INSTITUTE OF CANINE BIOLOGY

In all puppies that have been examined in published studies of hip development in dogs,***the hip joints have appeared normal at birth.*** Outside of gross deformity, there is never any evidence of imperfection or disease in the hip joint of newborn puppies.

***At the time puppies usually go to their new homes, much of the pelvis and hip joint has not yet ossified*** and can be easily damaged by physical trauma or abnormal forces.

***It is well known that two dogs with great hips can produce dysplastic puppies, and dogs with hips that aren't the best can produce puppies with good hips.***

Bone is a very "plastic" tissue. It is well supplied with blood vessels, and bone can be resorbed (e.g., when there is inadequate calcium in the diet), and new bone deposited in response to injury or biomechanical stress. In the hip joint (and others), the development from birth to the joint in the adult is not entirely genetically programmed. Instead, it is a response to the mechanical stresses on the bone. If those stresses are normal, the development of the joint will proceed normally. If there are abnormal stresses on the joint during development, the joint will be abnormal as well.

If all puppies are born with perfectly formed hip joints, how do some end up with dysplasia? This is the Million Dollar Question, but we've spent far more than a million dollars trying to solve it. We do know that if the head of the femur stays snugly tucked into the acetabulum while the puppy grows, hip dysplasia does not develop. However, if there is laxity in the joint - if the femur is a little loose in the socket - then the hip can become dysplastic.

Conducted by Nestle Purina in collaboration with a slate of veterinarians and academics, the study used 48 Labrador Retriever puppies from 7 litters. In each litter, puppies were paired and one assigned to the control group and one to the treatment group.  The control group was provided food *ad libitum* (unrestricted) *starting at 8 weeks*, and each puppy in the treatment group was fed 25% less than the amount consumed by its pair in the control group.  Their weight was monitored and hips x-rayed at regular intervals

They found that dogs that were fed less had dramatically lower incidence of hip dysplasia.

So, the Great Dane study found that dogs that were fed more as puppies grew faster and weighed more than puppies on a restrictred diet. The rapid growth affected the strength and structure of the bones, and the increased weight subjected the joints to abnormal biomechanical loading that resulted in lesions in the immature cartilage. In both the Danes and the Labradors, over nutrition of puppies promoted rapid growth that altered skeletal development in a way that had lifelong consequences for the dogs.

There are many studies now that show that heritability of hip phenotype is much less than 1.0, and in fact it is usually less than about 0.4. This means that genetics explains only a part of the variability in hip scores, and non-genetic ("environmental") factors are responsible for a considerable amount of the variation.

Because non-genetic factors can account for such a large part of the variation in hip phenotype, you might be able to substantially improve the hips in your puppies if you understand what those factors are and how to reduce their negative impact. This has received much less attention than genetics for some reason, but it should be possible to dramatically reduce hip dysplasia if we can deal with some of the non-genetic factors that seem to matter.

***Food consumption and body weight***
Food consumption and (therefore) the body weight of the puppy has a profound effect on the risk of developing hip dysplasia. In the Purina study that we discussed earlier, allowing puppies to free-feed ("ad libitum" food consumption) from 8 weeks resulted in an increased the rate of growth and a higher adult body mass compared with dogs on a restricted diet, which weighed 25% less from 1 year through adulthood.

There is an interplay of two factors, laxity and body weight, in the development of hip dysplasia. Greater laxity results in earlier development of dysplasia, and greater weight is associated with more severe damage. Both of these are consistent with biomechanics being the proximal cause of hip dysplasia, specifically the abnormal forces the hip joint is subjected to during growth of the puppy and in adulthood.

**Exercise**

The Krontveit study of large breeds found that the type of exercise the puppy was exposed to affected the risk of dysplasia. Puppies that lived on a farm from birth to weaning had a 30% lower risk of dysplasia than those from suburbia, presumably because of the sort of exercise they were exposed to. During the post-weaning period through 3 months, puppies that used stairs daily had an elevated risk of dysplasia, and those that got daily off-lead exercise in park-like terrain had a lower risk. Likewise, a study of adult Labradors in Sweden found that regular exercise chasing a ball or stick thrown by the owner more than doubled (2.2 to 2.6 times) the risk of hip dysplasia (Sallander et al 2006), and these activities have also been linked to development of osteochondrosis (Slater et al 1992).

**Effects of spay & neuter**
Spay/neuter status can be associated with differences in the incidence of hip dysplasia, but there are differences by breed, sex, and age. A study of Golden Retrievers and Labradors found higher rates of hip dysplasia in Golden Retriever males that were neutered younger than 11 months or after 2 years, but no effect of spay on females (Torres de la Riva et al 2013; Hart et al 2014). On the other hand, in Labradors, there was an elevated risk of hip dysplasia in females spayed before two years old but no effect of neutering on males.

While these data are interesting, they don't answer the question of what is the factor affected by spay/neuter that results in differences in the development of hip dysplasia. It could be endocrine, or differences in body mass, or the timing of growth plate closure, or some other thing, and added to the puzzle is why this mystery factor affects breeds differently. The effect is not huge in most cases - the largest was for Goldens neutered before 6 months (5% vs 10-15%). Hopefully there will be more studies that shed some light on the factors involved and why they should differ by breed, and in the meantime the best advice would be to postpone neutering until the dog is older than 6 months.

**Nutrition**

There is no evidence that nutrient *deficiencies* of any sort can result in hip dysplasia (Nap et al 1991), *but excesses of some vitamins and minerals can contribute to development of skeletal disease*. The quick summary: dietary carbohydrates and proteins do *not* affect the development of dysplasia unless the amounts in the diet are either insufficient or excessive for normal growth and development. But improper levels of some key minerals and "over-nutrition" (excess caloric intake) can have huge effects, *especially in puppies*.

**Calcium**Calcium and phosphorus (among other minerals) are required in the diet in specific amounts and proportions for proper bone development, and there are adverse consequences to both deficits and excesses. One difficulty with proper management of calcium is that it deposited in bone but can also be resorbed if calcium is deficient in the diet. Calcium in the body must be regulated carefully because it is critical for a variety of physiological process, for example muscle contraction both in skeletal muscle and the heart (Hazewinkel 1989). The body will compromise skeletal integrity by resorbing calcium from bones if it is deficient in the diet.

On the other hand, too much calcium in the diet can result in abnormal skeletal development. When Great Dane puppies were fed a diet after weaning (starting at 6-10 weeks) that was supplemented with three times the recommended calcium content, there were disturbances in cartilage and bone maturation and in bone remodeling (Goedegeburre & Hazewinkel 1986). High calcium intake decreases the activity of osteoclasts, the cells involved in bone remodeling, which of course is a critical process during the period when the puppy is growing quickly. So excess dietary calcium can actually retard growth.

***Phosphorus***
*Especially in large breeds, growing puppies with adequate calcium but low phosphorus develop severe disturbances in skeletal development, growth, and mineralization that are typical of rickets.* Puppies fed high levels of both calcium and phosphorus develop lesions resembling osteochondrosis (Shoenmakers et al 2000).

People that feed a home made diet believe that their dog is getting the adequate calcium if bones are included in the diet. The bioavailability of the calcium in bones can vary enormously, and of course there is no way to know if a dogs is receiving too little or too much calcium because blood levels are carefully regulated not a good reflection of imbalance. There is also no way to know if the dog is getting the right balance of calcium and phosphorus, and if feeding a meat-based diet the phosphorus is usually too high and the calcium is too low. If a home made diet will be fed to puppies, it should be evaluated by a veterinary nutritionist. *Otherwise a quality commercial puppy food should be fed while the puppy is growing.*

***Vitamin D***
Vitamin D is important for absorption of calcium and phosphorus from the gastrointestinal tract, so the control of calcium balance depends on the correct levels of vitamin D. In many species, including humans and dogs, vitamin D is synthesized by the skin when exposed to sunlight. This is usually nutritionally adequate for humans, but dogs apparently do not synthesize sufficient vitamin D to meet their needs (Hazewinkel 1989) so it must be supplemented in the diet. *Insufficient vitamin D or calcium will both result in rickets, in which there is inadequate calcification of growing bones before the closing of the epiphyseal plates. The soft bones that result are prone to fracture or deformity. On the other hand, excess Vitamin D can increase calcium absorption from the intestine and have the same effect as excessive calcium in the diet (Fries & Remedios 1995).*

***"Over-nutrition"***Simply because of the laws of physics, the weight of a puppy profoundly affects the magnitude of the forces experienced by the joints both standing and (especially) while in motion. Hip dysplasia does not develop unless there is laxity in the hip joint, because it is the incongruence between the head of the femur and the acetabulum that results in the biomechanical damage that is typical of hip dysplasia. So in a puppy with hip laxity, body weight is a critical risk factor for the development of dysplasia.

Some data suggest that rapid growth is linked to the development of hip dysplasia. This could be a direct consequence of growth or a secondary effect because fast-growing dogs get heavier at a younger age.

One thing that is critical to understand is that the nutrient content of dog food varies depending on whether it is intended for puppies vs adults, for "large breeds" vs others, and for active vs older dogs. Caloric content needs to be balanced with the content of vitamins and minerals to avoid under- or over-consumption of a key nutrient. *For example, you should not try to reduce growth rate of a large breed puppy by feeding an adult food instead of one for puppies. The adult food will have a lower energy density, but the levels of other nutrients might not be appropriate for growth of a puppy.* *Because the body of a puppy changes by the day while it grows, so an imbalance in some key nutrient that would have little effect on an adult dog can be a serious problem in a puppy.*

**The skeleton is growing for the first 5-6 months, and joints are vulnerable until ossification is complete (about 1 year). Exercise of puppies should be managed so that the muscles and soft tissues can mature and aid in** **stabilizing the joint while not exposing the puppy to risk of accidental damage or overuse.**

**Puppies that don't have "all four feet on the ground" can fall and, from the perspective of a human, the bed, porch, or a flight of stairs doesn't seem very formidable.**

**But to a puppy younger than about 5 months old, a fall (or jump) from any of these can cause significant damage to joints that are still developing.**

**New puppy owners should be given clear (strict!) instructions about weight management and appropriate activities for a growing puppy. Swimming under supervision is safe for puppies and an excellent way to strengthen muscles with no weight-bearing on the joints. Also, sitting puts the head of the femur deep in the socket (flexion and abduction of the back legs) and should be encouraged. Riser found that puppies that had hip laxity could be prevented from developing hip dysplasia if they were constrained to a cage so they would spend more time sitting.**