Lifelong diet restriction and radiographic evidence of osteoarthritis of the hip joint in dogs

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Objective—To evaluate the effects of diet restriction on development of radiographic evidence of hip joint osteoarthritis in dogs.

Design—Longitudinal cohort study.

Animals—48 Labrador Retrievers from 7 litters.

Procedures—Forty-eight 6-week-old puppies from 7 litters were paired with littermates by sex and weight, and each pairmate was randomly assigned to 1 of 2 groups of 24 dogs each. Starting at 8 weeks of age, 1 group was fed ad libitum (control fed) and the other was fed 25% less (restricted fed) of the same diet for life on a pairwise basis. The dogs' hip joints were radiographed in the standard ventrodorsal hip-extended view at multiple intervals prior to 1 year of age and at annual intervals thereafter on the basis of birth anniversary. A board-certified radiologist unaware of group assignment scored the radiographs for evidence of osteoarthritis.

Results—Prevalence of radiographic evidence of hip joint osteoarthritis in all dogs increased linearly throughout the study, from an overall prevalence of 15% at 2 years to 67% by 14 years. Restricted-fed dogs had lower prevalence and later onset of hip joint osteoarthritis. Median age at first identification of radiographic evidence of hip joint osteoarthritis was significantly lower in the control-fed group (6 years), compared with the restricted-fed group (12 years).

Conclusions and Clinical Relevance—Restricted feeding delayed or prevented development of radiographic signs of hip joint osteoarthritis in this cohort of Labrador Retrievers. Lifetime maintenance of 25% diet restriction delayed onset and reduced severity of hip joint osteoarthritis, thus favorably affecting both duration and quality of life. In addition, the data indicated that development of hip joint osteoarthritis was not bimodal in these dogs but occurred as a continuum throughout life. (*J Am Vet Med Assoc* 2006;229: 690–693)

Canine hip dysplasia is a highly prevalent, progressive, and frequently debilitating disease. Its inheritance is quantitative, meaning that its expression can be influenced considerably by environmental factors.[1-4] The prevalence of CHD is as high as 73% in some breeds of dogs.[5] Radiographic and clinical evidence of coxofemoral osteoarthritis is a common sequela of CHD, especially in older dogs.[6,7]

It is generally believed that degenerative changes will develop in joints of all dogs as they age, whereas dogs with CHD have radiographic signs of osteoarthritis well before the geriatric period.[7] Trauma or metabolic dysfunctions are also thought to affect expression of the disease.[8,9] One theory of pathogenesis for osteoarthritis is that excessive body weight and the associated increased stress on joints induce the transformation of passive hip joint laxity to functional hip joint laxity, thereby initiating osteoarthritis.[10] Excessive body weight has been determined as a risk factor for development of osteoarthritis in humans, guinea pigs, mice, and dogs.[9,11-14] Kealy et al have studied the effects of restricted feeding (and therefore weight control) on hip joint disease in the same dogs as reported here and have detected less radiographic evidence of osteoarthritis, compared with control-fed dogs, at 2 years,[15] 5 years,[16] and 8 years of age.[17]

The purpose of the study reported here was to evaluate the effect of food restriction on the development of radiographic evidence of osteoarthritis in hip joints throughout life in Labrador Retrievers.

Abbreviations

CHD	Canine hip dysplasia

Materials and Methods

Forty-eight 6-week-old Labrador Retriever puppies from 7 litters were allotted by pairing to 2 groups of 24 dogs each.[17] Two sires and 7 dams were selected from the existing research population[a] on the basis of availability at the time that litters were required for the study. Both sires and 3 of the 7 dams were determined to be radiographically normal by use of conventional subjective criteria applied to the ventrodorsal hip-extended radiograph. The litters were selected on the basis of availability. Puppies were paired by litter, sex, and weaning weight prior to random assignment to a feeding group. Dogs were housed in 2 × 19-m indoor-outdoor kennel runs with concrete floors, with 1 to 2 pairs/run. The amount of exercise that the dogs had was not controlled. All dogs were fed the same dry, extruded diet. One pairmate was fed ad libitum (control fed), and the other pairmate (restricted fed) was given 25% less of the same food on a daily basis. Diet and feeding schedules have been described.[15] When dogs were 3.25 years old, adjustments were incorporated into the feeding protocol to prevent development of obesity.[17]

Body weight and body condition scores were monitored throughout the study. A 9-point scale for body condition score was used.[18]

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The dogs were evaluated radiographically by use of general anesthesia with the standard ventrodorsal hip-extended view at 6 intervals prior to age 52 weeks and then at each birth anniversary for life. The ventrodorsal hip-extended radiographs were evaluated by a board-certified radiologist (DNB) for evidence of osteoarthritis.[6] Specifically, left and right hip joints of each dog were scored independently on the basis of sclerosis of the craniodorsal portion of acetabular subchondral bone, osteophytes on the cranial aspect of acetabular margin, osteophytes on the caudal aspects of acetabular margin, and femoral periarticular osteophytes.[6,16] Femoral head rimming and the caudolateral curvilinear osteophyte[19] were not used as definitive signs of osteoarthritis for this evaluation. The radiographs were marked in such a way that examiners were unaware of feeding-group assignments. Each dog's lifelong set of radiographs were evaluated sequentially and specifically for this study.

Dogs were monitored daily throughout life for signs of illness and abnormalities. When necessary, appropriate therapeutic measures for various health problems were used, consistent with established colony protocols and under the supervision of the attending veterinarian. Health management protocols were preestablished for the entire facility.[20]

Statistical analysis—The Kaplan-Meier product limit method was used to compare differences in the osteoarthritis-free interval (difference between groups in time to first diagnosis of radiographic evidence of osteoarthritis) between the control-fed and restricted-fed groups over the lifetime of the dogs. Linear regression was used to determine goodness of fit of a line to the age-based osteoarthritis prevalence data. Significance ($P < 0.05$) was determined by use of the log-rank test. All analyses were performed with statistical software.[b]

Results

Mean ± SD body weights were 24.2 ± 3.79 kg for the restricted-fed group and 33.7 ± 6.02 kg for the control-fed group after 8 years of age, as reported. Mean body weight of the restricted-fed dogs was 26% less than mean body weight of the control-fed dogs through 12 years of age.[20] Mean body condition score in the restricted-fed group was 4.6, compared with 6.7 in the control-fed group, as reported.[20]

Among all 48 dogs, the cumulative prevalence of radiographic evidence of hip osteoarthritis increased linearly ($r^2 = 0.987$; $P < 0.001$) throughout the study from 15% (7/48) at age 2 years, 26% (12/46) at age 5 years, and 40% (17/43) at age 8 years to 67% (32/48) by the end of life (median life span, 11.2 years for control-fed dogs and 13.0 years for restricted-fed dogs[21]). The osteoarthritis-free interval was significantly ($P < 0.001$) different between groups; median age at first identification of radiographic hip osteoarthritis was 6 years in the control-fed group and 12 years in the restricted-fed group (**Figure 1**).

From age 52 weeks, the difference between the 2 groups in prevalence of osteoarthritis was significant (Figure 1). At age 2 years, 6 of 24 (25%) control-fed dogs had radiographic evidence of hip osteoarthritis, compared with 1 of 24 (4%) restricted-fed dogs (**Figure 2**).

At age 5 years, 9 of 23 (39%) dogs in the control-fed group had radiographic evidence of hip osteoarthritis, compared with 3 of 23 (13%) dogs in the restricted-fed group. At age 8 years, 14 of 22 (64%) dogs in the control-fed group had radiographic evidence of hip osteoarthritis (2 dogs died before the age of 8 years), compared with 3 of 21 (14%) dogs in the restricted-fed group.

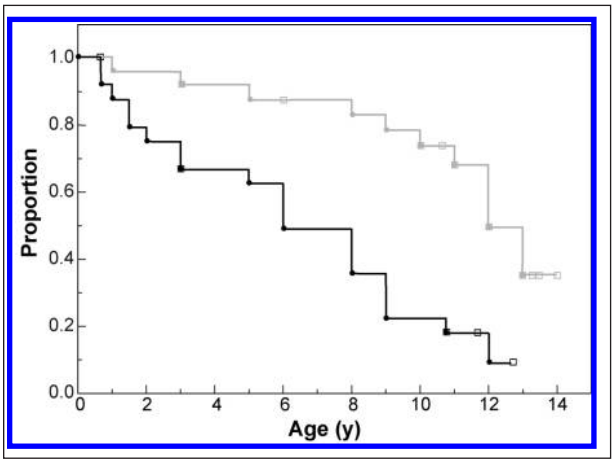

Figure 1—Results of Kaplan-Meier analysis for proportion of Labrador Retrievers (gray line = restricted-fed dogs [n = 24]; black line = control-fed dogs [24]) without radiographic evidence of hip joint osteoarthritis.

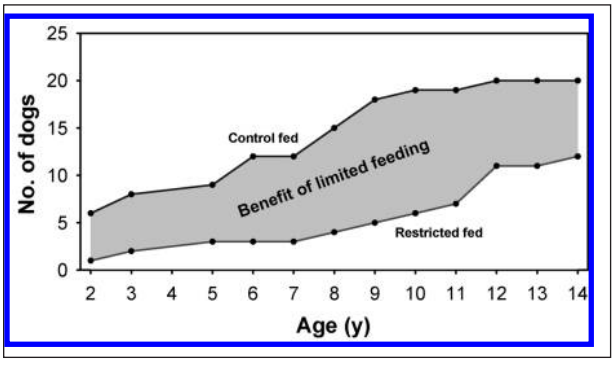

Figure 2—Cumulative prevalence of hip joint osteoarthritis in the same dogs as in Figure 1.

Cumulatively, by 14 years, 83% (20/24) of the control-fed group had developed radiographic evidence of hip osteoarthritis, compared with 50% (12/24) of the restricted-fed group.

Discussion

Initial phenotypic expression of CHD is recognized radiographically as femoral head subluxation on the hip-extended ventrodorsal radiographic projection that has been regarded as a standard, albeit, in our opinion, with minimal scientific support. Hip joint laxity and femoral head subluxation, if functional, induce pathologic consequences that include abnormal loading during weight bearing, leading to cartilage damage and bone remodeling. The end result of this self-perpetuating cycle of abnormal loading and remodeling is classical osteoarthritis characterized by synovitis, increased joint fluid, joint cartilage erosion, elongation and edema of the round ligament, thickening of the joint capsule, and osteophyte formation.[9,22,c]

In the present study, restricted feeding had a profound effect on the radiographic hip phenotype of the Labrador Retrievers. The onset of osteoarthritis was delayed among the restricted-fed dogs, compared with

control-fed pairmates. The paired feeding regimen was designed into the study, with stratification by weight and sex within litter, to minimize genetic differences among subjects as much as possible while allowing amount of diet fed to be the major variable. Prevalence of osteoarthritis in the present study was slightly different from that of earlier evaluations of the same dogs.[15-17] This discrepancy was attributable to the fact that radiographs were scored by the same radiologist at different times for annual evaluations for the earlier reports and later for longitudinal evaluations. Radiographs for this study were rescored to avoid introducing an early-late learning bias. Differences among the reports were minor and did not affect conclusions of the studies.

Longitudinal studies are essential to understanding the true biological behavior of complex diseases such as CHD and osteoarthritis. To the authors' knowledge, no similar studies have been published other than previous reports[15-17] of these dogs. Of particular interest and importance is the observation that radiographic evidence of osteoarthritis increased in prevalence long after age 1 to 2 years, which has been the accepted conventional age for radiographic evaluation for hip dysplasia. The concept of accurate hip screening by 2 years of age was originally proposed by Jessen and Spurrell,[23] whose data suggested that hip osteoarthritis and radiographic evidence of joint laxity have no appreciable incidence after 2 years of age, negating the need for hip evaluation later in life. This concept (use of 1 to 2 years of age as the accepted conventional age for hip screening) was subsequently adopted for hip-screening methodologies around the world.[24-27] However, the linear increase in prevalence of osteoarthritis over the life of the Labrador Retrievers in the present study refutes the conventional dogma that hip joint osteoarthritis occurs only early in life in dogs with CHD. Rather, a constant rate of development of radiographic changes was indicated by our data.

Diet restriction extends life span in a wide variety of vertebrate and invertebrate species.[22] Moreover, studies[28-32] of diet restriction in mammals such as rats, mice, and primates also reveal that increased longevity is associated with delay or prevention of species- and strain-specific diseases.

The association between body mass and the onset and progression of osteoarthritis has been reported in species other than dogs, such as guinea pigs and humans.[12,13] Thirty-three percent of osteoarthritis in the peripheral joints of women can be attributed to effects of obesity.[33] Obese women and men have 4- to 4.8-times increased risk, respectively, for developing osteoarthritis, compared with nonobese women and men.[33] Excessive body weight also has been associated with the onset of degenerative joint disease in the hock joints of broiler fowl fed ad libitum, compared with restricted-fed broiler fowl and a lighter fowl strain.[32] In addition, proteoglycan synthesis is decreased and degradation is increased in the joints of ad libitum–fed fowl, indicating impaired repair of articular cartilage.[32] Although the mechanism by which degenerative joint disease is mitigated by diet restriction is unclear, part of the explanation might be associated with responses that antagonize the transition from passive joint laxity to the more pathologic functional joint laxity that ultimately leads to osteoarthritis, perhaps modulated by inflammatory mediators.[34,35] In any event, the effects of restricted energy intake are consistent in many species.

Dogs vary considerably with respect to individual energy requirements; therefore, it is not feasible to specify a universal energy intake to achieve the benefits observed in the restricted-fed dogs of the study reported here. However, it is recommended that lean body conformation (body condition score of 4 or 5)[18] be maintained by use of appropriate caloric restriction in adult dogs and in growing puppies after age 8 weeks to maximize the opportunity to potentially delay or prevent development of many diseases of aging,[20,28-31] including coxofemoral osteoarthritis associated with CHD.[20] The present study examined restricted feeding for life; therefore, the impact of short-term diet restriction or other feeding regimens on development and progression of osteoarthritis is unknown and may be different. Effects of restricted feeding in dogs of breeds not susceptible to CHD or not as susceptible as Labrador Retrievers were not determined in this study and may also be different.

The recognition that development of osteoarthritis in CHD-susceptible dogs is linear into late life and not bimodal is a new observation with important implications, including clinical relevance for practicing veterinarians, orthopedic surgeons, dog breeders, and pet owners. Results of this study refute the findings of Jessen and Spurrell,[23] who reported that the osteoarthritis of CHD does not occur after 2 years of age. In fact, the prevalence of osteoarthritis was linear over the life span of these Labrador Retrievers, suggesting that onset of CHD can occur at any age, and raising serious concerns over the accuracy of conventional hip-extended radiography at 1 or 2 years of age. Hip phenotype can change markedly (from normal to abnormal) after 2 years of age. Breeds of dogs with high susceptibility to CHD should be kept lean for life, and dogs selected for breeding should have radiographic hip evaluations at regular intervals throughout life. We suggest that more exacting methods than use of the hip phenotype obtained from the standard hip-extended radiographic view should be used for selection of breeding candidates.[36]

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