Interpretation and use of BVA/KC hip scores in dogs

Ruth Dennis

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Hip dysplasia is a potentially debilitating orthopaedic disease in which laxity of the coxofemoral joint often leads to secondary osteoarthritis, a reduction in joint function and pain. It has been recognised for many years as being of particular importance in pedigree dogs, especially in larger breeds, and is known to be partly governed by genetic factors. In order to try to control canine hip dysplasia and to reduce its incidence, a number of radiographic screening programmes have been developed worldwide. In 1983, a scheme was established by the British Veterinary Association and supported by the Kennel Club to examine radiographs of dogs' hips by assessing different anatomical features and giving them a numerical score. This article describes the process of scoring in this scheme, explains how to interpret the score and gives advice on the use of hip scores in the selection of breeding animals.

Hip anatomy

In the natural 'wolf' state, the canine hip is a tight, well-fitting, ball and socket joint that permits full athletic function throughout the animal's entire life without the development of degenerative change. Such hips are still the norm in greyhounds, but relatively few other dogs today have such perfect joints. This is probably because domestication has removed the 'survival of the fittest' process by which natural selection occurs in the wild and because of selection by breeders for other traits, which has unwittingly perpetuated less than perfect hips.

Laxity of the soft tissues of the joint leads to subluxation or even complete luxation, resulting in abnormal stresses being placed on the bony and soft tissue components of the joint. This, in turn, results in remodelling and in many cases progresses to osteoarthritis (Fig 1). When hip dysplasia is present, secondary changes are likely to worsen with age.

The physical conformation of the hips (phenotype) is influenced partly by environmental factors (eg, weight

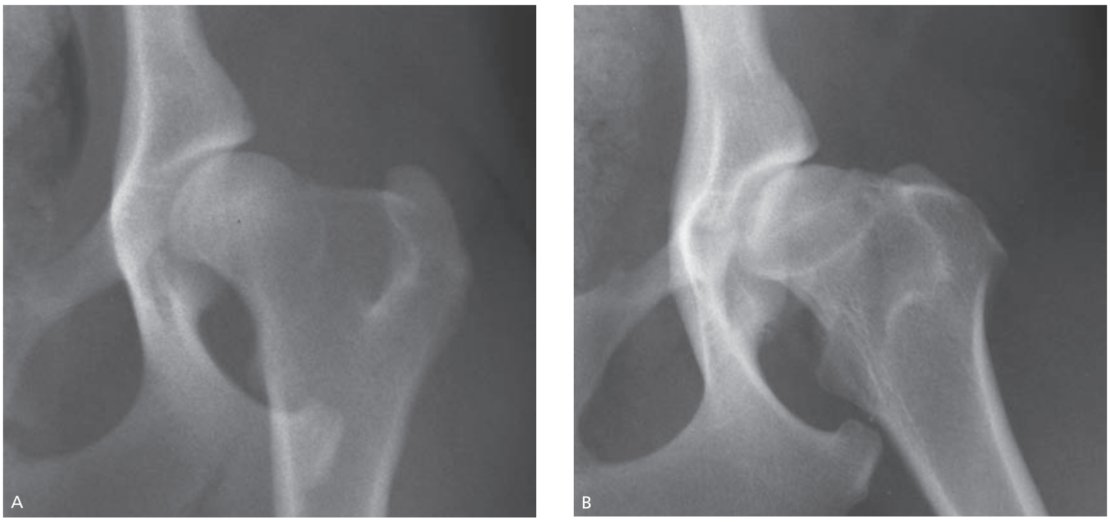

Fig 1: (a) Left hip joint of a 13-month-old labrador retriever with hip dysplasia. The femoral head is subluxated, the cranial acetabular edge is remodelled and a small amount of capsular new bone is visible on the femoral neck. This dog had a single hip score of about 16, which is much higher than the breed mean and median. (b) The same hip joint four years later showing marked progression of the changes. There is further femoral head subluxation, and severe remodelling and osteoarthritis of the femoral head and acetabulum have developed. The dog showed clinical signs at this stage. The single hip score was about 37

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and diet) and partly by genetic factors (genotype), which are governed by an unknown number of genes. As the condition is polygenic, development of a genetic screening test, while not impossible, lies some way in the future.

Although certain clinical manipulations may indicate whether a hip is markedly loose, it is not usually possible to assess the state of a dog's hips by clinical examination. Many dogs with hip dysplasia do not show signs of lameness or discomfort until later in life, by which time they may have been used for breeding.

Careful selection of breeding stock is known to reduce the incidence of hip dysplasia in the offspring. At present, such selection is made by assessing the hips of potential sires and dams radiographically.

Requirements for the BVA/KC scheme

Age and identification

For submission to the British Veterinary Association (BVA)/Kennel Club (KC) Hip Dysplasia Scheme, dogs must be at least one year of age in order to ensure skeletal maturity, although there is no upper age limit. For dogs intended for breeding, it is essential that the hips are assessed before mating to ensure that they are free of dysplastic changes or only minimally affected.

All dogs must have permanent identification in the form of a microchip or tattoo, and the number must be checked by the veterinary surgeon submitting the radiograph and shown on the image. Most dogs radiographed under the scheme are pedigrees that are registered with the KC, and for these animals the KC registration number must also be shown on the radiograph. However, dogs from any other country, dogs registered with other organisations and unregistered dogs may also be scored, with the images identified appropriately. Radiographs are submitted to the scheme from all over the world, including from countries where other hip dysplasia schemes are also in operation.

Radiograph

Radiographs are obtained under sedation or anaesthesia for several reasons:

- To minimise stress to the patient;
- To permit precise positioning of the pelvis and hips;
- To remove the need for the animal to be held, as x-rays are potentially hazardous for anyone doing so.

The radiographic view required by the BVA/KC scoring scheme, as for most other hip dysplasia schemes, is the extended ventrodorsal (VD) view (Fig 2). The dog is positioned on its back with its hindlegs extended caudally, resulting in a position similar to that of a standing human. The femora must be positioned parallel to each other and for this the stifles are rotated slightly medially and held in position with a tie or tape so that they lie in the sagittal plane with the patella superimposed over the centre of the distal femur. This position allows the femoral neck to be seen clearly, without superimposition by the greater trochanter, and facilitates the detection of new bone on the femoral neck. Examples of ideal and poor positionings are shown in Fig 3.

Fig 2: Anaesthetised dog positioned correctly for hip dysplasia radiography. The thorax is supported in a cradle, the hindlegs are extended and restrained using soft ties, and the stifles are rotated inwards using a third tie so that the femora lie parallel to each other and are projected in a true craniocaudal direction

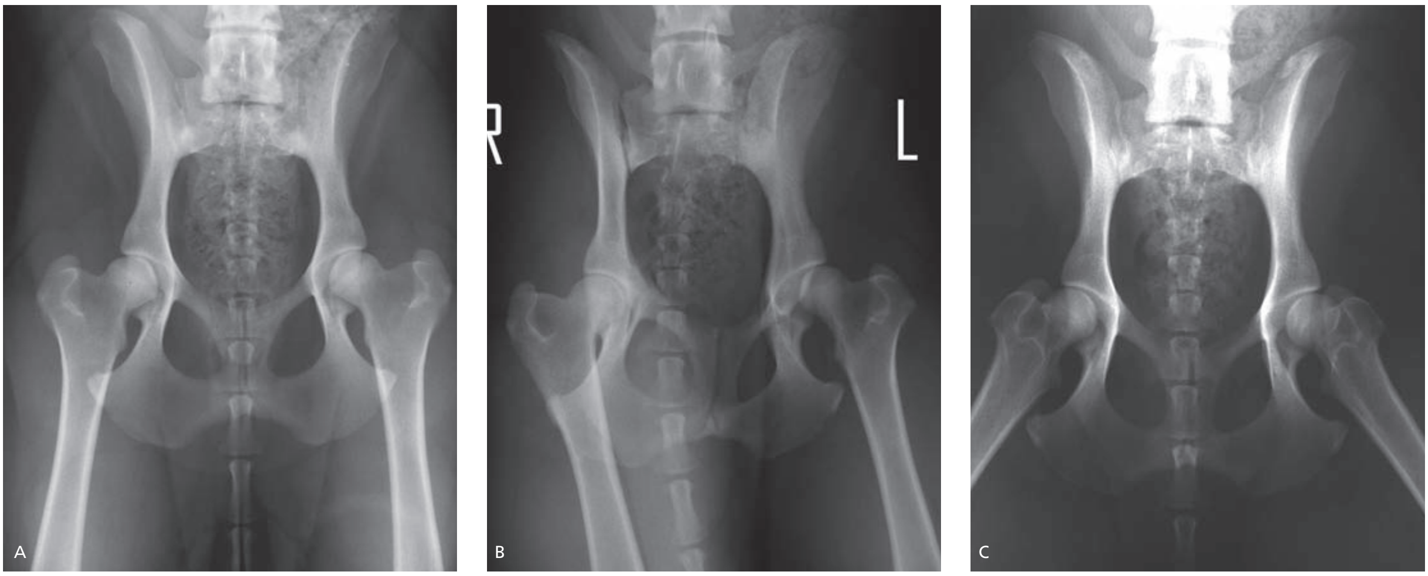


Fig 3: Ventrodorsal hip radiographs showing ideal and poor hip positions. (a) Correct positioning of the pelvis and femora. (b) Lateral tilting of the pelvis. The left side of the pelvis is closer to the film, resulting in the left hip appearing more subluxated than it really is, whereas the right hip appears better. This radiograph would be rejected as inadequate for scoring. However, with a mild degree of tilt, the effect on the two hips cancels out and the total hip score is acceptably accurate. (c) Inadequate extension and outward rotation of the femora, resulting in the greater trochanter being superimposed over the femoral neck, which cannot therefore be accurately assessed for the presence of arthritic new bone. The femora should be fully extended and rotated inwards so that the stifles lie in the sagittal plane (see Fig 2)

The extended VD position has several advantages:

- It is easy and safe to achieve;
- It is very repeatable;
- It requires no special positioning aids;
- It gives an excellent view of the hip joint in which all relevant anatomical areas can be seen.

Centring of the x-ray beam must be at the level of the hip joints, which can be achieved by palpation of bony landmarks such as the pubic symphysis and greater trochanters. Centring further cranially or further caudally will distort the appearance of the hip joints. Collimation must be sufficient to include the pelvis but it is not necessary to include the stifles; to do so requires either incorrect centring or an unacceptably large area to be irradiated.

It is important to avoid tilting the dog to the side (lateral rotation) as this will alter the appearance of the hips and may worsen the score, since the hip that is closer to the table may appear artefactually subluxated. It is also important that the technical quality of the image is of a high standard with optimum contrast and definition and all the necessary labelling. Radiographs that are poorly positioned or which are technically substandard may be rejected if the scrutineers feel that an accurate score cannot be given. Further details on radiography and submission are given in the BVA's Guidance Notes for the hip dysplasia scheme.

Scoring procedure

Hip radiographs are assessed at one or two scoring sessions that are held each week at the BVA's headquarters in London. Two scrutineers from a panel of 11 examine about 270 sets of radiographs (as printed film or in digital format) during each session, which lasts for several hours, agree on a score and sign the scrutineers' part of the certificates. All the scrutineers have further qualifications in radiology and/or orthopaedic surgery and have many years of experience in assessing hip radiographs. The whole panel meets annually to discuss matters pertaining to the hip scheme and to review a quality control exercise that runs throughout the year.

What do the hip scores mean?

Each hip (right and left) is examined for nine different anatomical features and a numerical score is given, with points being ascribed to abnormal features (Table 1). For eight of the features the score may be 0 to 6, and for one the score may be 0 to 5. The total score for each hip is then calculated (range 0 to 53), as is the total hip score (range 0 to 106). Hips with a perfect radiographic appearance score 0; the higher the score, the greater the degree of hip dysplasia ± secondary degenerative change. This scheme therefore allows a wide range of abnormality to be described, unlike some other hip dysplasia schemes in which only a handful of different categories exist.

The nine anatomical features assessed in the BVA/KC scheme are:

- Norberg angle;
- Subluxation;
- Cranial acetabular edge;
- Dorsal acetabular edge;
- Cranial effective acetabular rim;

Table 1: Criteria used as a guide by BVA/KC Hip Dysplasia Scheme scrutineers for scoring nine radiographic hip features

Score	Norberg angle (°)*	Subluxation	Cranial acetabular edge	Dorsal acetabular edge	Cranial effective acetabular rim
0	+15 and over	Femoral head is well centred in the acetabulum	Even curve, parallel to the femoral head throughout	Slight curve	Sharp, clean cut junction of the DAE and CrAE
1	+10 to +14	Femoral head centre lies medial to the DAE. The lateral or medial joint space is increased slightly	Lateral or medial quarter of the edge is flat and the lateral or medial joint spaces diverge slightly	Loss of S curve only in the presence of other dysplastic change	Indistinct junction of the DAE and CrAE
2	+5 to +9	Femoral head centre is superimposed on the DAE. There is an obvious increase in the medial joint space	Flat throughout most of its length	Very small exostosis cranially	Very small exostosis or very small facet
3	0 to +4	Femoral head centre is just lateral to the DAE. Half of the femoral head is within the acetabulum	Slight bilabiation	Obvious exostosis, especially cranially, and/or minor 'loss of edge'	Facet and/or small exostosis and/or slight bilabiation
4	–1 to –5	Femoral head centre is clearly lateral to the DAE. A quarter of the femoral head is within the acetabulum	Moderate bilabiation	Exostosis well lateral to the edge and/or moderate 'loss of edge'	Obvious facet and/or obvious exostosis and/or moderate bilabiation
5	–6 to –10	Femoral head centre is well lateral to, and just touches, the DAE	Gross bilabiation	Marked exostosis all along the edge and/or gross 'loss of edge'	Gross exostosis and/or facet and/or gross bilabiation
6	–11 and over	Complete pathological dislocation	Entire edge slopes cranially	Massive exostosis from the cranial to caudal edge	Complete remodelling. Massive exostosis and/or gross facet

*Relative to 90°, DAE Dorsal acetabular edge, CrAE Cranial acetabular edge, CaAE, Caudal acetabular ridge, AE Acetabular edge, AF Acetabular fossa

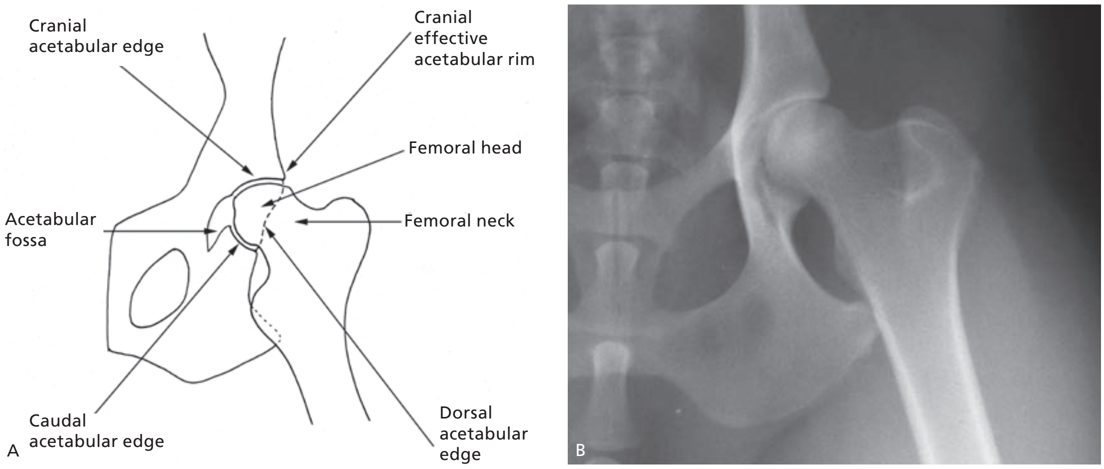


Fig 4: (a) Diagram of a normal hip joint showing the features that are assessed by the BVA/KC scoring scheme. (b) Excellent close-up of a near-perfect hip. The femoral head is rounded and its centre lies medial to the dorsal acetabular edge; the acetabulum is deep and the two bones show good congruency. This dog scored 2:2 = 4 (one point on each hip for subluxation and one for cranial acetabular edge, as the two bone surfaces are not quite perfectly congruent [see Table 1])

- Acetabular fossa;
- Caudal acetabular edge;
- Femoral head and neck exostoses;
- Femoral head recontouring.

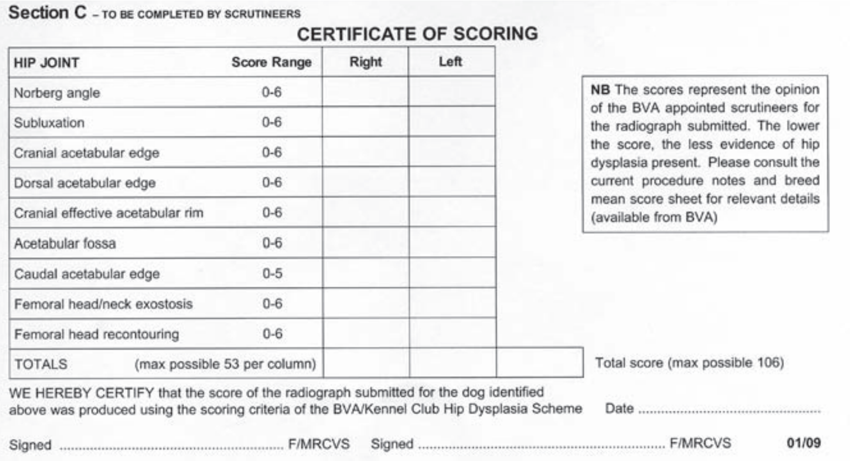
These features are shown in a normal hip in Fig 4, and may be divided into two groups:

- Those that describe the underlying joint laxity;
- Those that describe resulting secondary changes.

The first two features – Norberg angle and subluxation – describe the tightness or laxity of the hip joint as demonstrated on the radiograph. The appearance of the cranial acetabular edge may also be affected by subluxation since this widens the joint space between the edge and the femoral head and the two bone surfaces are no longer congruent.

The cranial acetabular edge and the remaining six parameters describe deviations from the ideal ball and socket conformation, ranging from slight changes in the shape of the bones resulting from minor remodelling to severe osteoarthritis. The higher the score in these parameters, the worse the osteoarthritis. Dogs with osteoarthritis should not be used for breeding as they definitely have hip dysplasia; however, not all dogs with lax hips go on to develop osteoarthritis, and it must be noted that the severity of degenerative change also depends on age. Hence, on the scoring

Acetabular fossa	Caudal acetabular edge	Femoral head and neck exostoses	Femoral head recontouring
Fine bone line curves medial and caudal from the caudal end of the CrAE	Clean line	Smooth, rounded profile	Nil
Slight increase in medial bone density. The 'fine line' is hazy or lost	Small exostosis at the lateral edge	Slight exostosis in 'ring form' and/or dense vertical line adjacent to the trochanteric fossa ('Morgan line')	Femoral head does not fit in a circle due to exostosis or bone loss
'Fine line' is lost and the ventral AE is hazy due to new bone. The notch at the CaAE is clear	Small exostosis at the lateral and medial edge	Slight exostosis visible on the skyline and/or density on the medial femoral head	Some bone loss and/or femoral head/neck ring of exostosis
Incomplete remodelling of the acetabulum, with the medial face lateral to the AF. The ventral AE is lost, the AF is hazy and the notch is irregular	Large exostosis and narrow notch	Distinct exostosis in 'ring form'	Obvious bone loss and distinct exostosis giving a slight conical appearance
Marked remodelling. The medial face of the acetabulum is clearly lateral to the AF. The ventral AE is lost and the notch is partly closed	Marked exostosis and 'hooking' of the lateral end	Obvious complete collar of exostosis	Gross remodelling. There is obvious bone loss and exostosis gives a mushroom-like appearance
Gross remodelling, with dense new bone throughout the acetabulum. The CaAE notch is lost and the AF is obscured	Gross distortion due to mass of new bone in the acetabulum. The notch is lost completely	Massive exostosis giving a mushroom-like appearance	Very gross remodelling with marked bone loss and much new bone
Complete remodelling and new articular surface, well lateral to the AF. The notch is lost	Void	Massive exostosis and infill of the trochanteric fossa and below the femoral head	Femoral head is improperly shaped due to maldevelopment of the femoral head centre


Section C – TO BE COMPLETED BY SCRUTINEERS

CERTIFICATE OF SCORING

HIP JOINT	Score Range	Right	Left
Norberg angle	0-6		
Subluxation	0-6		
Cranial acetabular edge	0-6		
Dorsal acetabular edge	0-6		
Cranial effective acetabular rim	0-6		
Acetabular fossa	0-6		
Caudal acetabular edge	0-5		
Femoral head/neck exostosis	0-6		
Femoral head recontouring	0-6		
TOTALS (max possible 53 per column)			

NB The scores represent the opinion of the BVA appointed scrutineers for the radiograph submitted. The lower the score, the less evidence of hip dysplasia present. Please consult the current procedure notes and breed mean score sheet for relevant details (available from BVA)

Total score (max possible 106)

WE HEREBY CERTIFY that the score of the radiograph submitted for the dog identified above was produced using the scoring criteria of the BVA/Kennel Club Hip Dysplasia Scheme

Date ....

Signed .... F/MRCVS Signed .... F/MRCVS 01/09

Fig 5: Scoring table on the hip dysplasia certificate

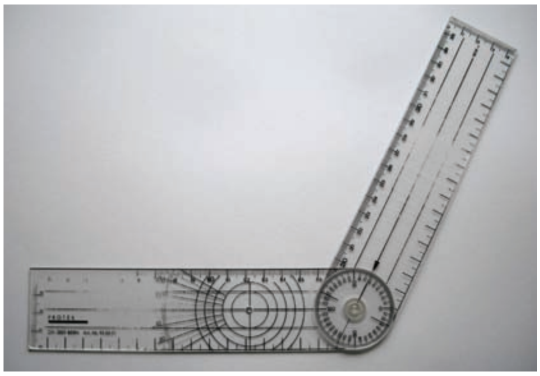


Fig 6: Müller ischiometer – an orthopaedic device used for measuring the Norberg angle on printed radiographs. The Norberg angle is measured electronically on digital images using specially designed software (Visbion)

certificate (Fig 5) many dogs will have scores for the first three parameters with 0 in the remaining sections; this means that the hips show some degree of laxity but as yet no secondary change. More detail about how each of the nine features is scored is given below and in Table 1.

Norberg angle

The Norberg angle is a measurement of two hip parameters:

- The severity of any subluxation;
- The depth of the acetabulum.

It is measured on film using an orthopaedic angle-measuring device or a goniometer (specifically a Müller ischiometer [Fig 6], designed for making measurements on human hips), which is laid over the radiograph. The centre of each femoral head is identified and marked with a small dot by finding the best fitting of several concentric circles marked on the ischiometer. The device is then positioned so that the two femoral head centres are joined by a line, and the angle between each centre and the cranial effective acetabular rim is measured. Special computer software has been developed so that the same measurements can be made on digital images.

In a good hip, the Norberg angle is 105° or greater (Fig 7). In a hip in which subluxation is present at the time of radiography or in which the acetabulum is shallow, the Norberg angle is reduced, and may even be less than 90° (Fig 7).

Subluxation

Subluxation is assessed by noting the position of the femoral head centre relative to the dorsal acetabular edge and taking into account the congruency of the fit between the femoral head and the cranial acetabular edge. The lower the score, the tighter and more closely fitting is the joint. Scores of 1, 2 and 3 are most common and indicate a less than perfect but reasonable hip, with 3 indicating definite but mild subluxation, since the femoral head centre lies just lateral to the dorsal acetabular edge. Scores of 4 and 5 indicate marked subluxation, while 6 represents complete dislocation.

Subluxation may be a dynamic process, with the hip moving in and out of the acetabulum at different times. It is therefore possible for the degree of subluxation shown on the radiograph to be less than its maximum when the dog is bearing weight and for subluxation to be underestimated. Some critics of the extended hip radiographic view suggest that the extended position tightens the joint capsule and reduces the degree of subluxation, but the number of subluxated hips seen on this view is still large, suggesting that this is not a major effect. The opposite situation cannot occur, that is, a hip that is genuinely tight will not appear subluxated on a radiograph. Clear guidance on the use of the hip score (breed only from dogs with scores well below the breed mean – see below)

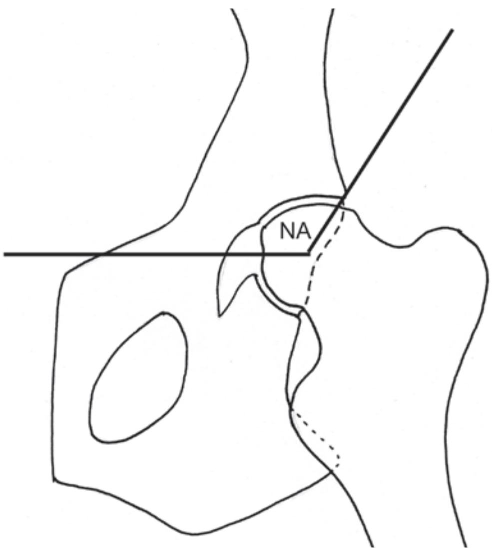
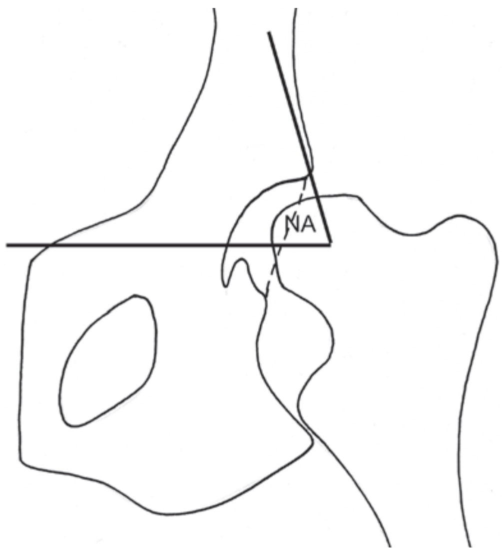


Fig 7: Diagrams showing a good hip (left), in which the Norberg angle (NA) exceeds 105°, and a dysplastic hip (right), in which a combination of femoral head subluxation and shallowness of the acetabulum has led to an NA of less than 90°



has taken account of the possibility that the degree of subluxation may be slightly underestimated in some dogs.

Cranial acetabular edge

The cranial acetabular edge is the part of the acetabular margin that is best seen radiographically. It is a continuation of the dorsal acetabular edge and is separated from the caudal acetabular edge by the acetabular fossa. It should be long and gently curving, contouring perfectly to the femoral head so that only a narrow gap is seen between them; this gap is referred to as the 'joint space' but consists of both the articular cartilage on the surface of the two bones and the synovial fluid between them. Subluxation and/or remodelling of the cranial acetabular edge causes widening of the joint space medially and/or laterally, resulting in a loss of congruency between the femoral head and the acetabulum.

The most common score for the cranial acetabular edge is 2, which is given when the edge is slightly shorter and straighter than in the perfect hip and/or there is slight loss of congruency between the bones. Scores of 1 or 2 are commonly seen in otherwise reasonable hips in which subsequent features all score 0. Scores of 3 and above indicate progressively more remodelling of the edge due to abnormal pressure from the femoral head, with scores of 4, 5 and 6 indicating that the acetabulum is markedly deformed. Abnormal subchondral sclerosis is often evident.

Dorsal acetabular edge

The dorsal acetabular edge is the top margin of the acetabulum in the standing animal and is therefore subjected to considerable wear and tear from the femoral head in subluxating hips. On the radiograph it is superimposed by the femoral head and correct radiographic exposure is important to ensure that it is clearly visible. The normal dorsal acetabular edge is a shallow S shape, and scores are given for deviations from this ranging from mild straightening or blurring to irregularity resulting from bone erosion or new bone formation.

Scores of 3 and above indicate significant change and are likely to be associated with scores in all or most of the other parameters.

Cranial effective acetabular rim

The cranial effective acetabular rim is not a clearly defined anatomical structure but is the region where the dorsal acetabular edge curves around to become the cranial acetabular edge. It is seen radiographically as an apparently sharp junction between the dorsal and cranial edges and the iliac shaft. This 'virtual' structure therefore represents a region that is particularly subject to abnormal wear in loose hips. Abnormalities progress from a slight blurring of the junction to overt wearing away of the bone, producing either a rounded shape or a flattened 'facet'. In more severe cases, spurs of new bone (osteophytes or exostoses) form at the site of attachment of the joint capsule in response to excessive tension. In the most severe cases, the whole area is remodelled and a defined cranial effective acetabular rim cannot be identified.

Low scores of 1 or 2 are common in otherwise reasonable hips, but scores of 3 and above indicate secondary change and are a component of osteoarthritis.

Acetabular fossa

The acetabular fossa is a roughly circular depression in the depth of the acetabulum and contains the origin of the teres (round) ligament, a short, strong band of tissue that attaches to the femoral head at a slightly flattened area, the fovea capitis. In lax hips, abnormal tension on the teres ligament causes the production of new bone at its origin, resulting in the acetabular fossa losing its clarity.

Any score other than 0 for the acetabular fossa indicates that osteoarthritis appears to be forming and will be associated with positive scores in other features. The fossa may eventually become completely filled with new bone and not be recognisable, giving scores of 5 or 6.

Caudal acetabular edge

The caudal acetabular edge is shorter and less well-defined than the cranial acetabular edge. Its medial end merges with the acetabular fossa and, like the acetabular fossa, any score indicates that osteoarthritis is forming, resulting in a loss of clarity or sclerosis of the edge. Positive scores in other parameters will always be present too.

The maximum score for the caudal acetabular edge is 5, whereas for the other parameters the maximum score is 6.

Femoral head and neck exostoses

The joint capsule is attached to the margin of the acetabulum and around the femoral neck. In the presence of hip laxity, the joint capsule is under abnormal tension and new bone is produced at its attachment to bone, particularly around the femoral neck. The earliest sign of new bone production is the 'Morgan line' or caudal curvilinear osteophyte, which extends a little way down the femoral neck and produces a fine, curving, radiopaque line; this is scored 1. As more new bone is produced on the femoral neck, it may be seen on the skyline (score 2), progressing to a ring and then a collar of new bone (scores 3 and 4, respectively). Continued development of these osteophytes encircling the femoral neck causes increasing distortion, with the proximal femur having a mushroom shape and scoring 5 or 6.

A score of 2 or more in this category indicates that osteoarthritis is definitely developing and is likely to worsen with age.

Femoral head recontouring

The normal femoral head, as mentioned above, is rounded, with a small, flattened area for attachment of the teres ligament. When marked hip dysplasia is present, continued instability of the joint causes the femoral head to change its shape progressively, and any deviation from its normal shape is scored as recontouring (remodelling). Severe recontouring is mainly seen in older dogs in which the changes have progressed further, but may also be seen in young dogs with complete luxation or severe subluxation, since the bones have never developed normally.

Fig 8: Borderline changes of hip dysplasia in a two-year-old labrador retriever, resulting in a single hip score of 5. There is minor subluxation such that the femoral head centre is superimposed on the dorsal acetabular edge, and medial divergence of the cranial joint space. This dog's total hip score was 5:5 = 10

Fig 9: Mild hip dysplasia in a 13-month-old labrador retriever, resulting in a single hip score of 9. The femoral head is subluxated and its centre lies lateral to the dorsal acetabular edge. There is flattening of the cranial acetabular edge, with widening of the joint space both medially and laterally. The cranial effective acetabular rim is indistinct. This dog's total hip score was 8:9 = 17

Fig 10: Moderate hip dysplasia in a 17-month-old labrador retriever, resulting in a single hip score of 18. The femoral head is clearly subluxated, the cranial acetabular edge and rim are slightly remodelled and periarticular new bone is forming on the femoral neck. This dog's total hip score was 13:18 = 31

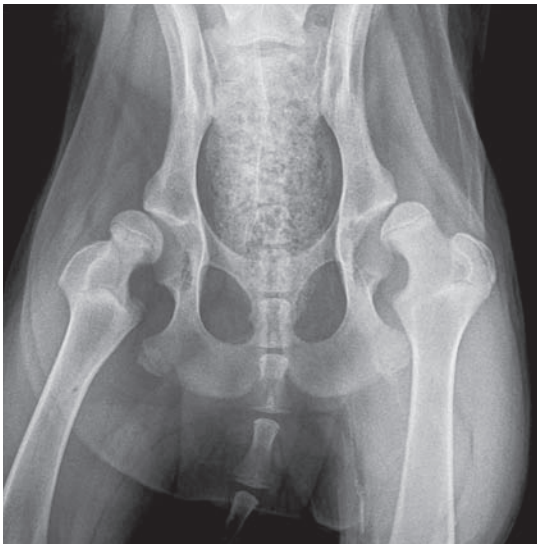


Fig 11: Severe hip dysplasia in a five-month-old German shepherd dog, indicated by complete luxation. At this age the dog is too young for official scoring

Total scores

While it is impossible to correlate a hip score exactly with grades of hip dysplasia given under other schemes, an approximate interpretation for total hip scores is as follows (assuming that the two hips are similar):

- 0 to 4 total score: perfect or near perfect hips (Fig 4);
- 5 to 10 total score: borderline changes that are unlikely to worsen with age (Fig 8);
- 11 to 20 total score: mild changes that may worsen with age, sometimes developing into osteoarthritis (Fig 9);
- 21 to 50 total score: moderate to marked hip dysplasia in which osteoarthritis is already a prominent feature, or severe hip dysplasia before arthritic change (Figs 10, 11);
- Above 50: severe to very severe osteoarthritis secondary to hip dysplasia (Fig 12).

If the scores of the two hips are markedly different, the worse of the two hips should be considered to be more representative of the dog's hip status, and doubling that single hip score will give a more realistic overall score for the purposes of selection for breeding. For example, a dog with a score of 12:3 should be considered to have a hip status similar to other dogs with a total score in the mid-20s.

Effect of age

It is known that age usually has an effect on less than perfect hips, as do environmental factors such as bodyweight, but for logistical reasons it is impossible to

Fig 12: Severe hip dysplasia in a two-year-old labrador retriever, resulting in a single hip score of 45. The femoral head is severely subluxated and there is extensive remodelling of the acetabulum. A combination of new bone at the femoral neck and recontouring gives the femoral head a mushroom shape. This dog's total hip score was 40:45 = 85

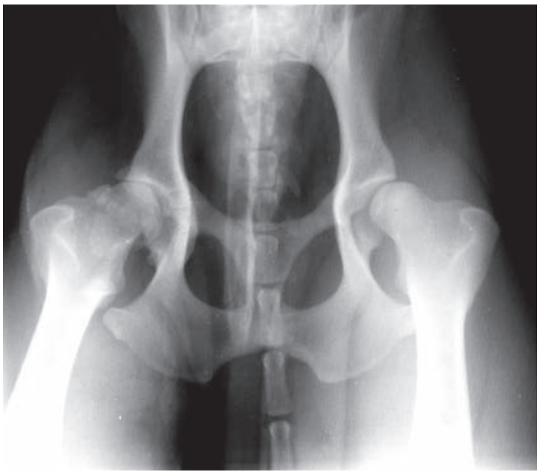


Fig 13: Marked bilateral hip subluxation but only unilateral osteoarthritis in an eight-year-old labrador retriever. This radiograph demonstrates that osteoarthritis is not an inevitable consequence of subluxation. (Picture, Colne Valley Veterinary Practice)

demand that all dogs are the same age at radiography for scoring. In the USA, dogs must be at least two years of age for radiography under the Orthopedic Foundation for Animals (OFA) scheme; in the UK, the minimum age is one year for historical reasons and would now be difficult to change. Clearly, breeding dogs should be radiographed before the first mating, but generally the younger a dog is at the time of radiography the less time there has been for the manifestation of age and environmental effects. Therefore, the presence of arthritic change in a young dog should be considered particularly significant and these animals should definitely be excluded from breeding.

In dogs without evidence of osteoarthritis, consideration of the Norberg angle and subluxation is particularly important. Hips with a total score higher than about 12 to 15 are likely to worsen with time and so when comparing different dogs, their age at radiography should be taken into consideration. Nevertheless, radiographs of older dogs often show marked subluxation with absent or minimal secondary osteoarthritis, and so development of degenerative change is not inevitable (Fig 13). This indicates that joint laxity is not necessarily an accurate predictor of future osteoarthritis in an individual dog, although the relative influence of genetic versus environmental factors for this is not known.

Heritability

A number of epidemiological and genetic studies have been carried out using information from extended hip radiographs, both in the UK using the BVA/KC's scoring scheme data and in other countries where alternative hip dysplasia assessment schemes exist. Some of these publications have examined not only the overall hip status but also component features of the radiographic appearance of the hip (Wood and others 2000a, 2002, Ohlerth and others 2001, Zhang and others 2009, Lewis and others 2010b). A wide variety of dog breeds have been included in these studies, and many instances of an improvement in hip dysplasia prevalence within a breed are documented, even where breeding selection pressure has not been rigid. In Sweden it has been mandatory since 1984 to know the hip status of both a sire and dam if their offspring are to be registered with the Swedish Kennel Club; this has led to a shift towards using dogs with better hips and a corresponding decrease in the prevalence of hip dysplasia in seven breeds studied: German shepherd dog, golden retriever, labrador retriever, Newfoundland, rottweiler, Bernese mountain dog and Saint Bernard (Swenson and others 1997). Statistical modelling has shown a strong, positive relationship between the hip scores of parents, grandparents and offspring, indicating that the genetic heritability of hip dysplasia is moderate to high (Wood and others 2000a,b, 2002). In particular, total hip score, Norberg angle and subluxation have been found to have significant heritability in a number of different studies (Wood and others 2000a,b, Ohlerth and others 2001, Zhang and others 2009, Lewis and others 2010b). This confirms that, overall, the extended VD radiographic view is a fairly reliable way of demonstrating the presence or absence of subluxation.

Norberg angle, subluxation and cranial acetabular edge have also been shown to be predictive of osteoarthritis in later life, although the heritability of such degenerative change has been shown to be more modest (Lewis and others 2010b). In breeds for which the effect of both the sire and dam has been examined, heritability has been shown to be higher from dams in flat-coated retrievers, Gordon setters and Newfoundlands (Wood and others 2000a,b) and from sires in labrador retrievers (Wood and others 2002). In practice, it may be that breeders are taking more care with their choice of sire, whereas in fact the dam's influence on its offspring's hip status may be larger in some breeds.

Use of the hip score

A major advantage of the BVA/KC scoring scheme is that it is possible to calculate an average (mean) score for each individual dog breed, and thus to evaluate a dog's hip status relative to others in its breed. This compensates for the fact that some breeds tend to have a relatively low incidence of hip dysplasia (eg, flat-coated retrievers and many of the sight hounds), whereas hip dysplasia is much more prevalent in other breeds (eg, otter hound, Sussex and clumber spaniels, Newfoundlands). Breed mean scores (BMSs) for most breeds have been published regularly by the BVA and are available on the Canine Health Schemes section of the BVA website. When selecting a dog for breeding, the traditional advice has been that only dogs with hip scores well below the BMS should be chosen in order to apply meaningful selection pressure. Ideally, only dogs with total scores of 10 or less should be used for breeding and, more specifically, when these scores arise only from parameters 1 to 3, with a 0 score for parameters 4 to 9 (ie, no detectable osteoarthritis). This is because total hip score, Norberg angle and subluxation have the highest heritability (Wood and others 2000a,b, 2002, Ohlerth and others 2001, Zhang and others 2009, Lewis and others 2010b), whereas secondary change is more likely to be influenced by age and environmental factors. In addition, a dog's own score should not be considered in isolation, but scores from its relatives should also be sought. These include the scores of its parents and grandparents, scores of other offspring from either parent (progeny testing, usually relating to sires) and scores from any siblings. Genetic research has shown that by considering scores from as many relatives as possible, the influence of environmental factors is minimised and the most accurate assessment of genotype is given. This is borne out in practice by certain breeds and lines of dogs in which good selection pressure has been applied and in which the incidence of hip dysplasia is now very low. A progressive reduction in BMS has been seen in the majority of UK breeds for which it has been calculated, but the reduction would be more marked if breeders practised a more rigid selection process (Table 2, Fig 14). In fact, nearly half of breeding labrador retrievers in the UK are not hip scored (Lewis and others 2010a).

Limitations of the BMS

The BMSs published are calculated as the average scores for all dogs submitted to the BVA/KC scheme since its inception in 1983, and in some cases are averaged over a very large number of dogs (eg, approximately 70,000 labrador retrievers). As a result, the published BMS does not necessarily reflect the precise current hip status in the breed, and downward or upward trends are not shown since the current hip scores are 'diluted' by scores of dogs from many previous generations. To overcome this, five-year rolling mean scores (the BMS for periods of the preceding five years) were initially produced for a number of the most popular breeds, and these show a convincing and steady reduction in hip score indicating an improvement in the hip status of these breeds (Table 2, Fig 14). Five-year rolling means are now being published for most breeds.

One criticism sometimes levelled at the BVA/KC scoring scheme is that, due to the impossibility of enforcement, it is not mandatory for all hip radiographs obtained to be submitted, so the true hip status of a breed may not be represented. It is possible that greater selection of submitted radiographs is being performed by submitting vets, although this seems

Table 2: Rolling breed mean scores and breed median scores for five-year periods in 21 popular breeds, calculated annually between 1996 and 2007, demonstrating an overall steady reduction in score in all breeds

	Mean											
Breed	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Labrador retriever	16·5	16·1	15·8	15·4	15	14·5	14·2	13·8	13·6	13·4	13·1	12·8
German shepherd dog	19·3	19·4	19	18·9	18·7	18·3	17·7	17·5	17·5	17·5	17·2	17
Golden retriever	19·5	19·2	18·7	18·1	17·6	17·3	17·1	16·8	16·7	16·6	16·2	15·7
Rottweiler	12·2	12	11·7	11·6	11·5	11·3	11·2	11·2	11·2	11·2	11·1	11
Border collie	15	15·1	14·9	14·4	14·2	13·7	13·2	12·6	12·7	12·4	12·3	12·2
Flat-coated retriever	9·5	9·2	9·1	8·9	9	9	8·9	8·8	8·8	8·6	8·5	8·3
Bernese mountain dog	17	17·1	16·8	16·1	15·5	15·7	15	14·3	14·2	14	13·3	13·3
Newfoundland	27·7	26·5	25·4	25	25	24·6	23·8	23·5	23·1	22·8	21·9	22·8
Siberian husky	7·9	7·8	7·7	7·8	7·8	7·7	7·6	7·6	7·6	7·7	8	8·1
Bearded collie	11·9	11·6	11·1	10·6	10·3	10·3	10·3	10·8	10·9	11	11	10·8
English setter	19·4	18·9	18·4	17·3	17·1	16·7	16·4	16·2	16·6	16·9	16·8	16·3
Gordon setter	26	25·1	24·2	23·7	23·2	21	20·2	18·7	18·5	18·6	17·9	18
Japanese akita	10·9	10·8	10·6	11	11	10·7	11	10·8	10·4	10·2	9·7	9·1
Weimaraner	13·7	13·7	13·1	12·7	12·5	12	11·7	11·5	11·4	11·2	11·1	11·1
Rhodesian ridgeback	12·1	12·1	12·1	11·7	11·1	11	10·4	10	10	10	9·9	9·9
Old English sheepdog	20·4	19·8	19·9	18·7	17·5	16·8	15·6	15·3	15·5	15·2	15·5	15
Tibetan terrier	14·4	13·5	12·7	13	13·3	13·1	12·8	13	12·7	12·4	12·3	12·3
Welsh springer spaniel	19·5	19·2	19	19·5	19·6	19·6	19·1	18·3	17·1	16·4	16·1	16·7
Samoyed	13·5	13·5	13	12·6	12·1	11·7	11·4	11·4	11·5	12	12·3	12·5
Airedale terrier	15·9	16·2	15·8	16	15·6	15·6	15·1	14·8	14·2	14·6	14·7	14·8
Hungarian vizsla	13	13	13	12·8	12·7	12·4	12·5	12·1	12·2	12·1	12·1	12

unlikely based on the number of submissions received by the BVA and the increasing public awareness of the importance of the Canine Health Schemes. The BVA emphasises the importance of submitting all hip radiographs, regardless of the likely score. However, if it is assumed that generally it is the radiographs of the worst hips that are not submitted and that this has not changed with time (because the vet and owner can see that they are likely to receive a high score and the dog is therefore not going to be used for breeding), the calculated BMS is biased downwards and this increases the selection pressure applied.

Introduction of the breed median score

The BMS, being the average score in a system in which dysplastic hips score higher than normal hips, is distorted upwards by very high scores of a relatively few, severely affected individuals. Thus, a dog with a score at or close to the breed mean is actually in the worse half of the breed. Several years ago it was realised that a more meaningful number was the median, that is, the

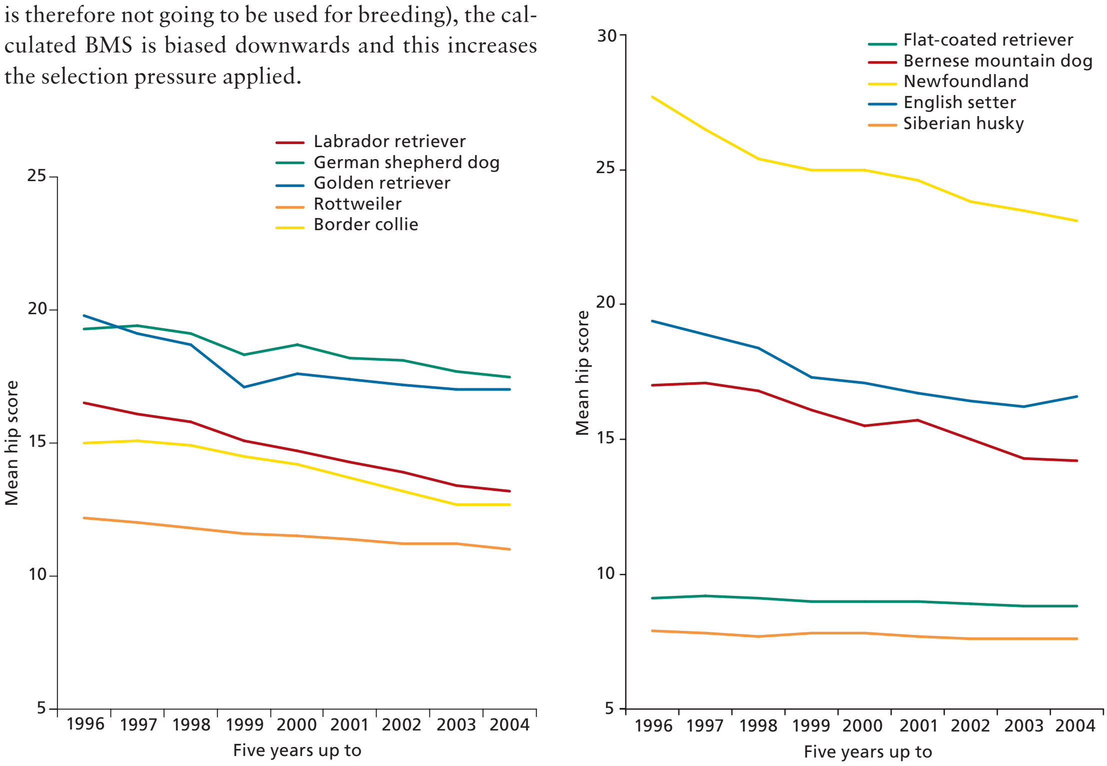


Fig 14: Rolling breed mean scores for five-year periods in the top 10 tested breeds, demonstrating a steady reduction in mean score for radiographs submitted in all 10 breeds. (Graphs, Professor Jeff Sampson)

					Median						
1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
12	11	11	11	11	11	10	10	10	10	10	10
13	13	13	13	12	12	12	12	12	12	12	11
14	14	13	13	13	13	12	12	12	12	12	11
9	9	9	9	9	9	9	8	9	9	9	8
12	12	12	12	12	11	11	11	11	11	11	11
8	8	8	8	8	8	8	8	8	8	8	8
12	12	12	11	11	11	10	10	10	10	10	10
19	18	17	17	17	16	15	15	14	13	13	13
8	8	8	8	8	8	8	8	8	8	8	8
11	10	10	10	10	10	10	10	10	10	10	10
14	14	14	13	13	13	13	13	13	13	13	12
19	18	18	17	16	15	15	13	13	13	13	12
8	8	8	8	8	8	9	8	8	8	8	7
11	12	11	11	11	10	10	10	10	10	10	10
9	9	9	9	9	9	9	8	8	8	8	8
9	14	13	13	12	12	11	11	12	11	11	11
11	11	10	10	10	10	10	10	10	10	10	10
14	14	14	14	14	14	14	13	13	13	12	12
11	11	11	10	10	10	10	10	10	11	10	10
13	13	13	13	13	12	12	11	11	11	11	11
12	12	12	12	12	12	12	11	11	11	11	11

Table 3: Breed median scores and breed mean scores for 118 breeds

Breed	Number	Range	Median	BMS	5y BMS
A: Breeds with scores of 1000 or more (33)					
Airedale terrier	1508	2-91	12	16	14
Akita	2255	0-92	7	10	8
Bearded collie	3136	0-92	10	11	10
Belgian shepherd dog (overall BMS)				10	
–Groenendael	456	0-104	9	11	8
–Laekenois	15	0-104	10	10	9
–Malinois	164	0-60	8	9	7
–Tervueren	934	0-93	9	10	8
Belgian shepherd dog pre-2000 unspecified	179			12	
Bernese mountain dog	4694	0-102	10	15	12
Border collie/working sheepdog	7327	0-89	11	13	12
Bullmastiff	1022	0-104	17	26	23
Cocker spaniel	1013	0-99	11	13	11
Doberman	1323	0-70	9	10	11
English setter	2885	0-95	13	18	16
Flat-coated retriever	5878	0-85	8	9	8
German shepherd dog	40924	0-106	12	18	16
Golden retriever	32906	0-106	12	18	15
Gordon setter	2416	0-104	14	23	15
Hungarian vizsla	1908	0-70	11	12	12
Irish setter	1246	0-100	11	15	14
Italian spinone	1146	0-89	10	14	11
Labrador retriever	70893	0-106	10	14	12
Leonberger	1362	0-89	9	12	11
Newfoundland	4205	0-106	15	26	21
Old English sheepdog	1765	0-100	12	18	13
Rhodesian ridgeback	2220	0-88	8	11	9
Rough collie	1064	0-89	9	12	9
Rottweiler	12307	0-99	8	12	10
Samoyed	1458	0-94	10	13	12
Siberian husky	3646	0-47	8	7	8
Tibetan terrier	2241	0-90	10	13	12
Weimaraner	2050	0-89	10	12	11
Welsh springer spaniel	1684	0-104	13	18	17
Grand total	***218230***				
B: Breeds with scores of 500 to 999 (16)					
Alaskan malamute	960	0-78	10	13	13
Australian shepherd dog	611	2-71	9	10	10
Briard	908	0-99	10	18	12
Chesapeake Bay retriever	501	0-61	9	11	10
Chow chow	775	0-106	8	14	16
Clumber spaniel	751	0-106	18	35	24
Dogue de Bordeaux	864	0-98	15	22	22
Elkhound	548	0-61	11	13	12
English springer spaniel	890	0-102	10	14	13
German shorthaired pointer	950	0-57	9	10	10
Irish water spaniel	828	0-102	12	17	13
Large Münsterlander	607	0-88	8	13	9
Pyrenean mountain dog	514	0-94	9	12	11
Soft-coated wheaten terrier	506	0-62	11	13	12
Standard poodle	765	0-74	11	14	13
Saint Bernard	544	0-90	15	21	20
Grand total	***11522***				

Median Score of the average dog (equal numbers of dogs have better and worse hips) calculated for the period 1992 to November 1, 2010
BMS Breed mean (average) score (total scores divided by number of dogs) given cumulatively since the inception of the BVA/KC scoring scheme in 1983 up to November 1, 2010
5y BMS BMS score for the five years to November 1, 2010 only
N/A Too few dogs scored in these breeds over the five-year period to allow a realistic calculation

score of the average or middle dog (not the same as the average score), at which equal numbers of dogs are both less severely and more severely affected. The median hip score for a breed is inevitably lower than the BMS over a given period of time, usually by several points. For example, the median score of the labrador retriever was 10 at a time when the BMS was 16, and therefore only those with scores below 10 would have been preferred for breeding. Breed median scores are now generated and additional advice for vets and breeders is that only dogs with scores below the median should be used for breeding (that is, the dog is in the better 50 per cent of the breed). This will apply more meaningful selection pressure, although some breeder education will be required to convey the difference between the BMS and breed median score.

The BMSs and breed median scores for 118 breeds and rolling BMSs and breed median scores for five-year periods in 21 popular breeds are given in Tables 2 and 3. The five-year rolling scores show a generally steady improvement in hip dysplasia status based on submitted radiographs, which is highly encouraging and confirms the overall success of the BVA/KC scoring scheme. Nevertheless, further improvement in

Table 3 continued

Breed	Number	Range	Median	BMS	5y BMS
C: Breeds with scores of 100 to 499 (29)					
Anatolian shepherd dog	191	0-68	10	14	11
Bouvier des Flandres	149	4-6	14	18	23
Boxer	401	0-75	13	16	16
Bracco Italiano	121	4-79	12	15	12
Brittany	437	0-74	13	17	17
Cavalier King Charles spaniel	270	0-92	13	16	15
Curly-coated retriever	439	0-59	9	11	10
Dalmatian	149	0-39	10	11	11
Field spaniel	207	0-70	11	16	16
Finnish Lapphund	182	6-45	12	13	14
German wirehaired pointer	342	0-77	10	11	11
Giant schnauzer	177	0-75	10	14	13
Great Dane	473	0-68	10	12	11
Hovawart	210	0-79	9	10	8
Hungarian puli	472	0-102	11	16	12
Hungarian wirehaired vizsla	314	4-60	11	13	13
Irish red and white setter	381	0-96	8	10	10
Mastiff	354	0-81	13	18	18
Maremma sheepdog	153	2-83	12	15	19
Norwegian buhund	140	2-76	12	15	12
Nova Scotia duck tolling retriever	397	0-70	10	11	11
Otterhound	209	4-106	40	44	48
Pointer	129	0-60	9	11	11
Polish lowland sheepdog	407	5-60	13	17	13
Shetland sheepdog	460	0-100	10	13	12
Spanish water dog	173	6-44	12	15	15
Sussex spaniel	154	7-101	33	39	44
Swedish vallhund	175	2-40	10	12	11
Tibetan mastiff	215	0-101	10	14	14
Grand total	***7881***				
D: Breeds with scores of 40 to 99 (21)					
Affenpinscher	58	6-90	12	17	18
Afghan	48	0-54	0	9	9
Australian cattle dog	73	5-56	11	12	13
Basenji	41	0-16	8	7	9
Beagle	56	10-71	17	21	20
Bloodhound	44	0-62	14	20	17
Canaan dog	51	4-45	11	12	10
Estrela mountain dog	62	1-89	14	25	21
Eurasier	91	3-27	10	10	10
German longhaired pointer	60	0-35	9	10	9
Irish wolfhound	75	0-36	2	6	10
Keeshond	53	0-63	12	12	13
Kerry blue terrier	63	4-66	12	15	12
Komondor	42	2-72	10	15	6
Miniature poodle	52	4-58	11	12	10
Portuguese water dog	70	4-63	12	17	17
Pyrenean sheepdog	97	3-77	12	13	11
Russian black terrier	43	8-90	42	36	32
Shar pei	61	4-81	11	17	7
Smooth collie	72	0-17	5	5	4
Staffordshire bull terrier	56	6-53	11	13	16
Grand total	***1268***				
E: Breeds with scores of 10 to 39 (20)					
Basset griffon vendeen PT	14	9-48	13	20	7
Beauceron	34	3-63	11	14	11
Bichon frise	17	4-19	9	10	11
Border terrier	15	6-63	10	13	10
Bulldog	25	9-96	44	42	45
Bull terrier	12	0-12	6	7	N/A
Greenland dog	25	6-60	10	17	11
Hungarian kuvasz	13	10-65	12	22	9
Japanese akita inu	39	6-59	8	13	10
Japanese shiba inu	35	0-35	8	10	N/A
Lagotto romagnolo	37	0-43	10	12	11
Löwchen	16	7-84	12	17	20
Miniature schnauzer	17	4-32	9	13	10
Neapolitan mastiff	36	7-95	22	27	45
Pug	30	8-72	16	23	23
Saluki	39	0-14	2	5	4
Slovakian rough-haired pointer	32	4-29	9	10	10
Schnauzer	26	6-70	12	23	11
Tibetan spaniel	39	2-31	8	12	N/A
Welsh corgi (Pembroke)	29	9-58	20	24	19
Grand total	***530***				

Box 1: Use of hip scores in selecting breeding animals

- Ensure that all potential parents (both sires and dams) are hip scored
- Evaluate the hip scores of parents, grandparents, siblings and previous offspring whenever possible
- Consider the score of the worse hip (on a perfectly symmetrical radiograph) to be more representative of the dog's hip status
- Compare the dog's total score with the breed median score (and compare the score of the worse of the two hips with half of this value) in order to assess the dog relative to others in the breed
- Take the dog's age at radiography into account
- Examine particularly the scores for the first three parameters (Norberg angle, subluxation, cranial acetabular edge), as they describe any underlying hip dysplasia and are usually predictive of subsequent osteoarthritis
- Do not breed from any dog that shows evidence of osteoarthritis (scores in parameters lower down in the scoring grid)
- Breed only from dogs with low hip scores for the breed – certainly less than the breed median score

hip status is possible with more stringent selection of breeding animals.

Summary

The extended VD hip radiographic view, used by most hip dysplasia assessment screening schemes, is safe, easy to reproduce and has been proven to give repeatable and credible results. Breeding based on the results of this radiographic projection has been shown to result in a reduction in incidence and severity of hip dysplasia in numerous breeds in different countries. Total hip score, Norberg angle and subluxation have been found to be not only significantly heritable but also predictors of subsequent osteoarthritis. The BVA/KC scoring scheme assesses hips both for underlying laxity (parameters 1 to 3 in the scoring table) and for secondary changes due to wear and tear and subsequent osteoarthritis. The traditional advice that only dogs with a total hip score well below the BMS should be used for breeding is now supported by the advice that only dogs with scores lower than the breed median score should be used. In addition, dogs with scores indicating that osteoarthritis is present (scores of 3 or more for parameters 3 to 5 and any score in parameters 6 to 9) should not only be excluded from breeding but also managed in such as way as to minimise progression of the changes, especially by weight control. When selecting breeding animals, an individual dog's hip score should not be considered in isolation – consideration of related dogs is vital (Box 1).

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Useful website

- www.bva.co.uk/canine_health_schemes/Canine_Health_Schemes.aspx. BVA's Canine Health Schemes

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Interpretation and use of BVA/KC hip scores in dogs

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