

Repeatability of dorsolateral subluxation scores in dogs and correlation with macroscopic appearance of hip osteoarthritis

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Objective—To determine whether dorsolateral subluxation (DLS) scores in young dogs could be used to reliably predict which dogs would develop evidence of hip osteoarthritis and whether DLS scores measured at various ages correlated with each other.

Animals—129 Labrador Retrievers, Greyhounds, and Labrador Retriever-Greyhound crossbreds.

Procedures—DLS scores were measured on radiographs taken at 4, 8, and 12 months of age and at necropsy (8 to 36 months of age). At necropsy, the hip joints were examined macroscopically and a score assigned for degree of cartilage degeneration.

Results—DLS scores at 4 ($n = 35$, $r_s = -0.62$), 8 ($n = 106$, $r_s = -0.54$), and 12 ($n = 15$, $r_s = -0.87$) months of age were significantly correlated with cartilage degeneration scores, and DLS scores at 8 months of age were significantly correlated with scores obtained at the time of necropsy ($n = 39$, $r_s = 0.87$). The DLS scores at 4 months of age were significantly different from scores at 8 months of age, but scores did not differ significantly thereafter. Likelihood ratios for cartilage lesions for low ($< 45\%$), intermediate (≥ 45 but $\leq 55\%$), and high ($> 55\%$) DLS scores at 8 months of age were 8.0, 2.6, and 0.2, respectively.

Conclusions and Clinical Relevance—Results suggest that DLS score at 8 months of age was a reasonable, albeit imperfect, predictor of the condition of the hip joint cartilage at necropsy. Thus, the DLS method might be useful for early identification of dogs with hip dysplasia. (*Am J Vet Res* 2001;62:1711–1715)

In dogs, hip dysplasia is a developmental trait marked by laxity of the hip joints and a lack of conformity of the articulating surfaces that leads to osteoarthritis.¹ Dysplastic dogs frequently also have evidence of osteoarthritis in other joints,²⁻⁴ suggesting that the primary defect is systemic, rather than restricted to the hip joints.

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Four radiographic methods of evaluating the hip joints in dogs for evidence of abnormalities associated with hip dysplasia have been described: the conventional extended-hip radiographic method,^{5,6} a distraction radiographic method described by Smith et al,^{6,7} a distraction radiographic method described by Flückiger et al,⁸ and a dorsolateral subluxation (DLS) method.^{9,10} The DLS method was specifically devised to evaluate passive subluxation of the femoral heads when the hip joints are placed in a simulated load-bearing position.^{9,10} For this method, dogs are anesthetized or sedated and positioned in sternal recumbency with their knee joints in contact with the table. A foam-rubber mold is used to support the dogs while a dorsoventral radiographic projection of the pelvis is obtained. The DLS score is then calculated as the percentage of the femoral head medial to the most lateral point of the cranial rim of the acetabulum on the radiographic projection. A method for evaluating the slope of the dorsal acetabular rim in dogs has also been described¹¹; however, the concepts underlying this method are similar to those of the DLS method.

The purposes of the study reported here were to determine whether DLS scores in young dogs could be used to reliably predict which dogs would develop macroscopic evidence of osteoarthritis and to determine whether DLS scores measured at 4, 8, and 12 months of age correlated with each other.

Materials and Methods

Dogs—Overall, 129 dogs of various ages were used in the study; all dogs were from a colony maintained at the James A. Baker Institute for Animal Health. Fifty-four of the dogs used in the study were purebred Labrador Retrievers, and 2 were purebred Greyhounds. The remaining 73 were Labrador Retriever-Greyhound crossbreds: 14 were 75% Labrador Retriever and 25% Greyhound, 37 were 50% Labrador Retriever and 50% Greyhound, and 22 were 25% Labrador Retriever and 75% Greyhound. A complete description of the colony has been published.¹²

Dogs were provided a commercial dog food and water ad libitum. The experimental protocol was reviewed and approved by the Institutional Animal Care and Use Committee of Cornell University.

Experimental protocol—In all dogs, DLS scores were measured at least once at 4, 8, or 12 months of age or at the time of necropsy. In some dogs, DLS scores were measured at 4 and 8; at 4 and 12; at 8 and 12; or at 4, 8, and 12 months of age. In addition, in some dogs, DLS scores were measured at the time of necropsy (before euthanasia) as well as at 4, 8, or 12 months of age. Dogs in which DLS scores were measured more than once were selected nonrandomly on the basis of availability of dogs of appropriate ages at the time

personnel and facilities were available. Similarly, dogs were selected for euthanasia on the basis of space limitations and the needs of other studies. Thus, age at the time of euthanasia ranged from 8 to 36 months.

Measurement of DLS score—For measurement of DLS scores, dogs were sedated with acepromazine (0.02 mg/kg of body weight, IV) and glycopyrrolate (0.01 mg/kg, SC) and anesthetized with propofol (6 mg/kg, IV). An endotracheal tube was inserted, and anesthesia was maintained with halothane. Dogs were maintained in a deep plane of anesthesia while radiographs were obtained; palpebral and hind limb withdrawal reflexes were not detected during this period. The DLS score was calculated by examining the dorsoventral radiographic projection of the pelvis, as described.^{9,10} All DLS scores were calculated by a single individual (AJW) who was unaware of cartilage degeneration scores that were assigned. No external load was applied as radiographs were obtained, as it has previously been reported that DLS scores obtained at 8 months of age were not affected by application of an additional external load.⁴ In addition, scores were not altered when dogs were sedated, rather than anesthetized, for the radiographic procedure.

Assignment of cartilage degeneration scores—Dogs were euthanized by administration of an overdose of barbiturate, and the hip joints were removed and placed in crushed ice. The hip joints were examined macroscopically within 2 hours after death, and a cartilage degeneration score from 0 to 2 was assigned to each joint. A score of 0 was given if the gross appearance of the articular cartilage was normal, a score of 1 was given if the articular cartilage contained an area of fibrillation or ulceration smaller than 0.5×1 cm, and a score of 2 was given if the articular cartilage contained an area of fibrillation or ulceration larger than 0.5×1 cm. Hip joints for which the cartilage degeneration score was 1 or 2 were considered to have osteoarthritis.^{13,14}

To the extent possible, individuals assigning cartilage degeneration scores were unaware of the results of radiographic evaluations. However, because some dogs with extreme DLS scores were intentionally selected for necropsy, this gross examination could not always be blinded.

Statistical analyses—The outcome variable was cartilage degeneration score at necropsy, because hip dysplasia has been associated with development of osteoarthritis. Because the outcome variable was ordinal and values for other variables (eg, percentage Greyhound or Labrador Retriever ancestry, age at necropsy) had asymmetric distributions, nonparametric methods were used for statistical analyses.

All analyses were done at the level of the individual dog. For each dog, the lower of the 2 DLS scores and the higher of the 2 cartilage degeneration scores were used, even if these scores were not for the same hip joint, because in our view, hip dysplasia is a bilateral and perhaps even systemic disease.

Simple associations between cartilage degeneration score and other variables were tested by use of the Spearman rank correlation method.¹⁵ This method was also used to test for correlations among DLS scores obtained at various ages. In addition, DLS scores were ranked as low (< 45%), intermediate (≥ 45 but $\leq 55\%$), or high (> 55%) on the basis of a priori cut points. Six 3×3 contingency tables were then created for pairwise comparisons of DLS scores obtained at 4, 8, and 12 months of age, and at the time of necropsy. The κ statistic was then calculated for each table to evaluate the measure of agreement among scores; a $\kappa < 0.40$ was considered indicative of poor agreement, and a $\kappa > 0.75$ was considered indicative of good agreement.¹⁶ Within-dog differences between DLS score at 8 months of age and DLS score at 4 months of age, between DLS score at 8 months of age and

DLS score at 12 months of age, between DLS score at 8 months of age and DLS score at the time of necropsy, and between DLS score at 12 months of age and DLS score at the time of necropsy were calculated, and 2-sided Wilcoxon sign rank tests were used to test, for each set of differences, the null hypothesis that the difference between scores was 0. For calculation of κ statistics and Wilcoxon signed rank tests, 2 dogs that were 8 months old at the time of necropsy were omitted. **Likelihood ratios (LR)** were calculated, using the formula: $LR = P(T+/D+)/P(T+/D-)$, where T+ was a positive test result, and D+ and D- were abnormal and normal cartilage, respectively. A LR > 1 indicates that a positive test result is more likely to be seen in a dog with abnormal cartilage than in a dog with normal cartilage.¹⁷ Likelihood ratios were calculated for DLS scores obtained at 4, 8, and 12 months of age and at the time of necropsy, using DLS score rankings (low, intermediate, and high) and cartilage degeneration scores (normal [score = 0] and osteoarthritic [score = 1 or 2]). The LR represents the odds that a particular DLS score ranking would come from a dog with evidence of osteoarthritis at necropsy versus a dog without any evidence of osteoarthritis at necropsy.

All statistical calculations were performed with standard software.^{b,c} For all analyses, values of $P < 0.05$ were considered significant.

Results

In 63 dogs, DLS score was measured only once; values for these dogs were, therefore, used only to calculate LR and were not used to determine repeatability of DLS scores. In the remaining 66 dogs, DLS score was measured more than once. In 45 of these dogs, DLS score was measured twice; in 19 of these dogs, DLS score was measured 3 times; and in 2 of these dogs, DLS score was measured 4 times (ie, at 4, 8, and 12 months of age and at the time of necropsy). In determining repeatability of DLS scores, we ignored the lack of independence among multiple pairwise comparisons.

Overall, 98 dogs were assigned a cartilage degeneration score of 0 at necropsy, 19 dogs were assigned a score of 1, and 12 were assigned a score of 2. Dogs were classified on the basis of percentage Greyhound ancestry (ie, 0 [purebred Labrador Retriever], 25, 50, 75, or 100% [purebred Greyhound]), and median percentage Greyhound ancestry was calculated for dogs grouped on the basis of cartilage degeneration score. Median percentage Greyhound ancestry was 50% (interquartile range, 0 to 50%; range, 0 to 100%) for dogs with a cartilage degeneration score of 0, 0% (interquartile range, 0 to 25%; range, 0 to 75%) for dogs with a cartilage degeneration score of 1, and 0% (interquartile range, 0 to 25%; range, 0 to 25%) for dogs with a cartilage degeneration score of 2. Thus, dogs with higher cartilage degeneration scores generally had lower percentages of Greyhound ancestry, and percentage Greyhound ancestry was significantly ($P < 0.001$) correlated with cartilage degeneration score ($r_s = -0.36$).

Similarly, dogs with higher cartilage degeneration scores were generally older than dogs with lower scores (age was unknown for 3 dogs). Median age at the time of necropsy was 9 months (interquartile range, 8 to 13 months; range, 8 to 36 months) for dogs with a cartilage degeneration score of 0, 15 months (interquartile range, 9 to 22 months; range, 8 to 28 months) for dogs with a cartilage degeneration score of

Table 1—Dorsolateral subluxation (DLS) scores obtained at various ages for 129 Labrador Retrievers, Greyhounds, and Labrador Retriever-Greyhound crossbreds

Age at which DLS score was measured	No. of dogs	DLS score (%)				
		Minimum	25th percentile	Median	75th percentile	Maximum
Dogs with cartilage degeneration score of 0*						
4 mo	27	57	62	67	71	81
8 mo	82	43	57	63	67	80
12 mo	8	56	58	62	63	64
Necropsy†	37	48	57	62	67	80
Dogs with cartilage degeneration score of 1						
4 mo	7	45	46	54	59	63
8 mo	15	28	40	44	59	78
12 mo	3	40	40	41	50	50
Necropsy	13	28	44	52	57	66
Dogs with cartilage degeneration score of 2						
4 mo	1	NA	NA	61	NA	NA
8 mo	9	30	32	40	47	52
12 mo	4	30	33	40	44	46
Necropsy	12	28	35	42	46	50

NA = Not applicable.
 *Cartilage degeneration scores were assigned at the time of necropsy. 0 = Gross appearance of the articular cartilage was normal; 1 = Articular cartilage contained an area of fibrillation or ulceration smaller than 0.5 × 1 cm; 2 = Articular cartilage contained an area of fibrillation or ulceration larger than 0.5 × 1 cm. †Dogs were euthanized at 8 to 36 months of age.

1, and 18 months (interquartile range, 15 to 18 months; range, 14 to 18 months) for dogs with a cartilage degeneration score of 2. Age at the time of necropsy was significantly ($P < 0.001$) correlated with cartilage degeneration score ($r_s = 0.36$).

In total, DLS score was measured at 4 months of age in 35 dogs, at 8 months of age in 106 dogs, at 12 months of age in 15 dogs, and at the time of necropsy in 62 dogs (scores were measured more than once in 66 dogs). Regardless of the age at which DLS score was measured, DLS score was generally higher for dogs with lower cartilage degeneration scores (Table 1), and DLS score was significantly associated with cartilage degeneration score ($r_s = -0.62$ for DLS score at 4 months versus cartilage score, -0.54 for DLS score at 8 months versus cartilage score, -0.87 for DLS score at 12 months versus cartilage score, and -0.72 for DLS score at the time of necropsy versus cartilage score; all $P < 0.001$). Of the 106 dogs in which DLS score was measured at 8 months of age, 82 had a cartilage score of 0, 15 had a cartilage score of 1, and 9 had a cartilage score of 2. Seventy-six of the 82 (93%) dogs with cartilage scores of 0 had DLS scores $\geq 45\%$, and 68 (83%) had scores $> 55\%$. In addition, 14 of the 24 (58%) dogs with cartilage scores of 1 or 2 had DLS scores $< 45\%$.

The DLS score was measured at 4 and 12 months of age in only 4 dogs, and DLS score was measured at 8 and 12 months of age in only 7 dogs. With these 2 exceptions, DLS scores obtained at various times were significantly correlated (Table 2), with correlation coefficients ≥ 0.56 , implying at least moderate repeatability of DLS scores over time. Median ages at the time of necropsy for dogs with low, intermediate, and high DLS scores at 8 months of age were 13 months ($n = 20$), 13 months (14) and 9 months (69), respectively.

Agreement among DLS scores at 4 months of age and scores obtained at other times was poor ($\kappa \leq 0.16$; Table 3). However, agreement among scores obtained at 8 months of age and scores obtained at 12 months of age or at the time of necropsy and among scores

Table 2—Spearman rank correlation coefficients (r_s) for DLS scores obtained at various ages in dogs

Ages at which DLS scores were measured	No. of dogs	r_s	P value
4 and 8 mo	35	0.69	< 0.001
4 and 12 mo	4	0.32	0.68
4 months and necropsy	16	0.56	0.02
8 and 12 mo	7	0.68	0.09
8 mo and necropsy	39	0.87	< 0.001
12 mo and necropsy	13	0.80	< 0.001

obtained at 12 months of age and scores obtained at the time of necropsy was moderate or good.

Within-dog differences between DLS scores obtained at various times ranged from -20 to 20% (Table 4). Inspection of the data did not reveal any clear patterns between cartilage degeneration score and within-dog difference in DLS score; therefore, cartilage score was not included in analyses of within-dog differences in DLS scores. The median difference between DLS scores obtained at 4 months of age and score obtained at 8 months of age was significantly ($P < 0.001$) less than 0, indicating that for dogs included in this study, DLS scores typically decreased between 4 and 8 months of age. Median differences for DLS scores at 8 months of age versus DLS scores at 12 months of age, for DLS score at 8 months of age versus DLS scores at the time of necropsy, and for DLS score at 12 months of age versus DLS score at the time of necropsy were not significantly ($P \geq 0.20$) different from 0, indicating that there were no significant changes in DLS score between 8 months of age, 12 months of age, and the time of necropsy.

Likelihood ratios for low ($< 45\%$), intermediate (45 to 55%), and high ($> 55\%$) DLS scores at 8 months of age were $14/24 \div 6/82 = 8.0$; $6/24 \div 8/82 = 2.6$; and $4/24 \div 68/82 = 0.2$, respectively. Thus, a low DLS score at 8 months of age (ie, a positive test result) was 8 times as likely to be from a dog with abnormal cartilage at necropsy as from a dog with normal cartilage at necropsy, whereas a high DLS score at 8 months of age

Table 3—Level of agreement (κ statistic) of DLS scores obtained at various ages in dogs and classified as low (< 45%), intermediate (≥ 45 but $\leq 55\%$), or high (> 55%)

Ages at which DLS scores were measured	No. of dogs	κ	SE	P value	Comments
4 and 8 mo	35	0.16	0.10	0.06	All 11 changes were to lower categories
4 and 12 mo	4	NA	NA	NA	The 1 change was to a lower category
4 mo and necropsy	16	0.33	0.16	0.02	All 3 changes were to lower categories
8 and 12 mo	7	0.42	0.16	0.004	Both changes were to lower categories
8 mo and necropsy	39	0.77	0.12	< 0.001	4 changes were to higher categories, and 1 was to a lower one
12 mo and necropsy	13	0.56	0.17	< 0.001	3 changes were to higher categories, and 1 was to a lower one

NA = Not applicable (κ statistic could not be calculated).

Table 4—Differences between DLS scores obtained at various ages in dogs

Ages at which DLS scores were measured	No. of dogs	Difference in DLS scores				
		Minimum	25th percentile	Median	75th percentile	Maximum
Dogs with cartilage degeneration score of 0*						
4 and 8 mo	27	-20	-11	-7	0	6
8 and 12 mo	5	-6	-5	2	3	4
8 mo and necropsy	20	-12	-3	0	4	20
12 mo and necropsy	6	-8	-8	-3	3	11
Dogs with cartilage degeneration score of 1						
4 and 8 mo	7	-19	-17	-9	-6	3
8 and 12 mo	1	NA	NA	-6	NA	NA
8 mo and necropsy	8	-12	-5	0	8	10
12 mo and necropsy	3	-4	NA	8	NA	9
Dogs with cartilage degeneration score of 2						
4 and 8 mo	1	NA	NA	-13	NA	NA
8 and 12 mo	1	NA	NA	-18	NA	NA
8 mo and necropsy	9	-5	-3	0	5	7
12 mo and necropsy	4	-5	-4	0	12	15

The DLS score obtained at the younger age was subtracted from the DLS score obtained at the older age; negative values indicate an increase in DLS score with age.
See Table 1 for key.

was only a fifth as likely to be from a dog with abnormal cartilage at necropsy as from a dog with normal cartilage at necropsy. The LR for the 4-month, 12-month, and necropsy DLS scores could not be calculated for all 3 DLS score categories, because some categories did not contain any dogs. However, the LR that could be calculated were of similar magnitudes to the corresponding LR for DLS scores at 8 months of age.

Discussion

Hip dysplasia in dogs leads to osteoarthritis. Thus, in the present study, we considered cartilage abnormalities at necropsy to be evidence of osteoarthritis and confirmation that dogs had hip dysplasia. Previous studies^{2,13,14,18} have defined the cartilage and connective tissue changes characteristic of osteoarthritis in the hip joints of dogs with dysplasia. The initial lesions develop in the perifoveal region, suggesting that abnormal forces result in stress in this area and lead to cartilage degeneration, bone remodeling, and pain. Computed tomographic images of dysplastic joints substantiate that the acetabulum impinges on the femoral head near the fovea.^{9,13}

In the present study, there was poor agreement

between DLS scores at 4 months of age and DLS scores at older ages. For example, the correlations between DLS scores at 4 months of age and DLS scores at 12 months of age and at the time of necropsy were only 0.32 and 0.56, respectively, and the agreement among scores, as indicated by the κ statistic, was poor. In addition, DLS scores decreased significantly between 4 and 8 months of age. Therefore, even though DLS scores were significantly correlated with cartilage degeneration scores, we suggest that DLS scores be measured clinically only after dogs are at least 8 months of age.

Dorsolateral subluxation scores obtained at 12 months of age had the highest correlation with cartilage degeneration scores ($r_s = -0.87$). However, 12 months of age may be rather late for owners making decisions about whether to neuter a particular dog or retain it as a potential breeding animal. In addition, this correlation was calculated on the basis of results for only 15 dogs. The correlation between DLS scores at 8 months of age and cartilage degeneration scores was also significant ($r_s = -0.54$), and this correlation was calculated on the basis of results for 106 dogs. The results suggest that DLS scores will not change significantly after 8 months of age, and 8 months of age may

be early enough to make decisions about which dogs to retain in many breeding programs.

Likelihood ratios for DLS score rankings at 8 months of age varied by a factor of 40. This large range in LR suggests that DLS scores obtained at 8 months of age may be clinically useful in differentiating dogs likely to develop osteoarthritis from dogs likely to not. In this study, we determined whether dogs had osteoarthritis on the basis of results of a macroscopic examination of the cartilage at the time of necropsy, which may not be the most sensitive measure, especially considering that half the dogs were euthanized before they were 13 months old, and severe lesions (score = 2) were not seen in dogs < 14 months old. However, cartilage lesions were identified at the time of necropsy in dogs as young as 8 and 9 months old.

The DLS score evaluates the chondro-osseous conformation of the hip joint in dogs. However, other factors, including time, amount of physical activity, and genotype, are likely involved in the progression from hip joint instability to overt osteoarthritis in dogs with hip dysplasia. Also, our data were based on results for only 2 breeds and their crossbred offspring. Long-term studies involving multiple breeds of dogs are needed to confirm or deny whether DLS scores obtained at 8 months of age can be used to predict which dogs will eventually develop clinical signs of hip dysplasia. However, DLS scores obtained at 8 months of age appear to be fairly stable over time in individual dogs and seem to be associated with a wide range of LR when ranked as high, intermediate, or low.

*Todhunter RJ, Farese J, Bertram J, et al. External effects on DLS hip score in dogs (abstr). *Vet Surg* 2000;29:476.

^bStatistix for Windows, version 2, Analytic Software, Tallahassee, Fla.

^cEpi Info 6, version 6.04b, Centers for Disease Control and Prevention, Atlanta, Ga.

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