Evaluation of a circumferential femoral head osteophyte as an early indicator of osteoarthritis characteristic of canine hip dysplasia in dogs

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Objective—To determine the relationship between a circumferential femoral head osteophyte (CFHO) and osteoarthritis characteristic of canine hip dysplasia, and to ascertain whether CFHO, like osteoarthritis, varies between diet-restricted and control-fed dogs.

Design—Longitudinal cohort study.

Animals—48 Labrador Retrievers.

Procedures—Dogs were paired by size, sex, and litter and assigned to 1 of 2 equal groups at 2 months of age. The control-fed group was fed ad libitum, and the diet-restricted group was fed 25% less on a pairwise basis of the same diet for life. The dogs' hip joints were radiographed yearly for life. Each radiograph was evaluated for radiographic signs of osteoarthritis characteristic of hip dysplasia and for the presence and severity of a CFHO.

Results—41 of the 48 (85.4%) dogs had a CFHO, which was detected at a median age of 5.4 years, and 33 of those 41 (80.5%) developed radiographic evidence of osteoarthritis. Nineteen (79.2%) dogs in the diet-restricted group and 22 (91.7%) in the control-fed group had a CFHO at a median age of 9 and 3 years, respectively. Of the dogs with a CFHO, 12 (63.2%) in the diet-restricted group and 20 (90.0%) in the control-fed group developed radiographic evidence of osteoarthritis characteristic of hip dysplasia at a median age of 11 and 6.5 years, respectively.

Conclusions and Clinical Relevance—Results indicated a relationship between the CFHO and subsequent development of radiographic signs of osteoarthritis. If a CFHO is present in Labrador Retrievers, it might be considered an early indicator of osteoarthritis. (*J Am Vet Med Assoc* 2007;231:889–892)

Canine hip dysplasia is a complex, quantitatively inherited disease of the hip joint that is characterized by various degrees of joint laxity, multiple biomechanical environmental factors that suggest gene-environment interactions, and osteoarthritis of differing severity and age of onset.[1-5] Definitive radiographic signs of hip joint osteoarthritis include femoral periarticular osteophyte formation, subchondral sclerosis of the craniodorsal margin of the acetabulum, osteophyte formation on the cranial or caudal acetabular margin, and bone remodeling.[1] Unfortunately, these changes may not be present radiographically until months to years after an individual dog has entered the breeding pool.[6]

Veterinarians and breeders presently rely on the accuracy of screening for CHD and osteoarthritis by 2 years of age to identify potential breeding candidates. However, a previous study[5] indicated that the standard screening method is subject to diagnostic inaccuracy.

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Presented in part in abstract form at the 30th Annual Conference of the Veterinary Orthopedic Society, Steamboat Springs, Colo, March 2003.
Research sponsored by and conducted at Nestle Purina Co, St Louis, Mo.

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Abbreviations

CHD	Canine hip dysplasia
CFHO	Circumferential femoral head osteophyte
CI	Confidence interval
CCO	Caudolateral curvilinear osteophyte

Determining susceptibility to CHD and hip osteoarthritis in young dogs at the earliest possible stage clearly is desirable for instituting preventive programs such as diet restriction to delay the onset and slow the progression of osteoarthritis in individual dogs.[4,6-8]

The CFHO radiographically appears as a radiopaque line that encircles the junction of the femoral neck and head at the region of the attachment of the joint capsule. The purpose of the study reported here was to determine the relationship between the CFHO and osteoarthritis associated with CHD and to ascertain whether CFHO, like osteoarthritis, varies between diet-restricted and control-fed dogs.

Materials and Methods

Dogs and housing—Forty-eight Labrador Retrievers from 7 litters were allotted to a lifelong paired-feeding study.[5-7] The dogs were paired at 6 weeks of age by sex and body weight within litter and assigned randomly to either control feeding or 25% diet restriction. All dogs

were housed in 2 × 19-m indoor-outdoor kennel runs with concrete floors. Free indoor-outdoor access was available, and activity was not restricted. All dogs were housed under the same environmental conditions for life, with no difference between feeding groups except for amount of food intake. Pen assignment was maintained for life by original pairing, with either 2 (1 pair) or 4 (2 pairs) dogs/pen. However, each dog was fed separately so that daily food intake could be measured.

Diets and feeding regimens—Control-fed and diet-restricted dogs ate the same dry, extruded diet.[4-6] From 8 weeks of age, each diet-restricted pairmate was fed a quantity equal to 75% of the amount of food that was consumed on the previous day by the respective control-fed counterpart. When the dogs were 3.25 years old, 2 adjustments were incorporated into the feeding protocol to prevent insidious development of obesity among all the dogs; the diet was switched from a 27% protein puppy growth formula to a 21% protein adult formula, and the amount of food given to control-fed dogs was 62.1 kcal of metabolizable energy/kg of ideal body weight. Diet-restricted pairmates continued to receive 75% of the food consumed by their corresponding control-fed pairmates.

Radiography—During general anesthesia, each dog was evaluated by use of ventrodorsal hip-extended radiography at 16, 30, and 52 weeks of age and then annually for life. Hip joint osteoarthritis was scored, as described in a previous study[4] using the same cohort, by a board certified radiologist (DNB) who was unaware of group assignments. Left and right hip joints were scored independently for the presence of sclerosis of the craniodorsal portion of acetabular subchondral bone, osteophytes on the cranial and caudal aspects of the acetabular margin, and femoral periarticular osteophytes, all of which were considered definitive radiographic evidence of osteoarthritis. Radiographs then were scored for the presence of the CFHO; grade 1 CFHO was defined as a thin, radiographically faint line at the junction of the femoral head and neck, grade 2 was defined as a thicker and more easily visible radiographic line at the same location, and grade 3 was defined as a thick radiopaque line that may have indistinct margins (**Figure 1**).

Statistical analysis—The Kaplan-Meier product limit method was used to estimate the proportion of dogs that did or did not develop a CFHO or osteoarthritis in each diet group. Statistical differences in the development of CFHO or osteoarthritis between diet groups were assessed by use of the log-rank test. To determine whether early radiographic presence of a CFHO can be interpreted as a risk factor for eventual development of osteoarthritis, the Fisher exact test was used when examining each diet group separately and the Mantel-Haenszel summary χ^2 test was used to give a weighted average when pooling the diets. Data are presented as median time to the development of CFHO or osteoarthritis and as frequencies and percentages for radiographic evidence of CFHO or osteoarthritis. Where applicable, data are presented as relative risk with 95% CIs. Differences were considered significant at $P < 0.05$. All analyses were performed with statistical software.[a]

Results

Forty-one of the 48 (85.4%) dogs had a CFHO, which was evident at a median age of 5.4 years. At the time of first diagnosis of CFHO, 35 dogs were assigned grade 1, 5 dogs were assigned grade 2, and 1 dog was assigned grade 3.

Of the 41 dogs that developed a CFHO, 33 (80.5%) developed definitive radiographic evidence of osteoarthritis and 8 did not. In 23 of these 33 (70%) dogs, CFHO was the first radiographic sign of hip joint osteoarthritis In the remaining 10 dogs, a CFHO was detected at the same time as the first definitive radiographic evidence of osteoarthritis was detected. At time of first diagnosis of radiographic osteoarthritis, 15 of the 33 dogs had grade 1 CFHO, 17 had grade 2, and 1 had grade 3. By the end of life, no dogs had grade 1 CFHO, 11 had grade 2, and 21 had grade 3. None of the 7 dogs that did not develop a CFHO during their lifetimes developed any radiographic evidence of hip joint osteoarthritis ($P < 0.001$). The sensitivity of a CFHO for eventual development of osteoarthritis was 100%, and the specificity was 46.7%. The positive predictive value was 80.5%, and negative predictive value was 100%.

Nineteen (79.2%) dogs in the diet-restricted group and 22 (91.7%) dogs in the control-fed group developed a CFHO. Median age at first CFHO identification was significantly ($P = 0.003$) later among the diet-restricted group (9 years), compared with the control-fed group (3 years; **Figure 2**). Of dogs with a CFHO, 12 of the 19

Figure 1—Ventrodorsal hip-extended radiographic views of the right hip joint of a Labrador Retriever indicating onset and progression of a CFHO (arrows) at various ages. From left to right, first radiographic view reveals no CFHO (4 years old), second radiographic view reveals a grade 1 CFHO (6 years old), third radiographic view reveals a grade 2 CFHO and osteoarthritis around the dorsal aspect of the femoral head and neck (8 years old), and fourth radiographic view reveals a grade 3 CFHO and osteoarthritis on the dorsal acetabular rim and dorsal and ventral aspects of the femoral head and neck (11 years old).

(63.2%) dogs in the diet-restricted group and 20 of the 22 (90.9%) dogs in the control-fed group eventually developed radiographic evidence of hip joint osteoarthritis. For reference, median age of diagnosis of osteoarthritis was 11.0 years in the diet-restricted group and 6.5 years in the control-fed group ($P < 0.001$; **Figure 3**).[6]

In the pooled sample of dogs, those dogs that had a CFHO at 2 years of age versus those that did not were 2.1 times as likely to develop further radiographic signs of osteoarthritis by the end of their lives (95% CI, 1.5 to 3.3; $P < 0.001$). In the control-fed group, dogs that had a CFHO at 2 years of age (median life span, 11.2 years) were 1.5 times as likely to develop further radiographic signs of osteoarthritis during their lifetimes, compared with those without a CFHO (95% CI, 1.0 to 2.9; $P = 0.09$), whereas dogs in the diet-restricted group (median life span, 13.0 years) were 2.7 times as likely to develop further radiographic signs of osteoarthritis during their lifetimes, compared with those without a CFHO (95% CI, 1.2 to 6.1; $P = 0.03$).

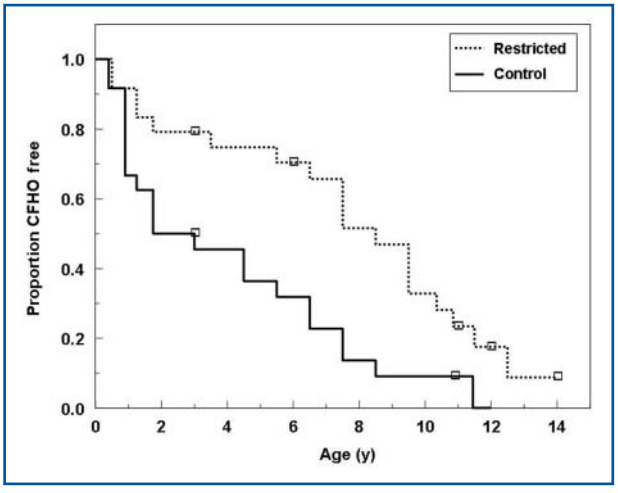

Figure 2—Kaplan-Meier curves of the percentage of dogs that developed a CFHO throughout their lifetimes. Restricted = Restricted-fed group. Control = Control-fed group. Notice that at time 0 (16 weeks of age), none of the dogs had a CFHO.

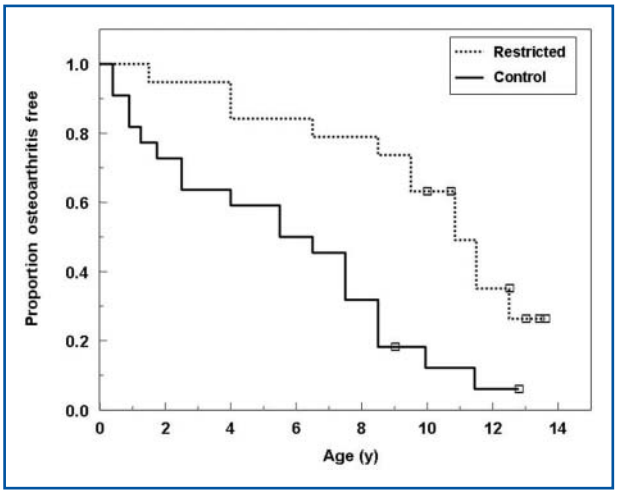

Figure 3—Kaplan-Meier curves of the proportion of dogs with a CFHO that eventually developed radiographic evidence of osteoarthritis during their lifetimes. Notice that at time 0 (16 weeks of age), none of the dogs had osteoarthritis. *See* Figure 2 for key.

Discussion

To the authors' knowledge, the pathogenesis of the CFHO is unknown. Previous research indicates that joint laxity and resultant loss of articular cartilage stimulate bony remodeling of the hip joint.[9] Observations of another possible early radiographic marker of CHD, the CCO, which has been associated with development of osteoarthritis, suggest that its pathogenesis involves osteophyte formation along the insertion lines of the joint capsule at the dorsocaudal aspect of the femoral neck.[10-12] In a previous study[12] on the same cohort of Labrador Retrievers, 20 dogs in the diet-restricted group developed a CCO at a median age of 1.5 years (mean, 4.0 years) and 11 then developed further evidence of osteoarthritis. In the control-fed group, 18 dogs developed a CCO at a median age of 0.8 years (mean, 2.3 years) and all 18 then developed further evidence of osteoarthritis.[12] Thus, approximate ages at first recognition of the CCO and the CFHO were similar among control-fed dogs, but diet-restricted dogs were younger at first recognition of the CCO.

The loss of the normal contour of the articular surface may either induce or predispose to femoral remodeling.[10] Osteophytes can form along the bordering articular surfaces and within the joint capsule.[10] The radiographic location of the CFHO suggests osteophyte formation within the insertion line of the joint capsule on the femoral head at a different location than the CCO, although no gross or histopathologic studies have been performed to verify this. On a ventrodorsal radiographic projection of the pelvis, the CCO is a short radiopaque line on the caudal aspect of the femoral neck, whereas the CFHO is a radiopaque line encircling the junction of the head and neck. Coupled with the observation that most dogs with CFHO developed osteoarthritis around the femoral head and acetabulum, it seems reasonable that like the CCO, the CFHO may be regarded as an early radiographic sign of osteoarthritis.

Previous studies[4,7,8] of the same cohort of dogs revealed that diet restriction reduced the prevalence and severity of radiographic evidence of osteoarthritis in the hip joint, compared with control-fed dogs. Similar findings in the present study with regard to the prevalence of the CFHO are evidence that the CFHO is a sign of impending osteoarthritis.

The prevalences of CFHO and osteoarthritis were not significantly different between diet groups. However, median age at detection of a CFHO was significantly less in the control-fed group, and a larger percentage of dogs in the control-fed group developed CFHO and radiographic evidence of osteoarthritis, compared with the restricted-fed group. Previous research on the same cohort showed that dogs in the control-fed group had an increased onset and severity of hip osteoarthritis over the lives of the dogs.[6] In the present study, dogs that developed a CFHO early in life developed radiographic evidence of osteoarthritis earlier than dogs that developed a CFHO later in life. From current and previous research, restricted feeding resulted in a delay in the development of both the CFHO and definitive radiograph evidence of hip osteoarthritis, which further supports the premise that the CFHO is in fact early osteoarthritis.[4,6-8]

At the time of first diagnosis of the CFHO, 35 of the dogs had a grade 1 CFHO. At the time of first radio-

graphic evidence of osteoarthritis, 17 dogs had a grade 2 CFHO. By the end of life, most dogs with osteoarthritis had a grade 3 CFHO. Previous studies[4,6-8] on the same cohort showed that once radiographic evidence of hip osteoarthritis was detected, it generally progressed throughout life. Through the lives of the dogs, the CFHO grade progressed as the osteoarthritis of CHD progressed, which supports the premise that the CFHO was early osteoarthritis.

A grade 1 CFHO can be difficult to observe on hip-extended radiographs, particularly if it is obscured because of poor radiographic technique or positioning. Yet, on the basis of results of the present study, if a grade 1 CFHO is detected radiographically, we believe it should be considered either early osteoarthritis or at least an important risk factor for future osteoarthritis. Similar studies should be conducted with other dog breeds. It is interesting that a radiodensity with a similar appearance can be observed in the same region in chondrodystrophic breeds, especially the Cardigan Welsh Corgi. In contrast to grade 1 CFHO, however, that radiopacity seems to represent a prominent sharp rim around the femoral head. Nonetheless, in breeds such as the Corgi, the distinction between that radiographic finding and the CFHO merits further study.

The sensitivity of the radiographic presence of a CFHO with regard to eventual development of osteoarthritis was 100%, and in 70% of dogs, CFHO preceded conventional radiographic evidence of the osteoarthritis of CHD, making it a definitive marker of impending CHD, if not osteoarthritis itself. Considering that the mean age of first diagnosis of CFHO was 5.4 years, popular hip-screening methods may not detect a CFHO if only a single radiograph is taken at 2 years of age. Repeated radiography throughout the life of a dog, particularly in breeds with high susceptibility to hip dysplasia, may be a better method to monitor for indicators of osteoarthritis.

Results of this study support a strong relationship between the CFHO and subsequent development of hip joint osteoarthritis. On the basis of these findings, we believe that the CFHO may be an early indicator of osteoarthritis characteristic of CHD and that it should not be disregarded as an incidental finding in Labrador Retrievers.

a. SAS, version 9.1, SAS Institute Inc, Cary, NC.

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