-five studies were included and reviewed (see Table 1). Included studies were grouped into one of two categories: epidemiology (n = 11) or pathophysiology (n = 16). Two studies were included in both epidemiology and pathophysiology.^{2,7}

Out of the 25 studies, 15 reported exact numbers of stifles that luxated medially (n=2023) and laterally (n = 718).^{2,7-20} Nine studies reported on unilateral (n=806) and bilateral luxation (973),^{7,8,10-12,15-17,21} but two studies reported equal unilateral and bilateral luxation,^{8,9} five studies reported more bilateral luxations (73%),^{7,10,12,15,16} and two studies reported more unilateral luxation (62%).^{11,17} Ten studies reported exact numbers of male (n = 2706) and female (n = 3001) dogs studied.^{2,7-13,18,20} Of those studies, only one had more male (19) than female (11) dogs included.²⁰ See Table 3.

Epidemiology Results

Epidemiology is the study of possible causal agents of a disease and possible control. Eleven studies related to the epidemiology of PL: eight grade 2b^{2,8-11,21-23} and three grade 4.^{3,7,24}

Patella luxation in dogs was the 7th most commonly diagnosed orthopedic condition, with a frequency of 4.8% (62 / 1292 dogs affected).³ In contrast, a study of pet store puppies showed PL as the most common congenital disease with a frequency of 7.2% (121 / 1679 dogs affected).²⁴ Several studies (n = 6) discussed the prevalence of PL in dogs with a focus on breed, sex, and dog size.^{2,7,11,22-24} Dogs will be described using the American Kennel Club Standards for weight (see Table 2).^{2,7,24}

A survey of orthopedic diseases in 4,419 patients to 4,419 matched controls provided an odds ratio for patellar luxation based on breeds.²² The greatest odds ratios were found in Great Pyrénées (64.0), Pomeranian (18.6), Silky Terrier (16.0), Miniature Pincher (14.4), and Chinese Shar-Pei (11.4). This means these breeds are at an elevated risk for patella luxation. Another survey study with 542 PL cases matched against 69,245 patients had the following breeds at the highest risk (P<0.001) for PL: Pomeranians, Yorkshire Terriers, Chihuahuas, Miniature and Toy Poodles, and Boston Terriers.²³ Purebreds with significantly low relative risk included: German Shepherd Dog, Labrador Retriever, Dachshunds, and Beagles. However, a more recent 2009 survey of dogs from three different orthopedic centers determined PL prevalence has increased in Labrador Retrievers.² Risk of PL in females was 1.5 times that of males.²³ Small breeds had a risk of approximately 12 times that of large dogs. This finding is similar to a study of pet store puppies with PL that determined 48.8% would likely weigh less than seven kilograms when mature, 26.4% would be between 7 and 15 kg, and 10% would weigh greater than 15 kg when mature.²⁴

A 1994 survey reviewed the medial records of 124 dogs.⁷ PL was classified as congenital (n = 91, 84%) or acquired (17), was medial (110, 89%) or lateral (14), and

unilateral (44) or bilateral (80, 65%). In small-breed dogs, medial PL represented 98% of luxations, in medium breeds 81%, in large breeds 83%, and in giant breeds 67%.

Although prevalence for medial PL is higher in each breed size, lateral PL prevalence generally increases as dog size increases. Overall, medial PL is the most common direction for PL, and the incidence of PL in large breed dogs is increasing.²

A unique study of PL in 317 dogs in Chiang Mai, Thailand revealed PL in 40.3% of dogs (n = 128).¹¹ Breeds affected by PL included: Poodle (34.37%), Pomeranian (28.91%), Chihuahua (12.50%), Yorkshire Terrier (10.94%), Shih Tzu (6.25%), Miniature Pinscher (5.47%), Siberian Husky (0.78%) and mixed breed (0.78%). Of the dogs in this study, only 10% of PL was caused by injury, meaning 90% were assumed to be congenital. In the following breeds the frequency of PL in female to male dogs was higher by an average of 25.10% (range 13.25 to 50.00%): Poodle, Pomeranian, Chihuahua, Yorkshire Terrier, Shih Tzu. Lateral luxation was found in 10.5% of small breed dogs and 100% of medium sized dogs. It should be noted, based on average weights, all of these dogs are considered small breeds except for the Siberian Husky (n = 1) and mixed breed (n = 1). Medial PL is the overwhelming majority of small breed dogs at 89.5%. This finding is similar to a study of pet store puppies with PL that determined 48.8% would likely weigh less than seven kilograms when mature, 26.4% would be between 7 and 15 kg, and 10% would weigh greater than 15 kg when mature.²⁴

Four studies examined specific breeds to identify a possible genetic causative factor in Dutch flat-coated retrievers, Dutch kooikers dogs, and Pomeranians.^{8-10,21}

A study evaluated the heritability of PL in 48 Dutch Kooiker dogs.⁸ Heritability of PL was 0.27 ± 0.07 . As a result of the Dutch screening program, the prevalence of PL

decreased from 28% in 1994 to 19% in 2009. PL had a complex inheritance pattern: in addition to genetic factors, environmental factors were deemed likely to play a role in the phenotypic expression of PL, potentially limiting the success of breeding programs. To be maximally effective, the breeding program had to combine pedigree, phenotype, and genotype analysis. Unilateral and bilateral luxation percentages were even.

In the study involving 3,834 flat-coated retrievers screened between 1990 and 2007, heritability of PL was 0.17 ± 0.03 .⁹ The prevalence of PL incidence decreased from 28 to 18%. Environmental factors also played a large role in the expression of PL. Breeding one affected parent increased the likelihood of PL in offspring by 45% compared to breeding two unaffected parents. 1.8-fold more females than males were reported to have PL. Forty-five affected flat-coated retrievers and 40 control flat-coated retrievers were assessed in a genome wide association analysis of 15,823 single nucleotide polymorphisms (SNPs).²¹ One hundred forty-four of these SNPs were genotyped in 95 flat-coated Retrievers. Nine SNPs, in eight genes on CFA07 and CFA31, were associated with PL. One synonymous SNP in a pseudogene of FM06 was unique to Flat-Coated Retrievers when compared to a variety of other breeds. Genome-wide association analysis followed by targeted DNA sequencing identified loci on chromosomes 7 and 31 as being involved in PL in Flat-Coated Retrievers.

DNA samples were collected from 59 Pomeranians originating from 15 lines in Thailand.¹⁰ PL was present in 75% of these dogs. Two thirds of dogs were female. Polymorphic microsatellites situated close to five genes were analyzed for phenotype linkages. An SNP on chromosome 7 could potentially be associated with medial PL in this study as well.

Pathophysiology Results

Sixteen studies evaluated aspects of the pathophysiology of PL: ten studies were grade 2b,^{2,4,12-18,25} three grade 4,^{7,19,20} and three grade 5.^{1,5,26} Three grade 5 studies and one 2b study were all literature reviews from 1971 (n=2), 1981, and 1993, and were used for general information on the pathophysiology of PL in dogs.^{1,4,5,26} Four studies evaluated **bone conformation** in relation to PL, including one or more of the following factors: hip joint laxity (Norberg angle), femoral conformation (femoral neck inclination (coxa vara or valga) or anteversion, femoral angulation), and tibial conformation (tibial angulation or torsion, tibial plateau slope). Eight studies evaluated **musculoskeletal soft tissues** in dogs with PL, including one or more of the following factors: patellar ligament length, quadriceps femoris muscle angle (Q-angle), and the relationship with cranial cruciate ligament injuries.

Though controversial, pathophysiological changes associated with PL vary from soft tissue changes to obvious bony malformations causing secondary tissue abnormalities.⁵ Soft tissue changes involve the medial or lateral joint capsules, while bony changes involve the femoral neck, distal femur, and the proximal tibia.¹ Typically, the greater the soft tissue or bony abnormalities, the more likely a Grade IV luxation will be associated.⁵ PL can be classified as traumatic or congenital. Traumatic PL can occur in any dog breed, but congenital PL is commonly associated with small dog breeds and the medial direction. Congenital luxation includes dogs with a luxated patella at birth and dogs with progressive recurrent PL. Recurrent PL can be described as a “sloppy” patella because of its uncharacteristic movement.²⁶ The latest literature review stated inadequate

evidence exists to identify what leads to musculoskeletal abnormalities and patella luxation.⁴

Bone Conformation

One study assessed cartilage erosion on the articular surface of the patella.¹³ Dogs with patella luxation were examined to determine if there was an association between cartilage erosion and body weight, luxation grade, gender or age. Out of 141 dogs reviewed, 55% were female (n = 80) and 45% were male (n=65). 25% (n=37) of male dogs and 39% (n = 56) of female dogs showed cartilage erosion. The median for cartilage erosion and gender was 30% for female dogs and 15% for male dogs. There was no correlation between cartilage erosion and grades I, II, or III ($0.1 < p < 0.2$), but grade IV dogs had a significant correlation with cartilage erosion ($p = 0.037$). A weak but significant correlation was between cartilage erosion and body weight ($p = 0.04$). Heavier dogs were more severely affected by cartilage erosion. No association was found for age.

The angle of inclination (AOI) of the femoral neck and medio-lateral bowing of the femur and tibia at the stifle were recorded for 155 dogs.² The average AOI of the hip was 148.95° , which is in the normal range of $140.5 - 156.5^\circ$ that was reported in previous studies. There was a significant difference between the stifles of the control population to the dogs with PL ($p < 0.001$) that suggests medial bowing of the femur is a feature of PL. Ten femurs were below the lower limit of 140.5° and 99 femurs were above the upper limit of 156.5° (i.e. coxa valga). Small breeds were at the greatest risk for coxa valga and giant breeds had the least risk. There was a sex association with being female and having coxa valga (1.285 CI 0.69, 2.39). There was a mild, but insignificant correlation (0.14) between tibial bowing and PL. 92% of luxations were medial (n=142) and 54% of

affected dogs were female. The authors could not determine whether PL is the cause or is a consequence of stifle angle abnormality.

MRI was used to measure the anteversion (A-T) angle and its influence on the lateromedial or mediolateral forces in PL.¹⁶ Pelvic limbs without patellar instability (n=45), limbs with PL (n=33), and six limbs with cranial cruciate ligament rupture (CCLR) were measured using MRI. The clinically “normal” stifles had a mean A-T angle of 7.6°, grade II PL had 8.6°, and grade III had -0.4°. The CCLR group had a mean angle of 4.8°. No significant differences were found in this study and the A-T angle of the femoral neck does not influence PL. However, the study did determine that MRI can be used to make exact measurements of the true anatomy of the femoral neck.

A study on tibial torsion focused on Yorkshire terriers with and without MPL.²⁰ Tibial torsion angle (TTA) was assessed using computed tomography and a relationship between MPL grade, TTA, and canine age was determined. As the MPL grade increased, the TTA decreased by 0.5° and age increased by 0.13 years. Medial PL decreased as weight increased. The authors concluded that torsional deformity in Yorkshire terriers contributes to medial PL development along with dog weight and age. There were 19 males (3 intact) and 11 females (3 intact), and there was no effect regarding sex or neuter status on medial PL grade.

Musculoskeletal Soft Tissues

A novel study in 2002 evaluated lateral radiographic views of 13 clinically normal large-breed cadavers.²⁵ The ratio between patellar ligament length to patellar length, the L:P ratio, was determined for each dog. The mean \pm SD L:P was 1.68 \pm 0.18 (95% CI, 1.33 to 2.03). The L:P was deemed to be a repeatable measure of vertical patellar position

that can be used as a quantitative method for diagnosing patella alta and baja in large-breed dogs

The vertical patellar position in large-breed dogs was measured based on the L:P ratio in clinically normal dogs and dogs with medial PL.¹⁹ The L:P was higher in dogs with medial PL than in clinically normal dogs. The mean \pm SEM was 1.71 ± 0.020 for normal dogs and 1.87 ± 0.025 for the medial PL group. The authors concluded that medial PL in large-breed dogs could be caused by the proximal displacement of the patella within the trochlear groove and subsequent abnormal tracking.

A study of three small dog breeds compared L:P ratios in dogs with and without medial PL.¹⁸ Radiographs of 14 cadavers were taken to identify the best stifle angle to measure the L:P ratio. The L:P ratio was the same for all five stifle angles in the cadavers ($p=0.195$). The L:P ratio was calculated for normal stifles and stifles with grade 1, 2, and 3 medial PL in 194 Pomeranians, 74 Chihuahuas, and 41 Toy or Standard Poodles. In the normal and medial PL affected stifles, there was no significant difference ($p=0.354$) in the L:P ratio overall, and there was no significant difference between the three breeds ($p=0.135$). A longer patella ligament did not play a role in the pathophysiology of medial PL in these small breed dogs. A proximo-distal patellar position was not associated with medial PL in Pomeranians, Chihuahuas, and Toy or Standard Poodles in this study.

Dogs with normal stifle joints ($n = 51$), the values for medial PL ($n = 46$) and lateral PL ($n = 9$) were compared.¹⁷ Two ratios were measured. The A:P ratio was defined as the distance from the proximal aspect of the patella to the transcondylar axis of the distal femur (A) to the patellar length (P). The PTL:DTW ratio was defined as the ratio of proximal tibial length (PTL) to distal tibial width (DTW). Radiographs were

obtained on 142 stifles. Measurements were compared between 66 control stifles (n =51), 65 stifles with MPL (n=46), and 11 stifles with LPL (n=9). Dogs with medial PL had larger A:P ratios ($P < 0.001$) than dogs with lateral PL ($P = 0.003$) when compared to the control group. Dogs with lateral PL also had an increased PTL:DTW ratio ($P=0.009$). Medium to giant breed dogs with relatively long patellar ligaments and patella alta appeared predisposed to medial PL and relatively long proximal portions of the tibia and patella baja was associated with LPL. Twelve of 65 (19%) stifles with MPL had grade I luxation, 31 (48%) had grade II, 13 (20%) had grade III and 9 (14%) had grade IV MPL. Among 11 stifles with LPL, 2 (18%) had grade I, 3 (27%) grade II, 2 (18%) grade III and 4 (36%) had grade IV LPL. Among the 46 dogs (65 stifles) with MPL, 27 (59%) were affected unilaterally and 19 (41%) had bilateral luxations. Seven of 9 (78%) LPL dogs had unilateral luxation whereas both limbs were affected in 2 (22%) dogs.

Early research into an association between PL and CCLR speculated an increased risk for older, small breed dogs for this combination of musculoskeletal complications.⁷ Dogs with congenital PL were 6.5 times more likely to have CCLR than dogs who acquired PL traumatically. Only three of 55 dogs that had PL and CCLR were under the age of five years. One study retrospectively viewed 32 dogs that underwent surgery for PL after CCLR surgery.¹⁴ Larger dogs are predisposed to CCLR, and smaller dogs predisposed to PL. However, large breed PL rates are increasing and PL occurs as a complication of CCLR surgery 0.18% of the time and most commonly in large breed dogs. A retrospective case series evaluated the severity of medial PL and frequency of CCLR in 266 stifle joints (n = 162 dogs).¹² Dogs ranged from 8.4 months to 16.7 years of age (mean =5.7 years), and were primarily small breed dogs (mean body weight was 5.45

kg). Unilateral medial PL was diagnosed in 58 dogs, and bilateral medial PL in 104 dogs. Forty-one percent of all dogs had concomitant CCLR. The mean age for dogs with only medial PL was 3.0 years. This significantly differs from the mean age of dogs with medial PL and concomitant CCLR (7.8 years). Dogs with grade IV medial PL had the most cases of CCLR when compared to other grades ($p = 0.02$).

The quadriceps angle (Q-angle) in dogs with congenital PL was measured using MRI.¹⁵ Thirty-eight dogs (76 stifles) were placed into groups (normal, grade I, grade II, and grade III) based on patellar instability. Thirteen dogs had no orthopedic problems and six dogs only had CCLR. Of the 19 dogs with congenital PL, 14 (74%) were affected bilaterally and 5 (26%) were affected unilaterally. Of the 33 limbs with PL, 30 (91%) were medial PL and 3 (9%) luxated laterally. For the 30 dogs with medial PL the grades were as follows: 8 (27%) were grade I, 11 (37%) were grade II, and 11 (37%) grade III luxations. MRI of every dog limb ($n = 76$) was taken, 37 pelvic limbs without patellar instability, 33 limbs with PL, and 6 limbs with CCLR were made. The method for determining the Q-angle was a line drawn between the cranial lip of the acetabulum to the femoral intercondylar notch. Then a second line is drawn from the femoral intercondylar notch to the tibial tuberosity. The angle between these lines is the Q-angle. A lateral deviation is defined as a lateral Q-angle, and a medial deviation is defined as a medial Q-angle. The normal group average Q-angle was 10.5° , the grade I group had a 12.2° average, the grade II group 24.3° , and the grade III group 36.6° . The average Q-angle of limbs with an isolated CCLR was 19.9° . MRI can be used to make exact Q-angle calculations in order to quantify the degree of patellar luxation.

DISCUSSION

Based on the current etiological evidence, certain trends can be seen throughout the studies. Of the ten studies that reported on gender, only one study had more males than females. One study found relative risk of PL was 50% higher in females than males, and intact males were at a lower risk for PL than neutered males.⁷ Another study found females to be more affected with patellar luxation (30% of all tested females) than males (17% of all tested males).⁹ The trend of more female than male dogs included in studies continues into the pathophysiology studies as well. A recent study was the only one to report on a higher incidence in spayed females.¹² A similar tendency is seen in human patients in that females are at a higher risk for osteoarthritis and cartilage damage to the knee.¹³

The increased female to male dog ratio included in studies is intriguing. There are multiple factors as to why this could be the case, such as overrepresentation, hormonal, genetic, or neuter status. Recent studies have begun including how many dogs are spayed and neutered. If the lack of hormones from spaying and neutering dogs is a factor in PL, there could be an explanation as to why more females are in studies than males. Female dogs may be more likely to be spayed than males neutered, because intact female dogs are more of a nuisance to owners than intact males. Likewise, intact male dogs would have better muscle mass than females, leading to more stable stifles. Future research should incorporate dog genders in the study and investigate reasons females may or may not have an increased risk.

All studies reporting on more than one breed found that MPL is more common than LPL. Smaller dogs have an increased incidence compared to larger breeds.^{7,23} Even

though medial PL is the most common directional luxation across all dog sizes, lateral PL prevalence increases as dog weight increases.⁷ For bony conformational abnormalities, heavier dogs had more cartilage erosion than smaller dogs because extra weight is biomechanically harder on the stifle. Extra weight and advanced age were contributing factors for the severity of PL in Yorkshire terriers that had torsional deformities.²⁰ For the study on AOI, the authors could not determine whether PL is the cause or is a consequence of stifle angle abnormality.

Age was a contributing factor in musculoskeletal soft tissue deformities as well. Older dogs have an increased tendency to have more medical conditions such as PL and/or CCLR.¹² Dogs with congenital PL were 6.5 times more likely to have CCLR than dogs who acquired PL traumatically.⁷ This is intuitive because dogs with congenital PL have had more abnormal forces acting on the muscles and joint than dogs that acquired PL through a traumatic event. Researchers have had a difficult time determining if CCLR is a cause or consequence of PL.

The Q-angle for dogs increased with each subsequent PL grade indicating that an increased Q-angle influences the severity of PL. One hypothesis is correction of underlying skeletal abnormalities is necessary to correct any Q-angle malalignment in order to successfully treat medial PL.²⁰

Results vary greatly across all studies concerning the ratios of unilateral to bilateral luxation in dogs. Earlier studies found unilateral luxation in 26 - 35% of dogs and bilateral luxation in 65 - 74%.^{7,15} A 2011, study had almost exactly the opposite of these results: uniluxation (63%) and biluxation (37%).¹¹ Two studies determined unilateral and bilateral luxation prevalence were similar.^{8,9}

Research has improved in content and quantity (see Graph 4) the last 20 years in regards to epidemiological and pathophysiological research in patella luxation in dogs. More studies are focusing on ways to prevent canine PL instead of only focusing on surgical management. Though research has improved in this area, the scope of epidemiological and pathophysiological research is broad. A narrowing of focus could benefit research as a whole. Many studies are investigating multiple variables at a time, leading to small subject numbers and questionable results. Future research should focus on one aspect of patella luxation. For example, two studies in this review focused on the connection between PL and CCLR in very different ways. One study associated PL as a complication to CCLR corrective surgery,¹⁴ and the other study investigated an association between PL and CCLR.¹² There is a gap in research in determining if PL is a cause or consequence of CCLR. Another example of the broad focus that could be narrowed is studies that include both large and small breed dogs in the same categories. Recent research has begun to divide these dogs into separate groups and report on them differently, which is the correct direction. More studies should focus on the PL grades to determine the best ways to prevent or manage PL for each separate grade. Genetic research is rapidly progressing for specific breeds that have a higher incidence of PL. As genetic research gains ground, more breeds should be investigated to see if a common gene among all dogs is linked to PL. In particular, the Labrador Retriever would be an interesting genetic study because of the current research showing a rapidly growing incidence of PL in the breed.

In conclusions, instead of a pure focus on surgical management research, epidemiology and pathophysiology research has been on rise since the early 2000s (see

Table 3). When considering the owners, genetic studies that benefit breeding programs and research into the specific causes of PL will aid in preventing dogs bred with musculoskeletal abnormalities. A focus on learning what the main causes of PL are and how to prevent them is the best way to keep dog owners from paying for costly surgeries or euthanizing their dogs instead.

TABLES AND GRAPHS

Table 1: Oxford Center for Evidence-based Medicine – Levels of Evidence⁶ *

	Etiology Studies	Pathophysiology Studies
Scale to use to grade evidence	Therapy / Prevention, Aetiology / Harm	Development of PL/associated diseases (CCL)/ Factors promoting or negatively impacting the occurrence or severity of patellar luxation
Grade 1a		
Grade 1b		
Grade 1c		
Grade 2a		
Grade 2b	8	10
Grade 2c		
Grade 3a		
Grade 3b		
Grade 4	3	3
Grade 5		3

* Two studies were included in both etiology and pathophysiology.^{2,7}

Table 2

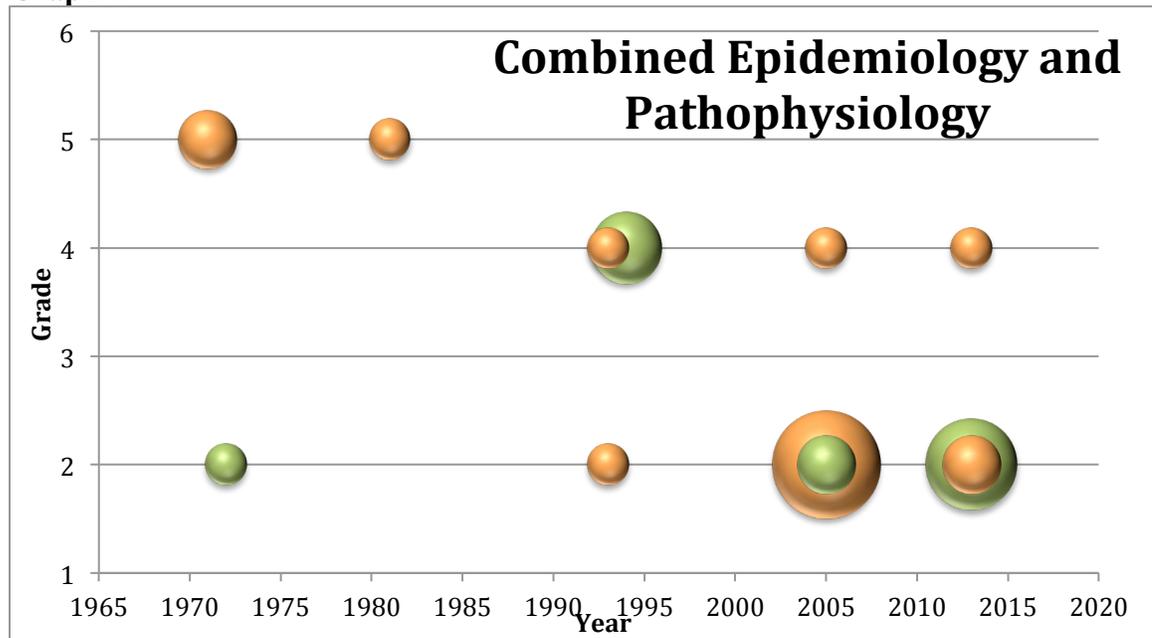
Kennel Club Standards for Weight

Small Breeds	9 kg or less
Medium Breeds	9.1 to 18.2 kg
Large Breeds	18.3 to 36.4 kg
Giant Breeds	36.5 kg or more

Table 3

Totals for Review			
Number of Studies Represented		N	Percent
15	Medial	2023	74%
	Lateral	718	26%
9	Unilateral	806	45%
	Bilateral	973	55%
10	Male	2706	47%
	Female	3001	53%

Graph 4



KEY	
Epidemiology	Green
Pathophysiology	Orange

Citations

1. DeAngelis M. Patellar luxation in dogs. *Vet Clin North Am* 1971;1:403-415.
2. Bound N, Zakai D, Butterworth SJ, et al. The prevalence of canine patellar luxation in three centres. Clinical features and radiographic evidence of limb deviation. *Vet Comp Orthop Traumatol* 2009;22:32-37.
3. Ness MG, Abercromby RH, May C, et al. A survey of orthopaedic conditions in small animal veterinary practice in Britain. *Veterinary and Comparative Orthopaedics and Traumatology* 1996;9:43-52.
4. Roush JK. Canine patellar luxation. *Vet Clin North Am Small Anim Pract* 1993;23:855-868.
5. Hulse DA. Pathophysiology and management of medial patellar luxation in the dog. *Vet Med Small Anim Clin* 1981;76:43-51.
6. Durieux N, Vandenput S, Pasleau F. Médecine factuelle: la hiérarchisation des preuves par le Centre for Evidence-Based Medicine d'Oxford. *Rev Med Liege* 2013;68:644-649.
7. Hayes AG, Boudrieau RJ, Hungerford LL. Frequency and distribution of medial and lateral patellar luxation in dogs: 124 cases (1982-1992). *J Am Vet Med Assoc* 1994;205:716-720.
8. Wangdee C, Leegwater PA, Heuven HC, et al. Prevalence and genetics of patellar luxation in Kooiker dogs. *Vet J* 2014;201:333-337.
9. Lavrijsen IC, Heuven HC, Breur GJ, et al. Phenotypic and genetic trends of patellar luxation in Dutch Flat-Coated Retrievers. *Anim Genet* 2013;44:736-741.

10. Soontornvipart K, Wangdee C, Kalpravidh M, et al. Incidence and genetic aspects of patellar luxation in Pomeranian dogs in Thailand. *Vet J* 2013;196:122-125.
11. Nganvongpanit K, Yano T. Prevalence of and Risk Factors of Patellar Luxation in Dogs in Chiang Mai, Thailand, during the Years 2006-2011. *Thai Journal of Veterinary Medicine* 2011;41:449-454.
12. Campbell CA, Horstman CL, Mason DR, et al. Severity of patellar luxation and frequency of concomitant cranial cruciate ligament rupture in dogs: 162 cases (2004-2007). *J Am Vet Med Assoc* 2010;236:887-891.
13. Daems R, Janssens LA, Beosier YM. Grossly apparent cartilage erosion of the patellar articular surface in dogs with congenital medial patellar luxation. *Vet Comp Orthop Traumatol* 2009;22:222-224.
14. Arthurs GI, Langley-Hobbs SJ. Patellar luxation as a complication of surgical intervention for the management of cranial cruciate ligament rupture in dogs. A retrospective study of 32 cases. *Vet Comp Orthop Traumatol* 2007;20:204-210.
15. Kaiser S, Cornely D, Golder W, et al. Magnetic resonance measurements of the deviation of the angle of force generated by contraction of the quadriceps muscle in dogs with congenital patellar luxation. *Vet Surg* 2001a;30:552-558.
16. Kaiser S, Cornely D, Golder W, et al. The correlation of canine patellar luxation and the anteversion angle as measured using magnetic resonance images. *Vet Radiol Ultrasound* 2001b;42:113-118.
17. Mostafa AA, Griffon DJ, Thomas MW, et al. Proximodistal alignment of the canine patella: radiographic evaluation and association with medial and lateral patellar luxation. *Vet Surg* 2008;37:201-211.

18. Wangdee C, Theyse LF, Hazewinkel HA. Proximo-distal patellar position in three small dog breeds with medial patellar luxation. *Vet Comp Orthop Traumatol* 2015b;28:270-273.
19. Johnson AL, Broaddus KD, Hauptman JG, et al. Vertical patellar position in large-breed dogs with clinically normal stifles and large-breed dogs with medial patellar luxation. *Vet Surg* 2006;35:78-81.
20. Fitzpatrick CL, Krotscheck U, Thompson MS, et al. Evaluation of tibial torsion in Yorkshire Terriers with and without medial patellar luxation. *Vet Surg* 2012;41:966-972.
21. Lavrijsen IC, Leegwater PA, Wangdee C, et al. Genome-wide survey indicates involvement of loci on canine chromosomes 7 and 31 in patellar luxation in Flat-Coated Retrievers. *BMC Genet* 2014;15:64.
22. LaFond E, Breur GJ, Austin CC. Breed susceptibility for developmental orthopedic diseases in dogs. *J Am Anim Hosp Assoc* 2002;38:467-477.
23. Priester WA. Sex, size, and breed as risk factors in canine patellar dislocation. *J Am Vet Med Assoc* 1972;160:740-742.
24. Ruble RP, Hird DW. Congenital abnormalities in immature dogs from a pet store: 253 cases (1987-1988). *J Am Anim Hosp Assoc* 1993;202:633-636.
25. Johnson AL, Probst CW, DeCamp CE, et al. Vertical position of the patella in the stifle joint of clinically normal large-breed dogs. *Am J Vet Res* 2002;63:42-46.
26. Horne RD. Canine patellar luxation (a review). *Vet Med Small Anim Clin* 1971;66:211-218.