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Skeletal morphology and morphometry of the lumbosacral junction in German shepherd dogs and an evaluation of the possible genetic basis for radiographic findings

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ABSTRACT

The aim of this study was to identify skeletal variations in the lumbosacral junction (LSJ) of the German shepherd dog (GSD) compared with other large breeds. The radiographic traits of the LSJ were investigated in a group of 733 GSDs and a control group of 334 dogs of other breeds that were matched in terms of size. Nine morphological and 17 morphometric traits were recorded and analysed. Furthermore, the possibility of a genetic basis for these radiographic features was evaluated by calculation of genetic variance components.

Five of the morphological and 14 of the morphometric traits varied significantly between the GSD group and the control group ($P < 0.05$). Osteochondrosis of the sacral endplate (SOC) had a higher prevalence in the GSDs (10.1%) compared with controls (5.7%). The majority of LSJ degenerative changes recorded from the radiographs occurred in the GSDs. The extent and relative proportion of lumbosacral step formations were greater in the GSD group compared with controls ($P < 0.001$). The lumbosacral vertebral canal height was reduced in the GSD compared with the control dogs ($P < 0.001$) suggesting a primary stenosis. This was accentuated by an abrupt tapering of the vertebral canal at the level of the LSJ indicated by a lumbosacral ratio of 1.51 in the GSD.

The skeletal morphology and morphometry of the LSJ in the GSD seem to be different from that found in other large dogs. For multiple traits frequently observed in GSD such as SOC, step formations, and LSJ stenosis, moderate to high non-zero heritabilities were noted. As these features are also assumed to promote lumbosacral disease, selection against these traits is suggested.

Introduction

Cauda equina syndrome (CES) refers to a complex of clinical signs caused by lumbosacral vertebral canal stenosis and subsequent compression of the cauda equina nerve roots. The breed most commonly affected by clinical signs related to lumbosacral stenosis is the German shepherd dog (GSD) (Indrieri, 1988; Watt, 1991; Ness, 1994; Danielsson and Sjöström, 1999; DeRisio et al., 2000; Suwankong et al., 2008). The aetiopathogenesis of the disease is considered to be complex and congenital, developmental and acquired abnormalities may contribute to narrowing of the lumbosacral vertebral canal, nerve root compression, and progressive clinical signs (Lang et al., 1992; Morgan et al., 1993; DeRisio et al., 2000; Seiler et al., 2002; Flückiger et al., 2006; Meij and Bergknut, 2010).

Individual characteristics of lumbosacral morphology predisposing the GSD to CES have been identified in previous studies. Lumbosacral transitional vertebrae (LTV) and sacral osteochondrosis (SOC) are believed to contribute to the breed-predisposition for CES because of their pathological potential and frequent occurrence in the breed (Lang et al., 1992; Morgan et al., 1993; Hanna, 2001; Damur Djuric et al., 2006; Flückiger et al., 2006). There may be a genetic background for conditions promoting CES (Lang et al., 1992; Morgan et al., 1993; Damur Djuric et al., 2006; Flückiger et al., 2006), and at least partial genetic determination is indispensable in the justification and efficacy of breeding selection against traits predisposing the GSD to lumbosacral stenosis. However, to date, the only trait known to increase the risk of CES in which the genetic background has been investigated is LTV (Wigger et al., 2009) and these authors give a heritability range of 20–30% in the GSD. Information on the genetic involvement of many other skeletal characteristics of the lumbosacral junction (LSJ) is lacking.

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A number of studies have examined the diagnostic value of several radiographic and tomographic features in the quest to differentiate between dogs with and those without clinical signs of CES (Mattoon and Koblik, 1993; Morgan et al., 1993; Schmid and Lang, 1993; Rossi et al., 2004; Scharf et al., 2004; Flückiger et al., 2006; Suwankong et al., 2006; Steffen et al., 2007). However, extensive interbreed comparisons regarding the general skeletal conformation of the LSJ have not been undertaken using normal dogs. In light of the high incidence of CES in GSDs, there is a need for comprehensive data on the general LSJ differences between GSDs and other dogs of similar size. Knowledge of the morphological and morphometric variations of the LSJ of GSDs compared to other large dogs would help to understand why GSDs are prone to lumbosacral disease.

The purpose of this study was to analyse the variation in congenital, developmental and acquired features of the LSJ between clinically normal GSD and dogs from other large breeds. Morphological and morphometric radiographic traits of the LSJ in a large population of GSDs were investigated and compared with a control group. We hypothesized that there is breed-specific variation in the radiographic morphology and morphometry of the lumbosacral region in the GSD. Furthermore, our aim was to determine potential genetic involvement in the development of phenotypic characteristics of the LSJ based upon the pedigree data of the GSD.

Materials and methods

Study design and patient material

The observational study was based on a retrospective analysis of radiographic material from the Small Animal Clinic, Department of Veterinary Clinical Sciences, University of Giessen. The study comprises a group of GSDs and a control group containing other canine breeds matched to the GSD in terms of size. All dogs were presented for the purpose of screening for canine hip dysplasia (CHD) according to the Fédération Cynologique Internationale (FCI). To meet the inclusion criteria of this study, the clinical histories of the dogs had to be devoid of back pain or gait abnormalities, and the medical records had to be negative for lumbosacral pain, hind limb ataxia, and neurological deficits at the time of presentation. To be included in the control group, the height of the withers of a specific breed had to overlap within the range 60–65 cm for males and 55–60 cm for females according to the breed standard of the FCI. For all dogs, a lateral radiograph of the pelvis in neutral position centered on the LSJ (Morgan, 1993) was available and had been obtained at the request of the owner.

Evaluation of radiographs

Image analysis was performed using a dedicated computer software program (DicomWorks 1.3.5 imaging software[1]). All images were reviewed by a radiology resident (NO) who was unaware of the breed of the dog. In case of equivocal findings images were re-evaluated by the resident and a board-certified radiologist (BT), and consensus was reached.

Nine qualitative traits were evaluated and graded binary according to their absence (grade 0) or presence (grade 1). These included SOC, LTV identified by the presence of a radiolucent disc space between the first and second sacral segment, spondylosis deformans of the opposing lumbosacral vertebral endplates ($SPON^{7/1}$) and the opposing endplates of the lumbar vertebrae 6 and 7 ($SPON^{6/7}$), lumbosacral facet joint arthropathy (ARTH), sclerosis of the cranial sacral endplate (SCLER), opacification associated with the intervertebral disc space (O-DISC) or vertebral canal (O-CAN), and reduced delineation of the ventral contour of the sacral roof (ROOF). The morphological traits and their abbreviations are summarized in Table 1.

The following 17 quantitative morphometric traits were obtained from the radiographs and scaled as continuous measurements based on previously published methods (Wright, 1980; Feeney and Wise, 1981; Walla, 1986; Morgan and Bailey, 1990; Mattoon and Koblik, 1993; Schmid and Lang, 1993; Scharf et al., 2004). The metric measurements are quoted in mm, and the angles in degrees (°). Lumbosacral step formations (STEP) were measured at the level of the caudal endplate of L7 as the distance between two lines joining the dorsal contour of the vertebral bodies of L7 and S1. Width of the lumbosacral intervertebral space (IVS) was defined as the distance between the centers of the opposing lumbosacral endplates along a line dividing the vertebral body of S1 into equal halves. The lengths of the vertebral bodies of L6 (L_L6), L7 (L_L7), and S1 (L_S1) were measured as a line intersecting these vertebral bodies. The heights of the bodies of L6 (H_L6) and L7 (H_L7) were measured in the mid-portion of the vertebral bodies. The height of S1 (H_S1) was measured at the level of the cranial sacral endplate. The height of the vertebral canal was measured at six locations—the cranial and caudal endplate of L6 (CAN_L6_{CR}, CAN_L6_{CD}), L7 (CAN_L7_{CR}, CAN_L7_{CD}), and the sacrum (CAN_S1, CAN_S3). Table 2 summarizes the morphometric traits including their abbreviations and units of measurements.

To compensate for possible bias from individual body size, the values obtained from metric measurements were normalized using anatomical reference points within the same radiograph as stated below. The unitless normalized values are indicated by the superscript REL.

$$^{REL}STEP = STEP/CAN\_L7_{CD},$$

$$^{REL}IVS = IVS/CAN\_L7_{CD},$$

and

$$^{REL}L\_X = L\_X/[(L\_L6 + L\_L7 + L\_S1)/3],$$

$$^{REL}H\_X = H\_X/[(H\_L6 + H\_L7 + H\_S1)/3],$$

$$^{REL}CAN\_X_{CR} = CAN\_X_{CR}/H\_X,$$

$$^{REL}CAN\_Y_{CD} = CAN\_Y_{CD}/H\_X,$$

with

$$X = L6, L7, S1 \text{ and } Y = L6, L7, S3 \text{ respectively}.$$

The lumbosacral ratio (LS_R) was calculated by dividing the vertebral canal height $^{REL}CAN\_L7_{CD}$ by the vertebral canal height $^{REL}CAN\_S1$ as in a previous study (Mattoon and Koblik, 1993). The lumbosacral angle was recorded in two different ways. The dorsal lumbosacral angle (LS_A_D) was derived from a line aligned with the dorsal contour of the vertebral body of the lumbar vertebrae 6 and 7 and a line that joined the dorsal contour of the sacral vertebral bodies. The central lumbosacral angle (LS_A_C) was measured between lines intersecting the vertebral bodies of the last lumbar vertebrae and the sacrum centrally. In addition, the intervertebral angle (EP_A) was obtained from the lines being tangential to the opposing lumbosacral vertebral endplates.

Statistical analysis of radiographic traits

The prevalence of the morphological traits among the two groups was calculated. Descriptive statistics were computed for the morphometric traits. In the analysis of variance, both morphologic and morphometric data were analysed for significant differences regarding group, sex, and age. Group (GSD, control group) and sex (male, female) were regarded fixed effects; age at the time of presentation was included as linear covariate. To allow for eventual differences between the groups caused by the varying age at presentation, age within the group was taken into account. Preliminary trials revealed that the effect of sex between the groups was negligible. Thus, the interaction between group and sex was not integrated in the statistical model applied (model 1):

$$y_{ijkm} = \mu + bA_i(Gr_j) + RGr_j + S_k + e_{ijkm}$$

where y_{ijkm} is the morphologic or morphometric trait obtained from the radiographs, μ is the model constant, $A_i(Gr_j)$ is the age within the group in months with the linear regression factor b, RGr_j is the fixed effect of the group (GSD group vs. control group), S_k is the fixed effect of sex, and e_{ijkm} is the random residual error.

When prior testing revealed an influence of the presence of an LTV on a trait, the presence of an LTV was integrated in the model as a fixed effect and the respective model was used for that specific trait (model 2):

$$y_{ijklm} = \mu + bA_i(RGr_j) + RGr_j + G_k + LTV_l + e_{ijklm}$$

where LTV_l is the fixed effect of the presence of an LTV.

For the morphologic traits, a GENMOD procedure (Generalized Linear Model) was employed using a binominal distribution function and probit link function. The analysis of variance of the morphometric traits was exhibited using the SAS-procedure General Linear Model (GLM). Results were considered significant at $P < 0.05$. All statistical analyses were performed using a commercial statistical software package (SAS version 9.2, SAS Institute).

Genetic analysis

In a subset of the GSD group, pedigree data archived by the national GSD Kennel Club was available, and for these dogs, analyses of genetic variance components were performed. The morphological and morphometric criteria of these dogs were analysed for a possible partial genetic background. The genetic analysis of the morphological traits was restricted to traits with a proportion >5%. Hence, two of the morphological traits ($SPON^{7/1}$ and $SPON^{6/7}$) were excluded.

[1] Puech, P., and Boussel, L. See: <http://www.dicomworks.com/> – accessed January 2008.