

Prevalence of various radiographic manifestations of osteochondrosis and their correlations between and within joints in Dutch Warmblood horses

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Summary

Reasons for performing study: Osteochondrosis (OC) is the most important orthopaedic developmental disorder in horses and may manifest in several different forms. No detailed study on the prevalence and/or interrelation of these forms is available, even though these data are a prerequisite for conclusive genetic studies.

Objectives: To assess the prevalence of the various manifestations of OC as detected radiographically and to evaluate possible relationships between their occurrence within the same joint and between different joints.

Methods: The FP (femoropatellar), TC (tarsocrural) and MCP/MTP (metacarpophalangeal/metatarsophalangeal) joints of 811 yearlings selected randomly, descending from 32 representative stallions, were radiographed and scored for the presence and grade of osteochondrotic lesions. Results were compared at the sire, animal, joint and predilection site levels.

Results: In the FP joint, the percentage of animals showing normal joint contours in all sites was 60.7%. For the TC joint and the combined MCP/MTP joints, these figures were 68.6 and 64.6%, respectively. For all joints combined, the percentage dropped to 30.5%. Sedation improved detection of OC lesions in the FP joint. There was a high correlation between the right and left joints. The correlation between flattened bone contours and fragments was considerably less.

Conclusions: Scoring on a detailed scale is necessary to achieve good insight into the prevalence of OC. Observations on the right and left joints can be combined in further analyses, whereas flattened bone contours and fragments should be evaluated as statistically different disorders.

Potential relevance: This study provides insight into the prevalences of various manifestations of OC and their relationships, within and between joints. These results form the basis for detailed quantitative and/or molecular genetic studies that should lead to the establishment of breeding indices and/or genetic marker sets for OC.

Introduction

Osteochondrosis (OC) is the most important orthopaedic developmental disorder in horses. It is a disturbance in the physiological process of endochondral ossification that occurs in young, growing individuals. Irregular ossification leading to the formation of thick cartilage plugs may, in combination with biomechanical influences, result in the formation of focal necrotic areas, detachment of cartilage flaps, and eventually the formation of loose fragments (Jeffcott 1997; van de Lest *et al.* 1999). When loose fragments are present, the term osteochondritis dissecans (OCD) is used. The most common clinical sign of OC is nonpainful joint distension. Other clinical signs can be reduced range of motion in the joint, a positive response to flexion tests and varying degrees of lameness. These signs are usually associated with the onset of training and therefore suggest activation of subclinical lesions through biomechanical influences (Jeffcott 1997). The aetiology of OC is still not fully understood, but there is agreement that the disorder is multifactorial in origin (Jeffcott 1991; Philipsson *et al.* 1993; Wittwer *et al.* 2006).

Osteochondrosis is common in warmblood breeds, Thoroughbreds and Standardbreds (Jeffcott 1991; Philipsson *et al.* 1993; Stock *et al.* 2005), but is also found in a coldblood population (Wittwer *et al.* 2006). Previous studies across a range of breeds reported prevalences of osteochondrotic lesions or fragments in the limb joints between 7 and 64% (Hoppe 1984; Hoppe and Philipsson 1985; Schougaard *et al.* 1990; Grøndahl and Dolvik 1993; Philipsson *et al.* 1993; Sandgren *et al.* 1993; Jeffcott and Henson 1998; Ricard *et al.* 2002; Pieramati *et al.* 2003; Schober *et al.* 2003; Wittwer *et al.* 2006). The large range in prevalence may be attributed to different definitions of OC, the use of preselected datasets, differences in breeds, in scales used for OC scoring or in the number of predilection sites screened.

The radiographic definition of OC poses a particular problem. Bony fragments seen at certain predilection sites, such as the distal tibial ridge or the lateral femoral trochlea, are with high certainty osteochondrotic in nature. Many of the loose fragments located at the palmar or plantar side of the metacarpophalangeal or

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metatarsophalangeal joints, however, are of traumatic origin (Sønnichsen *et al.* 1982; Dalin *et al.* 1993; Nixon and Pool 1995). Nevertheless, in some studies, all radiographically visible fragments are classified as OC, whereas other reports discriminate between fragments probably caused by OC and fragments of other origin. Flattening of the bone contour at certain predilection sites is commonly interpreted as OC (Butler *et al.* 1993), but the relationship between flattening and osteochondrotic fragments has not been proven.

Osteochondritis is a dynamic disorder; during the first few months *post partum*, lesions may repair spontaneously (Dik *et al.* 1999; van Weeren 2006a). The age at which horses are subjected to radiography is therefore of great importance. Dik *et al.* (1999) showed that lesions were permanent from age approximately 5 months in the TC joint, but stability was reached later, at age approximately 8 months in the FP joint.

The first results using high-throughput molecular genetic screening of DNA indicate that the genetic background of OC may be extremely complicated, with different genes affecting different locations (Wittwer *et al.* 2007). For a molecular genetic approach to succeed, the phenotypic definition of the disorder must be evident, with known prevalences and relationships of the various phenotypic forms. In the absence of these data, molecular genetic approaches are not yet fully applicable. Quantitative genetic approaches, such as selection using estimated breeding values for stallions based on progeny information, can also be effective, considering heritabilities found and heritable factors contributing to the multifactorial influences on OC (van Weeren 2006b). However, until now, selection against OC has not been very effective in practice, possibly because of the incomplete phenotypic definition. In studies designed to fill this gap, prerequisites are a sufficiently large population sample that is well defined for age, gender and parentage, and a detailed and consistent radiographic scoring system.

TABLE 1: Predilection sites per joint judged for osteochondrosis on digital radiographs

	Predilection site	Judged on radiograph*
FP joint		
1	Lateral femoral trochlea	1
2	Medial femoral trochlea	1, 2
3	Trochlear groove	1
4	Patella	1, 2
5	Other predilection sites	2
TC joint		
1	Sagittal ridge of distal tibia	2, 3
2	Lateral trochlea of talus	2
3	Medial trochlea of talus	2
4	Lateral malleolus of tibia	1
5	Medial malleolus of tibia	1
6	Base of talus	1, 2
7	Other predilection sites	1, 2, 3
MCP/MTP joint		
1	Proximodorsal part of the sagittal ridge of the 3rd metacarpal/metatarsal bone	1

FP = femoropatellar; TC = tarsocrural; MCP/MTP = metacarpophalangeal and metatarsophalangeal. *The numbers indicate the radiographic projection used. For FP joint: 1 = lateromedial radiograph; 2 = dorsopalmar lateral oblique. For TC joint: 1 = dorsopalmar; 2 = lateromedial; 3 = dorsopalmar lateral oblique. For MCP/MTP joint: 1 = lateromedial.

This study used radiographic data from 811 Dutch Warmblood animals to assess the prevalence of the various radiographic manifestations of OC and to evaluate relationships between occurrences of these forms within joints, and between joints and their contralateral homologues.

Materials and methods

Materials

Data were collected from 811 animals of the Royal Dutch Warmblood horse population during 2005 ($n = 593$) and 2006 ($n = 218$). Animals descended from 32 breeding stallions and 801 dams, some of which had been diagnosed as OC negative; however, for most the dam's status was unknown. The breeding stallions were representative for the population of approved sires with at least 25 registered offspring in breeding seasons 2005 and 2006. For approval as a breeding stallion within the Royal Warmblood Studbook of the Netherlands (Koninklijk Warmbloed Paardenstamboek Nederland; KWPN) studbook, an OC-free status is a prerequisite. The number of animals per sire varied from 22–28. Animals were a random sample of the available offspring of each stallion. The animals varied in age with a minimum age 9 months (mean \pm s.d. 12 ± 2.6 months); in gender (47.3% males); in percentage Thoroughbred in the pedigree (from 0–58%); in withers height (149 ± 5.7 cm); and in chest circumference (165 ± 9.3 cm). Animals were scored from 1–3 for body condition, 1 being underfed, 2 having a normal condition and 3 being overweight. The horses had been reared by a large variety of breeders and therefore feeding, housing and exercise levels varied widely.

Methods

Animals were scored for OC based on radiographs from 8 joints: the femoropatellar (FP), tarsocrural (TC), metacarpophalangeal (MCP), and metatarsophalangeal (MTP) joints. A total of 28 predilection sites per animal were scrutinised for the presence of OC lesions: 5 in the FP joint, 7 in the TC joint, and one in each of the MCP and MTP joints (Table 1). At each site, OC was scored on a categorical scale from A–E (Table 2), adapted from Dik *et al.* (1999), but converting the original 0–4 quantitative scale to A–E to emphasise the categorical character of the trait (Table 2). *Score A* indicates 'normal joint contour' *scores B* and *C* 'flattened bone contours' and *scores D* and *E* indicate 'fragments'. The radiographs were of comparable quality and taken by 15 preselected equine practices, 2 of which were responsible for 61% of all radiographs. Eighty-five percent of the animals were sedated for the radiographic examination. An experienced radiologist judged all radiographs. Prevalences were calculated at the level of sire, animal, joint and site.

To investigate the relationships between the various forms of OC in different joints and between contralateral homologues, a cluster analysis was performed (Anon 2005). Results of the cluster analyses were used also to reduce the number of variables needed to summarise the OC status of an animal.

Cluster analysis is a statistical technique in which similar variables are grouped based on the correlations between those variables. Because cluster analysis relies on correlations between variables, the observations have to be quantitative values rather than categorical scores. To enable calculation of correlations, categorical OC scores were transformed for each predilection site

TABLE 2: Classification of findings of osteochondrosis (OC) on digital radiographs in 5 OC categories (Dik *et al.* 1999)

Grade	Classification	Bone contour	Subchondral bone texture	Fragment(s)
A	Normal	Rounded	Diffuse density	Absent
B	Minimal	Smoothly flattened	Obscure lucency	Absent
C	Mild	Irregularly flattened	Obvious, ill-bordered local lucency	Absent
D	Moderate	Small, rounded/irregular concavity	Obvious, well-defined local lucency	Small fragment(s) ¹
E	Severe	Large, rounded/irregular concavity	Obvious, well-defined extensive lucency	Large fragment(s) ¹

¹Small fragments are <5 mm; large fragment are ≥5 mm.

into a quantitative value (see below for a detailed description of the transformation). Subsequently, quantitative values of predilection sites were added to summarise the OC status of a specific joint and of the entire animal, distinguishing between flattened bone contours and fragments.

This procedure resulted in 3 quantitative traits, both for each joint and for the entire animal: the trait ALL, representing the overall OC value including both flattened bone contours and fragments; the trait FLAT, representing flattened bone contours only; and the trait FRAG, representing fragments only. Therefore the trait ALL summarises the overall OC status of either a joint or the entire animal, assuming that flattened bone contours and fragments are variants of the same disorder (which is unknown *a priori*). The traits FLAT and FRAG summarise the OC status separately for flattened bone contours and fragments. Hence, each animal had ALL, FLAT and FRAG values for each of its joints, as well as an overall value for ALL, FLAT and FRAG. The overall value for an animal was obtained by summing the ALL, FLAT and FRAG values for each of its 8 joints. Subsequently, cluster analysis was applied to the FLAT and FRAG values for each of the 8 joints, giving a total of 16 traits on each animal.

For the transformation of categorical scores into quantitative values, a continuous normally distributed liability underlying the categorical scores was assumed (Fig 1). A liability model is a common way to analyse polygenic traits showing discrete phenotypic categories (Falconer 1965). In this model, liability values within a certain range correspond to a particular phenotypic category, the range being determined by the incidence of that category. In Figure 1, for example, the area below a liability value of 0.8 equals the incidence of *score A*, so that liabilities below 0.8 correspond to *score A*. The area between liabilities of 0.8 and 1.3 equals the incidence of *score B*, so that liabilities of 0.8–1.3 correspond to *score B*, and so on.

Each categorical score was transformed into the mean liability value for that score. *Score A*, for example, was transformed into a value of -0.354, which is the mean liability value of the area below a liability of 0.8 (Fig 1). Analogously, *score B* was transformed into the mean liability value of the area between liabilities of 0.8 and 1.3 (note that Figure 1 depicts an example for a specific joint; liability values differ for other joints).

Because we distinguished between an overall OC-value, flattened bone contours and fragments, each categorical score was transformed into 3 quantitative values: ALL, FLAT and FRAG. For the trait ALL, the normal distribution was split into 5 categories, corresponding to A–E, as illustrated in Figure 1. For the traits FLAT and FRAG, the normal distribution was split into 3 categories, representing A, B, and C for FLAT, and A, D, and E for FRAG. Values for ALL, FLAT, and FRAG were calculated for each joint by summing the values of all sites within that joint and for each animal by summing all values in the entire animal.

Results

The number of sites that could not be judged because of technical reasons varied among joints and among equine practices, but it was <1% for most sites. Only with respect to the patella was this figure substantially higher at 10.1%. In general, the FP joint appeared to be the most difficult joint for obtaining consistently good radiographs (Table 3).

Prevalences

Sire level: The prevalence of OC varied substantially among stallions ($P < 0.001$ using a general linear model in SAS; Anon 2005), indicating a relatively high heritability for OC. The percentage of offspring with normal joint contours, *score A*, in all predilection sites varied 12–58%. The percentage of offspring with at least one *score B* varied among stallions from 22–57%. For *scores C, D* and *E* these ranges were, respectively, 0–32%, 3.6–32% and 0–32%. The breeding specialisation of the stallion, for either showjumping or dressage, did not affect the prevalence.

Animal level: For the analysis at the animal level, animals were grouped based on their worst OC score. The MCP joints were combined with the MTP joints as suggested by the cluster analysis (see section cluster analysis below). This procedure resulted in 5 groups: =A, animals with *score A* at all sites; ≤B, animals with one or more *score B*, but no *scores C, D*, or *E*; ≤C, animals with one or more *score C*, but no *scores D* or *E*; ≤D, animals with *score D* but no *score E*; and ≤E, animals with *score E*. The percentage of animals that were =A was 61% for the FP joint, 69% for the TC joint, and 65% for the MCP/MTP joints (Table 4). At the level of the entire animal, 30% of all animals were in group =A;

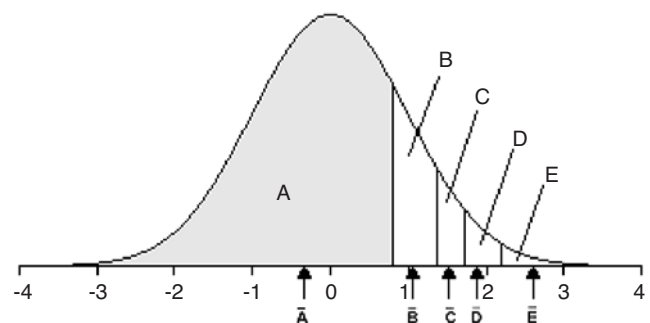


Fig 1: Example of a normal distribution (numbers on x-axis indicate number of s.d.) representing the percentage of the osteochondrosis (OC) scores A–E in the metacarpophalangeal joint and the metatarsophalangeal joint to calculate the linear OC score. An animal with 2 predilection sites scored A, one scored B, and one scored E in the metacarpophalangeal joint and the metatarsophalangeal joint will have a linear OC value of $2 \times -0.354 + 1 \times 1.067 + 1 \times 2.618 = 2.977$ for these joints.

24% animals were in group $\leq B$; 14% animals were in group $\leq C$; 17% animals were in group $\leq D$; and 14% animals were in group $\leq E$. At the animal level, the animal with the lowest number of score A had 11 score A out of 28 sites.

Joint level: For each joint, the average percentages of the left and right homologues are presented (Table 3). In the FP joint, 90.9% of the sites were scored A. In the TC and the MCP/MTP joints, this figure was respectively 96.0 and 78.9%. In the FP and the MCP/MTP joints, relatively more flattened bone contours than fragments were found, in contrast to the TC joint.

Predilection site level: For the analysis at site level, a different scale was used. In the FP joint, 91.4% of flattened bone contours were found in the lateral femoral trochlea and the trochlear groove (sites 1 and 3), and 96.3% of fragments were found at the lateral femoral trochlea (site 1) (Table 3).

In the TC joint, 92.6% of the flattened bone contours were found at the sagittal ridge of the distal tibia, the lateral and medial trochlea of the talus (sites 1, 2, and 3), and 94.4% of fragments were found at the sagittal ridge of the distal tibia and the lateral trochlea of the talus (sites 1 and 2).

TABLE 3: Prevalence of osteochondrosis at the joint and site levels

	Predilection site ⁴					Mean		
	LFT	MFT	TG	Pat	Other			
FP joint								
%A	88.96	98.40	78.99	88.72	99.75	90.92		
%B	1.05	0.43	15.60	0.86	0.06	3.60		
%C	1.48	0.49	4.93	0.31	0	1.44		
%D	2.47	0.12	0	0	0	0.52		
%E	5.49	0.18	0	0	0	1.13		
%NJ	0.55	0.37	0.68	10.11	0.18	2.38		
TC joint	Sag	LTT	MTT	LMT	MMT	BT	Other	
%A	92.23	90.44	92.66	99.45	97.41	99.51	100	95.96
%B	1.17	4.01	4.93	0	0.62	0.06	0	1.54
%C	0.31	0.99	1.79	0	0.31	0.06	0	0.49
%D	3.27	3.58	0.06	0.06	0.25	0.12	0	1.05
%E	1.54	0.55	0	0	0	0.06	0	0.31
%NJ	0.06	0.31	0.55	0.43	1.42	0.18	0	0.43
MCP/MTP joint	MCP PSR	MTP PSR						
%A	80.83	76.88						78.86
%B	12.03	10.48						11.26
%C	2.16	5.06						3.61
%D	2.90	5.18						4.04
%E	0.56	1.73						1.15
%NJ	1.55	0.68						1.12

FP = femoropatellar; MCP/MTP = metacarpophalangeal and metatarsophalangeal; TC = tarsocrural. For each joint, the mean of the left and right homologues is presented. In the MCP/MTP joint, site 1 represents the front limbs and site 2 the hindlimbs. %A indicates percentage 'normal joint contour', %B indicate percentage smooth flattened bone contours, %C indicate percentage irregular flattened bone contours, %D indicate percentage small fragments and %E indicate percentage large fragments. NJ = could not be judged. In the FP joint: LFT = lateral femoral trochlea; MFT = Medial femoral trochlea; TG = trochlear groove; Pat = patella; Oth = other predilection sites. In the TC joint: Sag = Sagittal ridge of distal tibia; LTT = lateral trochlea of talus; MTT = medial trochlea of talus; LMT = lateral malleolus of tibia; MMT = medial malleolus of tibia; BT = base of talus; Oth = other predilection sites. In the MCP/MTP joint: PSR = proximodorsal part of the sagittal ridge of the third metacarpal/metatarsal bone.

In the MCP/MTP joints, prevalences were similar, varying from 12.7–16.1% for flattened bone contours and from 3.3–7.3% for fragments. Higher percentages for scores B–E were found in the MTP joints than in the MCP joints.

Relationships

Correlations within and between joints: The correlation between the overall OC scores, ALL, in the entire animal and in the FP joint was 0.60. For the TC joint and the MCP/MTP joints, these figures relative to ALL were, respectively, 0.65 and 0.67 (not shown in the Table). Therefore, all joints are approximately equally correlated with ALL at the animal level.

At the joint level, the correlation between the FP joint and the TC joint was 0.10, as was also the case between the FP and MCP/MTP joints; between the MCP/MTP and TC joints, the correlation was 0.14 (not shown in the table).

At joint level, the correlations between the left and right homologues, separately for FLAT and FRAG, were moderately high, varying from 0.33 to 0.55 (Table 5). However, the correlations between FLAT and FRAG were small, ranging from nonsignificant to 0.26 (Table 5).

Cluster analysis: The cluster analysis visualises the relationships between observations in different joints, between left and right homologues, and between flattened bone contours and fragments within joints (Fig 2). The length of the branches until clustering with another variable represents the reduction in the proportion of variance explained by the newly created variable (2 variables clustered together) compared to the separate variables used originally.

The results show high similarity between the right and left homologues. Lower similarities were found between the MCP/MTP joint, and still lower similarities between flattened bone contours and fragments. The lowest degree of similarity was found when grouping different joints. Clustering left and right homologues and the MCP/MTP joints reduced the number of variables from 16 to 6; and the proportion of variance explained was reduced to 62%.

Discussion

This is the first investigation, to our knowledge, that examined in detail the prevalence of various manifestations of OC in a large population of horses selected to exclude as much as possible any

TABLE 4: Prevalence of osteochondrosis at the animal and joint level

	FP	TC	MCP/MTP	Entire animal
=A	61	69	65	30
$\leq B$	19	13	17	24
$\leq C$	9	5	6	14
$\leq D$	3	10	9	17
$\leq E$	9	4	3	14

A = % of animals with a score of A at all predilection sites; $\leq B$ = % of animals with one or more B scores, but no C, D, or E scores; $\leq C$ = % of animals with one or more C scores, but no D or E scores; $\leq D$ = % of animals with one or more D scores, but no E scores; and $\leq E$ = % of animals with one or more E scores. Results refer either to a specific joint (FP = femoropatellar; TC = tarsocrural; MCP/MTP = metacarpophalangeal and metatarsophalangeal) or to the entire animal. Results for joints are averages of the left and right homologues.

TABLE 5: Pearson correlation coefficients of the linear osteochondrosis (OC) values

	Flattened bone contours						Fragments					
	FP		TC		MCP/MTP		FP		TC		MCP/MTP	
	R	L	R	L	MCP	MTP	R	L	R	L	MCP	MTP
FIFR		0.39	0.07*	0.01*	0.05*	-0.01*	0.26	0.17	0.04*	0.05*	0.03*	0.07
FIFL			0.08	0.07	0.05*	0.05*	0.15	0.12	0.01	-0.00*	0.03*	0.05*
FITR				0.33	0.10	0.08	0.03*	0.03*	0.07	0.08	0.04*	0.01*
FITL					0.11	0.04*	0.01*	0.01*	0.10	0.05*	0.01*	0.03*
FIMC						0.33	0.08	0.12	0.06*	0.02*	0.15	0.20
FIMT							0.11	0.09	0.03*	-0.01*	0.13	0.15
FrFR								0.55	0.02*	0.08	0.04*	0.10
FrFL									0.05*	0.10	0.07	0.10
FrTR										0.49	-0.02*	-0.00*
FrTL											0.08	0.00*
FrMC												0.35
FrMT												

The first one or 2 letters refer to the joint: F = FP (femoropatellar) joint; T = TC (tarsocrural) joint; MCP = metacarpophalangeal joint; MTP = metatarsophalangeal joint. The next letters refers to either FI = FLAT or Fr = FRAG (FLAT = continuous OC values for flattened bone contour; FRAG = continuous OC values for fragments). The last letter refers to R = right or L = left. *Not significantly different from zero, with P>0.05.

bias by preselection. The balanced design of a representative sample of randomly drawn animals in this study was unique.

The age at which the animals were subjected to radiography was chosen to be 12 months on average, with a minimum age of 9 months, because previous findings showed that lesions were not permanent before age 8 months (Dik *et al.* 1999). Including older horses would have increased the risk of selection in the data because of culling or export related to OC. The percentage of animals invited for a radiographic examination that the owners declined was 45%. Refusal to participate appeared to be unrelated to OC; there was no association between the percentage of nonparticipating owners and the mean OC score per stallion.

Osteochondrosis is mostly scored as a binary trait, while the multifactorial origin of the disorder implies a continuous character (Jeffcott 1991; Philipsson *et al.* 1993; Wittwer *et al.* 2006). Scoring on a detailed scale is needed to obtain good insight into the prevalence of OC, and knowing the prevalences is a prerequisite for further genetic analysis. The detailed method of scoring in the present study, together with the virtual absence of preselection, resulted in a relatively low prevalence of normal joint contours compared to previous studies (Schougaard *et al.* 1990; Grøndahl and Dolvik 1993; Philipsson *et al.* 1993; Stock *et al.* 2005; Wittwer *et al.* 2006). In fact, when only the FP joint was considered in the study population, around 60% of the animals had normal joint contours. When the TC and MCP/MTJ

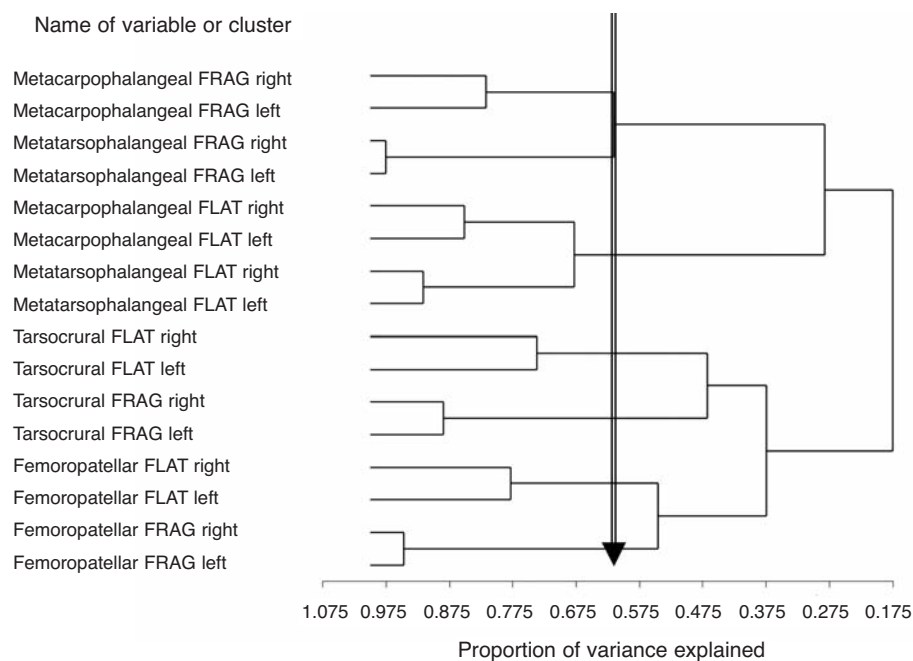


Fig 2: The tree from the cluster analyses visualises the associations between left and right joints and FLAT and FRAG (FLAT = continuous osteochondrosis [OC] values for flattened bone contour; FRAG = continuous OC values for fragments) based on the correlation matrix using linear OC scores. The length of the branches of the tree until the cluster with another variable represents the reduction in the proportion of variance explained by the newly created variable (2 variables together) compared to the separate variables originally used.

joints were also included, this figure dropped to 45 and 30%, respectively. Therefore, in addition to the age effect and the lack of preselection, an important reason for the low percentages of animals with normal joint contours in this study is that many radiographs were taken and many sites scored. Therefore, the 30% entirely OC-free animals in this study cannot be compared to figures from other studies, which are all based on less comprehensive screening within preselected populations.

Empirically, it has long been recognised that OC often presents bilaterally. The results of the present study confirm this clinical impression; the cluster analysis showed that the right and left joints were very similar. Perhaps more unexpectedly, it became clear that this bilateralism also was true to a much lesser extent for flattened bone contours and fragments. Therefore, it can be concluded that the right and left joints can be combined in further analyses, but flattened bone contours and fragments will have to be evaluated as statistically different disorders. This necessity does not preclude, however, the possibility that associations between flattened bone contours and fragments have a genetic basis. The low correlations (0.10–0.14) between joints indicate that animals with high OC values in one of the joints did not necessarily have higher values in other joints, which again points to the probably complex genetic background of OC.

In the TC joint, 3 radiographs were taken. The dorsopalmar projection was used to judge the lateral and medial malleolus of the tibia and the base of the talus (Table 1). In these sites, flattened bone contours and fragments were very rare (0.67%). This low percentage brings into question the usefulness of this projection for detecting OC in the TC joint. Further, sedated animals had higher OC values in the FP joint (results not shown). This suggested that sedation facilitates the detection of OC in the FP joint. Given these observations, reduction of the number of projections and standard sedation might be considered as amendments to the standard protocol for OC screening that is used by the KWPN (Anon 1994).

The outcome of the study confirms some empirically based assumptions (such as the strong left/right relationship at joint level), but calls others into question (such as the assumed relationship between flattened bony contours and fragments). A detailed phenotypic description of OC as presented in this study is a necessary basis for further quantitative and molecular genetic studies. The hope is that such molecular investigations may lead to the eradication of or at least a reduction in the prevalence of this disorder.

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