Patellar luxation in four dog breeds in the Netherlands

Trends in incidence and gradation between 1994 and 2011

OBJECTIVES- This study evaluated the incidence and gradation of patellar luxation in four dog breeds in the Netherlands, presented for patellar luxation (PL) examination to one of the 'Meutstege' group certified orthopaedic surgeons between 1994 and 2011.
STUDY DESIGN- Retrospective study.
ANIMALS- 4288 dogs; Flat-Coated Retriever (FCR), Jack Russel Terrier (JR), Dutch Kooiker (KK) and Chihuahua (CHI) breed.
METHODS- PL was graded according to Putman's grading system by a limited group of experts. The results were filed. Different trends in PL were analysed.
RESULTS- The incidence for PL in Flat-Coated Retrievers was 6% in 2011. The Dutch Kooiker dog has an incidence of 14% for PL, the Jack Russel Terrier 8% and the Chihuahua 48%.
There was a significant downward trend for FCR, KK and JR during the examination period, but not for CHI. In all four breeds most affected animals had grade 1 PL. In the FCR and JR grade 2 and 3 were seen occasionally, but there was no significant decrease in the amount of animals with grade 2 or 3 in time. A decrease was seen though in the KK. The Chihuahua had the most diffuse distribution, with high percentages of animals with patellar luxation grade 1 and 2. The sex ratio (males:females) was 1:1.73 for the FCR, 1:1.25 for the KK, 1:2.53 for the JR and 1:1.15 for the CHI.
The percentage of 'loose' patella in the animals that were graded 'free' of PL was 26% in the FCR, 20% in the KK, 27% in the JR and 37% in the CHI. FCR was the only breed were LPL was more common than MPL. The ratio MPL: LPL in this breed was 1:1.69. In the other breeds MPL was more common, the ratios for KK, JR and CHI were respectively 1:0.72, 1:0.86 and 1:0.03.
RELEVANCE- Although many studies have been conducted, the cause and mode of inheritance of patellar luxation are still unknown.(1) The aim of this study was to obtain information about the current (2011) incidence and gradation of patellar luxation in these breeds in the Netherlands and to see the course of patellar luxation in time. The trends in different dog breeds were compared and factors influencing the occurrence of patellar luxation in the population were described.

Introduction

The stifle joint of the dog comprises the femorotibial, femoropatellar and the proximal tibiofibular joint. The joints between the femur and sesamoids (medial and lateral fabellae) in the origins of the gastrocnemius muscle and between tibia and sesamoid in the tendon of the popliteus muscle are also part of the stifle joint.

The patella (kneecap) is a sesamoid bone developed in the insertion of the quadriceps femoris muscle, the main extensor of the stifle. The patella is located in the trochlear groove of the femur and has limited sideways flexibility. Distally, the patella is joined to the tibial tuberosity by a single patellar ligament.(2)

The patella modifies the direction of pull of the extensor muscles and acts as a lever arm by reducing the force necessary to extend the stifle. It centralizes the forces of the different quadriceps muscle bellies and provides a smooth gliding mechanism for the muscle with little friction because of its cartilage cover.(3, 4)

In certain dogs, the patella can dislocate out of the trochlear groove. This condition is known as patellar luxation. Luxation of the patella can be traumatic or congenital in origin. The former can occur at any time in any breed, usually after a blow to the lateral aspect of the stifle. The latter is the most common and considered hereditary, because luxation occurs at an early age.(4)

Proper anatomic alignment of the extensor mechanism with the underlying skeleton is the primary component of patellar stability.(5) Therefor the cause of congenital patellar luxation is related to abnormalities in the limb, such as retroversion of the femoral head, coxa vara, rotation and bowing of the distal femur or tibia and a shallow trochlear groove, that cause malalignment of the quadriceps group. It is difficult to appoint abnormalities as cause or effect of patellar luxation, since an abnormality causing luxation may lead to further deformities and more severe luxation.(6)

Hereditary patellar luxation is often seen in dogs of smaller breeds, such as Miniature and Toy Poodles, Pomeranians, Cavalier King Charles Spaniels, Yorkshire Terriers and Chihuahuas. However, patellar luxation may be seen in larger breeds as well, such as Boxers, Flat-Coated Retrievers and Labrador retrievers.(6, 7) Medial patellar luxation (MPL) is most common in all sizes, but lateral PL (LPL) is more common in large breed dogs than in dogs of smaller breeds. A study of 124 dogs, examined between 1982-1992 found patellar luxation to be medial in 98% and lateral in 2% of the cases in small breeds and 67% MPL and 33% lateral patellar luxation (LPL) in giant breeds.(8)

t.e.s.bruinen@uu.nl

The male:female ratio was found to be 1:1.5 by Hayes *et al.*(1994), which was almost identical to that of previous reports.(8, 9) The development of the condition can be influenced by hormonal factors, as spayed or neutered dogs have a higher risk to develop PL.(10) Recent studies in large breeds show males to be more often affected. It is therefore suggested that PL may be more common in small breed female dogs and large breed male dogs.(11, 12)

Breed predisposition and frequent bilateral involvement have led to the assumption that PL could be hereditary, although it is likely to be a polygenetic, multifactorial disease.(6, 8, 9) Collagen genes were suggested to be involved in PL and investigated in a study by Soontornvipart *et al.*(2012), but this study indicated these genes were not involved in the pathogenesis of PL in Pomeranian dogs. Nevertheless, a region on chromosome 7 was found that could possibly be associated with PL.(1) A recent study reports the heritability of patellar luxation in Flat-Coated Retrievers to be 0.17 ±0.03, which is moderate, indicating that environmental factors play an important role. Breeding with one affected parent increased the prevalence of patellar luxation in offspring with 45% compared to two unaffected parents.(13) Therefore it is recommended not to breed with affected animals, nor to repeat the mating that resulted in offspring with patellar luxation.(6)

Patients with patellar luxation show different clinical symptoms. Puppies or young adults may show an intermittent ‘skipping’ gait. This means the dog pulls the leg up for several steps and, after returning it to the ground, resumes his normal locomotion with no sign of lameness. A second category includes middle-aged or older dogs with a more constant hind limb lameness. There will be a long history of intermittent lameness and a ‘skipping’ gait. Other (young) dogs can have more severe and permanent luxations and will tend to hold the limb in a semi-flexed position. When the problem is bilateral, affected dogs will often adopt a crouching stance and ‘bunny-hopping’ gait. Finally, there is a significant number of asymptomatic dogs, that show few or no clinical signs. Clinical symptoms can also vary with the age and may worsen if the animal gains weight.(4, 6, 14)

Patellar luxation left untreated may lead to lameness, progressive cartilage wear, osteoarthritis and can contribute to cruciate ligament injury.(15) Cranial cruciate ligament tears are found in dogs with patellar luxation and have been proposed to be caused, at least in part, by loss of the normal stabilizing forces of the quadriceps muscle group against cranial drawer motion in dogs with patellar luxation. Angular and rotational deformities in the distal part of the femur

t.e.s.bruinen@uu.nl

and proximal part of the tibia are also hypothesized to place abnormal stress on the collateral and cruciate ligaments; these stresses, combined with the normal aging process in these structures, could account for the ligament tears in dogs with patellar luxation.(8) However, Campbell *et al.*(2010) found no significant association between MPL grade 1, 2 and 3 and the frequency of concomitant cranial cruciate ligament rupture. The significant association (P=0.02) between MPL grade 4 and ligament rupture was speculated to be caused by the lack of the caudally directed vector force of the femoropatellar joint, which placed increased strain on the ligament.(10)

Multiple surgical techniques have been described for the correction of PL. They significantly improve limb use in dogs with lameness, as reported by Roy, Wallace, Johnston and Wickstrom (1992) and other studies. Surgery may improve patellofemoral articulation but may not improve stifle biomechanics sufficiently to prevent progression of osteoarthritis. Sometimes, osteoarthritis may even be the result of imperfect techniques for correction of patellar luxation.(16)
Arthurs *et al*. (2006) reported that postoperative complications developed in 18% of all dogs, but were significantly (P=0.08) more common in dogs weighing more than 20 kg. Reluxation occurred after 8% of the surgical procedures, accounting for 65% of major complications (requiring further surgery) such as reluxation, implant loosening, fractures or septic arthritis.(17)

To achieve a better insight in patellar luxation we need to know what the trends for patellar luxation are. A standard diagnostic procedure for patellar luxation has been described.(18) In the Netherlands there are specialists in small animal surgery and orthopaedics qualified for screening, some other countries have trained vets but many have no formal patella screening program. The situation in the Netherlands with a large database of results and long history of screening is unique. Evaluating the trend of the disease in time in dog breeds that have been monitored for a long time, might help us to learn more.
The objective of this study was to describe the phenotypic trend for the incidence and gradation of PL for different breeds. Also, the distribution between MPL and LPL, the distribution of loose and normal patella and the sex ratio of dogs with PL were investigated. Different breeds can be compared and the results of this screening program evaluated. Influences of screening bias, breeding policies and strategies will be discussed. The outcome of this study could be used in breeding programs and aetiology studies.

t.e.s.bruinen@uu.nl

Materials and Methods

Selection of animals

For this analysis different dog breeds were selected from the 'Meutstege' database. The database contained 44 dog breeds in total, with differences in the number of dogs and the timespan in which they were examined. A large group, with data from some years ago as well as recent data, was necessary to draw conclusions about the development in time. Therefore, selection from the 44 dog breeds was based on the following criteria: The total number of dogs examined per breed had to be more than 300, the examination of dogs for this breed had to be continued ten or more years and the number of tested dogs born in 2010 and 2011 had to be more than 30. The data from 2010 and 2011 were completed in the 'Meutstege' database. Flat-coated Retrievers (FCR), Dutch Kooiker Dogs (KK), Jack Russel Terriers (JR) and Chihuahuas (CHI) were selected for this study. The Chihuahua was included in this study despite the fact that this breed wasn't followed for ten years. However, PL is common in Chihuahuas and the breeding organisation obliged testing for PL since 2010 before mating is allowed, resulting in a recent large increase of tests for PL in this breed.
The Flat-Coated Retriever is a gundog breed from the United Kingdom. With an ideal weight between 25-36 kg., this is a medium size breed according to the Fédération Cynologique Internationale (FCI). The Dutch Kooiker Dog, also called Dutch Decoy Dog or Small Dutch Waterfowl Dog (body weight of 9-11 kg.) and the Jack Russel Terrier (body weight of 6-8kg.) are small size breeds. The Chihuahua is a miniature or toy breed, with an ideal weight between 1.5-3 kg.(19, 20)

For each breed certain criteria were appointed to select the time period that would be used in this study. The selection criteria were that each year had 5 or more results and that there were no missing intermediate years. The results of dogs born in 2012 were omitted. This is because testing is only done after 12 months of age, so only dogs born in the first months of 2012 could already be tested at this point. Other results had to be omitted because of missing birth year. An overview of the numbers of omitted dogs and the resulting numbers of dogs included in this study, is shown in Table 1. In Appendix Table A1 the original dataset per breed and birth year can be found.

Table 1. Overview of dogs omitted and included in this study

	Flat-Coated Retriever	Dutch Kooiker dog	Jack Russel Terrier	Chihuahua*
Omitted because of not meeting selection criteria	447	22	7	24
Omitted because of missing birth year	1508	86	3	8
Number of dogs included in this study	2597	907	401	383
Birth years included dogs	1994-2011	1994-2011	2002-2011	2006-2011*

*= This breed hasn't been followed and examined for ten years yet, but is included in this research because of the high risk for PL in Chihuahua breed dogs and the large amount of results since the breeding organisation obliged testing from 2010 onward.

Examination

Dogs of at least 12 months old were brought for examination on a voluntary basis to a certified orthopaedic surgeon, who is part of the 'Meutstege' group. Surgeons of the group also visited shows, family days and breeding days of different breeding organisations and tested dogs then, thereby actively collecting results. The surgeons used the 'Meutstege'-protocol to examine and score PL in an uniform manner.

Following this protocol they reported the breed, name, sex, date of birth, pedigree number, asked for locomotion problems in the past or present and examined the dog in standing position and lateral recumbence. The trochlea femoris were palpated laterally and medially to check for arthritis or luxated patella. The surgeon tried to manually luxate the patella in different positions and also checked for pain or crepitation. Dogs were graded using an adapted version of Putnam's scoring system.

Each stifle was classified free (normal or 'loose', loose meaning the patella can be manually positioned on the ridges of the trochlear groove, but not out of the groove completely), grade 1 (manually luxable patella with spontaneous repositioning), grade 2 (spontaneous luxation with repositioning upon active extension), grade 3 (constant spontaneous patellar luxation which can be manually reduced), or operated (when the stifle had been operated). The direction of the luxation (medial, lateral or both) and whether the patella could be luxated by torsion of the tibia alone were recorded for each stifle (Appendix Fig. A2). All this information was coded with an alphabetical and numerical score as shown in Table 2. Animals free of patellar luxation received a score of 100, when assessed as grade 1 400, with torsion luxable on the right and/or left side, towards medial and/or lateral each 75 points extra,

when grade 2 700 and grade 3 or operated 1000. The numerical score was merely for research purposes.

Table 2. Alphabetical*, numerical and grade score of patellar luxation

Findings	Left patella	Right patella	Grade	Numerical score
Normal	A	B	Free	100
Loose towards lateral side	P	Q	Free	100
Loose towards medial side	R	S	Free	100
Loose towards lateral and medial side	T	U	Free	100
Grade 1 luxable towards lateral side	C	D	Grade 1	400
Grade 1 luxable towards lateral side and luxable with torsion of the tibia	G	H	Grade 1	475-550-625-700
Grade 1 luxable towards lateral and medial side	O	Z	Grade 1	400
Grade 1 luxable towards lateral and medial side and luxable with torsion of the tibia	I	J	Grade 1	475-550-625-700
Grade 1 luxable towards medial side	E	F	Grade 1	400
Grade 1 luxable towards medial side and luxable with torsion of the tibia	V	W	Grade 1	475-550-625-700
Grade 2 luxable towards lateral side	K	L	Grade 2	700
Grade 2 luxable towards medial side	M	N	Grade 2	700
Operated (or grade 3 or grade 4)	X	Y		1000

*= All combinations of alphabetical scores for left and right patella were possible. The combination gave information about the grade and direction of the luxation in the left and right stifle.

Owners received a patella certificate (result form; Appendix Fig. A1) of which they sent a copy to the club for publishing in the bulletin or to be saved in the club archive. This was mandatory in some breeding organisations. The examination form (Appendix Fig. A2) and a copy of the pedigree were sent in by the specialist for entry in the database.

Pedigree lists

The Dutch Kennel Club provided pedigree records (Appendix Table A2). These records show how many males and females each year were registered for the different breeds. With these numbers, the fraction of the total population that is analysed in this study was calculated. The FCR and the KK records provided for 2011 were incomplete.

Analysis

To find the incidence of patellar luxation in time in all four breeds, the percentage of affected dogs (gr.1, gr.2, gr.3 and operated) out of the total screened population per breed was calculated. This revealed the current situation in all four breeds, as well as the trend over the years.

Furthermore, the gradation in time was evaluated to see if the average grade of affected animals decreased, increased or remained the same in time. For example, if the amount of gr.2 animals decreased and the amount of gr.1 animals increased, the severance of patellar luxation in that population would be decreased. Therefore an overview was made for each breed to compare the amount of animals with different grades of patellar luxation.

The sex ratio in the affected group was calculated. This ratio of male to female cases is based on the assumption that the population observed is equally divided between males and females. Since this is not true in this study (there are more females than males tested), the relative risk (RR) was calculated. $RR= (a_1/n_1)/(a_0/n_0)$ where a_1 is the number of exposed ('female') animals with the disease, a_0 is the number of exposed ('female') animals without the disease, n_1 is the total amount of exposed (female) animals and n_0 the total amount of non-exposed (male) animals). A rate of 1 would indicate that the risk was the same in the test group (females) as in the comparison group (males), a $RR < 1$ would mean the test group had a lower risk than the comparison group and a $RR > 1$ means the test group had a higher risk.(9, 21)

The distribution between 'normal' and 'loose' patella in the group of animals graded 'free' of PL was evaluated by using the alphabetical scores (loose patella P,Q, R,S,T,U and normal patella A,B). The percentage of animals (graded 'free') that have one or two loose patellae was calculated for each breed. These percentages were analysed to assess the amount of loose patella and make a comparison between breeds.

Finally, the distribution between medial and lateral patellar luxation in all four breeds was calculated, analysed and compared with other literature. The amount of alphabetical scores for medial patellar luxation (E, F, V, W, M, N) and lateral patellar luxation (C, D, G, H, K,L) were compared. Included were the amount of scores for MPL or LPL in both legs, in the same or different grades. MPL or LPL in the right or left stifle in all gradations, when the other leg is not affected, was also included.

This means that for MPL the amount of dogs with alphabetical combinations EF, VW, MN, EW, EN, VF, VN, MF, MW, EB, EQ, ES, EU, VB, VQ, VS, VU, MB, MQ, MS, MU, AF, PF, RF, TF, AW, PW, RW, TW, AN, PN, RN and TN were added up. For LPL the amount of

dogs with alphabetical combinations CD, GH, KL, CH, CL, GD, GL, KD, KH, CB, CQ, CS, CU, GB, GQ, GS, GU, KB, KQ, KS, KU, AD, PD, RD, TD, AH, PH, RH, TH, AL, PL, RL and TL were added up. The total amount of scores indicating MPL were compared with the amount of scores indicating LPL. Animals that both had lateral and medial patellar luxation or luxation to both sides were excluded, since this would blur the outcome. Animals scoring X and/or Y were not included in this calculation either, since there was no information whether the luxation was medial or lateral.

Results

In Table 3 an overview of the number of dogs per breed for each year is given. That number as a percentage of the total registered population is also given.

Table 3. Numbers of tested dogs per year and tested dogs as a percentage of the total number of dogs registered at the Dutch Kennel Club

	FCR	Percentage of Kennel Club registered dogs	KK	Percentage of Kennel Club registered dogs	JR	Percentage of Kennel Club registered dogs	CHI	Percentage of Kennel Club registered dogs
1994	6	0.92	10	2.03				
1995	7	0.96	8	1.71				
1996	11	1.33	15	2.77				
1997	108	14.56	32	6.45				
1998	163	24.04	29	6.32				
1999	218	33.18	37	8.20				
2000	169	25.53	45	9.15				
2001	217	31.68	49	8.13				
2002	202	28.25	57	11.03	9	1.34		
2003	235	32.41	50	9.65	13	1.81		
2004	220	32.93	61	12.71	51	9.07		
2005	174	26.44	89	20.51	61	11.96		
2006	190	28.83	76	17.63	50	12.59	11	1.47
2007	165	28.55	61	13.20	62	11.25	13	1.52
2008	128	26.61	75	16.27	47	11.35	35	3.17
2009	167	34.50	54	15.25	47	11.38	58	4.85
2010	134	24.14	72	23.30	35	7.97	115	8.21
2011	83	incomplete	87	incomplete	26	6.57	151	11.05

Dog breeds: FCR= Flat-Coated Retriever; KK= Dutch Kooiker dog; JR= Jack Russel Terrier; CHI= Chihuahua.

t.e.s.bruinen@uu.nl

The percentages from Table 3 are reproduced in Fig. 1. This figure represents the portion of the registered population that is tested for PL and included in this study. There are distinct differences between the breeds. Noticeable is that the Flat-Coated Retriever remained at a stable level around 30% since 1998. The percentages of the Dutch Kooiker dog slowly increased and in 2010 23% of the population was tested. Of the Jack Russel Terriers 10% of the total population was tested between 2005 and 2009, but this percentage decreased in 2010 and 2011. The Chihuahua started very low but had a marked increase in 2010 and 2011.

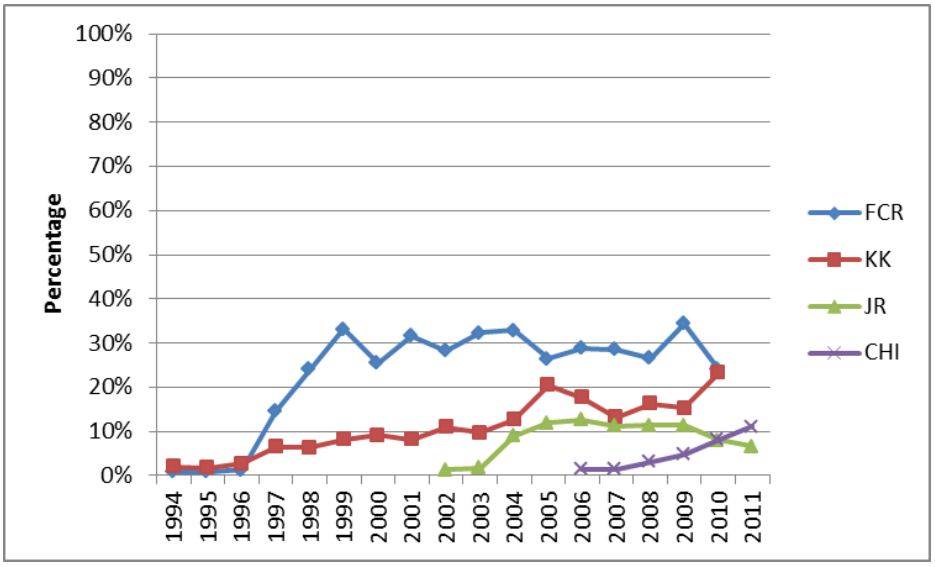

Fig. 1. Percentage tested dogs from total number of registered dogs at Dutch Kennel Club per breed in time. Dog breeds: FCR= Flat-Coated Retriever; KK= Dutch Kooiker dog; JR= Jack Russel Terrier; CHI= Chihuahua.

Incidence

In Figure 2 the incidence of patellar luxation can be found for the FCR, KK, JR and CHI. For the FCR and KK the incidence results both started in 1994, but the incidence of PL in the FCR was much higher than the incidence in the KK. In the FCR there was a fast decrease in PL between 1995 and 1997. After 1997 the incidence remained around 20% until 2009. Between 2009 and 2011 there was another decrease, resulting in an final incidence of 6%. In the KK the course was more unstable. There were small decreases and increases in some years, resulting in a 14% incidence for PL in 2011. The JR started in 2002 around 33% and decreased fast, ending around the same point as the FCR (8%). The Chihuahua had a more than 50% incidence in 2006, going up and down and ending just under 50% (48%). In conclusion, there was a downward trend for all breeds, except for the Chihuahua. See

t.e.s.bruinen@uu.nl

Appendix Table A3 and A4 for the numbers and percentages of affected dogs per breed per year.

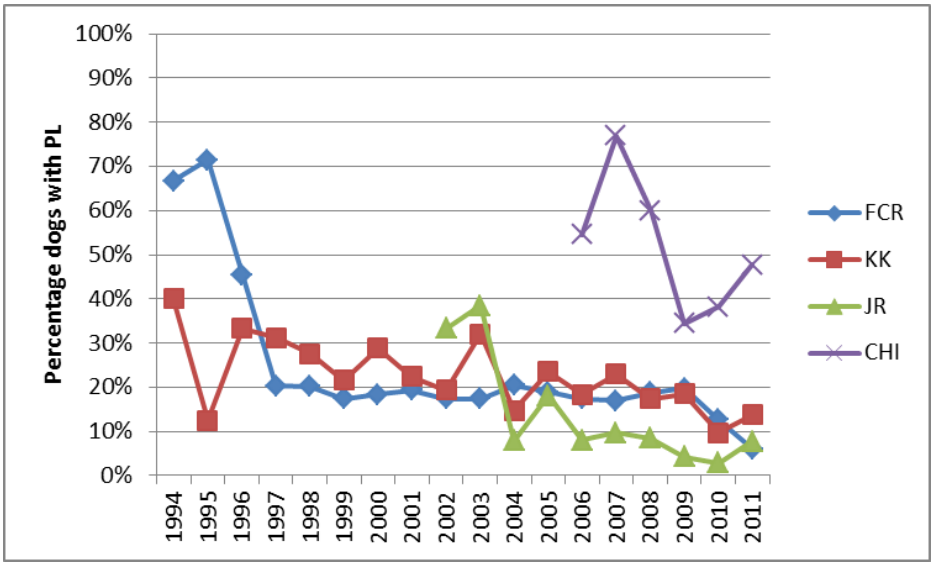

Fig. 2. Incidence of patellar luxation between 1994-2011 in 4288 screened dogs of four different breeds. Dog breeds: FCR= Flat-Coated Retriever; KK= Dutch Kooiker dog; JR= Jack Russel Terrier; CHI= Chihuahua; PL= Patellar luxation.

Gradation

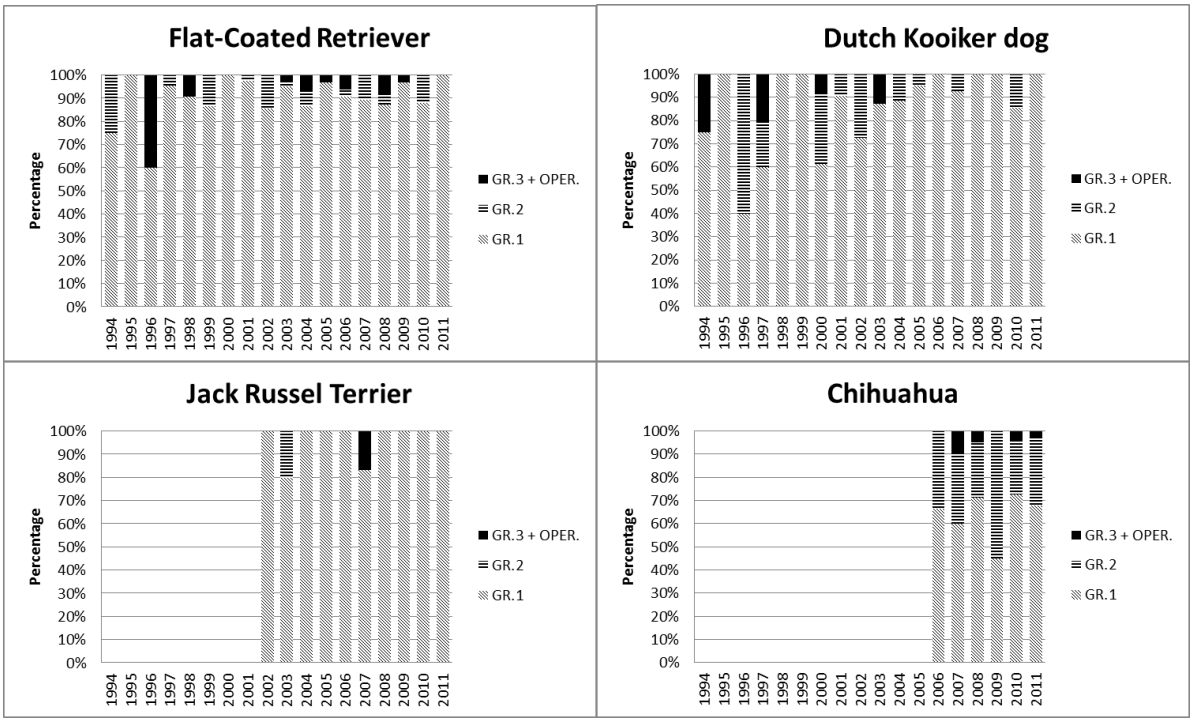

Fig. 3. Gradation of patellar luxation between 1994-2011 in 876 dogs with PL. PL= Patellar luxation. Gradation: GR.1= animals with grade 1 patellar luxation; GR.2= animals

t.e.s.bruinen@uu.nl

with grade 2 patellar luxation; GR3 + OPER.= animals with grade 3 patellar luxation or animals that had surgery. The percentages are calculated as a percentage of all animals of that breed with PL.

Figure 3 shows the trend in gradation of PL. Of the affected Flat-Coated Retrievers more than 50% were gr.1 each year. In 1994 and 1996 a high percentage of respectively gr.2 and gr.3 animals was found. There was no obvious decrease in gradation. In 2011 all tested animals were gr.1, but this was found in 1995 and 2000 as well. A visible decrease was seen though in the Dutch Kooiker Dog, where the amount of gr.2 affected animals gradually decreased. In the Jack Russel Terrier, grade 1 was most common in every year and incidentally (2003 and 2007) different scores were found as well. The Chihuahua had the most diffuse distribution, with high percentages of gr.1 and gr.2 and some gr.3. In 2009 there were more grade 2 animals than grade 1. The complete dataset can be found in Appendix Table A5-A8.

Sex ratio

In Table 4 is visible that females had a higher risk for PL in all four breeds. The Flat-Coated Retriever females had a relative risk of 1.73, meaning the sex ratio for males:females is 1:1.73. The Dutch Kooiker Dog females had a relative risk of 1.25, the Jack Russel Terrier females 2.53 and the Chihuahua females 1.15.

Table 4. Sex ratio in 4288 dogs screened for patellar luxation between 1994-2011

Breed	FCR	FCR	KK	KK	JR	JR	CHI	CHI
Sex	male	female	male	female	male	female	male	female
Affected	167	307	69	118	6	36	47	126
Free	1092	1031	314	406	113	246	68	142
Ratio	1:	1.73	1:	1.25	1:	2.53	1:	1.15

Dog breeds: FCR= Flat-Coated Retriever; KK= Dutch Kooiker dog; JR= Jack Russel Terrier; CHI= Chihuahua. Affected= animals with patellar luxation (≥ grade 1); Free= animals without patellar luxation.

t.e.s.bruinen@uu.nl

Loose patella

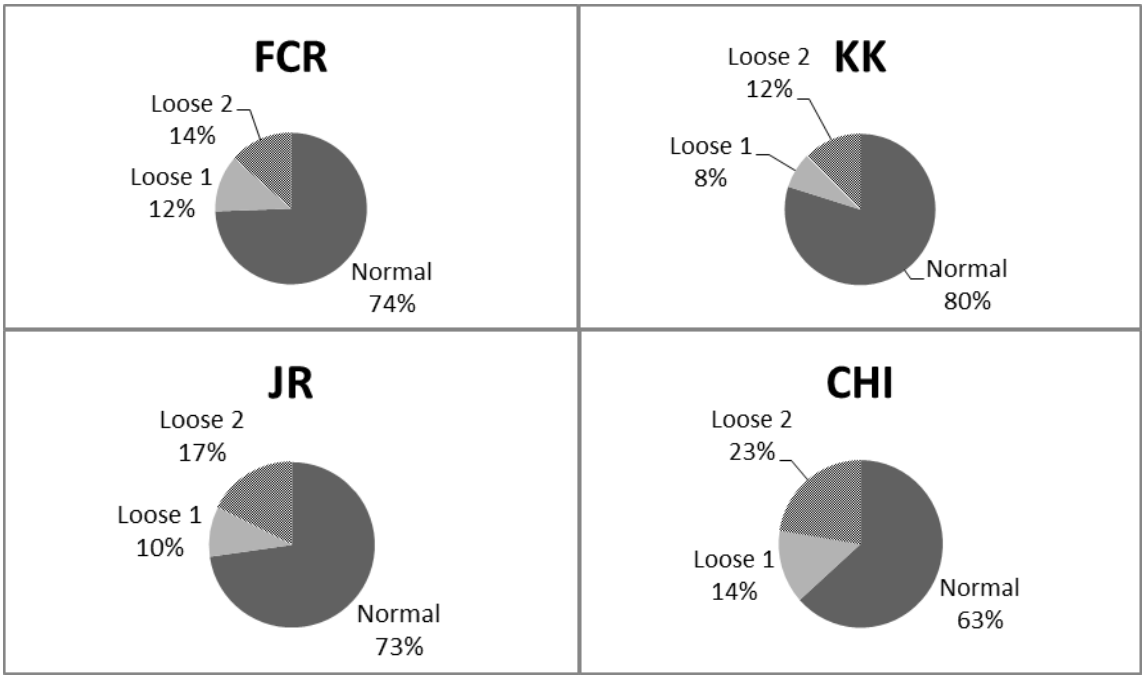

Fig. 4. Percentage of animals with 'loose patella' in 3412 dogs that were graded 'free' of patellar luxation. Loose 1= one stifle has a loose patella; Loose 2= both stifles have loose patella. Dog breeds: FCR= Flat-Coated Retriever; KK= Dutch Kooiker dog; JR= Jack Russel Terrier; CHI= Chihuahua.

The percentage of animals with one or two loose patellae (Fig. 4) did not differ much between breeds. Of the FCR animals without PL 26% had one or two loose patellae, of the KK 20%, the JR 27% and of the CHI dogs 37% had one or two loose patellae. Animals with two loose patellae were more common than animals with one loose patella.

Distribution MPL and LPL

In the FCR database 158 animals were found with MPL and 267 with LPL. This makes the ratio MPL:LPL in the FCR 1:1.69. In the KK this was 95:68 or 1:0.72. MPL was thus more common in the KK. In accordance with the KK MPL was more common in the JR and CHI. In the JR the ratio was 21:18 or 1:0.86 and the CHI 159:5 or 1:0.03, indicating there were far more cases of MPL than LPL in the Chihuahua. In Appendix Table A9-A12 all alphabetical combinations found in the database with number of occurrence are listed for each breed.

t.e.s.bruinen@uu.nl

Discussion

Research population

To make statements about the population, the sample must be representative of the population from which it is taken. Strictly, this means there should be random selection from all possible members of the entire population. However, this is generally not feasible. Then, it is important that we try to ensure that the individuals in the sample are a true reflection of those in the population.(22)

This study has a screening bias. In some breeds more animals were tested than in others. The Flat-Coated Retriever is overrepresented in our study, even after omitting numerous results of that breed because of missing birth year. Likewise, some years have more results than others. Naturally, when the results are more abundant, the conclusions we deduce from them will be better. Because of this screening bias, the confidence interval should be larger. Most animals were examined by the same experienced, board certified veterinary orthopaedic specialist (FJM). Therefore the measurement error is expected to be relatively small.

By calculating the fraction of the entire population of pedigree dogs that is tested and used in this study, the differences in representation of the breeds in this study is given (Table 3 and Figure 1). Of all registered FCR around 30% were tested yearly. This high percentage is partly due to the fact that specialists visited many family days organised by the FCR breeding organisation. At these days, complete nests were tested for PL, instead of only prospective mating dogs. The percentage of tested Dutch Kooiker dogs slowly increased until 23% in 2010. Of the Jack Russel dogs approximately 10% was tested yearly and for the Chihuahua this was between 1-10%. The Chihuahua had a marked increase of tested dogs in 2010 and 2011, which can be explained by fact that the breeding policy obliged testing from 2010 onward.

These differences could also be due to breeding policy. For example, testing on patellar luxation is done since 2005 for Chihuahuas, but is mandatory since 2010. As a result, a large increase in tested animals is seen since 2010. Furthermore, the attention for PL has increased in all breeds, usually resulting in more screening.

The population in this study is not a reflection of the entire population of the chosen breeds, but of the possible future breeding population. Since PL is hereditary, it is useful to look at the population that could possibly pass on patellar luxation to a next generation.

t.e.s.bruinen@uu.nl

Incidence

The incidence we found in these 4 breeds are different than reported in other countries. For example, the Orthopedic Foundation for Animals (OFA) reported 5.7 % (n=1141) of Chihuahuas were affected and only 1.6% (n=1973) of Flat-Coated Retrievers.(23) In our study this is respectively 47% and 6%.

These differences may be explained by the fact that in America only clinically affected (≥ grade 2) animals are reported. Grade 1 animals that have no or little clinical symptoms are missed. In our screening program, animals with PL are mostly grade 1. This is also part of the selection bias. After excluding grade 1 affected animals, the results may be more similar to those of the OFA. Another explanation for the difference in incidence reports might be changes between the European and American population of these dog breeds.

The differences between incidence in these dog breeds can be explained by their predisposition, the policy of the breeding organisation and how long that policy has been implemented. The Dutch Kooiker Dog breeding organisation only allows free animals and free x grade 1 animals to mate. This is also the policy of the Flat-Coated Retriever and Jack Russel Terrier breeding organisation. The Dutch Chihuahua club has obliged testing since 2010, but there are no restrictions for breeding with affected animals. It is interesting to see the difference in trends between these two groups. It could be assumed that the policy of the FCR, KK and JR is more successful. But since the results of the Chihuahuas are not collected during the same time span as the other breeds, we have to be careful with our conclusions.

In the FCR there was a fast decrease in incidence in PL between 1995 and 1997, which was probably due to the low number of results in 1994-1996 and therefore not representative for the population. 1997 is the first year more than 100 results were acquired and is therefore likely to give a better insight in the incidence of patellar luxation. The downward peak in the incidence of the Kooiker and the fast decrease of the Jack Russel Terrier in the first years might also have been due to low numbers of results. The trend of the incidence in the Chihuahua is varied, at all points.

Gradation

Most affected animals of all breeds in this study were grade 1. This is different than Gibbons *et al.* reported for 70 large breed dogs.(12) They found most animals to be grade 2. This is due to the above mentioned difference in reporting. Grade 1 PL may be discovered during screening, without necessary clinical symptoms in the animal. Without this screening program, only lame animals (≥grade 2) are discovered. Furthermore, breeders, owners and

t.e.s.bruinen@uu.nl

veterinarians in the Netherlands are well aware of the predisposition to PL in some breeds. Severe cases are detected early and seldom offered for screening, since affected animals may not be used for breeding purposes. For Gibbons *et al.* (2006) the opposite is probably true, since only lame animals are offered to the clinic and reported.
In the Dutch Kooiker dog, the severity decreased the most, other breeds remained more or less at the same level, with some peaks in grade 2 or 3 animals.

Sex ratio

The pedigree dogs registered at the Dutch Kennel Club had a sex ratio of approximately 1:1 (Appendix Table A2). But for breeding, more females are used than males. Therefore our results were biased and we could not compare the affected females and males directly. By using the relative risk we found the sex ratio in the Flat-Coated Retriever to be 1:1.73. For the KK it was 1:1.25, the JR 1:2.53 and the CHI 1:1.15.
Other studies reported an overall ratio of 1:1.5(8) and 1:1.86 for small breed dogs(24). It was suggested by Gibbons *et al*.(2006) that patellar luxation is more common in females of small breeds, but in male large breed dogs, since they reported a ratio of 1.8:1 in large breed dogs.(12)
Therefore it was expected that the ratio in the Flat-Coated Retriever would be opposite to that of the other breeds, since this was the only medium breed in this study. In all four breeds in this study though, female dogs were predisposed compared to male dogs. The ratio of the Flat-Coated Retriever was a bit higher than reported by Hayes et al., but the ratio of the Kooiker Dog and Chihuahua were lower. Those differences may, again, be due to the large amount of grade 1 animals included in this study. The sex ratio in the Jack Russel is much higher than reported before. No explanation was found for this finding.
There are different theories about the female predisposition to patellar luxation. It was suggested by Gustafsson *et al*.(1969) that estradiol effected the growth of the cartilage of the condyles. They found the condyles to be lower in dogs injected with estradiol benzoate for a longer period.(25) In human medicine the effect of female hormones on anterior cruciate ligament (ACL) injury is being studied. The literature states that women have a 4 to 6 fold increased incidence of ACL injury. The hormones controlling the menstrual cycle influence the laxity of the ligament. What phase of the cycle females are most at risk remains to be clarified.(26)

t.e.s.bruinen@uu.nl

Other research has suggested the possibility that the initial problem in PL may be more muscle-related. Since the muscles in male dogs are better developed, this could contribute to the predisposition for females.(4, 14)

Loose patella

Another difference between breeding organisations is whether they value the terms 'loose' and 'solid' patella (patella can be manually positioned on the ridges of the trochlea or not). This is one of the factors assessed by the orthopaedic surgeons. The Kooiker breeding organisation suggests to mate dogs with loose patellas only with dogs with 'solid' patellas, but there are no obligations. Some breeding organisations are considering no or restricted mating with animals with 'loose' patella. To see the possible implications this would have the distribution between 'normal' and 'loose' patella in this group was investigated. Since approximately 25% of the free animals have one or two loose patella, this would mean a large reduction of the possible breeding population. Furthermore, an unpublished study showed no clinical relevance in the term 'loose patella'. Breeding with animals with loose patellae did not significantly increase the prevalence of PL in the offspring compared to breeding with animals with normal patella.(13)

Distribution MPL and LPL

Of all four breeds, LPL was most common in the FCR. Since LPL occurs more often in large breed dogs, this was expected. However, MPL was still expected to be the most common in all breeds. That more LPL than MPL was found in the FCR was unexpected. A possible explanation could be that LPL is more often asymptomatic (grade 1) than MPL. Since there are a lot of grade 1 animals tested in this screening program, this could account for the difference with other studies. Further research has to be done to test this hypothesis. For the KK, the JR and the CHI medial patellar luxation (MPL) was most common, which was in accordance with literature for small breeds.(8)

Conclusion and Recommendations

The direct cause of patellar luxation is still unknown. An estimated heritability of 0.17 for PL in the Dutch Flat-Coated Retriever indicates that environmental factors play a large role in the presentation of the disorder.

Although the incidence of patellar luxation has decreased, this decrease was small and little progress is made in the last years. For the breeds that have been monitored and tested for

more than ten years (FCR, KK and JR) other measures are necessary to further reduce patellar luxation. Estimated Breeding Values include phenotypic information of all screened relatives and therefore give more information. PL free animals that have never been exposed to the (unknown) environmental stimuli, can have a high genetic susceptibility and transmit this to their offspring. EBV can help to make a selection among PL free animals. Therefore inclusion of breeding values could improve the effect of breeding programs and further reduce the incidence of PL.

t.e.s.bruinen@uu.nl

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Appendix

Table A1. Original dataset per breed and birth year

Years	FCR	KK	JR	CHI	Total
Unknown	1508*	86*	3*	8*	1605
1975	1*				1
1977	1*				1
1978	10*				10
1979	3*				3
1980	2*				2
1981	13*				13
1982	17*				17
1983	24*				24
1984	30*				30
1985	53*				53
1986	64*				64
1987	53*				53
1988	63*	2*			65
1989	84*	2*			86
1990	21*	6*			27
1991		4*			4
1992	4*	3*			7
1993	3*	3*			6
1994	6	10			16
1995	7	8			15
1996	11	15			26
1997	108	32			140
1998	163	29			192
1999	218	37			255
2000	169	45	3*		217
2001	217	49	3*		269
2002	202	57	9		268
2003	235	50	13		298
2004	220	61	51	1*	333
2005	174	89	61	5*	329
2006	190	76	50	11	327
2007	165	61	62	13	301
2008	128	75	47	35	285
2009	167	54	47	58	326
2010	134	72	35	115	356
2011	83	87	26	151	347
2012	1*	2*	1*	18*	22
Total	4552	1015	411	415	6393

*= Omitted from this study. Dog breeds: FCR= Flat-Coated Retriever; KK= Dutch Kooiker dog; JR= Jack Russel Terrier; CHI= Chihuahua

t.e.s.bruinen@uu.nl

U I T S L A G P A T E L L A O N D E R Z O E K

Naam hond : . . . . . .

Ras : . . . . . Geslacht: reu / teef

Geboorte datum : - -

NHSB nummer : . . . . . .

Tatoeage/chip nummer: . . . . . .

Eigenaar : . . . . . te . . . . . .

Bij klinisch onderzoek van bovenstaande hond op . . . . . (datum) werd

[ ] geen aanwijzing gevonden voor het bestaan van een patella-luxatie: (Patella "vrij").

[ ]* vastgesteld dat de horizontale verschuifbaarheid van de patella (links en/of rechts) vrij groot is (naar binnen [en] buiten), deze is echter niet uit de groef te disloceren.

[ ] vastgesteld, dat de patella (links en/of rechts) niet voldoende stabiel in haar groef op het dijbeen zit. Zij is door draaien aan het scheenbeen en/of door zijwaartse druk te disloceren naar buiten en/of naar binnen. Er is sprake van een patellaluxatie Graad 1.

[ ] vastgesteld, dat de patella (links / rechts) bij beweging, tijdens het staan of lopen spontaan (af en toe /regelmatig) van haar plaats schiet naar binnen / buiten.
Er is sprake van een patella-luxatie Graad 2.

[ ] Bijzonderheden: (0.a. Graad 3 of 4, of evt. operatie): . . . . . .

. . . . . .

Opgemerkt dient te worden, dat het bovenstaande dier werd onderzocht in het kader van een inventarisatie binnen het ras, en dat vooralsnog over de wijze van vererving onvoldoende bekend is, om te kunnen zeggen dat er bij het fokken met normale ("vrije") dieren geen patella-luxatie kan optreden bij de nakomelingen.

. . . . . (ondertekening)

Naam dierenarts: . . . . . te . . . . . .
Specialist Chirurgie van Gezelschapsdieren

* vermelding gebeurt alleen ter documentatie, heeft geen betekenis voor fokadvies

Fig. A1. Result form.

t.e.s.bruinen@uu.nl 10-5-2013

BEVINDINGEN PATELLA ONDERZOEK

Onderzoek werd verricht door: . . . . . te . . . . . Hij/Zij verklaart het tatoeage/chip-nummer van de hond gecontroleerd te hebben: en in orde bevonden / dit nummer was niet leesbaar (doorhalen hetgeen niet van toepassing is). (Handtekening). . . . . .

Naam hond :
Ras : Geslacht: reu / teef

NHSB nummer: Uitslag code:

Tatoeage / chip nummer:

Eigenaar : te

ANAMNESE (vraag aan de eigenaar):
Ooit klachten gehad bij het lopen? neen ja:
Heeft U aanmerkingen op het gangwerk (gehad)? neen ja:

STAAND ONDERZOEK:

Patella op haar plaats?	Links:	ja	neen
	Rechts:	ja	neen
Patella te luxeren?	Links:	neen	ja -> lat./med.
	Rechts :	neen	ja -> lat./med.

LIGGEND ONDERZOEK:

LINKER KNIE: hond is . . .. gespannen

Patella in de trochlea?	ja	neen	--> lat. - mediaal
Patella over rand te drukken	neen	ja	--> lat. - mediaal met/zonder rotatie
Patella alleen door torsie van de tibia al luxabel?	Neen	ja	--> lat. - mediaal
Crepitatie	neen	ja	
Crista midden voor?	ja	neen	. . . . .

RECHTER KNIE: hond is . . . . . .gespannen.

Patella in de trochlea?	Ja	neen	--> lat. - mediaal
Patella over rand te drukken	neen	ja	--> lat. - mediaal met/zonder rotatie
Patella alleen door torsie van de tibia al luxabel?	Neen	ja	--> lat. - mediaal
Crepitatie	neen	ja	
Crista midden voor?	ja	neen	

Overige bijzonderheden: . . . . . .

C O N C L U S I E : . . . . . .

Ondergetekende, eigenaar/hoeder van bovenstaande hond verklaart dat de voor onderzoek aangeboden hond de hierboven beschreven hond is, en dat hij/zij bekend is met de door de rasvereniging gestelde regels, en toestemming geeft om de resultaten van het onderzoek te gebruiken voor het officiële fokprogramma.

(ondertekening): . . . . . .(datum) . . . . . .

(Form. dd. 1-4-94. Copyright Meutstege) ((Kopie van) dit formulier + kopie stamboom opsturen naar Meutstege

Fig. A2. Examination form.

t.e.s.bruinen@uu.nl

Table A2. Dutch Kennel Club registered number of dogs each year (male and female)

		FCR			KK			JR			CHI	
	TOTAL	M	F	TOTAL	M	F	TOTAL	M	F	TOTAL	M	F
1990	49	16	33	53	22	31	84	30	54	153	57	96
1991	334	167	167	300	160	140	213	61	152	676	346	330
1992	622	324	298	496	254	242	238	78	160	712	381	331
1993	555	299	256	579	301	278	1545	765	780	710	373	337
1994	654	352	302	492	244	248	1357	695	662	698	348	350
1995	731	394	337	467	218	249	1346	686	660	678	332	346
1996	827	419	408	541	314	227	1146	571	575	668	330	338
1997	742	385	357	496	276	220	1148	572	576	608	310	298
1998	678	356	322	459	240	219	1049	542	507	546	279	267
1999	657	307	350	451	238	213	1059	553	506	548	270	278
2000	662	337	325	492	271	221	967	485	482	517	255	262
2001	685	357	328	603	330	273	926	453	473	512	262	250
2002	715	386	329	517	281	236	673	332	341	467	223	244
2003	725	388	337	518	265	253	720	378	342	525	271	254
2004	668	349	319	480	232	248	562	295	267	631	305	326
2005	658	320	338	434	224	210	510	268	242	707	344	363
2006	659	337	322	431	220	211	397	185	212	747	361	386
2007	578	296	282	462	247	215	551	294	257	856	432	424
2008	481	251	230	461	235	226	414	205	209	1104	549	555
2009	484	245	239	354	181	173	413	210	203	1197	551	646
2010	555	277	278	309	154	155	439	235	204	1400	687	713
2011	67*	41*	26*	36*	25*	11*	396	184	212	1367	669	698

*= records for FCR and KK in 2011 were not complete. Dog breeds: FCR= Flat-Coated Retriever; KK= Dutch Kooiker dog; JR= Jack Russel Terrier; CHI= Chihuahua.

t.e.s.bruinen@uu.nl

Table A3. Number of dogs with patellar luxation (PL) per breed per year

	FCR		KK		JR		CHI	
	PL	Total	PL	Total	PL	Total	PL	Total
1994	4	6	4	10				
1995	5	7	1	8				
1996	5	11	5	15				
1997	22	108	10	32				
1998	33	163	8	29				
1999	38	218	8	37				
2000	31	169	13	45				
2001	42	217	11	49				
2002	35	202	11	57	3	9		
2003	41	235	16	50	5	13		
2004	45	220	9	61	4	51		
2005	33	174	21	89	11	61		
2006	33	190	14	76	4	50	6	11
2007	28	165	14	61	6	62	10	13
2008	24	128	13	75	4	47	21	35
2009	33	167	10	54	2	47	20	58
2010	17	134	7	72	1	35	44	115
2011	5	83	12	87	2	26	72	151

Dog breeds: FCR= Flat-Coated Retriever; KK= Dutch Kooiker dog; JR= Jack Russel Terrier; CHI= Chihuahua.

t.e.s.bruinen@uu.nl

Table A4. Percentage of dogs with patellar luxation (PL) per breed per year.

	FCR	KK	JR	CHI
1994	0.67	0.40		
1995	0.71	0.13		
1996	0.45	0.33		
1997	0.20	0.31		
1998	0.20	0.28		
1999	0.17	0.22		
2000	0.18	0.29		
2001	0.19	0.22		
2002	0.17	0.19	0.33	
2003	0.17	0.32	0.38	
2004	0.20	0.15	0.08	
2005	0.19	0.24	0.18	
2006	0.17	0.18	0.08	0.55
2007	0.17	0.23	0.10	0.77
2008	0.19	0.17	0.09	0.60
2009	0.20	0.19	0.04	0.34
2010	0.13	0.10	0.03	0.38
2011	0.06	0.14	0.08	0.48

Dog breeds: FCR= Flat-Coated Retriever; KK= Dutch Kooiker dog; JR= Jack Russel Terrier; CHI= Chihuahua.

t.e.s.bruinen@uu.nl

Table A5. Quantity of results for different grades of patellar luxation in Flat-Coated Retriever dogs screened for PL between 1994-2011

FCR	GR.1	GR.2	GR.3	Operated
1994	3	1		
1995	5			
1996	3		2	
1997	21	1		
1998	30			3
1999	33	5		
2000	31			
2001	41	1		
2002	30	5		
2003	39	1		1
2004	39	3	1	2
2005	32			1
2006	30	1		2
2007	25	3		
2008	21	1	1	1
2009	32			1
2010	15	2		
2011	5			

FCR= Flat-Coated Retriever; PL= Patellar luxation; GR.1= animals with grade 1 patellar luxation; GR.2= animals with grade 2 patellar luxation; GR.3= animals with grade 3 patellar luxation; Operated are the animals that had surgery.

t.e.s.bruinen@uu.nl

Table A6. Quantity of results for different grades of patellar luxation in Dutch Kooiker dogs screened for PL between 1994-2011

KK	GR.1	GR.2	GR.3	Operated
1994	3			1
1995	1			
1996	2	3		
1997	6	2		2
1998	8			
1999	8			
2000	8	4		1
2001	10	1		
2002	8	3		
2003	14			2
2004	8	1		
2005	20	1		
2006	14			
2007	13	1		
2008	13			
2009	10			
2010	6	1		
2011	12			

KK= Dutch Kooiker Dog; PL= Patellar luxation; GR.1= animals with grade 1 patellar luxation; GR.2= animals with grade 2 patellar luxation; GR.3= animals with grade 3 patellar luxation; Operated are the animals that had surgery.

Table A7. Quantity of results for different grades of patellar luxation in Jack Russel Terrier dogs screened for PL between 2002-2011

JR	GR.1	GR.2	GR.3	Operated
2002	3			
2003	4	1		
2004	4			
2005	11			
2006	4			
2007	5			1
2008	4			
2009	2			
2010	1			
2011	2			

JR= Jack Russel Terrier; PL= Patellar luxation; GR.1= animals with grade 1 patellar luxation; GR.2= animals with grade 2 patellar luxation; GR.3= animals with grade 3 patellar luxation; Operated are the animals that had surgery.

t.e.s.bruinen@uu.nl

Table A8. Quantity of results for different grades of patellar luxation in Jack Russel Terrier dogs screened for PL between 2006-2011

CHI	GR.1	GR.2	GR.3	Operated
2006	4	2		
2007	6	3	1	
2008	15	5	1	
2009	9	11		
2010	32	10	2	
2011	49	21	2	

CHI=Chihuahua; PL= Patellar luxation; GR.1= animals with grade 1 patellar luxation; GR.2= animals with grade 2 patellar luxation; GR.3= animals with grade 3 patellar luxation; Operated are the animals that had surgery.

Table A9. Alphabetical combinations found in the FCR database with number of occurence

FCR	B	D	F	H	J	L	N	Q	S	U	W	Y	Z
A	1580	21	23	1		1		72	42	14	2	2	1
C	37	111	7	2		2	1	29	5	10	1		4
E	16	3	53	1				6	15	4	2		2
G	3	1		3									1
I					2								
K	6	2				2				1			
M			1				4			1	1		
O		2	2						1				2
P	68	22	3	1				149		7			1
R	46	2	11				1	3	65	1	2		
T	14	3	8	2	1		1	10	6	46			2
V	1		2			1					1		
X	3	1								1		7	

FCR= Flat-Coated Retriever. Letters on horizontal axis are codes on the patellar examination form about the right stifle. Letters on vertical axis are codes of the patellar examination form about the left stifle. Explanation of the alphabetical codes can be found in Table 2.

t.e.s.bruinen@uu.nl

Table A10. Alphabetical combinations found in the KK database with number of occurence

KK	B	D	F	H	J	L	N	Q	S	U	W	Y	Z
A	575	8	5	1			3	7	9	2	5	2	2
C	15	19	1		1			3			2		1
E	9	1	26				1	1	5				
G	7	1		4				1			1		1
I					3				1				
K						1			1				
M	2						5				1		
O						1							3
P	25	4		1				16	1				
R	7	2	5						60		1		
T	5		1							13			
V	5		6				1	1	2		10		
X	3						1						

KK= Dutch Kooiker dog. Letters on horizontal axis are codes on the patellar examination form about the right stifle. Letters on vertical axis are codes of the patellar examination form about the left stifle. Explanation of the alphabetical codes can be found in Table 2.

Table A11. Alphabetical combinations found in the JR database with number of occurence

JR	B	D	F	H	N	Q	S	U	W	Z
A	261			1		2	9			
C	3	9				1				1
E	3		9				2			
G				2						
M					1					
O	1									
P	6	2				16				
R	16		1				37		2	
T	2					2		8		
V			1				1		1	
X			1							

JR= Jack Russel Terrier. Letters on horizontal axis are codes on the patellar examination form about the right stifle. Letters on vertical axis are codes of the patellar examination form about the left stifle. Explanation of the alphabetical codes can be found in Table 2. The absence of letters means the alphabetical code was not found in the database.

t.e.s.bruinen@uu.nl

Table A12. Alphabetical combinations found in the CHI database with number of occurence

CHI	B	D	F	J	L	N	Q	S	U	W	Y
A	133	1	9			3	2	12			1
C	1	2			1	1					
E	15	1	61			6		9		3	
I				1							
K										1	
M	1		8			28		1		1	
P	2						4	1			
R	14		6			2		41			
T									1		
V	1		1			1				3	
X						2					2

CHI= Chihuahua. Letters on horizontal axis are codes on the patellar examination form about the right stifle. Letters on vertical axis are codes of the patellar examination form about the left stifle. Explanation of the alphabetical codes can be found in Table 2. The absence of letters means the alphabetical code was not found in the database.

t.e.s.bruinen@uu.nl