SMALL ANIMALS

Associations among exercise duration, lameness severity, and hip joint range of motion in Labrador Retrievers with hip dysplasia

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Objective—To evaluate factors associated with lameness severity and hip joint range of motion in dogs with hip dysplasia and to assess the association between hip joint range of motion and degree of lameness.

Design—Prospective case series.

Animals—60 client-owned Labrador Retrievers with hip dysplasia.

Procedures—Owners completed a questionnaire regarding their dogs' daily exercise duration and type (ie, low impact vs high impact) and lifestyle. Range of motion of affected hip joints was measured with a transparent plastic goniometer. The presence of subluxation or luxation of hip joints as a consequence of hip dysplasia and the size of the largest osteophytes or enthesophytes of hip joints on ventrodorsal radiographic images of the pelvis were recorded. Multivariate analyses were performed to identify factors associated with lameness, loss of hip joint flexion, and loss of hip joint extension and to identify factors associated with the presence of large osteophytes.

Results—Exercise was associated with a decrease in the severity of lameness in dogs with hip dysplasia. The strength of this inverse relationship increased with longer exercise duration. Lameness was more severe in dogs with hip joint luxation than in dogs without luxation. Hip joint extension was 1° lower for each year of age, and osteophyte or enthesophyte size was 1 mm larger with each 3-year increase in age.

Conclusions and Clinical Relevance—Longer daily exercise duration was associated with lower lameness scores in dogs with hip dysplasia. Dogs with hip joint luxation secondary to hip dysplasia had higher lameness scores than did dogs without hip joint luxation. (*J Am Vet Med Assoc* 2013;242:1528–1533)

Osteoarthritis is the most common orthopedic disease in humans and dogs.[1–3] In humans, osteoarthritis leads to the formation of larger osteophytes and decreases joint ROM more than other diseases that result in joint pain, such as rheumatoid arthritis or other immune-mediated arthropathies.[4] Decreased joint ROM in humans with osteoarthritis leads to increased levels of disability and physical limitations.[5–7] Ranges of motion of the hip joint and knee are linked to demographic, clinical, and articular factors in humans, including age, gender, body mass index, features of joint degeneration, pain, and stiffness.[8,9] In dogs, little is known about potential changes in joint ROM secondary to orthopedic diseases or about the impact of these potential changes on limb function. The association of sex, training, and stifle joint ROM with passive hip joint ROM in racing Greyhounds was evaluated in 1 study.[10] The ROM of osteoarthritic joints of a small group of Labrador Retrievers was reported in another study.[11]

The purpose of the study reported here was to evaluate factors associated with lameness and hip joint ROM in dogs with CHD and to assess the association between ROM and degree of lameness in these dogs. It was hypothesized that longer durations of daily exercise would be associated with a lower degree of lameness, a loss of hip joint extension would be associated with a higher degree of lameness, and large osteophytes or enthesophytes and shorter durations of daily exercise would be associated with less hip joint extension. To test these hypotheses, a prospective clinical assessment was conducted in Labrador Retrievers referred to the teaching hospital for the management of osteoarthritis of the hip joint.

Abbreviations	
CHD	Canine hip dysplasia
ROM	Range of motion

Materials and Methods

Study design—Labrador Retrievers referred to the orthopedic service at the North Carolina State University Veterinary Teaching Hospital between 2001 and 2011 with clinical or radiological evidence of osteoarthritis of 1 or both hip joints were candidates for inclusion in the study. Inclusion criteria included a pain response to hip joint extension or radiographic evidence of CHD (including hip joint subluxation, hip joint luxation,

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or the presence of osteophytes). Exclusion criteria included previous surgery involving the hip joint, having a disease other than CHD in the affected pelvic limb, and having incomplete data. This study was approved by the institutional animal care and use committee, and clients provided informed consent.

Data collection—A single investigator (DJM) collected data. Dogs underwent a physical examination and gait evaluation. Owners of eligible dogs were surveyed about their dogs' exercise habits, sleeping location, severity and duration of disability, current medications, and nutritional supplements. Data were recorded on a standardized form.

Dogs were sedated, and goniometric measurements of each hip joint were made in triplicate with a 15-cm-long (6-inch-long) transparent plastic goniometer (**Figure 1**).[12] The median value of the 3 goniometric measurements was used for analysis. Ventrodorsal radiographic views of the pelvis obtained by the referring veterinarian were observed. If previous radiographs were unavailable or were obtained > 4 weeks earlier, new radiographs were obtained while dogs were under sedation. On a ventrodorsal radiographic image of the pelvis with the hip joints in extension, the size of the largest osteophyte or enthesophyte visible on the cranial aspect of the acetabulum or at the base of the femoral neck at the isthmus between the femoral neck and greater trochanter was measured and recorded. For these measurements, digital radiographs were calibrated with a magnification marker; a magnification of 9% was assumed on printed radiographs. On the same radiographic image, subluxation was defined as the presence of an increased joint space between the acetabulum and the femoral head, and luxation was defined as the absence of overlap between the femoral head and acetabulum.

Data classification—Dog beds were classified as soft (> 5-cm thick) or hard (≤ 5-cm thick). Dogs were classified as residing indoors, indoors and outdoors, or outdoors on the basis of their living and sleeping habits. Body condition score was evaluated on the basis of a 9-point scale.[13] Type of daily exercise was classified as low impact if it included leash walks or swimming and as high impact if it included retrieving, playing with other dogs, running or jogging, hunting, or field trial. If the patient engaged in both high- and low-impact activities, the overall classification remained high impact. Duration of daily exercise was grouped into 3 categories: 0 to 20 minutes, 20 to 60 minutes, or > 60 minutes. Affected limb lameness was graded as none (score, 1), mild (2), moderate (3), or severe (4), as described in another study.[14]

Statistical analysis—Mean values of hip joint flexion, hip joint extension, and lameness scores were compared between dogs not receiving medication or supplementation and dogs receiving an NSAID or prednisone. Comparisons were made via *t* tests when data were normally distributed or Wilcoxon signed rank tests when data were not normally distributed. Normality of distribution was checked via a Shapiro-Wilk test. For descriptive statistics, data from the left and right hip joints in bilaterally affected dogs were considered independent. Data from dogs receiving injectable polysulfated glycosaminoglycans or oral nutraceutical supplements were not included in this statistical analysis because the numbers of dogs receiving polysulfated glycosaminoglycan injections or specific oral nutraceuti-

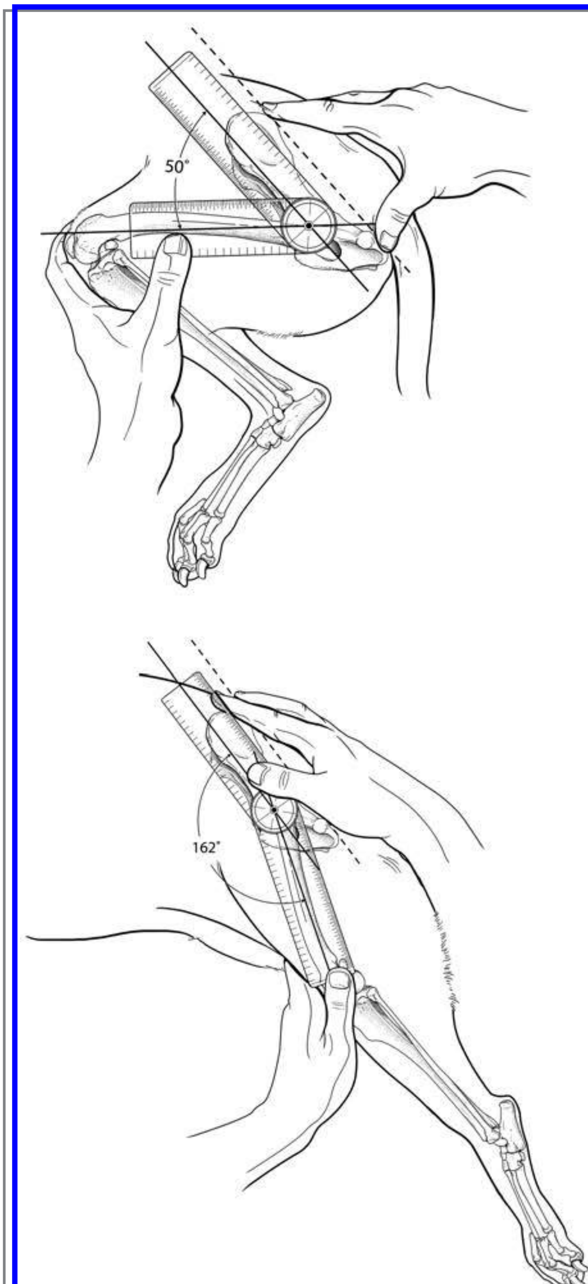

Figure 1—Hip joint flexion (top) and extension (bottom) measured with a transparent plastic goniometer. One arm of the goniometer is held parallel to the line joining the tuber sacrale and the dorsal and lateral aspect of the tuber ischiadicum. The center of the goniometer is placed approximately 10 mm cranial and distal to the greater trochanter. The other arm of the goniometer is aimed at a point equidistant to the patella and the lateral fabella. The flexion and extension angles in the illustrations were the mean flexion (50°) and mean extension (162°) angles from 12 healthy Labrador Retrievers enrolled in a previous study.[12] (Reprinted with permission from *Clinical instructions for use of your goniometer* [pamphlet]. Duluth, Ga: Merial Ltd)

cal supplements were deemed too small for meaningful statistical analyses.

Linear regression models were developed to determine whether age, body weight, body condition score, exercise duration, exercise type (low-impact exercise vs high-impact exercise), severity of osteoarthritis (measured as size of the osteophytes in millimeters), hip joint side, duration of lameness, and presence of hip joint subluxation or luxation were associated with lameness score, hip joint extension value, and hip joint flexion value.[15,a] A similar analysis was performed to identify factors that were associated with the size of osteophytes or enthesophytes. Factors significantly associated with the outcomes of interest were identified via 2-stage analyses involving univariate analysis, followed by multivariate analysis. First, potentially significant ($P < 0.15$) factors were identified with F tests. Then, all models combining these potentially significant variables were built, and models with the smallest Akaike information criterion were selected. For these analyses, hip joints from dogs with bilateral CHD were considered as correlated observations and hip joints from different dogs were considered as independent observations. Bed types and environment were excluded from statistical analyses because there were too few dogs sleeping on hard beds or living in an indoor-outdoor combination or outdoors. Medications and nutritional supplementation were excluded from statistical analyses because of their heterogeneity. Regression analysis was used to assess the association between hip joint extension and lameness score, hip joint flexion and lameness score, and hip joint extension and flexion. Values of $P < 0.05$ were considered significant.

Results

Sixty-one Labrador Retrievers were originally eligible for inclusion in the study. One dog was subsequently excluded because of lack of goniometric measurements. Of the 60 dogs included, 8 had data from 1 hip joint excluded for the following reasons: total hip joint replacement (n = 6), hip joint surrounded by a large lipoma (1), or lack of pain response to palpation as well as lack of radiographic signs of CHD (1). Therefore, data from 112 dysplastic hip joints from 60 dogs were included in the study (8 dogs had data from 1 hip joint included, and 52 dogs had data from 2 hip joints included).

Mean ± SD age of the 60 dogs was 4.2 ± 4.0 years (median, 2.1 years; range, 4 months to 14.8 years). There were 27 neutered females, 22 neutered males, and 11 sexually intact males. Dogs had a mean ± SD body weight of 34.6 ± 7.8 kg (76.1 ± 17.2 lb; range, 7.8 to 60 kg [17.2 to 132 lb]) and a median body condition score of 5 (range, 3 to 9; first quartile, 5; third quartile, 6).

Of the 60 dogs, 11 slept on hard surfaces and 49 dogs slept on soft surfaces. Fifty dogs were kept indoors, 3 dogs were kept indoors and outdoors, and 7 dogs were kept outdoors. Seven dogs included in the study exercised < 20 min/d, 20 dogs exercised 20 to 60 min/d, and 33 dogs exercised > 60 min/d. Twelve dogs engaged in exercise limited to low-impact activities, and 48 dogs engaged in high-impact activities.

No lameness was observed in 52 limbs, mild lameness was observed in 53 limbs, moderate lameness was observed in 1 limb, and severe lameness was observed in 6 limbs. The median duration of lameness was 2 months (range, 0 to 74 months; first quartile, 0 months; third quartile, 7 months). Mean hip joint extension was 156 ± 10° (range, 124° to 171°). Mean hip joint flexion was 39 ± 5° (range, 25° to 51°). Mean osteophyte or enthesophyte size was 3 ± 3 mm (range, 0 to 13 mm). Mean difference in osteophyte or enthesophyte size between hip joints within dogs was 1 ± 2 mm (median difference, 0 mm; range, 0 to 7 mm). Of 112 hip joints, 33 were neither subluxated nor luxated, 70 were subluxated, and 9 were luxated.

Nineteen dogs did not receive medications or supplements to manage their osteoarthritis, 22 were treated with an NSAID (6 different NSAIDs were given; 1 dog was also given an injectable polysulfated glycosaminoglycan, and 4 received oral administration of a nutraceutical supplement), 2 were treated with prednisone (1 dog also received oral administration of a nutraceutical supplement), 1 was treated with an injectable polysulfated glycosaminoglycan only, and 16 received oral administration of a nutraceutical supplement only (7 different nutraceutical supplements were given). Hip joint flexion data were normally distributed. Hip joint extension and lameness data were not normally distributed. The mean ± SD hip joint flexion did not significantly ($P = 0.698$) differ between dogs not receiving medication or supplementation (38 ± 4°) and dogs receiving an anti-inflammatory (38 ± 5°). The mean hip joint extension did not significantly ($P = 0.787$) differ between dogs not receiving medication or supplementation (155 ± 11°) and dogs receiving anti-inflammatory medications (157 ± 8°). The mean lameness score did not differ significantly ($P = 0.890$) between dogs not receiving medication or supplementation (1.7 ± 0.8) and dogs receiving anti-inflammatory medications (1.8 ± 0.8).

Univariate analysis resulted in identification of 3 factors that potentially were associated with the degree of lameness and 4 factors that potentially were associated with hip joint extension and hip joint flexion. Multivariate analysis findings confirmed that exercise duration ($P = 0.022$) and the presence of hip joint luxation ($P = 0.022$) were significantly associated with lameness scores. Mean ± SD lameness scores were lower for dogs exercising 20 to 60 min/d (1.9 ± 0.8) than for dogs exercising < 20 min/d (2.1 ± 1.0), and mean lameness scores were lower for dogs exercising > 60 min/d (1.5 ± 0.6) than for dogs exercising 20 to 60 min/d. A decrease in mean lameness score was present in dogs exercising > 60 min/d, compared with dogs exercising < 20 min/d. The type of exercise (low impact vs high impact) was not associated with lameness score. The mean lameness score of affected limbs was higher for subluxated hip joints (1.6 ± 0.7) than for hip joints without subluxation (1.5 ± 0.7) and was higher for luxated hip joints (2.3 ± 1.0) than for subluxated hip joints. Multivariate analysis confirmed that age ($P = 0.002$) and body weight ($P = 0.008$) were significantly associated with hip joint extension **(Figures 2 and 3)**. Univariate analysis identified 4 factors that were potentially associated with the size of osteophytes or enthesophytes. Multivariate analysis confirmed that age ($P < 0.001$) and the presence of hip joint luxation ($P = 0.010$) were significantly associated with the size of osteophytes or enthesophytes. The model indicated that osteophytes or enthesophytes were approximately 1 mm larger with each 3-year increase in age. An increase in lameness score was significantly ($P = 0.003$) associated with a decrease in hip joint extension (**Figure 4**). The model indicated that a 50° loss of hip joint extension would lead to a 1-grade increase in lameness score. Approximately 1° of hip joint extension/y was lost. A significant association between lameness score and hip joint flexion was not identified.

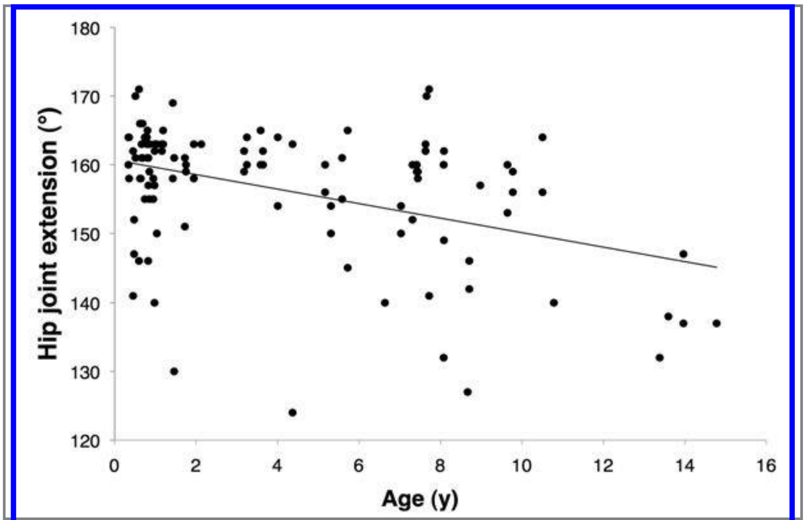

Figure 2—Scatterplot of hip joint extension of 112 joints versus age for 60 dogs with hip dysplasia. There is an approximate yearly loss of 1° of extension. The solid line represents the linear trendline.

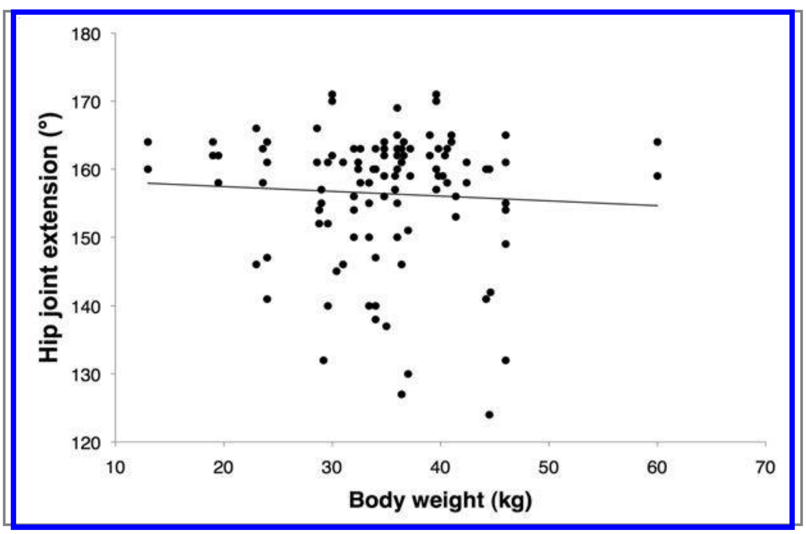

Figure 3—Scatterplot of hip joint extension of 112 joints versus body weight for 60 dogs with hip dysplasia. There is a loss of hip joint extension with an increase in body weight. The solid line represents the linear trendline.

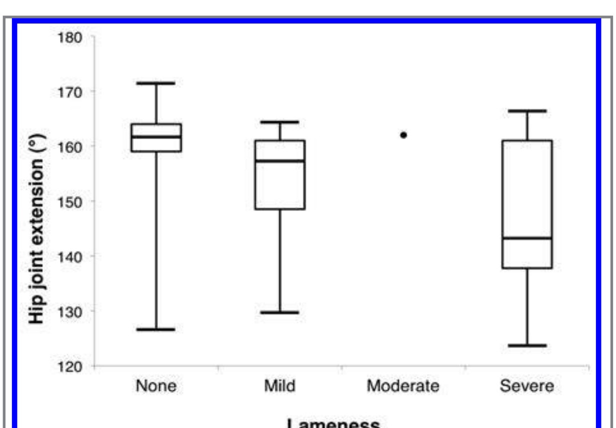

Figure 4—Box-and-whiskers plot of hip joint extension in 112 hip joints of 60 dogs with hip dysplasia without limb lameness (52 joints) and with mild (53), moderate (1), or severe (6) lameness in the affected limb. Median hip joint extension is 162°, 157°, and 143° for no lameness (none), mild lameness, and severe lameness, respectively. Boxes indicate the 25th to 75th percentiles; horizontal lines within each box indicate the median value. Whiskers represent the smallest and largest values. Dot represents single data point.

Discussion

The objective of the study reported here was to evaluate the associations among exercise duration and type, hip joint ROM, hip joint subluxation, and lameness in a homogenous group of dogs with hip joint osteoarthritis. Labrador Retrievers were selected for the present study because they are the most common dog breed and because their hip joint angles were described in a study[12] that validated goniometry. A single investigator performed all measurements to minimize variability. The study reported here covered a long period because of stringent enrollment criteria and because active efforts were not made to recruit and enroll subjects.

In the present study, a significantly lower mean lameness score was found for dogs with > 60 minutes of daily exercise, compared with that for dogs with < 20 minutes of daily exercise. This finding may be in agreement with the conventional wisdom that arthritic dogs with active lifestyles have fewer signs of lameness than do sedentary arthritic dogs. Although an inverse association was found between exercise duration per day and lameness score, it is not known whether more exercise resulted in lower lameness scores or whether high lameness scores resulted in less exercise in this population of dogs with CHD. In humans, osteoarthritis of the knee has been shown to be associated with a decrease in objectively measured exercise.[16] However, increasing exercise has been shown to decrease pain and improve joint function in human patients with osteoarthritis of the hip joint.[17] Evidence-based guidelines for patients with osteoarthritis of the hip joint and knee recommend aerobic, muscle-strengthening, and water-based exercises.[18] The findings of the study reported here indicate that high-impact exercises are as beneficial as low-impact exercises in dogs with CHD. Similarly, for 39 people with osteoarthritis of the knee, high-intensity exercises, defined as exercises performed with a heart rate at 70% of heart rate reserve, were as beneficial as low-intensity exercises performed at 40% of heart rate reserve.[19] These limited findings highlight the need to further investigate the relative benefits of low-intensity and high-intensity exercises in dogs and people with osteoarthritis.[20] The duration and type of exercise of dogs enrolled in the present study were determined by an owner questionnaire. The use of activity monitors would have increased the precision of these data and validated responses on the owners' questionnaire. Activity monitors have been used to assess the amount of exercise in dogs with osteoarthritis.[21] In humans, objective devices more appropriately rank physical exercise than do questionnaires.[22] Also, the results of the present study may have been affected by the presence of orthopedic problems in the forelimbs.

Dogs with hip joint luxation secondary to CHD had much higher lameness scores than did dogs without luxation or with subluxation in the present study. This suggests that hip joint luxation secondary to CHD may be more debilitating than is conventionally thought and that management guidelines may need to differ for dogs with osteoarthritis of the hip joint with and without luxation. A significant relationship was not identified between being overweight and having a high lameness score. This finding may not be extrapolated to the general population of dogs because it may have been biased by the fact that data were collected from a group of dogs that were referred for management of their clinical signs of CHD. Dogs with CHD that lacked clinical signs of CHD and without a radiographic diagnosis of CHD would not have been enrolled in the present study. The present study was not designed to assess whether dogs that are of optimal body weight are less likely to have clinical signs of CHD than dogs that are overweight; therefore, it cannot be ascertained whether, in the general population of dogs, being overweight increases the likelihood of detecting CHD in dogs and increases clinical signs of CHD. Although little is known about the relationship of obesity and fitness in dogs, it is known that osteoarthritis progresses more rapidly in overweight dogs with CHD, compared with siblings at optimal weight.[23] In a small clinical study[24] involving 9 dogs with CHD, the severity of lameness decreased when overweight dogs lost weight. In another clinical study[25] involving 14 dogs with osteoarthritis of the hip or elbow joint, a decrease in the degree of lameness assessed by means of force plate analysis was observed after a mean weight loss of 8.85%. This is in agreement with evidence-based findings in humans.[18] In the present study, a significant relationship was not found between osteophyte or enthesophyte size and lameness score. This suggests that the presence and size of osteophytes or enthesophytes are not key determinants of the degree of lameness in dogs with CHD. This is in agreement with a previous study[26] that identified a low correlation between osteophytes present in the stifle joint and the degree of pelvic limb lameness in 41 dogs.

In the present study, hip joint extension and flexion were assessed and evaluated in relation to lameness scores. Hip joint extension decreased in older dogs, compared with younger dogs, and in heavier dogs, compared with lighter dogs. These differences were small (10° decrease in extension for a 10-year increase in age) and most likely have limited clinical importance. Dogs with severe lameness, however, had a relatively large loss of hip joint extension (median extension was 16° lower for dogs with severe lameness, compared with mild lameness). These findings indicate that a loss of hip joint extension could be used as a predictor for the presence of osteoarthritis in dogs, as it is done in humans.[27] Factors beyond aging may be responsible for the severe loss of extension present in some hip joints of dogs with CHD. However, little is known overall about factors influencing joint ROM in dogs with osteoarthritis. Because association does not mean causation, a conclusion cannot be made as to whether a loss of hip joint extension precedes, parallels, or follows the development of pelvic limb lameness in dogs. In the present study, a significant association between lack of hip joint extension and the presence of hip joint luxation was not identified. This suggests that the loss of hip joint extension occurs through a mechanism that is not directly related to the presence of hip joint luxation. This mechanism is not known but could be linked to an increase in joint capsule thickness. Pain, morning stiffness, sex (male), a higher body mass index, osteophytosis, and an increase in thickness of the femoral neck (femoral buttressing) have been associated with a decreased ROM of hip joints in humans with early osteoarthritis.[8] A better knowledge of factors leading to large losses in hip joint extension in dogs with CHD would improve the management of this subset of dogs. In the present study, the duration of daily exercise and osteophyte or enthesophyte size were not significantly associated with loss of hip joint extension.

Factors associated with a loss of flexion in dogs of the present study were not identified. Hip joint flexion may decrease in dogs with osteoarthritis because of periarticular fibrosis. In contrast, hip joint flexion could increase in dogs with osteoarthritis as a result of a loss in quadriceps and gluteal muscle mass. The contact between the quadriceps and the gluteal muscle groups may be one of the limiting factors to hip joint flexion. This form of contact is named soft-tissue approximation end feel.[28]

Osteophyte or enthesophyte size was larger in older dogs and in dogs of the present study with hip joint luxation secondary to CHD. Overall, the rate of osteophyte or enthesophyte growth, as determined from the statistical model, was slow (1 mm every 3 years). The mechanism of growth of osteophytes is not clearly understood. Osteophyte initiation and growth are possibly due to the stimulation of cells at the chondrosynovial junction by polysaccharides derived from degradation of articular cartilage.[29] It could also be the consequence of mechanical instability.[30] In a short-term study[31] of experimentally induced osteoarthritis in guinea pigs, osteophyte production was stimulated by exercise. A significant relationship between the duration of daily exercise and osteophyte or enthesophyte size was not identified in the study reported here.

Interestingly, 105 of 112 hind limbs evaluated for lameness in the present study had either no visible signs of lameness or only mild signs of lameness. These findings could represent an underestimation of the lameness present in the dogs because lameness, when judged visually, may not be accurately assessed unless lameness is severe.[32] Nevertheless, these results suggest that Labrador Retrievers with CHD can walk with discreet signs of lameness when CHD is managed conservatively. This is in agreement with 1 study[33] in which 38 of 50 (76%) conservatively managed dogs with CHD were reported to have no gait abnormalities or a slight or intermittent lameness. The conservative management of CHD involves medical and nonmedical treatments.[34] Some dogs enrolled in the present study were receiving oral or injectable medications and nutritional supplements aimed at alleviating the pain resulting from CHD. A difference in lameness score, hip joint flexion, and hip joint extension was not found between dogs receiving anti-inflammatory medications (NSAID or prednisone) and dogs not receiving medication. Eight medications and 7 nutraceutical supplements were given. Also, administration regimens differed widely between treated and untreated dogs. Because of that heterogeneity, specific medication protocols were excluded from multivariate statistical analyses. The efficacy of specific long-term medical treatments on exercise, degree of lameness, and hip joint ROM should be evaluated in prospective trials. Exercise patterns recorded for dogs of the present study may not have reflected their exercise patterns over a lifetime because most owners were aware of the presence of CHD and osteoarthritis and they may have modified their dogs' exercise either as a spontaneous response or in response to the advice of a caregiver.

a. SAS, version 9.2, SAS Institute Inc, Cary, NC.

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