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Identification of risk factors for lameness in dressage horses

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ABSTRACT

The aim of this study was to describe the prevalence of illness and lameness at different anatomical sites in registered United Kingdom dressage horses and to identify risk factors for lameness. A questionnaire was sent to all 11,363 registered members of *British Dressage* in 2005, with one questionnaire assigned per horse. Four multivariable logistic regression models were developed for each section of the questionnaire. A final mixed effects logistic regression model was developed which combined the results from all prior models. Owners reported that 33% of horses had been lame at some time during their career, with 24% of these within the previous 2 years. A number of factors were associated with the occurrence of lameness in the last 2 years, including age, height, indoor arenas, horse-walkers, lunging (as protective), back problems, arenas that become deeper in wet conditions and sand-based arenas. These factors were included as variables in a final model to provide information for selection of horses, development of safer arenas and more effective training regimens to minimise the onset of lameness.

Introduction

Although dressage has increased in popularity and horses are becoming increasingly valuable, there has been little investigation of the importance of injury in preventing horses training and competing, or of the factors that may increase the risk of injury. A previous study has shown that there was a difference in the type and location of injuries sustained by horses doing different sports, and at elite and lower level of the same sport (Murray et al., 2006). It is therefore likely that there are features of training or management of horses doing a particular sport that predispose to these types of injuries. There may therefore be aspects of training or management of dressage horses that could be modified to decrease the risk of injury.

Both clinical reports and a previous investigation in a referral clinic have indicated a higher risk of suspensory ligament injury in both elite and non-elite dressage horses than in horses undertaking general-purpose exercise or doing other sports (Dyson, 2002; Kold and Dyson, 2003; Murray et al., 2006). However, there has been no previous investigation into the health patterns of the dressage horse population outside veterinary clinics. In order to target and prevent serious health problems, it is important to determine the relative impact of different diseases and injuries within the dressage horse population and to identify risk factors that contribute to their occurrence.

It was hypothesised that lameness would be the most prevalent health problem in dressage horses, that suspensory ligament injury would be a frequent cause of lameness, and that there would be identifiable risk factors associated with lameness. The objectives of the study were to describe the prevalence and patterns of lameness and illness in registered UK dressage horses, and to identify risk factors for lameness.

Materials and methods

The study was undertaken using a questionnaire-based design with a source population of all registered dressage horses in the UK. Pre-tested questionnaires were sent to all members of *British Dressage* (n = 11,363) with the December 2005 issue of the bimonthly *British Dressage* magazine. A prize draw and postage paid envelopes were used as incentives for questionnaire completion and return. It was not possible to send reminder cards or duplicate questionnaires.

Questionnaire design

Questionnaires were completed for individual horses so each member could provide information on more than one horse. Individual members were invited to request extra copies of the questionnaire from the research team. The questionnaire was divided into four sections: (1) horse and rider information; (2) horse injury and illness; (3) training and management; (4) training surface and arena information. The variables collected are listed in Table 1 and a copy of the questionnaire is available from the corresponding author.

Data input

Data from questionnaires was transferred into an Access database using word recognition software (TELEform v.8.2). Questionnaires were scanned in batches, automatically and manually verified, and then automatically entered into a

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Table 1
Information requested in the questionnaire and tested as separate variables in the univariate and multivariable analyses with lameness in the last 2 years as the outcome.

General aspect under question	Specific variable questioned
Section 1: Horse and rider details	Horse gender Horse breed Horse height Horse age Horse training level Horse competing level Horse highest competitive level Horse length of time competing Horse frequency of competing Horse previous occupation Horse shoeing Rider group
Section 2: Horse injury and illness	Illness: system affected, type Back problems: diagnosis, treatment Lameness: episodes in the last 6 months, 6–12 months, 1–2 years, 2–5 years, ever Most recent bout of lameness: duration Most recent lameness: time unable to train Most recent lameness: time unable to compete Most recent lameness: limb affected Most recent lameness: veterinary diagnosis Previous lameness in last 2 years: limb affected Previous lameness in last 2 years: veterinary diagnosis
Section 3: Training and management details	Hours per week turned out vs. stabled Non-dressage exercise: type Non-dressage exercise: hours per week Dressage training: sessions per week Dressage training: Warm up duration Dressage training: Warm up proportion of time in each pace or type Dressage training: training session duration Dressage training: training session proportion of time in each pace Dressage training: training session proportion of time in collected, extended, working paces, transitions, specific movements Dressage training: Cool down duration
Section 4: Training surface and arena information	Surface type: frequency of training Most used arena (referred to in all subsequent questions) Surface components and manufacturer Base-presence, type Arena indoor vs. outdoor Arena ownership Arena size Number of horses using arena per day Age of surface and time of resurfacing Arena maintenance frequency Problems using arena Arena surface properties under normal conditions Arena surface properties under wet conditions Arena surface properties under dry conditions Watering: frequency and method

database. Repeatability was confirmed by re-entry of 10% of the questionnaires via the word recognition software, and re-entry of the same 10% of questionnaires manually. Error rate for double entry by TELEform was <1.8%, whilst manual entry resulted in a 5% error rate.

Statistical analysis

Descriptive statistics were performed for all variables using Analyse-It for Microsoft Excel, (version 3) and Epi info (version 3.3.2, 2005). To investigate the effect of lower or higher competitive level, horses were divided into non-elite and elite categories. *British Dressage* competition levels of preliminary (P), novice (N), elementary (E) and medium (M) were classed as non-elite and advanced medium (AM), advanced (A), Prix St Georges (PSG), Intermediare I (Inter I), Intermediare II (Inter II) and Grand Prix (GP) were classed as elite. Continuous data was assessed for normality using the Kolmogorov–Smirnoff test for normality. Differences between elite and non-elite groups were investigated using Student's t test or the Mann–Whitney test, dependent on the results of the Kolmogorv–Smirnoff tests. Chi-squared tests were used to identify differences in the proportion of horses being lame in the last 2 years at different levels of competition.

Univariate logistic regression was performed to identify associations between potential explanatory variables and the dependent variable 'lameness in the last 2 years'. Initially four multivariable models were created, one for each section of the questionnaire, using the forward stepwise procedure. Variables that had P values $\leqslant 0.25$, from the univariate analysis, were considered for inclusion in the final models. Variables were retained if they significantly reduced the residual deviance of the model (Likelihood Ratio Statistic [LRS] $P < 0.05$). A final multivariable model, combining all four sections of the questionnaire, was then developed (Reeves et al., 1996). All variables from the previous multivariable models were considered for inclusion in this model and all variables that had P values $\leqslant 0.25$ from the original univariate analysis were entered into the final model to check for confounding. At this stage the effect of respondent level clustering was also accounted for by including a respondent identifier as a random effect in the final model. Mixed effects logistic regression was performed using STATA SE 9.2 (StataCorp, College Station).

The fit of the final single-level multivariable model was assessed using the Hosmer–Lemeshow goodness-of-fit test (Hosmer and Lemeshow, 2000). Regression diagnostics were performed and covariate patterns with the greatest leverage, delta betas, delta χ^2 and delta deviance values were identified. Individual observations within these covariate patterns were then removed from the model and changes in the value of the coefficients were examined (Hosmer and Lemeshow, 2000). The predictive ability of the model was determined by generating a receiver operating characteristic (ROC) curve.

Results

There was a 22.5% (2554/11363) questionnaire response rate with 80% of horses (2032/2554) from non-elite, 11% of horses (292/2554) from elite levels and 9% (230/2554) of owners not reporting a competition level for their horse. These numbers reflected the registered population of horses for the same year of 88% (9956/11363) registered in non-elite levels and 12% (1407/11363) registered in elite levels.

Descriptive analysis

Lameness was the most frequently reported health problem, with 33% (851/2554) of horses having been lame at some time during their career. A respiratory problem was reported in 4.6% (118/2554) of horses (recurrent airway obstruction $n = 58$, upper airway obstruction/noise $n = 30$, infection $n = 49$, other $n = 25$) and 3.3% (84/2554) of horses had a previous digestive disturbance (colic $n = 78$, gastric ulceration $n = 22$, diarrhoea $n = 15$, other $n = 9$). Few horses had cardiac (0.4%; 11/2554), reproductive (0.4%; 11/2554) or urinary (0.2%; 4/2554) problems. Approximately 10% of horses had 'other' problems, the majority of which (247/2554), on further examination, were lameness related.

Twentyfive percent (644/2554) of horses were reported to have had a 'back problem', although the majority (80%; 515/644) of these had not been diagnosed by a veterinary surgeon. Regions of 'the back' were classified by a veterinary surgeon into anatomical locations, based on the description given by the respondents, as 38% (113/295) unknown, 28% (82/295) thoracolumbar, 21% (61/295) pelvic, 10% (30/295) sacroiliac, 2% (5/295) cervical and 1% (4/295) sacrum. Complementary therapy was the most commonly used treatment (63%: 404/644), followed by saddle fitting (24%; 152/644), veterinary involvement (20%; 129/644), rest (20%: 128/644), a change in training (13%; 85/644) and other treatment (6%; 38/644). Only 2.5% (12/471) of those treated reported treatment by veterinary care alone and 3% (14/471) combined veterinary treatment with saddle fitting, rest, change in training and/or other treatment but not complementary therapy. There were no significant differences in any aspects of 'back problems' between the non-elite and elite horses.

Horses that had been lame in the last 2 years were examined in more detail. Twenty-four per cent (605/2554) of horses had been lame at sometime in this period. Forelimb lameness was most common, with 23% (139/605) of horses reported to have had left forelimb lameness, 20% (121/605) right forelimb lameness and 12% (71/605) bilateral forelimb lameness. Twelve per cent (73/605) of horses were reported to have had left hindlimb lameness, 11% (68/605) right hindlimb lameness and 6% (38/605) bilateral hindlimb lameness. Three limbs were affected in 3% (18/605) and all four limbs in 1% (6/605) of lame horses.

For horses lame in the last 2 years, the median (range) time taken off training was 3 months (1–48 months) and time off competing was 5 months (1–57 months). The median and inter-quartile range (IQR) time off training and competing for each competitive level of horse is shown in Fig. 1. Elite horses spent significantly more time off training ($P = 0.028$), but not competing ($P = 0.061$), than non-elite horses with lameness.

There was no significant difference in proportion of horses with lameness in the last 2 years in the elite (25%, 73/292) and non-elite (23.9%, 485/2032) groups. However, the highest proportion of lameness was in the Grand Prix (50%, 5/10) and Intermediare II (33%, 2/6) horses (Fig. 2).

When looking at the most recent episode of lameness for which a site of injury was reported (28.6%, 730/2554), the most frequently reported, with or without veterinary diagnosis, was the foot (31.2%, 228/730), followed by the suspensory ligament (13.3%, 97/730) and the tarsus (11.4%, 83/730). The sites of injury seen in elite and non-elite horses were similar (Fig. 3). Veterinary diagnosis was stated for 82% (600/730) of the most recent episodes of lameness but when taken into account did not affect the most frequent injury seen. The pattern of injury site remained the same even when only the previous 2 years were included in analysis.

Risk factors for lameness in the last 2 years

Univariate analysis

In addition, to the variables that were retained within the multivariable models a number of other variables were marginally significant in the univariate analysis (see Table 2). In Section 1, on horse details, both the level of training and competition, the length of time in competition, number of competitions per month and year and hind feet only shoeing were associated with the likelihood of lameness. As was digestive illness in Section 2 detailing horses health. The third Section covering training and management regimens indicated that a high number of training sessions per week and a low level of training at specific movements for each competition level was associated with the likelihood of injury. Time turned out, jumping, spending a large proportion of training time in working paces and a greater than 10% of training in transitions and extended paces were suggested as protective.

In Section 4 detailing training surfaces and arenas, surfaces that became deep, patchy or uneven in normal conditions, and patchy in hot/dry conditions were associated with lameness. Surfaces that remained uniform in dry/hot conditions were indicated as protective against lameness. Horses trained on privately owned yards, either respondents' own or someone else's were less likely to have been lame in the previous 2 years than those trained on arenas at livery yards or training yards. Arenas without a base increased the

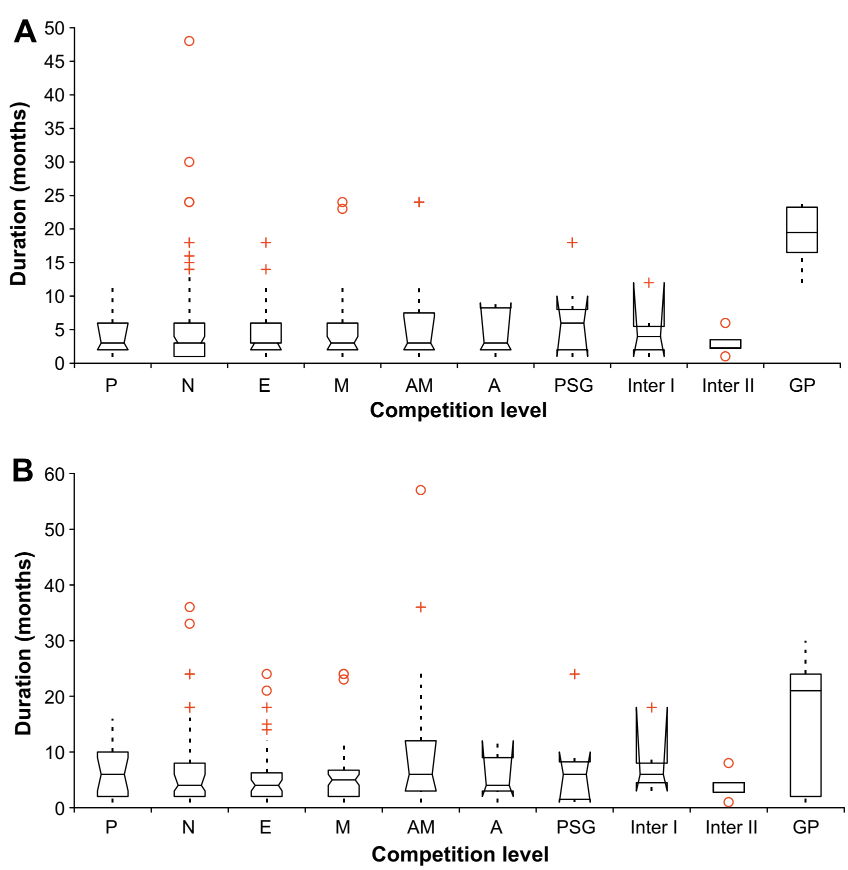

Fig. 1. Median (and IQR) time in months off (A) training and (B) competition due to lameness in the last 2 years. The notched boxes show the median by the middle line, the confidence interval is presented by the notch either side and the IQR by the box extremities, '+' shows observations between 1.5 and 3.0 IQRs away from the quartiles, 'o' show far outlier observations over 3.0 IQRs away from quartiles. P = preliminary, N = novice, E = elementary, M = medium, AM = advanced medium, A = advanced, PSG = Prix St Georges, Inter = Intermediare, GP = Grand Prix. Seven horses were removed due to having >100 months off training and/or off competition.

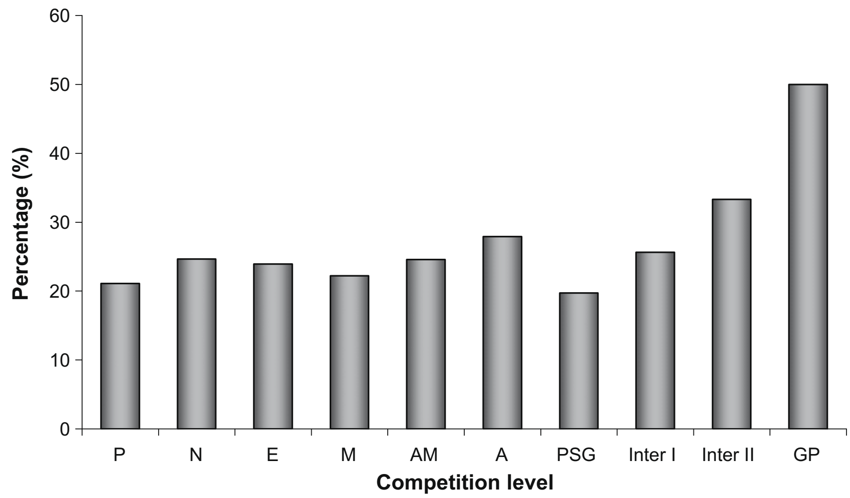

Fig. 2. Proportion of horses in each competition level that experience lameness in the 2 years previous to responding to the questionnaire. Key; P = preliminary; N = novice; E = elementary; M = medium; AM = advanced medium; A = advanced; PSG = Prix St Georges; Inter I = Intermediare I; Inter II = Intermediare II; GP = Grand Prix.

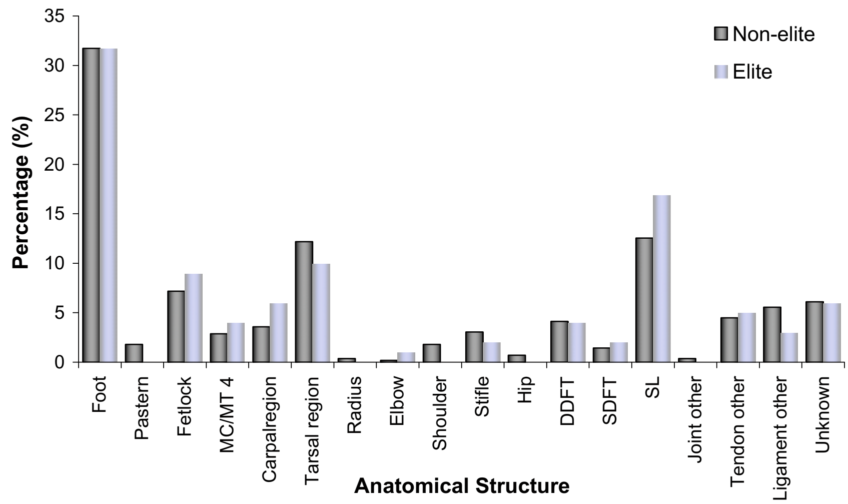

Fig. 3. Proportion of anatomical structures injured in the most recent episode of lameness previous to the questionnaire in non-elite and elite dressage horses. Key: MC/MT 4 = fourth metacarpal/tarsal; DDFT = deep digital flexor tendon; SDFT = superficial flexor tendon; SL = suspensory ligament.

risk of lameness. Tripping and losing balance were associated with lameness.

Preliminary multivariable models (Table 3)

Section 1. Horse and rider details. Older horses were more likely to have had an episode of lameness in the previous 2 years. For every extra year of age the likelihood of lameness increased by 1.06 times. This equated to a 33% increase in risk for horses at the 75th per centile (12 years old) compared to horses at the 25th per centile (7 years old). Taller horses were also more likely to have been lame in the previous 2 years. Horses at the 75th per centile (170 cm) were 15% more likely to have been lame than horses at the 25th per centile (163 cm). Horses that had a career as a flat racehorse before starting dressage training were 1.9 times more likely to have been lame than all other study horses.

Section 2. Horse health. History of a previous respiratory illness was associated with lameness in the previous 2 years (OR = 4.33). Horses with a previous 'back problem' that was resolved by complementary therapy (OR = 3.12) or by rest (OR = 1.76) were more likely to have been lame in the last 2 years.

Section 3. Management and exercise regimen. The amount of time spent exercising on a horse walker and walking during warm-up, before dressage training, were both significantly associated with lameness. For every extra hour spent using a horse walker the likelihood of lameness increased by 1.11 times. Horses that did 7 h per week compared to 1 h per week were 1.9 times more likely to have been lame. A longer time spent walking during warm-up (OR = 1.03) was associated with a small increase in likelihood of lameness. Most horses did either 5 (n = 923; 36%) or 10 (n = 843; 33%) min walking before dressage training. Lameness was 1.16 times more likely in horses doing 10 min of walking, than for horses doing 5 min of walking during warm-up. Lunging as part of a normal exercise regimen was associated with a reduced likelihood of lameness in the previous 2 years. Horses that were regularly lunged (n = 1,228; 48%) were 0.8 times less likely to have been lame in the previous 2 years, than horses that were not normally lunged.

Section 4. Training surfaces and arenas. The manner in which the most used riding surface reacted during wet conditions was associated with the likelihood of lameness. Horses that most often

Table 2
Separate univariate table for risk factors developed for each of the sections of the questionnaire.

	OR	SE	95% CI	*P* value
Section 1. Horse details variable				
Height (cm)	1.02	0.006	1.01–1.03	0.001
Age (years)	1.05	0.013	1.03–1.08	<0.001
Training level	2.23	0.75	1.15–4.32	0.018
Current competition level Grand Prix	3.74	2.44	1.04–12.4	0.043
Highest competition level				
Novice	1.34	0.301	0.86–2.08	0.191
Elementary	1.34	0.303	0.86–2.09	0.185
Advanced	1.92	0.64	1.0–3.7	0.051
Grand Prix	2.59	1.28	0.98–6.82	0.054
Length of time in competition (years)	1.05	0.015	1.02–1.07	0.002
Number of competition per month	1.05	0.04	0.97–1.12	0.222
Number of competitions per year	0.99	0.01	0.98–1.00	0.111
Previous career				
Show jumper	1.17	0.15	0.91–1.5	0.215
Flat racing	2.06	0.64	1.11–3.8	0.021
Pleasure/pony club/riding club	0.84	0.11	0.65–1.07	0.172
Shoeing				
Hind feet only	9.34	7.64	1.89–46.4	0.006
Front feet only	0.76	0.15	0.52–1.11	0.161
Section 2. Horse health Variable				
Has the horse had a previous respiratory illness?				
No (reference)	1			
Yes	5.18	1.00	3.75–7.57	<0.001
Has the horse ever had a digestive illness?				
No (reference)	1			
Yes	2.51	0.57	1.61–3.9	<0.001
Has the horse ever had a back problem that was resolved by:				
Complementary therapies?	3.86	0.44	3.09–4.82	<0.001
Veterinary involvement?	3.92	0.72	2.74–5.16	<0.001
Saddle fitting?	3.75	0.64	2.69–5.22	<0.001
Rest?	3.99	0.73	2.78–5.71	<0.001
Change in training	3.65	0.81	2.36–5.64	<0.001
No back problem (reference)	1			
Section 3. Exercise regimen variable				
Time spent turned out (hours per week)	0.998	0.0001	0.996–1.0	0.165
Does the horse have additional non-dressage exercise of:				
Jumping	0.83	0.08	0.68–1.02	0.073
Horse walker	1.30	0.17	0.99–1.67	0.060
Lunging	0.83	0.08	0.7–1.0	0.052
None (dressage training only)	1			
Time spent jumping (hours per week)	0.92	0.54	0.82–1.04	0.188
Time spent using a horse walker (hours per week)	1.104	0.03	1.04–1.18	0.003
Time spent lunging (hours per week)	0.92	0.05	0.84–1.01	0.092
Number of dressage training sessions per week	1.02	0.12	1.00–1.05	0.034
Time spent walking during warm-up before dressage training (minutes)	1.51	0.39	0.91–2.5	0.108
Time spent using a horse walker as warm-up before dressage training (minutes)	1.03	0.13	1.00–1.05	0.047
Proportion of dressage training spent working on movements specific to the level of competition				
10–19%	1.53	0.36	0.97–2.24	0.070
20–29%	1.89	0.43	1.21–2.96	0.005
70–79%	1.55	0.43	0.9–2.67	0.117
80–89%	1.90	0.54	1.09–3.31	0.023
90–100%	1.84	0.69	0.88–3.84	0.104
Proportion of dressage training spent in working paces 90–100%	0.53	0.25	0.21–1.33	0.177
Proportion of dressage training spent working on transitions <10% (reference) >10%	1 0.67	0.14	0.44–1.02	0.060
Proportion of dressage training spent in extended paces <10% (reference) >10%	1 0.84	0.08	0.69–1.02	0.080
Section 4. Training surfaces and arenas variable				
Sand as the most frequently used surface	1.24	0.12	1.03–1.49	0.020
Fibres as the most frequently used surface	1.29	0.21	0.94–1.77	0.109
Rubber as the most frequently used surface	1.21	0.12	1.0–1.48	0.054
Woodchip as the most frequently used surface	1.40	0.30	0.91–2.13	0.124
If the arena has sand as a component is it:				
Coarse (reference)	1			
Fine	1.26	0.15	1.0–1.59	0.054
If the arena has rubber as a component is it:				
Mixed in (reference)	1			
A top layer	1.20	0.16	0.92–1.55	0.174
Number of times per week the horse trains on a surface of sand	0.94	0.3	0.88–1.01	0.087
Does the arena have a base?				
Yes (reference)	1			
No	1.11	0.06	0.99–1.25	0.062
Most commonly used arena type				
Indoor (reference)	1			

(*continued on next page*)

Table 2 (*continued*)

	OR	SE	95% CI	*P* value
Outdoor	0.65	0.09	0.50–0.85	0.002
Is the arena most frequently trained in owned by:				
The respondent/private (reference)	1			
A livery yard or training yard	1.71	0.17	1.04–2.07	<0.001
Other	0.37	0.22	0.11–1.21	0.099
Number of horses train on the surface per day	1.01	0.01	1.0–1.03	0.138
Age of school (years)	0.98	0.01	0.96–1.0	0.033
Does the horse trip when training?				
No (reference)	1			
Yes	1.28	0.15	0.02–1.60	0.030
Does the horse lose balance when training?				
No (reference)	1			
Yes	1.29	0.17	1.0–1.66	0.052
Does the horse most often use an arena that becomes 'deep' in normal conditions?				
No (reference)	1			
Yes	1.37	0.18	1.05–1.77	0.018
Does the horse most often use an arena that becomes 'patchy' in normal conditions?				
No (reference)	1			
Yes	1.45	0.17	1.15–1.83	0.002
Does the horse most often use an arena that becomes 'uneven' in normal conditions?				
No (reference)	1			
Yes	1.43	0.20	1.09–1.88	0.011
Does the horse most often use an arena that becomes 'deeper' in wet conditions?				
No (reference)	1			
Yes	1.41	0.21	1.06–1.89	0.019
Does the horse most often use an arena that becomes 'boggy' in wet conditions?				
No (reference)	1			
Yes	1.52	0.24	1.12–2.07	0.007
Does the horse most often use an arena that remains 'uniform' in hot/dry conditions?				
No (reference)	1			
Yes	0.74	0.7	0.62–0.89	0.002
Does the horse most often use an arena that becomes 'deeper' in dry/hot conditions?				
No (reference)	1			
Yes	1.18	0.12	0.96–0.15	0.114
Does the horse most often use an arena that becomes 'patchy' in hot/dry conditions?				
No (reference)	1			
Yes	1.72	0.33	1.18–2.51	0.005
Does the horse most often use an arena that becomes 'firmer' in hot/dry conditions?				
No (reference)	1			
Yes	1.31	0.20	0.97–1.76	0.076
Does the horse most often use an arena that alters in 'other ways' in hot/dry conditions?				
No (reference)	1			
Yes	1.25	0.21	0.91–1.73	0.173

trained on surfaces that became boggy (OR = 1.52) or deeper (OR = 1.41) during wet conditions, were more likely to have been lame in the previous 2 years. Horses that trained most often on outdoor arenas were less likely to have been lame in the previous 2 years compared with horses that most often trained in indoor arenas (OR = 0.61). Horses that most often used an arena with a sand surface were 1.36 times more likely to have been lame compared with horses that used other surfaces. For horses that trained on sand there was also a small but significant negative association between the number of times per week that horses trained on sand and the likelihood of lameness. For every extra sand-based training session per week the likelihood of lameness reduced by 0.91 times.

Final multivariable model (Table 4)

In the combined mixed effects multivariable logistic regression model the majority of variables were retained and the size of the coefficients for age and height did not change significantly. The associations between lameness and a previous career as a flat racehorse, previous respiratory illness, time spent walking during warm-up and arenas that become boggy in wet conditions were no longer significant and were therefore excluded from the model. The odds ratios and standard errors for the associations with time spent using a horse walker, lunging as part of training, deep arenas during wet conditions, indoor arenas and use of sand-based surfaces changed significantly when the rider level random effect was included in the model. For all of these variables the size of the odds ratio became greater (i.e. further from '1') and the standard errors increased. The associations between lameness and back problems resolved with complementary therapies or rest were replaced by a variable that included all occurrences of back problems, regardless of the treatment. The occurrence of a back problem in the previous two years was strongly associated with lameness over the same period (OR = 12.61; 95% CI = 5.77–27.5; $P < 0.001$).

Model diagnostics and goodness-of-fit

The final multivariable model was not significantly affected by influential covariate patterns. The Hosmer–Lemeshow goodness-of-fit statistic was 6.8 (eight degrees of freedom, *P* value = 0.56), indicating that there was no evidence that the model did not fit the data well. The model was therefore considered to be reasonably calibrated. The predictive ability of the model as measured by the area under the receiver operating characteristic (ROC) curve (0.66) was just below acceptable (Hosmer and Lemeshow, 2000).

Discussion

This is the first study that has specifically aimed to investigate prevalence of and risk factors for the most common types of injury and disease in dressage horses, using a large scale questionnaire study. The hypotheses were supported, with lameness being the

Table 3
Separate multivariable logistic regression models developed for each of the sections of the questionnaire.

	Coefficients	OR	SE	95% CI	*P* value
Section 1. Horse details variable					
Age (years)	0.06	1.06	0.01	1.03–1.08	<0.001
Height (cm)	0.02	1.02	0.01	1.01–1.03	<0.001
Previous career as a flat racehorse					
No (reference)		1			
Yes	0.66	1.9	0.32	1.04–3.61	0.037
Section 2. Horse health variable					
Has the horse had a previous respiratory illness?					
No (reference)		1			
Yes	1.47	4.33	0.2	2.91–6.43	<0.001
Has the horse ever had a back problem that was resolved by:					
Complementary therapies?	1.14	3.12	0.13	2.43–4.01	<0.001
Rest?	0.57	1.76	0.21	1.17–2.66	0.007
No back problem (reference)		1			
Section 3. Exercise regimen variable					
Time spent using a horse walker (hours per week)	0.1	1.11	0.03	1.04–1.18	0.002
Time spent walking during warm-up before dressage training (minutes).	0.03	1.03	0.01	1.00–1.05	0.027
Is lunging part of the normal exercise regimen?					
No (reference)		1			
Yes	−0.23	0.80	0.09	0.66–0.96	0.016
Section 4. Training surfaces and arenas variable					
Does the horse most often use an arena that becomes 'boggy' in wet conditions?					
No (reference)		1			
Yes	0.42	1.52	0.17	1.09–2.11	0.013
Does the horse most often use an arena that becomes 'deeper' in wet conditions?					
No (reference)		1			
Yes	0.34	1.41	0.16	1.03–1.92	0.03
Most commonly used arena type					
Indoor (reference)		1			
Outdoor	−0.5	0.61	0.14	0.46–0.79	<0.001
Is sand the most frequently used type of arena surface?					
No (reference)		1			
Yes	0.31	1.36	0.1	1.12–1.66	0.002
Number of times per week trained on a sand surface	−0.09	0.91	0.04	0.85–0.98	0.016

Table 4
Final multivariable logistic regression model of horse, health, exercise and training surfaces risk factors for lameness in the previous 2 years.

Variable	Coefficients	OR	SE	95% CI	P value
Age (years)	0.18	1.20	0.04	1.10–1.30	<0.001
Height (cm)	0.06	1.06	0.02	1.03–1.1	0.001
Most commonly used arena type					
Indoor (reference)		1			
Outdoor	−1.62	0.20	0.45	0.08–0.48	<0.001
Time spent using a horse walker (hours per week)	0.44	1.55	0.20	1.20–2.0	0.001
Is sand the most frequently used type of arena surface?					
No (reference)		1			
Yes	0.64	1.90	0.58	1.05–3.45	0.035
Is lunging part of the normal exercise regimen?					
No (reference)		1			
Yes	−1.01	0.36	0.36	0.20–0.68	0.001
Number of times per week trained on a sand surface	−0.21	0.81	0.09	0.66–0.99	0.044
Does the horse most often use an arena that becomes 'deeper' in wet conditions?					
No (reference)		1			
Yes	1.72	5.60	2.89	2.03–15.42	0.001
Occurrence of at least one a 'back problem' in the last 2 years?					
No (reference)		1			
Yes	2.53	12.61	5.03	5.77–27.5	<0.001

most prevalent problem, with foot, suspensory ligament and tarsal injury being the most common sites of lameness. Risk factors were detected for lameness in the previous 2 years, which could potentially be used in guidance for protection against lameness in dressage horses.

Prevalence of lameness

Lameness was identified as the most common injury or disease in the dressage horse. More than 30% of owners reported that their horse had experienced at least one episode of lameness during their career. Nearly a quarter of horses were reported to have been lame at least once in the previous 2 years, which formed a significant proportion of the dressage horse population, particularly in view of the extended period of time reported off work and competing. Lameness is therefore likely to be having a significant effect on the dressage industry and has potential welfare implications. Over this period, there was no difference in the likelihood of lameness in elite or non-elite horses. However, elite horses tended to be off work for longer, possibly reflecting differences in the severity of lameness, in the level of athletic requirements in the elite and non-elite horse, or in the ability of a skilled or less skilled rider to detect or mask ongoing problems.

The types of lameness reported are likely to be a reflection of types of lameness observed in the general horse population, and also of injuries particularly found in dressage horses. Foot pain was the most frequent type of lameness reported, which may reflect the prevalence of foot pain in the general horse population. The high incidence of reported tarsal and suspensory ligament injury in this study are similar to the results of a previous study into lameness in dressage horses within a referral clinic (Murray et al., 2006). In collected paces there is increased tarsal loading and joint compression (Holmstrom and Drevemo, 1997), which may predispose to tarsal injury in dressage horses. The pattern of subchondral bone thickness in the distal tarsal bones, reflecting loading pathways, is different in elite performance horses compared with general-purpose horses (Murray et al., 2007). This may be related to circling and other specific movements, and potentially predisposes to pathological change. Dressage horses have an increased risk of suspensory ligament injury compared to horses doing other sports (Dyson, 2002; Kold and Dyson, 2003; Murray et al., 2006), also supported by the results of the current study. Considerable load is experienced by the suspensory ligament in movements, such as collected trot, piaffe and passage, in which the metatarsophalangeal joint is extended and the tarsal joints are in flexion (Holmstrom and Drevemo, 1997).

A high scoring trot is often characterised by advanced diagonal placement (Clayton, 1997) in which only one hindlimb is load bearing. This can result in a longer stance duration and greater extension of the metatarsophalangeal joint (Holmstrom et al., 1994, 1995), with subsequent increased load on the suspensory apparatus. Selecting horses with advanced diagonal placement may therefore increase the risk of injury of the suspensory apparatus. Horses that move extravagantly at non-elite levels may be prone to injury to the proximal aspect of the suspensory ligament in forelimbs because of insufficient muscle strength and coordination to prevent hyperextension of the carpus and metacarpophalangeal joint during extension.

In contrast to studies in Thoroughbred racehorses (Meagher, 1976; Rick et al., 1983; Ellis, 1994; Bassage and Richardson, 1998; Zekas et al., 1999), there was no increased predilection to left or right sided lameness. This probably reflected the fact that dressage horses train on both reins, whereas racehorses often train and/or race in one direction only.

Risk factors

Some of the identified risk factors predisposed horses to lameness, but others may be associated with lameness because owners and riders use different methods of management following lameness, particularly if the associations were the result of injury rather than the cause.

Horse details

This study demonstrated an increased likelihood of lameness associated with both older and bigger horses. Similar associations with age or size have been demonstrated during investigations of musculoskeletal injury in racehorses (Mohammed et al., 1991; Bailey et al., 1997, 1998; Cohen et al., 1997; Perkins et al., 2005a), and both tendon injuries (Takahashi et al., 2004; Perkins et al., 2005b; Parkin et al., 2006) and fractures (Hill et al., 1986) in racehorses. It is probable that accumulated micro-damage or degenerative changes associated with age and increased duration of training may predispose to injury and lameness. Large horses may place greater torque in the distal aspect of the limbs, potentially increasing biomechanical forces. Further investigations of the effect of weight and height on the occurrence of lameness may help to identify modifications to management and training regimens that would reduce the potentially detrimental impact of exercise on larger horses.

Horse health

We found that back pain was significantly associated with lameness. Clinically, back pain is frequently seen in association with lameness, either as a secondary muscular problem or with concurrent pathology in both a limb and the back. The majority of back problems were not based on a veterinary diagnosis. It is therefore likely that for a number of horses with lameness, back pain was a clinical symptom due to muscle pain secondary to an altered gait. Many riders seek non-veterinary advice when a horse's performance is diminished. The results of this study, however, indicated the importance of early intervention by a veterinarian skilled in recognition of low grade lameness.

Management and exercise regime

One of the main aims of this study was to identify associations between lameness and management or training regimens. Lunging was associated with a reduced likelihood of lameness which was possibly due to adaptation of the musculoskeletal system to different types of exercise and potentially improved proprioceptive conditioning (Holm et al., 2004; Cressey et al., 2007). It is also possible that horses being lunged were fitter or maybe warmed up and cooled down more effectively than those that are not lunged. In the univariate analysis, time spent turned out and undertaking jumping exercises were also associated with a marginally significant reduced likelihood of lameness. This finding could assist in the development of more complete and 'professional' exercise regimens to maintain fitness and readiness for competition. Conversely, owners of less robust horses, that may be inherently more prone to lameness, may be less likely to lunge these horses due to the common perception that lunging places extra strain on joints.

Horse-walkers have increased in use in recent years as a means of exercising more than one horse at a time, or as part of warm-up and/or cool down or as part of a continued exercise programme following injury. The current study suggested that the more time a horse spent on a horse walker the greater the likelihood that it would have been reported lame in the last 2 years. We speculated that horse-walkers tended to be used more often for rehabilitation following injury, rather than being a cause of injury. This hypothesis has been substantiated by a further study, which suggested that horse-walkers were used for cool down, warming up and rehabilitation in approximately equal proportions (Walker et al., 2008). It is therefore possible, if not likely, that the association between horse-walkers and lameness is an example of an effect of injury rather than a cause.

Training surfaces and arenas

The location and surface used in training arenas were associated with risk of lameness in the last 2 years. Horses that usually worked in indoor arenas were more likely to have been lame than those worked on outdoor arenas. This may reflect various factors such as arena size, surface characteristics or arena maintenance. In the univariate analysis, the ownership of the arena was also associated with the risk of lameness. Horses trained on private arenas were less likely to be lame than those trained on livery or training yard arenas. This may be due to the greater number of horses training on a surface at livery and training yards each day, between maintenance sessions. Privately owned arenas with less use may be less likely to be associated with lameness as they are usually better maintained and avoid the surface becoming uneven or deep.

A surface with sand as the major component was the greatest risk for lameness. However, there was also a small beneficial effect (i.e. a reduction in risk) the more often a sand surface was used. These findings probably illustrated the process of adaptation in bones, tendons, joints and muscles, and possibly also in the cardiorespiratory system. Initial exposure to a different surface could result in tissues experiencing different loads, or loads in excess of those to which they were adapted, or through fatigue leading to incoordination and abnormal loading directions and magnitudes. The process of adaptation to exercise has been demonstrated in bone, (Murray et al., 2001, 2007; Rubin and Lanyon, 1984), tendon (Smith and Goodship, 2008) and, in young horses, in joints (Firth and Rogers, 2005; Firth, 2006). Results from the current study suggested that the musculoskeletal tissues became less prone to injury as the horse continued to work on a surface, even if the surface presented a greater initial baseline risk. It could therefore be extrapolated that for a horse adapted to a single surface, a sudden change in surface conditions could increase the risk of injury. However, it is possible that a gradual introduction to different surface characteristics might be beneficial in training if this led to improved fitness or muscle development.

Maintaining a uniform surface under dry conditions had some protective effect against lameness. However, alteration of surface characteristics to boggy or deep under wet conditions, and a patchy or uneven surface under normal conditions increased the risk of lameness. Horses have a higher heart rate working in deep sand than on concrete (Sloet van Oldruitenborgh-Oosterbaan et al., 1991), which indicated that the horses were working harder under deeper conditions, and may therefore fatigue more rapidly if not adapted to these conditions. Deeper surfaces have also been associated with increased incidence of injury in racehorses (Hill et al., 1986; Mohammed et al., 1991, 1992). Our study supported previous reports which concluded that effective surface management is crucial to the maintenance of a safe training environment for many sport horses (Parkin et al., 2004; Verheyen et al., 2005; Parkin, 2007). Greater efforts to develop surfaces and maintenance protocols that maintain a consistent training surface could benefit not only dressage horses, but other sports horses as well.

Methodological considerations and limitations

It was interesting to note the substantial effect that inclusion of the rider identifier as a random effect had on the parameters retained in the final model. The majority of point estimates for the odds ratios moved significantly further from '1' and, as expected, standard errors increased. This was particularly apparent for the variables most related to training regimens or surface usage i.e., the variables that are most likely to be very similar for all horses ridden by the same rider at the same yard. This illustrated the importance of accounting for the hierarchical nature of data such as these, and showed that it was possible to severely underestimate the strength of the association for different risk factors when random effects were not included. It was also important to note that the size of the standard errors of the odds ratios increased alongside the increases in point estimates, resulting in wider confidence intervals and introducing a greater degree of uncertainty in the true size of the effect for most risk factors.

The 22.5% response rate was disappointing, but was a good reflection of the pattern of membership. Access to the membership database was restricted so it was not possible to identify non-responders, send reminder cards or duplicate questionnaires to individuals who did not respond to the first mailing. Anonymous questionnaire mailings have been shown to reduce response rates by 9% (Asch et al., 1997). Conversely, the ability to send reminders with a copy of the questionnaire and to telephone a reminder both increased response rates by 14% (Asch et al., 1997).

Conclusions

The small number of respondents should be considered when attempting to extrapolate these findings to the wider dressage horse population. Although the pattern of respondents was similar to the registered membership in relation to horse level, it was possible that the respondents to the current questionnaire had horses, arenas or training practises with particular characteristics that predisposed them to a greater or lesser risk of injury. Nevertheless, as this was the first epidemiological study specific to dressage horse injury, the authors believe that the information provided is valuable and should form the basis for future hypothesis driven intervention studies.

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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References

Asch, D.A., Jedrziewski, M.K., Christakis, N.A., 1997. Response rates to mail surveys published in medical journals. Journal of Clinical Epidemiology 50, 1129–1136.
Bailey, C.J., Reid, S.W.J., Hodgson, D.R., Suann, C.J., Rose, R.J., 1997. Risk factors associated with musculoskeletal injuries in Australian Thoroughbred racehorses. Preventative Veterinary Medicine 32, 47–55.
Bailey, C.J., Reid, S.W.J., Hodgson, D.R., Bourke, J.M., Rose, R.J., 1998. Flat, hurdle and steeple racing: risk factors for musculoskeletal injury. Equine Veterinary Journal 30, 498–503.
Bassage, L.H., Richardson, D.W., 1998. Longitudinal fractures of the condyles of the third metacarpal and metatarsal bones in racehorses: 224 cases (1986–1995). Journal of the American Veterinary Medical Association 212, 1757–1764.
Clayton, H.M., 1997. Classification of collected trot, passage and piaffe based on temporal variables. Equine Veterinary Journal, 50–53.
Cohen, N.D., Peloso, J.G., Mundy, G.D., Fisher, M., Holland, R.E., Little, T.V., Misheff, M.M., Watkins, J.P., Honnas, C.M., Moyer, W., 1997. Racing-related factors and results of prerace physical inspection and their association with musculoskeletal injuries incurred in Thoroughbreds during races. Journal of the American Veterinary Medical Association 211, 454–463.
Cressey, E.M., West, C.A., Tiberio, D.P., Kraemer, W.J., Maresh, C.M., 2007. The effects of ten weeks of lower-body unstable surface training on markers of athletic performance. Journal of Strength and Conditioning Research 21, 561–567.
Dyson, S.J., 2002. Lameness and poor performance in the sport horse: dressage, show jumping and horse trials. Journal of Equine Veterinary Science 22, 145–150.
Ellis, D.R., 1994. Some observations on condylar fractures of the third metacarpus and third metatarsus in young Thoroughbreds. Equine Veterinary Journal 26, 178–183.
Firth, E.C., 2006. The response of bone, articular cartilage and tendon to exercise in the horse. Journal of Anatomy 208, 513–526.
Firth, E.C., Rogers, C.W., 2005. Musculoskeletal responses of 2-year-old Thoroughbred horses to early training. Conclusions. New Zealand Veterinary Journal 53, 377–383.
Hill, T., Carmichael, D., Maylin, G., Krook, L., 1986. Track condition and racing injuries in Thoroughbred horses. Cornell Veterinary Journal 76, 361–379.
Holm, I., Rosdahl, M.A., Friis, A., Risberg, M.A., Myklebust, G., Steen, H., 2004. Effect of neuromuscular training on proprioception, balance, muscle strength, and lower limb function in female team handball players. Clinical Journal of Sports Medicine 14, 88–94.
Holmstrom, M., Drevemo, S., 1997. Effects of trot quality and collection on the angular velocity in the hindlimbs of riding horses. Equine Veterinary Journal, 62–65.
Holmstrom, M., Fredericson, I., Drevemo, S., 1994. Biokinematic differences between riding horses judged as good and poor at the trot. Equine Veterinary Journal, 51–56.
Holmstrom, M., Fredericson, I., Drevemo, S., 1995. Biokinematic effects of collection on the trotting gaits in the elite dressage horse. Equine Veterinary Journal 27, 281–287.

Hosmer, D.W., Lemeshow, S., 2000. Applied Logistic Regression, second ed. John Wiley and Sons, New York, USA. pp. 143–186.

Kold, S.E., Dyson, S.J., 2003. Lameness in the dressage horse. In: Ross, M., Dyson, S. (Eds.), Diagnosis and Management of Lameness in the Horse. W B Saunders, St Louis, USA, pp. 975–983.

Meagher, D.M., 1976. Lateral condylar fractures of metacarpus and metatarsus in horses. In: Proceedings of the Annual Convention of the American Association of Equine Practitioners 22, pp. 147–154.

Mohammed, H.O., Hill, T., Lowe, J., 1991. Risk factors associated with injuries in Thoroughbred horses. Equine Veterinary Journal 23, 445–448.

Mohammed, H.O., Hill, T., Lowe, J., 1992. The risk of severity of limb injuries in racing Thoroughbred horses. Cornell Veterinary Journal 82, 331–341.

Murray, R.C., Vedi, S., Birch, H.L., Lakhani, K.H., Goodship, A.E., 2001. Subchondral bone thickness, hardness and remodelling are influenced by short term exercise in a site specific manner. Journal of Orthopaedic Research 19, 1035–1042.

Murray, R.C., Dyson, S.J., Tranquille, C., Adams, V., 2006. Association of type of sport and performance level with anatomical site of orthopaedic injury diagnosis. Equine Exercise Physiology, Equine Veterinary Journal, 411–416.

Murray, R.C., Branch, M.V., Dyson, S.J., Parkin, T.D.H., Goodship, A.E., 2007. How does exercise intensity and type affect equine distal tarsal subchondral bone thickness? Journal of Applied Physiology 102, 2194–2220.

Parkin, T.D.H., 2007. Workshop report – epidemiology of training and racing injuries. Equine Veterinary Journal 39, 466–469.

Parkin, T.D.H., Clegg, P.D., French, N.P., Proudman, C.J., Riggs, C.M., Singer, E.R., Webbon, P.M., Morgan, K.L., 2004. Race and course level risk factors for fatal distal limb fracture in racing Thoroughbreds. Equine Veterinary Journal 36, 521–526.

Parkin, T.D.H., Rogers, K., Stirk, A.J., Newton, J.R., Webbon, P.M., Hillyer, L.L., 2006. Risk factors for tendon strain injury during racing in Great Britain. In: Proceedings of the Sixteenth International Conference of Racing Analysts and Veterinarians, Tokyo, Japan, pp. 323–324.

Perkins, N.R., Reid, S.W.J., Morris, R.S., 2005a. Risk factors for musculoskeletal injuries of the lower limbs in Thoroughbred racehorses in New Zealand. New Zealand Veterinary Journal 53, 171–183.

Perkins, N.R., Reid, S.W.J., Morris, R.S., 2005b. Risk factors for injury to the superficial digital flexor tendon and suspensory apparatus in Thoroughbred racehorses. New Zealand Veterinary Journal 53, 184–192.

Reeves, M.J., Salman, M.D., Smith, G., 1996. Risk factors for equine acute abdominal disease (colic): results from a multi-center case-control study. Preventative Veterinary Medicine 26, 285–301.

Rick, M.C., Obrien, T.R., Pool, R.R., Meagher, D., 1983. Condylar fractures of the third metacarpal bone and third metatarsal bone in 75 horses – radiographic features, treatments, and outcome. Journal of the American Veterinary Medical Association 183, 287–296.

Rubin, C., Lanyon, L., 1984. Regulation of bone formation by applied dynamic loads. Journal of Bone and Joint Surgery 66, 397–402.

Sloet van Oldruitenborgh-Oosterbaan, M.M., Wensig, T.H., Barneveld, A., Breukink, H.J., 1991. Workload in the horse during vaulting competition. In: Persson, S.G.B., Linholm, A., Jeffcott, L.B. (Eds.), Equine Exercise Physiology, third ed. ICEEP publications, Davis, California, pp. 331–336.

Smith, R.K., Goodship, A.E., 2008. The effect of early training and the adaptation and conditioning of skeletal tissues. Veterinary Clinics of North America: Equine Practice 24, 37–51.

Takahashi, T., Kasashima, Y., Ueno, Y., 2004. Association between race history and risk of superficial digital flexor tendon injury in Thoroughbred racehorses. Journal of the American Veterinary Medical Association 225, 90–93.

Verheyen, K.L., Henley, W.E., Price, J.S., Wood, J.L.N., 2005. Training-related factors associated with dorsometacarpal disease in young Thoroughbred racehorses in the UK. Equine Veterinary Journal 37, 442–448.

Walker, T.J., Murray, R.C., Parkin, T.D.H., 2008. Does use of horse walkers increase the risk of lameness in dressage horses. In: Proceedings of the Forty Seventh British Equine Veterinary Association Congress, Liverpool, 10–13 September, pp. 340.

Zekas, L.J., Bramlage, L.R., Embertson, R.M., Hance, S.R., 1999. Characterisation of the type and location of fractures of the third metacarpal metatarsal condyles in 135 horses in central Kentucky (1986–1994). Equine Veterinary Journal 31, 304–308.