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Review

Diagnosis, genetic control and preventive management of canine hip dysplasia: A review

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ABSTRACT

Despite expensive screening and breeding programmes, hip dysplasia (HD) continues to be one of the most common orthopaedic diseases in dogs. The vast majority of dogs afflicted with HD show minimal to no clinical signs, but it can also be a highly debilitating condition for both working and pet dogs. Hip joint laxity is considered a major risk factor for the development of degenerative joint disease and a definitive diagnosis is made if characteristic signs are evident on a ventrodorsal view of the pelvis. Early prediction of the condition can be made using stress radiographic techniques to evaluate the passive hip laxity.

The diagnosis of HD may be used for the purpose of selecting breeding stock or to decide on the best treatment approach. Breeding programmes based on individual dog phenotypes have been ineffective and a selection procedure based on breeding value (BV) estimation is recommended. Traditional conservative and surgical treatment approaches are reserved for dogs with overt clinical signs of the disease but such treatments can be expensive and aggressive, and are often ineffective in eliminating clinical signs or subluxation and in preventing the development of degenerative joint disease. The implementation of breeding programmes based on BVs and further research into early prediction/diagnosis of HD and effective preventive treatment approaches are essential.

Introduction

Hip dysplasia (HD) is an inherited, non-congenital disease that is particularly prevalent in large and giant breeds of dog (Mäki et al., 2004; Janutta and Distl, 2006; Ginja et al., 2008b) and the expression of HD genes may be influenced by a number of environmental factors (Silvestre et al., 2007). HD is a biomechanical disease characterised by abnormal development of the hip joint and can be a highly debilitating condition for both working and pet dogs (Moore et al., 2001; Vezzoni et al., 2008). However, the vast majority of dogs afflicted with HD show minimal or no clinical signs (Barr et al., 1987; Ginja et al., 2008b). In more severely affected dogs, medical and/or surgical treatment is sometimes indicated (Farrell et al., 2007; Vezzoni et al., 2008).

By convention, a definitive diagnosis is made only if characteristic signs of HD are evident on a standard ventrodorsal radiograph of the pelvis (Corley, 1992; Flückiger, 1995; Gibbs, 1997). Hip joint laxity (HJL) is considered a major risk factor leading to abnormal weight-bearing forces and subsequent development of osteoarthritis during or after maturity (Smith et al., 1995; Ginja et al., 2008c). HJL estimated using the distraction index in stress radiographs in dogs at 4 months (Lust et al., 1993; Ginja et al., 2008c) and 2 months of age (Ginja et al., 2009) was correlated or associated with HJL and HD after 1 year of age.

Preventive therapeutic recommendations for predisposed patients can be confusing due to the disease's unpredictable clinical progression and the lack of published scientific data documenting the long-term efficacy of the available treatments (Puerto et al., 1999; Farrell et al., 2007). Therefore, active genetic control based on diagnostic tests of the condition and selective breeding is the best tool to achieve genetic changes decreasing the disease to acceptable levels (Farrell et al., 2007; Ginja et al., 2008b; Janutta et al., 2008). Humans can also be affected by developmental HD, but the therapeutic protocols are well defined and preventive management is always recommended and can even begin immediately after birth (Gerscovich, 1997; Wenger and Bomar, 2003).

The purpose of this review is to clarify and discuss, based on the current knowledge, HD diagnostic techniques, control strategy recommendations and preventive management approaches. It is hoped this will bring veterinarians up-to-date and help further educate breeders and owners about the condition.

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Diagnosis

Clinical signs

The clinical presentation of dogs with HD is very variable and does not correlate with the radiographic changes in joint morphology (Barr et al., 1987; Ginja et al., 2008b). Progression of the disease also varies and the clinical signs can sometimes be due to concurrent neurological or orthopaedic diseases of the hind limbs (Barr et al., 1987). Some chronic hip alterations (i.e. bony remodelling, fibrosis and thickening of the joint capsule) can actually improve joint congruity and stability, which can result in a spontaneous improvement in hind-limb function (Barr et al., 1987; Riser, 1975).

In general, there are two ages at which animals present with overt clinical signs of HD: (1) dogs younger than 1 year of age with hip instability and overloading of some articular areas and where pain is caused mainly by tearing or stretching of the round ligament, synovitis and acetabular microfractures (Riser, 1975; Manley et al., 2007) and (2) adult dogs with chronic pain from osteoarthritis (Manley et al., 2007). Gait abnormalities, such as stiffness, reduced height of step, shortened stride length, bunny hopping, difficulty in rising, climbing stairs or in jumping over obstacles are the typical clinical signs (Fry and Clark, 1992; Ginja et al., 2008b).

Clinical examination

A complete clinical examination should include observation of the patient at rest, walking and trotting, and re-examination after vigorous exercise (Fry and Clark, 1992). A number of clinical tests that can give information about the hip joint have long been advocated (Fry and Clark, 1992). These can be separated into two groups: (1) to provide information on HJL, recommended mainly for use on young animals (Ortolani, Bardens and Barlow tests) and (2) to detect signs of osteoarthritis (palpation and range of motion tests). These clinical tests are usually performed on sedated or anaesthetised animals (Fry and Clark, 1992). However, it would be very helpful for animal comfort to develop a clinical HD screening technique on fully conscious young animals, similar to the routine clinical HD screening examination of human neonates, which are never anaesthetised or sedated.

The Ortolani test is a common physical manipulation examination that is used in veterinary clinical medicine to diagnose HJL (Chalman and Butler, 1985; Ginja et al., 2008c). The dog is placed in lateral recumbency; the examiner stands behind the animal and grasps the upper stifle firmly putting the hip in a neutral position and the femur parallel to the surface of the examination table (Chalman and Butler, 1985; Ginja et al., 2008c). A proximally directed force is applied to the shaft of the femur to elicit hip subluxation, while the pelvis is supported with the other hand. Then the stifle is slowly abducted to reduce the hip joint. Hip joints are considered to exhibit a positive Ortolani sign when a palpable or audible 'clunk' is present during hip joint reduction. If a 'clunk' cannot be elicited, the result of the Ortolani test is considered negative (Fig. 1) (Chalman and Butler, 1985; Ginja et al., 2008c).

A positive Ortolani test suggests excessive laxity, but its absence does not always indicate a tight hip (Puerto et al., 1999; Ginja et al., 2008c). Fibrosis and thickening of the joint capsule, and the acetabular rim and femoral head destruction prevent the detectable clunk (Puerto et al., 1999; Ginja et al., 2009). In positive cases, the Ortolani technique can be used to determine the angles of reduction (AR) and subluxation (AS), as the inclination of the femur relative to the sagittal plane at the moment of reduction and subluxation, respectively. This is particularly relevant when a triple pelvic osteotomy or pubic symphysiodesis are being considered (Vezzoni et al., 2005, 2008).

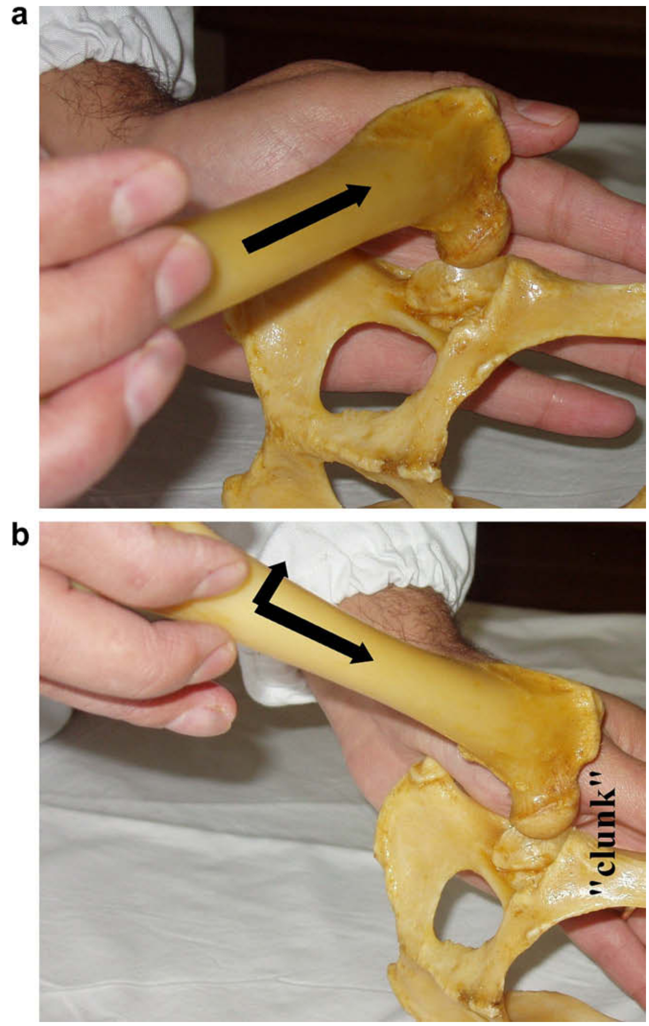

Fig. 1. Ortolani test performed with the dog in lateral recumbency. The hip is positioned in a neutral position with the femur parallel to the table and firm pressure is applied along the long axis of the femur (arrow), which subluxates the femoral head when there is increased hip joint laxity (a). While still applying proximal force, the limb is slowly abducted (arrow), and the femoral head reduces back into position within the acetabulum (b).

Barlow's test was first described in the human medical literature (Barlow, 1962; Gerscovich, 1997) and is used in babies up to the age of 6 months; the baby is placed on its back, the hips are flexed to a right angle into mid-abduction, and the knees are fully flexed. The middle finger of each hand is placed over the greater trochanter and the thumb is applied to the inner side of the thigh. Forward and backward pressure is exerted by the fingers. If there is movement of the femoral head, the hip is considered unstable (Barlow, 1962; Gerscovich, 1997). This test was developed because the Ortolani test in newborn babies (up to the age of 1 year) was found not to be entirely satisfactory (Barlow, 1962). In neonates, when the hip is abducted in the Ortolani test, the dislocated femoral head slides so smoothly over the lower rim of the acetabulum that it does not make a clunk, and the hip therefore appears to be normal (Barlow, 1962). We believe that the Ortolani test also lacks sensitivity in puppies around 8 weeks of age (Adams et al., 2000; Ginja et al., 2009) but is most sensitive in young dogs older than 4 months (Adams et al., 2000; Ginja et al., 2009).

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Barden's test is recommended to evaluate HJL in puppies at 6–8 weeks of age (Bardens and Hardwick, 1968). With the animal in lateral recumbency, the examiner stands behind the puppy and grasps the upper femur (Bardens and Hardwick, 1968; Ginja et al., 2009). Upward pressure is applied by this hand to elevate the femur horizontally (Bardens and Hardwick, 1968; Ginja et al., 2009). The index finger of the other hand is placed on the greater trochanter and its mobility is used to estimate HJL (Bardens and Hardwick, 1968). A lever device can be used to measure the HJL (Ginja et al., 2009). Barden's original work considered this test as diagnostic for early HD, but other researchers have failed to repeat these findings, considering it a subjective test (Adams et al., 2000; Ginja et al., 2009). The examiner dependence and the inherent subjectivity in estimating or measuring a few mm of clinical HJL creates a potential for errors, and thus makes predicting HJL or HD unreliable (Ginja et al., 2009).

Crepitus may be detected during palpation of the hip joint with osteoarthritis (Fry and Clark, 1992). The range of motion might be decreased due to osteophytes, capsular fibrosis, subluxation or fixed luxation (Fry and Clark, 1992; Farrell et al., 2007). The normal range of motion of the hip joint is: (1) flexion 70–80°; (2) extension 80–90°; (3) abduction 70–80°; (4) adduction 30–40°; (5) internal rotation 50–60° and (6) external rotation 80–90° (Newton, 1985).

Radiographic studies

Radiographically, the first signs of HD can be noted by the seventh week characterised by femoral head subluxation and a lag in the development of the craniodorsal acetabular rim (Fig. 2) (Riser, 1975). Radiographic studies can also be separated into two main groups: (1) to evaluate joint congruence and to detect signs of osteoarthritis using the standard ventrodorsal hip extended view (SVDV) and (2) to provide information on HJL demonstrated by stress radiography (PennHIP, dorsolateral subluxation [DLS], Flückiger and Half-Axial Position [HAP] methods). All these radiographic techniques should or must be performed under anaesthesia or heavy sedation, which facilitates accurate positioning, laxity and decreases the need for repeat films and human restraint. Radiation safety rules do not allow human restraint in some countries, such as the United Kingdom.

The SVDV is a universal view that involves placing the dog in dorsal recumbency on the X-ray table, with the rear limbs extended parallel to each other and the stifles internally rotated (Ginja et al., 2008b). The correct positioning of the dog is of utmost importance for an accurate radiographic interpretation; the pelvis should be positioned symmetrically with the femurs parallel to each other and the patellae superimposed over the centre of the femoral condyles (Ginja et al., 2008b). However, there are currently several different schemes in use for the radiographic scoring of HD, with a high degree of correlation between their results, mainly based on the degree of subluxation, joint congruence and remodelling of the bone. According to the Orthopaedic Foundation for Animals (OFA) guidelines commonly used in the United States, seven grades should be used (three normal, one borderline and three dysplastic) (Corley, 1992). The Fédération Cynologique Internationale's (FCI) system is most commonly used in continental European countries and uses five grades (one normal, one borderline and three dysplastic) (Ginja et al., 2008b). The British Veterinary Association/Kennel Club scoring scheme is commonly used in the UK and is based on a detailed points system for the assessment of radiographic features. Nine parameters for each joint are evaluated and each parameter is given a score between 0 and 6 (except for one parameter which is scored 0–5). The total score thus ranges from 0 to 106 (Gibbs, 1997).

There are other screening and scoring methods in other countries, such as the system used in Switzerland, which evaluates six parameters using a score of 0–5 (total score ranging from 0 to 30) (Flückiger, 1995) and one in France, which uses the FCI scale but does not require any sedation or anaesthesia for radiographic evaluation (Genevois et al., 2008). A lack of muscle relaxation clearly influences the HD score and is preferred by owners (Malm et al., 2007; Genevois et al., 2008). The SVDV has been considered to lack sensitivity when it comes to detecting HJL because the standard position tightens the joint capsule, the ligaments of the femoral head and associated muscles (Fig. 3) (Smith et al., 1990; Vezzoni et al., 2005).

a

b

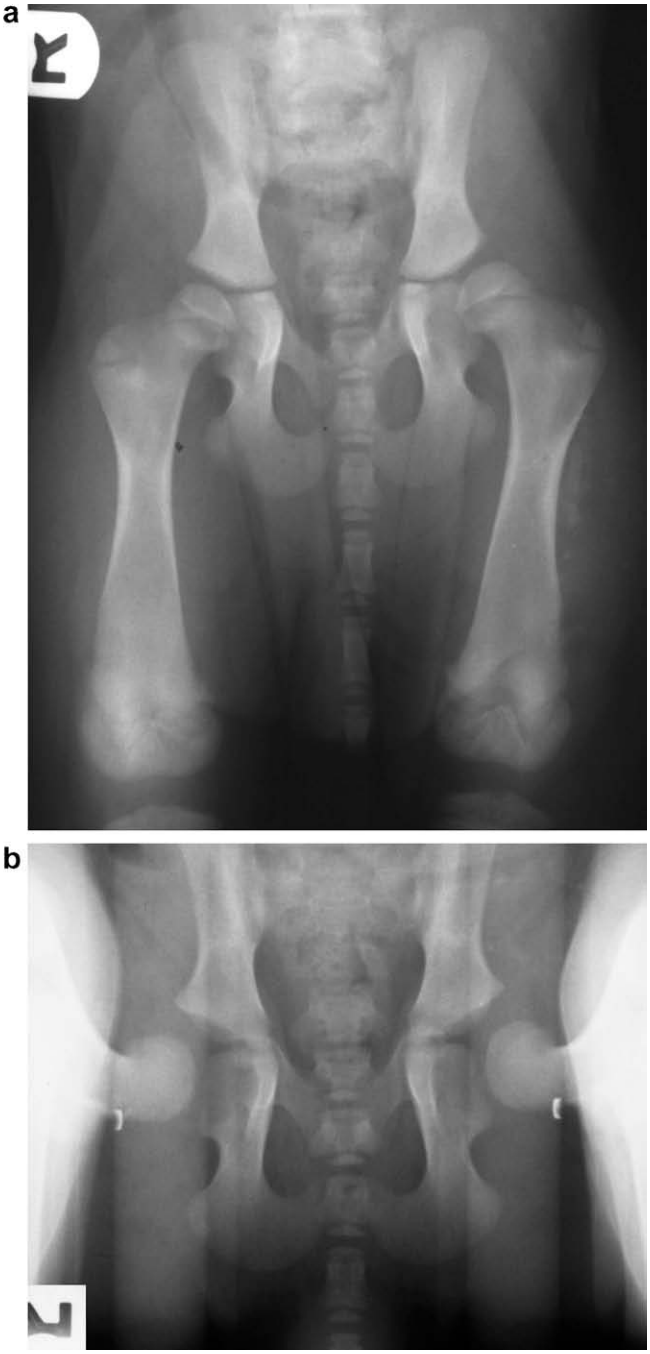

Fig. 2. Standard ventrodorsal hip extended view of a skeletally immature 8-week-old female Estrela mountain dog puppy, which later developed severe hip dysplasia, demonstrating obvious bilateral incongruence between the femoral head and the acetabulum (a). PennHIP distraction view of the same puppy demonstrating an early high passive hip laxity (b).

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Fig. 3. Standard ventrodorsal hip extended view of a 15-month-old female Estrela mountain dog, demonstrating an acceptable congruence between the femoral head and the acetabulum (a). PennHIP distraction view of the same dog demonstrating moderate passive hip laxity in the left hip (b).

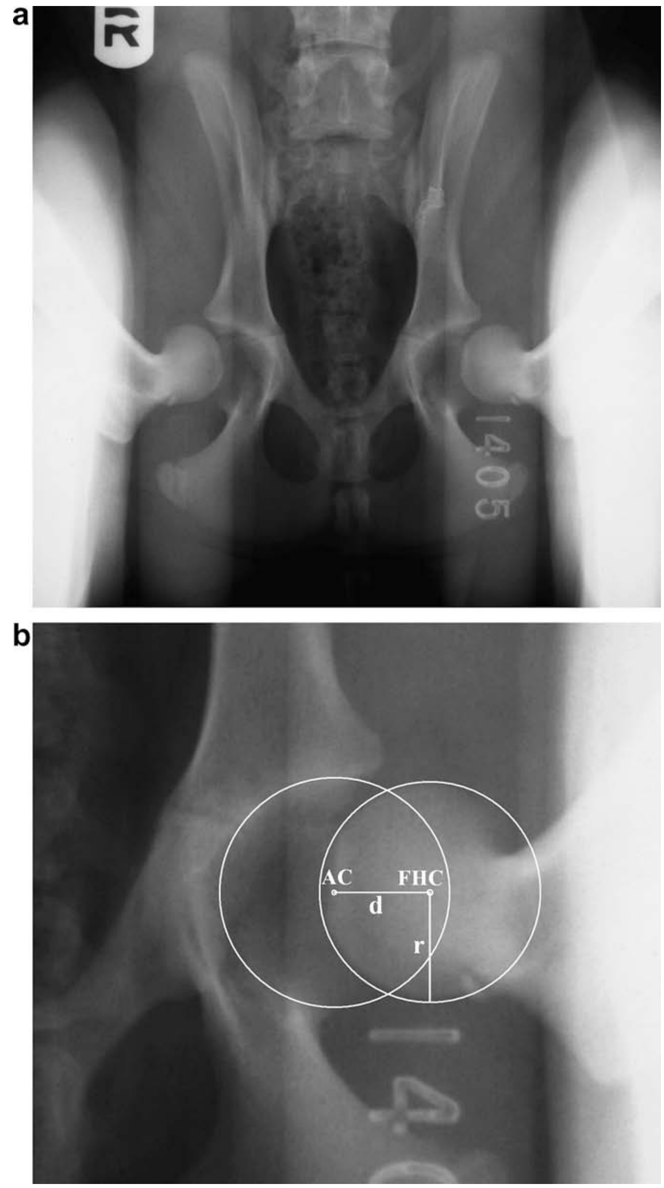

Fig. 4. PennHIP distraction view (a). Left hip detail, femoral head centre (FHC), acetabular centre (AC), femoral head radius (*r*) and distance between FHC and AC (*d*) – the distraction index is calculated dividing the distance *d* by the femoral head radius (b).

The PennHIP method requires appropriate training to certify users and incorporates three radiographic views of the dog in the supine position: hip-extended, compression and distraction (Smith et al., 1990). The multiple radiographic views and manual restraint required are its main disadvantages (Ginja et al., 2007). The distraction view is taken with the hips at a neutral position and maximally displaced laterally using the PennHIP distractor, and is used to estimate HJL by calculating the distraction index (DI) (Smith et al., 1990). To calculate the DI, the distance between the geometric centres of the acetabulum and the femoral head is divided by the radius of the femoral head (Fig. 4) (Smith et al., 1990). The DI ranges from 0 to >1, with 0 representing full congruency of the hip joint and 1 representing complete luxation (Smith et al., 1990).

For the DLS test, no manual restraint is required, the dogs are placed in sternal recumbency in a 'kneeling' position on a foam containing openings for the limbs and the hind limbs are fixed in an adducted position with medical tape, proximal to the stifles and around the hocks (Farese et al., 1998). The hips are slightly extended to avoid radiographic superimposition of the femoral head/acetabulum and femoral diaphysis (Farese et al., 1998). The HJL is estimated by calculating the DLS score. To calculate the DLS score, the perpendicular distance between the most medial edge of the femoral head and the lateral margin of the cranial acetabulum is divided by the diameter of the femoral head (Fig. 5) (Farese et al., 1998). The openings in the pad allow both stifles to make direct contact with the table and transmit force along the longitudinal axis of the femur to the hip joints (Farese et al., 1998). The DLS showed a strong correlation with the DI in 8-month-old dogs (Farese et al., 1998). However, there is evidence that these two methods measure different components of the hip joint; the DLS test is specially indicated to evaluate the chondro-osseous conformation and the DI represents passive laxity of the joint and is independent of the potential stabilising effects of the acetabulum on femoral head position within the joint (Farese et al., 1999). The intra-articular injection of 2 mL of sodium hyaluronate increased the mean DI by 56% and decreased only minimally (2.5%) the mean DLS score (Farese et al., 1999).

The Flückiger method takes the stress view with the dog placed in dorsal recumbency on the X-ray table (Flückiger et al., 1999). The femurs are positioned at a 60° angle to the table surface, the stifles are adducted and manually pushed craniodorsally by the examiner during X-ray exposure. The degree of laxity is calculated in the same way as the DI but is defined as the subluxation index (Flückiger et al., 1999).

The HAP method is well described by Vezzoni et al. (2005). The animals are positioned in dorsal recumbency on the X-ray table and the stress created is very similar to the PennHIP distraction view, but uses a different trapezoidal-shaped distractor. The hips are also maximally displaced laterally using the distractor and the laxity is calculated using the DI formula (Vezzoni et al., 2005).

Other diagnostic techniques

Ultrasonography is very commonly used in human neonates for the early confirmation of developmental HD, and has also been evaluated in puppies for the early diagnosis of HD (Gerscovich, 1997; Adams et al., 2000). However, certain aspects of the canine

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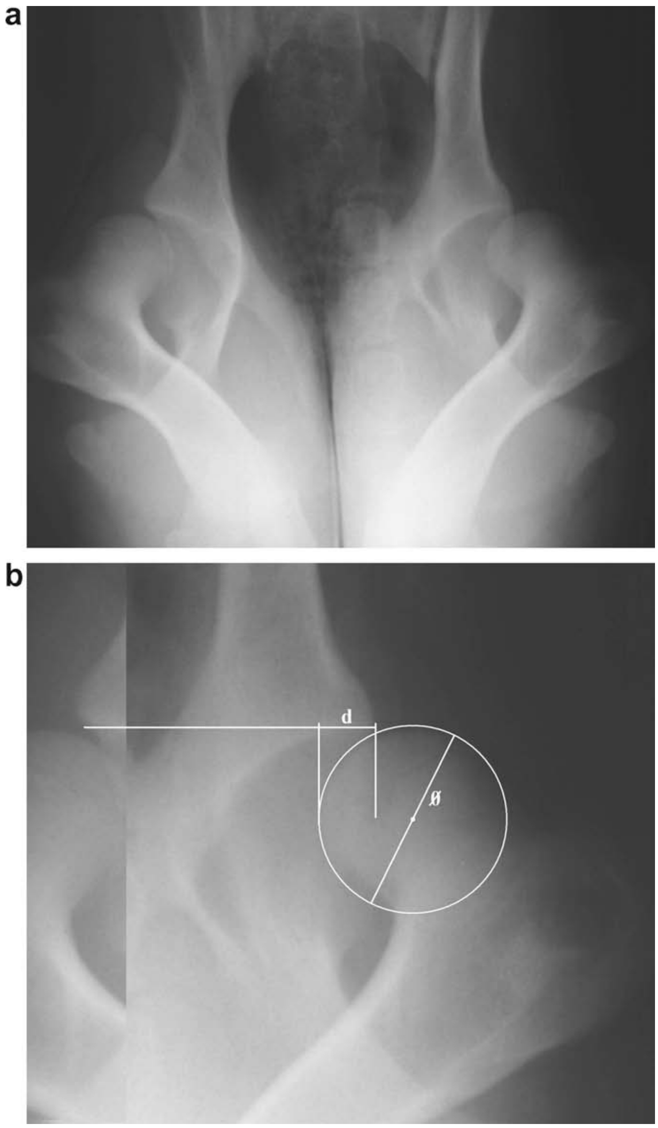

Fig. 5. Dorsolateral subluxation view (a). Left hip detail of dorsolateral subluxation score measurement, a straight line joints the cranial acetabular lateral margin, two perpendicular lines are dropped from this line at the lateral margin of the cranial acetabulum and from the most medial edge of the femoral head, the distance between these parallel lines (*d*) is divided by the widest diameter of the femoral head (θ) (b).

disease, such as its non-congenital nature, the absence of acetabular chondro-osseous alterations in 8-week-old puppies in a magnetic resonance imaging (MRI) study, the impossibility of acetabulum evaluation after 8 weeks of age due to femoral head ossification, and the absence of satisfactory results in previous studies do not support the use of this technique in dogs (Fig. 6) (Greshake and Ackerman, 1993; Ginja et al., 2009).

Between the ages of 8 and 16 weeks, dynamic ultrasonographic methods to quantify HJL would be feasible (O'Brien et al., 1997) but there are no ultrasonographic threshold reference levels for HJL and dynamic ultrasonographic methods have been associated with errors of precision in repeated measurements (O'Brien et al., 1997). Doppler sonography examination of the medial arterial blood supply to the hip joint was also investigated but its changes were not associated to HJL or HD (Rademacher et al., 2005). Increased synovial fluid volumes detected by MRI examination of 8-week-old Estrela mountain dog puppies were associated with HJL and HD later in life (Fig. 7) (Ginja et al., 2009). These results warrant further

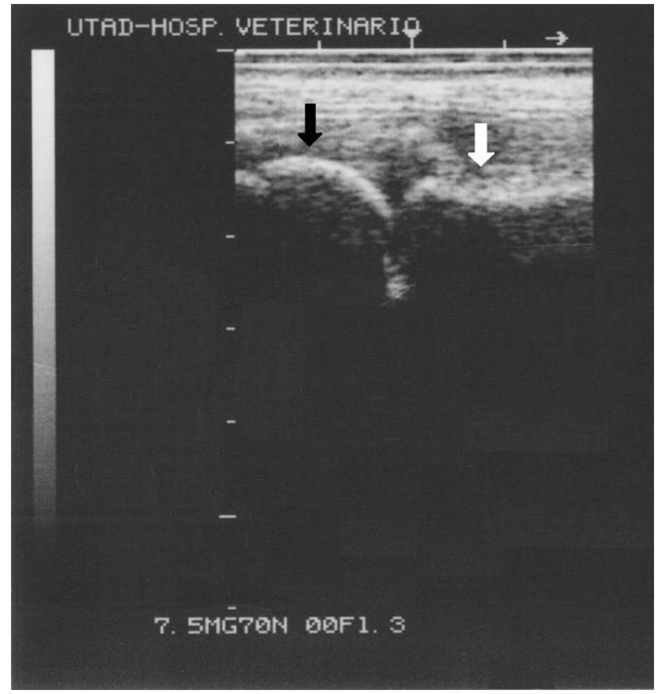

Fig. 6. Dorsolateral ultrasonographic image of the left hip joint of an 8-week-old Estrela mountain dog puppy. Note the horizontal linear appearance of the ilial wing (white arrow) and curvilinear femoral head (black arrow), which makes the ultrasonographic visualization of the acetabulum impossible.

research in other breeds and/or using other imaging techniques for abnormal synovial fluid detection, such as ultrasonography (Ginja et al., 2009).

Computer-assisted force plate and kinematic gait analysis have been used to objectively evaluate HJL and HD in dogs and affected dogs' responses to treatment (McLaughlin et al., 1991; Lopez et al., 2006). However, sometimes the differences detected in gait abnormalities were subtle due to introduced artefacts and a lack of precision (Poy et al., 2000). Improved methods to analyse gait may identify other abnormalities in dogs with inadequate hip-joint conformation (Poy et al., 2000). A recent study determined that even HD with subclinical and subtle radiographic signs influences joint kinematics (Bockstahler et al., 2007).

The isolation of genetic markers for disease diagnosis has been attempted (Chase et al., 2004; Todhunter et al., 2005). Studies based on complex segregation and molecular genetic analysis suggest that major dominant and recessives genes for HD exist in dogs with a few major genes responsible for the major differences in favourable or unfavourable hip conformation (Todhunter et al., 2005; Mäki et al., 2004). The possible existence of major genes and the detection of quantitative trait loci associated with HD could be important for HD diagnosis and future selection against HD, which will enable the elimination of carriers from breeding programmes and will be a suitable instrument for HD eradication (Janutta and Distl, 2006).

Genetic control

Controlling polygenic diseases like HD requires selective breeding programmes (Smith, 1998). While there are no definitive molecular diagnostic tests, the animal's genotype is estimated by evaluating hip phenotype (Smith, 1998). The relationship between phenotype and genotype results in the concept of heritability, defined as the ratio of additive genetic variance to the overall phenotypic variance (Smith, 1998; Silvestre et al., 2007). The phenotypic

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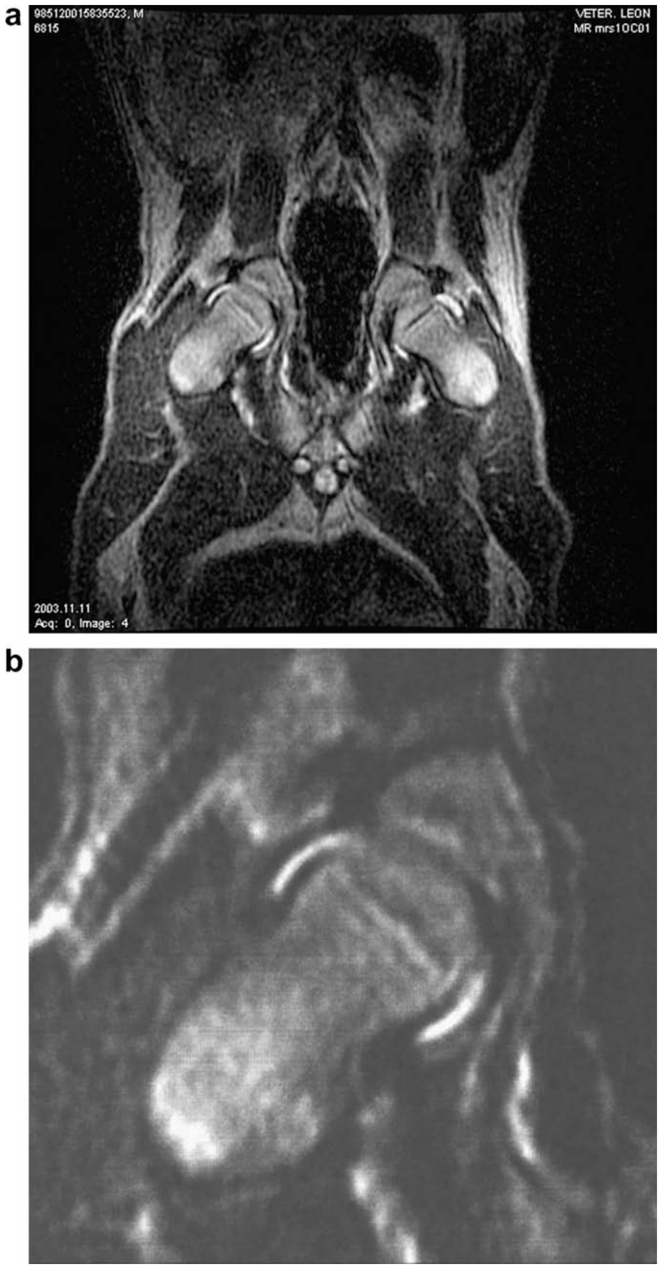

Fig. 7. Dorsal T2-weight central magnetic resonance imaging slice of an 8-week-old Estrela mountain dog puppy demonstrating the synovial fluid in caudal and cranial femoral head-and-neck recesses (a). Detail of the right hip joint (b).

expression of HD in dogs genetically predisposed to the condition may be modified by environmental risk factors such as nutrition, exercise, bodyweight, birth weight, number of puppies in the litter, age of the dam, floor cover, pre-weaning mortality rate in the litter, season of birth and hip laxity (Mäki et al., 2000; Ginja et al., 2008b). HJL heritability has been shown to be higher than the heritability of HD, at 0.85 and 0.43, respectively (Ginja et al., 2008a; Silvestre et al., 2007). Therefore, when using similar selection pressures the genetic improvement using the HJL as reference would be bigger than using the HD score.

Worldwide, the predominant mode of choosing breeding candidates is to make selections based on the individual animal's HJL or HD phenotype (Corley, 1992; Smith, 1998; Janutta et al., 2008). In previous studies the effectiveness of phenotypic mass selection in reducing HD has shown variable results, being considered not effective by some (Mäki et al., 2002) but resulting in phenotypic and genetic improvement according to others (Janutta et al., 2008). Since early HJL determination is a reliable method for predicting HD, the two hip evaluations can be used complementarily for the purposes of phenotypic selection of breeding stock (Ginja et al., 2008c). However, some of the possible major genes were found to be recessive, making the use of phenotypic selection against HD ineffective and resulting in very small or negligible genetic progress (Mäki et al., 2004). Dogs with a normal radiographic phenotype can still be carriers of certain dysplasia genes and transmit these genes to their offspring (Mäki et al., 2000; Ginja et al., 2008b). Even if there are phenotypic and genetic improvements, when heritability is low or prevalence decreases, breeding progress is harder to achieve and a longer period of time is required to achieve further improvement (Janutta et al., 2008).

Breeding value (BV) estimates are commonly used in farm animal breeding and have been used in animal selection for polygenic traits, such as milk yield and growth rate, with good results (Flückiger et al., 1999; Ginja et al., 2008b). The BV is a genetic parameter derived from the hip quality of relatives and offspring (Silvestre et al., 2007). It gives a more precise measure of a dog's genetic quality than individual records alone (Silvestre et al., 2007; Janutta et al., 2008). However, preliminary results from 5 years of selection in the German population of German shepherd dogs indicated that the introduction of BV prediction has not led to further genetic improvement over mass selection (Janutta et al., 2008).

For estimating BVs the threshold models are recommended for categorical traits (i.e. HD grades) (Silvestre et al., 2007) and linear models for continuous traits (i.e. HJL) (Ginja et al., 2008a). The calculation of BVs includes vectors of liabilities, fixed effects, animal effects, permanent environmental effects and residue (i.e. random environmental and non-additive genetic effects), and incidence matrices relating the effects to the scores (Mäki et al., 2000; Silvestre et al., 2007). The BV scale ranks animals and different levels of selection pressure can be applied for HD genetic control (Silvestre et al., 2007; Ginja et al., 2008b). Genetic progress is expected when the BV is used as a selection criterion in animal populations (Mäki et al., 2004; Janutta et al., 2008).

Preventive management

Currently, HD is generally diagnosed by worsening of symptoms when osteoarthritis is already at an advanced stage. This renders practically useless any conservative or surgical therapy that limits the development of the disease or its severity. Treatments are focused on alleviating pain and improving the function of the hip joints and quality of life (Johnson et al., 1998; Farrell et al., 2007).

Some conservative and surgical (e.g. juvenile pubic symphysiodesis) preventive management procedures have been proposed for skeletally immature dogs with clinical evidence of their predisposition for HD but without typical clinical signs (i.e. lameness) (Manley et al., 2007; Vezzoni et al., 2008).

The basis of HD preventive treatments in human neonates is to achieve hip joint congruence during acetabulum development and is often successful leading to the best long-term results (Gerscovich, 1997; Wenger and Bomar, 2003). The depth of the acetabulum cavity and its cup-like shape are determined by the presence of the spherical femoral head (Wenger and Bomar, 2003).

Preventive conservative management

Some dogs affected with HD will show signs of pain at 5–6 months of age and apparent spontaneous remission from pain at 9–11 months (Riser, 1975). This may be associated with the healing of microfractures of the dorsal acetabular rim (Riser, 1975). Restricting exercise during this time period can help prevent worsening of the secondary arthritic changes that occur with HD (Riser, 1975; Vezzoni et al., 2008).

Limiting food consumption to 75% of the amount given to ad libitum-fed control dogs after 8 weeks of age resulted in a 67% reduction in HD prevalence at 2 years of age (Kealy et al., 1992). Prevention of obesity is recommended as a way to decrease the stress placed on joints and periarticular tissues (Vezzoni et al., 2008). A non-weight bearing activity such as swimming may yield the positive benefits of exercise on muscle strength and cartilage nutrition without the undesirable secondary effects (Vezzoni et al., 2008).

Puppies treated prophylactically with intramuscular injections of poly-sulfated glycosaminoglycans showed less subluxation than untreated animals (Lust et al., 1992). The published outcomes of long-term results of non-surgical management of HD in dogs are controversial, some being considered favourable (Barr et al., 1987) and others unfavourable (Farrell et al., 2007; Vezzoni et al., 2008). Conservative management may be effective in palliating the discomfort associated with HD or HJL, but is unlikely to prevent development and progression of osteoarthritis (Manley et al., 2007; Vezzoni et al., 2008).

Severely restricting exercise by confining puppies in a cage has been reported as an alternative for young dogs with predisposition to HD development (Riser, 1975). By confining a puppy in a small area they stay seated for long periods, thereby maintaining an abduction-flexion position, which supports a forced hip congruence (Riser, 1975). However, this treatment is not recommended since such dogs do not develop socially.

Juvenile pubic symphysiodesis

Juvenile pubic symphysiodesis (JPS) is a minimally invasive surgical procedure without internal fixation devices that is performed on puppies at 15–20 weeks of age and at risk of developing HD (Patricelli et al., 2002; Vezzoni et al., 2008). During JPS, electrocautery is applied to the growth plate of the pubis inducing thermal necrosis of the germinal chondrocytes (Patricelli et al., 2002; Vezzoni et al., 2008). The pubic growth plate undergoes premature closure, without affecting growth of the ischial and acetabular portions, which results in a ventrally underdeveloped pelvis (Manley et al., 2007). The normal growth of the dorsal aspect of the pelvis results in an increase in acetabular coverage, better articular congruity and diminution of subluxation forces (Patricelli et al., 2002). Improvement in clinical signs, hip conformation and/or arresting development of HD after JPS have been observed and are considered satisfactory in dogs with mild signs of susceptibility to HD (Patricelli et al., 2002; Vezzoni et al., 2008). Some unfavourable environmental conditions (i.e. 'over nutrition', uncontrolled physical activity) before JPS can produce beneficial effects on joint biomechanics and might explain some less satisfactory results (Vezzoni et al., 2008).

The technique has been considered to be of minimal or no clinical effectiveness in puppies with severe initial signs of susceptibility to HD (Vezzoni et al., 2008). In another study, the procedure was unsuccessful in reducing subluxation or the development of osteoarthritis (Manley et al., 2007). In severe cases of HD, acetabular ventroversion occurs slowly and the femoral heads slip laterally along the sloped and rounded lateral acetabular border, so acetabular congruity is never obtained (Vezzoni et al., 2008). Vezzoni et al. (2008) suggested JPS for all puppies with a positive Ortolani sign, an AR of between 15° and 35°, an AS between 0° and 10°, an inclination of the dorsal acetabular rim between 7° and 12°, and DI < 0.75. JPS causes a decrease in the area of the pelvic inlet and obviously masks the hereditary defect (Vezzoni et al., 2008). On the other hand, some dogs with moderate HJL and with positive Ortolani signs do not develop clinical signs of HD (Puerto et al., 1999). This suggests that pelvic surgery should not be carried out indiscriminately in all puppies and its results should be examined carefully in controlled prospective clinical trials – accurate prediction of the clinical HD outcome is essential (Puerto et al., 1999).

Triple pelvic osteotomy

Triple pelvic osteotomy (TPO) is the most popular surgical semi-preventive treatment for HD in dogs (Vezzoni et al., 2005; Manley et al., 2007). TPO is normally performed in animals that already show overt clinical signs, that are younger than 12 months of age and that are free from or show minimal radiographic signs of osteoarthritis (Johnson et al., 1998). In human neonates with HD, TPO is considered to be an aggressive treatment and is only considered when other surgical and non-surgical preventive treatments have failed (Gerscovich, 1997; Wenger and Bomar, 2003).

TPO also results in ventrolateral rotation of the acetabulum and involves osteotomies of the pubis, ischium and ilium and subsequent rotation and fixation of the acetabular segment with a plate and screws (Manley et al., 2007). The ideal candidate for TPO should have a positive Ortolani sign, be between 6 and 12 months of age and be free of radiographic signs of osteoarthritis (Johnson et al., 1998; Manley et al., 2007). Vezzoni et al. (2005) recommend TPO for all dogs aged between 5 and 7 months that present with an AR between 25° and 40°, an AS between 10° and 30°, an inclination of the dorsal acetabular rim between 10° and 25° and no or minimal osteoarthritis.

After TPO, dogs appear to have a better biomechanical stability and in some studies TPO was considered good in resolving clinical lameness (Johnson et al., 1998) and reducing the progression of osteoarthritis (McLaughlin et al., 1991). Force plate analysis has also indicated that loads transmitted through dysplastic hips increased after TPO and were greater than untreated hips (Johnson et al., 1998; McLaughlin et al., 1991). However, dogs with a high HJL prior to surgery are likely to have a less favourable outcome (Manley et al., 2007). Some studies also indicated that this technique is not suitable for eliminating the HJL characteristic of HD or the progression of osteoarthritis (Johnson et al., 1998; Manley et al., 2007). We think that for the greatest level of success an accurate selection of candidates for TPO is essential.

Conclusions

Despite the HD screening and breeding programmes based on phenotypic selection, the prevalence of HD remains high. HD control programmes based on BVs are recommended. Early screening methods, controlled prospective clinical trials and alternative preventive surgical procedures are needed, mainly for young dogs with high PHL and great predisposition to developing severe HD, since the current management methods are considered to be ineffective.

Conflict of interest statement

None of the authors of this paper has a financial or personal relationship with other people or organisations that could inappropriately influence or bias the content of the paper.

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