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Days-lost to training and competition in relation to workload in 263 elite show-jumping horses in four European countries

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ABSTRACT

Orthopaedic, or other, injuries in sports medicine can be quantified using the 'days-lost to training' concept. Both the training regimen and the surface used in training and racing can affect the health of racehorses. Our aim was to associate 'days-lost to training' in elite-level show-jumpers to horse characteristics, training and management strategies, and the time spent working on various training and competition surfaces. We designed a longitudinal study of professional riders in four European countries. Data were recorded using training diaries. Reasons for days-lost were classified into non-acute and acute orthopaedic, medical, hoof-related, and undefined. We produced descriptive statistics of training durations, relative to type of training, surfaces used, and days-lost. We created zero-inflated negative-binomial random-effects models using the overall days-lost as outcome. In the whole dataset, duration variables related to training surfaces were analysed as independent. The Swedish data only were also used to test whether duration variables were related to competition surfaces.

Thirty-one riders with 263 horses provided data on 39,028 days at risk. Of these, 2357 (6.0%) were days-lost (55% and 22% of these were due to non-acute and acute orthopaedic injuries, respectively) in 126 horses.

In the all-country model, controlling for season, a significant variable was country. Switzerland and the UK had lower incidence-rate ratios (IR) compared to Sweden (IRs 0.2 and 0.03, respectively). Horses with previous orthopaedic problems had almost a doubled IR (1.8) of days-lost due to orthopaedic injury, compared to baseline. If the horse had jumping training more than 1 min per day at risk the IRs were 6.9–7 (compared to less than this amount of time); this was, however, likely an effect of a small baseline. Variation in training was a protective factor with a dose–response relationship; the category with the highest variation had an IR of 0.1.

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In the Swedish model, controlling for season, there was an association of year (IR 2.8 year 2010). Further, if the horse rested >17–25% of the days at risk, or >33% of the DAR2, had IRs 3.5 and 3.0, compared to less time. Horses ≥6 years had IRs of 1.8–2.0, compared to younger horses. Limited training use of sand surface was a risk-factor (IR 2.2; >4 ≤ 12 min/day at risk), compared to not training on sand. Training/competing on sand-wood was a protective factor (IRs 0.4–0.5) compared to not using this surface.

1. Introduction

A large share of the disease burden of ridden horses is orthopaedic (Penell et al., 2005; Murray et al., 2010a). In horses trained for specific tasks (e.g. show jumping or dressage), orthopaedic and other problems may lead to 'days-lost to training'. This term is used to indicate days when individuals did not train, though training would have taken place had they been healthy. The concept has been used both in human medicine (McLain and Scott Reynolds, 1989; Darrow et al., 2009) and in Thoroughbred racehorses in the UK (Jeffcott et al., 1982; Rossdale et al., 1985; Verheyen and Wood, 2004; Dyson et al., 2008; Ramzan and Palmar, 2011), South Africa (Olivier et al., 1997), Australia (Bailey et al., 1999), and Germany (Lindner and Dingerkus, 1993). Most days-lost to training in racehorses were due to lameness.

Like racehorses, sport horses are also prone to develop orthopaedic problems, resulting in days-lost to training. The nature of these orthopaedic problems differs between disciplines and competition level (Dyson, 2002; Murray et al., 2006, 2010a). For example, dressage horses (at both the elite and non-elite levels) are at a higher risk of injuring the hindlimb suspensory ligaments, whereas elite-level show-jumping horses are at a higher risk of injuring the forelimb superficial-, and deep-digital flexor tendons. These specific injury sites in show-jumping horses are likely related to the high loading these forelimb structures are subjected to when landing after an obstacle (Meershoek et al., 2001a,b; Hernlund et al., 2010).

The impact of physical challenges to a horse depends on several factors. These include the physical condition of the horse in question, possible individual vulnerability or pre-existing injury, and the training programme of the horse (total workload, intensity, variation, continuity). The surface used for training and racing is a risk factor for the orthopaedic health of racehorses (Cheney et al., 1973; Parkin et al., 2004; Perkins et al., 2005). However, information about sport horses is limited (Egenvall et al., 2008; Murray et al., 2010b), warranting further investigation.

We longitudinally monitored elite show-jumping horses. Our aim was to associate days-lost in training to horse characteristics, training and management strategies, and the time spent working on various training and competition surfaces. The variability of training/activity was addressed in a separate study (Lönnell et al., 2013).

2. Materials and methods

2.1. Design and sample size

We designed a prospective longitudinal study of show-jumping riders and horses conducted in four European countries in 2009 (Lönnell et al., 2013). The numbers that were aimed at (300 horses in each country that were supposed to contribute each 0.5 horse year at risk) were based on sample-size calculations under simplifying assumptions that in retrospect were realised to have been inadequate for the data obtained. Because fewer data than expected were collected during 2009 and data-collection routines were well secured in Sweden, we decided to continue the study in Sweden during 2010. Sports rankings (as far as possible) were compared between responders and non-responders as an indication of selection (non-response) bias.

2.2. Riders

2.2.1. The Netherlands

Criteria for selection of Dutch riders were that they performed at International level in a yard with more than five sport horses. Thirty-two riders met the criteria and were invited to participate. Most declined, mainly due to time constraints – but also confidentiality issues. Twelve riders initially agreed to participate.

2.2.2. Sweden

Rankings by the Swedish Equestrian Federation (http://tdb.ridsport.se/rider_rankings/search) for 2008 were used as the basis for selection of elite riders. The inclusion criteria were a top – 100-ranked rider in 2008 (riders competing at advanced level), a minimum of five horses in training, and being based in one of four geographical areas in southern and central Sweden. Riders based in dealing yards were excluded, due to the expected high turnover of horses. Thirty-three riders met the criteria and were invited to participate; of these three could not be reached and seven declined participation because of lack of interest, time constraints, or planned stays abroad. Three show-jumping riders performing at advanced and/or professional level – but with ranking outside the Top 100 – were also approached and included (bringing the total to 26 recruited participants). Ten riders (nine of whom had participated in 2009) agreed to participate for a second season in 2010.

2.2.3. Switzerland

Rankings by the Swiss Equestrian Federation for 2008 were used as the basis for selection of elite riders. Professional riders approached for the study were in the Top 60 for Switzerland, (competing at advanced level), with a minimum of five horses in training. Twenty-five professional riders met the criteria and were invited to participate either by telephone or in person. Twelve declined to participate, due to time constraints. Thirteen professional riders in 10 yards agreed to participate.

2.2.4. The UK

Rankings by British Show jumping for 2008 were used as the basis for selection of elite riders. The inclusion criteria was a 'Top 100 Team GBR' ranking or a 'Top 50 Top Young Rider List' ranking in 2008, with a minimum of five horses in training. Twenty riders met the criteria and were invited to participate. Ten declined to participate, due to time constraints. Ten riders agreed to participate.

2.3. Horses

Riders were asked to select horses that were ≥3 years of age and expected to stay in the yard for training and competition for the main part of the study period (both years).

2.4. Baseline protocols

All riders were visited before the start of the study by one researcher in each country. Riders provided baseline data on participating horses: year of birth, country of origin, sex (mare, stallion, gelding), years in yard, and whether the horse had ≥1 week rest in the preceding year due to orthopaedic problems. Riders also provided data on the training regimens they used: the frequency and amount of dressage (i.e. flatwork), jumping, hacking, and fitness work (mainly canter/gallop and hill work). The latter data were mainly used for correct interpretation of the training protocol data (see below). Each arena surface used was evaluated for whether its superficial layer consisted of sand (and whether this was wax-coated), fibre, rubber, wood (chips), turf, or their combinations. Riders also used roads, forest tracks/paths, and various grass surfaces; if none of the mentioned categories applied, these latter surfaces were categorised as 'other'. Each arena was identified using specific abbreviations (e.g. SA for sand arena), which were used by the riders to document their surface usage.

2.5. Data collection and training protocols

The data-acquisition period was scheduled for up to 6 months and typically took place during the main outdoor competition season. In Sweden, this was 15th April to 15th October 2009 and 1st May to 31st October 2010. In Switzerland and the Netherlands, the riders started in a staggered manner from 1st May 2009. In the UK, the riders collected data from 1st August 2009 to 31st December 2009. Riders could choose when they both entered and left the study.

Participating riders maintained daily training and competition records and data (on paper forms provided for the study) on veterinary events and days-lost. The riders were provided with protocols monthly and were asked to return these on a monthly basis.

The daily records included details on availability and health status of the horse (healthy, not optimally fit/sound and not fit/sound). The time spent in the pasture or paddock was documented (in hours and minutes). The minutes spent on a walker, on a treadmill, lunged, long-reined, or led in-hand was also recorded. For each of four ridden training categories (hacking, dressage, fitness, and jumping) the surface used (as identified in the baseline protocols) and the minutes of exercise were recorded. The duration (in minutes) for the ridden activities was defined as the time from mounting the horse until the end of the riding session. Competition data registered comprised class(es) competed in and duration. In the Swedish data, competition-surface composition was characterised using the Swedish Equestrian Federation database (http://tdb.ridsport.se) and classified as: sand, fibre, rubber, wood, turf, or other (or their combinations; rubber and wood were in the form of chips). The class information was checked versus this database and added in case it was missing. In addition the recording form had a box in which free-text comments could be made for every piece of information as deemed of interest by the rider (for example, if they used a surface not found in their own list).

2.5.1. Data on health problems

Veterinary/injury records for each horse were kept on a daily basis. The reasons for reduced work or days when horses were not trained were assigned to at least one of five categories: symptoms of unclear origin (e.g. slight gait irregularity), lameness, hoof/shoeing, back, and medical conditions. Comments and additional information could also be entered throughout the days-lost period when needed. Riders stated whether a diagnosis was made by themselves, a veterinary surgeon, a chiropractor/physiotherapist/osteopath, farrier, or other person.

2.5.2. Definition of days—lost, inclusions, and exclusions

Days-lost were defined as days when horses were not trained due to health reasons (based on health status and data on health problems). Whether or not a day was classified as a day-lost was determined from the veterinary data and the health classification.

Inclusion criteria for days-lost:

- Horses were deemed unfit and did not perform work over the level of the resting-day definition.
- Horses were deemed fit in the training protocol but were exercised at a significantly lower intensity and duration on a single day and this was in conjunction with days when horses were deemed unfit.
- Days when waiting for the farrier because of a lost shoe.
- Days of prophylactic health care entailing reduced work.

Exclusion criteria:

- If horses were deemed unfit on a single day but performed work over the level of the resting-day definition. An example would be if the horse started in competition and was found to be lame later the same day.
- Single days of prophylactic health care, if in normal work.

2.5.3. Definition of categories for days-lost

In Sweden, diagnoses made by veterinary surgeons could (to a certain extent and with permission from the rider) be verified by telephone calls. This was to confirm the diagnosis and treatment. Days-lost were divided (based on the protocols and the development of the disease episodes) into acute or non-acute orthopaedic problems, medical problems, hoof disorders and undefined problems. Acute orthopaedic problems included traumatic injuries (e.g. accidents in competition, during travel or at home). All other orthopaedic problems were categorised as non-acute. Hoof disorders included all hoof problems including waiting for the farrier for lost shoes and hoof abscesses. Only one category was assigned per day. For descriptive purposes, a more-detailed categorisation was also made. Sub-categories were problems originating from the metacarpophalangeal or metatarsophalangeal joint, distal interphalangeal joint, talocrural joint, femoropatellar or femorotibial joint, scapulohumeral joint, tendon injuries, ligament injuries, accidents, hoof problems, muscular problems, cuts, skin problems, colic, diarrhoea, respiratory illness, back problems, and undefined problems.

2.5.4. Definitions of days trained and rest days

Rest days were days when healthy horses did not train, or were in reduced work (as defined for days-lost) – but due to management decisions. Thus, post competition rest days, post fitness-training rest days, and normal weekly rest days, were classified as part of the training program. The categorisation of the data on rest days was based on whether the rider perceived the day as rest, as well as on the actual activity provided.

2.6. Data management

Daily training and injury data for each horse were entered in an Excel (Microsoft Corporation, Redmond, WA 98052-6399, USA) spreadsheet that was identical to the daily diary sheet and from which riders and researchers could get direct feed-back on the monthly training (Lönnell et al., 2013). Data were checked with the riders in case of incomplete or unlikely data. Scrutinising adjacent data from at least three similar trainings sessions of the same horse, manual imputation was made when single values were missing and likely values could be found. This was mainly done when the information on surface or work duration was missing, because the type of work was a priori filled in (see protocol in Lönnell et al., 2013), to identify absent information on time or arena/surface type. Assuming that absent information was introduced by simple forgetfulness, in practice very small discrepancies for duration might have been generated by the imputation, and perhaps arenas were misclassified in case of riders with access to many different arenas. In most cases a certain arena type will almost always have been most logical, depending on activity. The data were imported into SAS (SAS Institute Inc., Cary, NC 27513, USA) and descriptive analyses were performed (after merging the veterinary data, the horse-baseline data, the arena-categorisation data and the competition-surface data). Periods of rest that had not yet ended at the end of the study period were deleted (because some horses ended their training with several weeks of rest, often at the end of the season and for undefined reasons).

2.6.1. Analyses

Data are presented for each of the training categories with the following additions or exceptions. Data on field and paddock turnout were combined. Fitness work was divided into climbing (hill work) and canter work. Data on long-reining, treadmill, and loose cantering were incorporated in broader categories; see also Lönnell et al. (2013). In cases when riders had not noted the time of competition, 40 min were added for one class, and a total of 60 min for two classes.

We used two definitions of horse-days at risk (DAR). DAR1 was used as denominator for days-lost and included all days for which horses had registered data. For measurements involving days rest, outdoor confinement, and training, the denominator was DAR2 (defined as DAR1 minus days-lost). We analysed activities as minutes or hours per DAR2.

Descriptive analyses were assessed by country and most often the two seasons in Sweden.

2.6.2. Modelling

We created zero-inflated random-effects negative-binomial models, in the software R (glmmADMB version 0.7.3, http://glmmadmb.r-forge.r-project.org/). We used the overall days-lost to training as outcome and the natural log of DAR1 as offset. Because the days-lost counts contained many zeros but, when positive, could be substantial (theoretically fitted by a Poisson or negative-binomial model), this model strategy was selected (Dohoo et al., 2009): Models were built using (i) data from all countries and (ii) the Swedish data where training-duration variables related to competition surfaces were tested; in the whole dataset (i), only time variables related to training surfaces were analysed (all relative to DAR2). There was one line of data for each horse. For horses included during two years, time-varying covariates were set to those from 2009 (age, time at yard, previous orthopaedic health status).

We tested each of the independent variables, with rider as a random effect (only fixed-effects negative-binomial/count effects allowed in glmmADBM). To decide on the format of a continuous variable, its distribution (in the whole dataset) was studied. If dominated by zeros, a categorised format was selected, but if distributed roughly as Normal (or at least, Uniform), three to seven equidistant categories were created which were then used to test for linearity while modelling; Table 1 demonstrates the variables. We incorporated waxed-sand surfaces into the various sand or sand combinations. A few times, categorised variables were further amalgamated during modelling when categories with similar estimates were merged.

To analyse activity and surface variations, we created new variables. We calculated the proportions of activity used for the most common work types, i.e. dressage, hacking, jumping, competing, lunging, and fitness. Ignoring all but the highest category, a low proportion was deemed if at least one category contributed > 50% of the time, followed by >40 ≤ 50%, >30 ≤ 40%, >20 ≤ 30%, and ≤20%. Proportional training times on the most common surface types were defined for sand, turf, other, sand-fibre, and sand-wood surfaces analogously. For the surface variations the categories were (low > 50% in at least one category, >40 ≤ 50%, >30 ≤ 40% and ≤30%).

Table 1
Frequency tables for horses with and without days-lost (DL) and *p*-values from zero-inflated negative-binomial modelling. Data are from all countries (NL; the Netherlands, CH; Switzerland, UK; United Kingdom, SE; Sweden, 31 riders; 263 horses) and SE (18 riders; 145 horses) during 2009/2010. Rider was included as a random negative-binomial effect in all models. Time at yard was missing for 1 horse. Turnout has different baselines in the 2 models.

Variable/unit	Category/unit	All countries No. horses			SE No. horses		
		DL	No DL	*p*-value	DL	No DL	*p*-value
Country	NL	19	29	NE			
	CH	21	19				
	UK	7	23				
	SE(BL[a])	79	66				
Gender	Mare	61	61	0.30	36	30	0.68
	Stallion	11	19		8	8	
	Gelding (BL)	54	57		35	28	
Breed	SWB[b]	54	50	0.74	54	50	0.20
	Other	46	48		19	10	
	NL (BL)	26	39		6	6	
Age category (years)	≥8	58	52	0.23	30	17	0.29
	6–7	39	39		26	20	
	≤5 (BL)	29	46		23	29	
Time at yard (whole years)	>4	41	30	0.38	25	19	0.19
	3–4	11	12		6	3	
	1–2	20	36		11	17	
	<1 (BL)	54	58		37	27	
Mean class competed (cm)	>140	31	10	0.23	16	8	0.42
	>120 ≤ 140	58	65		37	31	
	≥100 ≤ 120	28	41		20	15	
	<100 (BL)	9	21		6	12	
Study year	2010	54	37	0.01	54	37	0.03
	Only 2009 (BL)	72	100		25	29	
Rest (% of DYAR2[c])	>33%	27	39	0.52	24	16	0.03
	>25 ≤ 33%	24	31		14	23	
	>17 ≤ 25%	40	30		25	14	
	≤17% (BL)	35	37		16	13	
Previous orthopaedic problems	Yes	32	14	0.01	23	9	0.001
	No (BL)	94	123		56	57	
Whether worked in[d]	April	58	46	0.50	57	42	0.02
	May	107	93	0.08	76	55	0.71
	June	111	93	0.05	72	50	0.38
	July	106	83	0.02	69	43	0.23
	August	102	85	0.96	65	46	0.20
	September	92	69	0.33	53	31	0.60
	October	83	67	0.84	43	23	0.65
	November	100	120	0.49	0	0	
	December	110	132	0.91	0	0	
Dressage (min/DAR2)	>19	16	20	0.33	4	1	0.24
	>15 ≤ 19	25	17		15	3	
	>11 ≤ 15	45	39		27	26	
	>7 ≤ 11	29	42		23	25	
	≤7 (BL)	11	19		10	11	
Hacking (min/DAR2)	>12	16	16	0.95	10	2	0.88
	>10 ≤ 12	7	7		6	3	
	>8 ≤ 10	11	9		8	6	
	>6 ≤ 8	8	16		8	12	
	>4 ≤ 6	17	18		11	12	
	>2 ≤ 4	29	27		19	20	
	>0 ≤ 2	31	29		15	10	
	never (BL)	7	15		2	1	
Jumping (min/DAR2)	>5	15	13		12	22	
	>4 ≤ 5	29	12		24	8	
	>1 ≤ 4	78	13		43	32	
	≤1 (BL)	4	28		0	4	
Competing (min/DAR2)	>6	31	31	0.48	14	13	0.51
	>4 ≤ 6	31	40		23	21	
	>2 ≤ 4	45	42		32	23	
	>0 ≤ 2	14	10		8	4	
	Never (BL)	5	14		2	5	
Turnout (h/DAR2)	>8	13	9	0.26	13	9	0.47
	>6 ≤ 8	11	10		11	10	
	>4 ≤ 6	16	18		16	18	
	>2 ≤4	31	22		28	19	
	>0 ≤ 2 BL-SE	51	70		11	10	

Table 1 (*Continued*)

Variable/unit	Category/unit	All countries No. horses			SE No. horses		
		DL	No DL	*p*-value	DL	No DL	*p*-value
	Never (BL)	4	8		0	0	
Mechanical walker	>40	36	24	0.15	17	16	0.78
(min/DAR2)	≤40	90	113		62	50	
Time led by hand	>2	38	24	0.86	24	13	0.52
(min/DAR2)	>1 ≤ 2	17	14		10	8	
	>0 ≤ 1	37	38		21	12	
	Not led (BL)	34	61		24	33	
Lunging	>3	30	37	0.34	18	17	0.55
(min/DAR2)	>1.5 ≤ 3	33	43		15	23	
	>0 ≤ 1.5	44	34		37	24	
	Never (BL)	19	23		9	2	
Activity variation[e]	Highest	9	20	0.03	8	13	0.12
	High	38	46		27	28	
	Medium	43	40		27	16	
	Low (BL)	36	31		17	9	
Training duration							
Sand	>20	8	20	0.03	0	0	0.04
(min/DAR2)	>12 ≤ 20	13	25		14	29	
	>4 ≤ 12	42	26		35	26	
	≤4 (BL)	63	66		30	11	
Turf	>4.5	14	24	0.38	11	8	0.29
(min/DAR2)	>3 ≤ 4.5	14	11		9	9	
	>1.5 ≤ 3	20	10		13	7	
	>0 ≤ 1.5	11	11		8	7	
	Never (BL)	67	81		38	35	
Other	>10	31	25	0.30	23	7	0.30
(min/DAR2)	>8 ≤ 10	12	11		8	7	
	>6 ≤ 8	12	21		12	17	
	>4 ≤ 6	21	16		15	8	
	>2 ≤ 4	16	21		8	15	
	>0 ≤ 2	23	20		8	7	
	Never (BL)	11	23		5	5	
Sand-fibre	>12	49	40	0.35	19	7	0.77
(min/DAR2)	>0 ≤ 12	41	47		31	25	
	Never (BL)	36	50		29	34	
Sand-wood	>2	24	17	0.26	24	17	0.12
(min/DAR2)	>0 ≤ 2	15	13		14	11	
	Never (BL)	87	107		41	38	
External training	Ever	29	11	0.95	29	11	0.67
	Never (BL)	97	126		50	55	
Surface variation[e]	Highest	17	16	0.79	12	11	0.83
	High	31	33		26	25	
	Medium	42	36		27	16	
	Low (BL)	36	52		14	14	
Training and competition duration							
Sand	>10				21	15	0.69
(min/DAR2)	>4 ≤ 10				19	33	
	>1 ≤ 4				14	8	
	≤1 (BL)				25	10	
Turf	>7				10	10	0.22
(min/DAR2)	>5 >= 7				11	9	
	>3 ≤ 5				11	11	
	>1 ≤ 3				30	14	
	≤1 (BL)				17	22	
Other	>10.5				20	7	0.57
(min/DAR2)	>7.5 ≤ 10.5				12	10	
	>4.5 ≤ 7.5				24	19	
	>1.5 ≤ 4.5				12	20	
	≤1.5 (BL)				11	10	
Sand-fibre	>20				5	3	0.51
(min/DAR2)	>14 ≤ 20				10	0	
	>8 ≤ 14				16	14	
	<2 ≤ 8				19	15	
	≤2 (BL)				29	34	
Sand-turf	>1				8	3	0.45
(min/DAR2)	>0 ≤ 1				29	12	
	Never (BL)				42	51	

Table 1 (*Continued*)

Variable/unit	Category/unit	All countries No. horses			SE No. horses		
		DL	No DL	*p*-value	DL	No DL	*p*-value
Sand-wood	>1				43	32	0.01
(min/DAR2)	>0 ≤ 1				17	15	
	Never (BL)				19	19	
Competition duration							
Sand	>1.3				36	36	0.39
(min/DAR2)	>0 ≤ 1.3				31	20	
	Never (BL)				12	10	
Turf	>1.5				35	29	0.76
(min/DAR2)	>0 ≤ 1.5				30	15	
	Never (BL)				14	22	
Sand-fibre	Ever				39	24	0.65
	Never (BL)				40	42	
Sand-turf	Ever				37	15	0.55
	Never (BL)				42	51	
Sand-wood	>0.5				29	31	0.07
(min/DAR2)	>0 ≤ 0.5				20	9	
	Never (BL)				30	26	

[a] BL-baseline.
[b] SWB-Swedish warmblood.
[c] DAR2-days at risk when perceived healthy; %.
[d] The baselines (IR = 1) are not given for each of the month variables.
[e] The activity/surface variation categories were from low to high and they were > 50% of one type of training/surface, >40–50%, >30–40% and >20–30%.

Variables with likelihood ratio *p*-value < 0.05 were then included in unreduced multivariable models, because of the design forcing country in the all-country model. After reduction ($p < 0.05$) two-way interactions were tested upon this main-effects model. After this, dummies for whether a horse was included from April to December (for Sweden excluding November and December), and for age category were forced upon the final models mainly to control for confounding. (We noted that some factors were not independent of each other. For example, all of training on sand, competing on sand, and both training and competing on sand were tested; the latter obviously were related to the other two variables.) The zero-inflation and alpha parameters in glmmADMB were used to assess that zero-inflated and negative-binomial models, respectively, improved model fit. All continuous duration variables (including the proportion rest) were assessed for simple, bivariable collinearity by using Spearman's rank correlation (an absolute value >0.7 was considered to indicate collinearity).

2.6.3. Ethical permission

The Swedish part of the study was carried out under ethical permission number C266/8 (Uppsala Djurförsöksetiska nämnd). In the Netherlands, Switzerland and the UK this non-interventional study did not require ethical approval under the respective Acts of Animal Experimentation.

3. Results

3.1. Compliance and data completeness

Of the recruited riders in the Netherlands, Sweden, Switzerland, and the UK, three of 12, 18 of 26, five of 13, and five of eight riders, respectively, provided useable data. One rider entered data electronically and all the rest filled out a paper protocol. Reasons given by riders in all countries for drop out were: time constraints, staff or rider illness/accident, staff movement, and death of a family member/co-owner. When competition class was missing, we determined this using venue websites (tdb.ridsport.se or www.britishshow jumping.co.uk).

Four months of data from three Swedish riders were lost during delivery (mainly in the postal mail). Short periods in the beginning of the data-acquisition period were deleted in five horses because horses entered the study period with days-lost. Data from six horses/horse seasons were not used because they were too incomplete or horses never really entered training. Data from one Swedish rider was partly deleted from the first season because they were incomplete. In addition, approximately 200 horse-days within the otherwise-used data periods were deleted because most registrations were missing.

In the Netherlands, both participating ($n = 3$) and non-participating ranked riders ($n = 29$) had a median 2009 ranking of 22 (min/max 4/33 and 1/43, respectively). In Sweden, participating ranked riders ($n = 16$) had a median 2009 ranking of 168 (min/max 106/368) and non-participating ($n = 17$) of 200 (min/max 43/409). In Switzerland, ranks were not retrievable. In the UK, participating riders ($n = 5$) had a median 2009 ranking of 35 (min/max 9/47) and non-participating riders of 18 (min/max 1/56; $n = 15$).

3.2. Riders and horses

Thirty-one riders with 263 horses were recruited to the study. Some recruited riders in all four countries had additional stable riders engaged in training and/or competition, but with the study rider having main responsibility. Six riders in Sweden shared yards, giving a total number of 28 training yards. Each rider had between three and 28 horses (median 8 horses). In 2009 and 2010 in Sweden, 120 and 93 horses were followed, respectively (of which 65 horses participated in both years). Horses contributed from 9 DAR1 to 371 DAR1 (median 152 DAR1). Of the 39,028 DAR1, the distribution by month was April (4.3%), May (17.2%), June (18.6%), July (16.4%), August (15.9%), September (14.2%), October (9.9%), November (2.5%) and December (1.2%). In Sweden, there were 14,847 DAR1 in 2009 and 10,458 DAR1 in 2010.

Demographic variables are given in Table 2. For time-dependent covariates (age, time at yard, and ≥1 week rest due to orthopaedic problems previous year), data are provided for each season. All horses were European warmbloods.

3.3. Days-lost to training and competing

The total number of horses with days-lost to training during the study period was 126 and the total days-lost to training during the study period was 2357 (Table 3). A new event was defined as soon as there were DAR2 in between two days-lost periods. There were 233 events (ranging within horse from one to seven events) – though many of these will have been related to the same problem. By rider, the fraction of days-lost varied from 0% to 21%. The main reason for days-lost was orthopaedic problems: non-acute and acute together represented 77% ((1304 + 520)/2357) of days-lost. Of the orthopaedic problems, 29% (520/(520 + 1304) were acute.

The main diagnoses for the days-lost were accidents (466 days, 20% of the days-lost; 20 horses), inflammation of the metacarpophalangeal or metatarsophalangeal joint (305 days, 13%; 17 horses), ligament disorders (296 days, 13%; 6 horses), hoof problems (275 days, 12%; 27 horses), back problems (257 days, 11%; 28 horses), unspecified problems (191 days, 8%; 19 horses), problems of the femoropatellar/femorotibial joint (186 days, 8%; 20 horses), cuts (176 days, 7%; 13 horses) and tendon injuries (173 days, 7%; 5 horses). There were local differences, for example 'hamstrings treatment' was performed at one yard in the Netherlands but not in any other country.

3.4. Rest days, training, competition, and surfaces

The horses rested for 24% of all healthy days (DAR2), which varied per rider from 10% to 38%. Horses trained between 45% and 77% of the available days, and competed between 6% and 16% of the days. Training and activity variables (75th and 90th percentiles for min/DAR2) are given in Tables 4 and 5. Three riders never included fitness work and 15 riders did a mean of ≤2 min fitness/DAR2, eight did >2 ≤ 5 min, while five did >5 min/DAR2. Treadmill training and long-reining was used by one or two riders each, for individual or several horses. Total time exercised per rider varied from 19 to 49 min per DAR2 and between 4.0 and 6.2 sessions/week (for more detail, see Lönnell et al., 2013). Nine of the Swedish riders trained on arenas outside their regular arenas. The proportional surface usage per

Table 2
The numbers of horses among the 31 riders and 4 countries (NL; the Netherlands, SE; Sweden, CH; Switzerland, UK; United Kingdom) in a study of training in professional show- jumping horses in 2009/2010. The age of the horses and time at the yard are based on the horse seasons (time at the yard was missing for one horse).

Country	No. riders	No. horses	No. horse seasons	Gender						Country of horse's origin						Previous health problems		Age (year)		Time at yard (year)		Class competed (cm)	
				Gelding		Mare		Stallion		NL		SE		Other		No. seasons	%	Mean	s.d.	Mean	s.d.	Mean	s.d.
				No.	%	No.	%	No.	%	No.	%	No.	%	No.	%								
NL	3	48	48	18	38	21	44	9	19	36	75	0	0	12	25	5	10	6.9	2.2	2.0	2.2	129	12
SE	18	145	208	63	43	66	46	16	11	12	8	104	72	29	20	51	25	7.0	2.6	3.1	2.7	130	13
CH	5	40	40	15	38	23	58	2	5	6	15	0	0	34	85	8	20	9.1	3.1	2.8	1.9	131	12
UK	5	30	30	15	50	12	40	3	10	7	23	0	0	23	77	1	3	8.2	2.6	1.8	1.7	134	11
Total	31	263	320	111	42	122	46	30	11	61	23	104	40	98	37	55	17	7.3	2.7	2.8	2.5	130	13

Table 3
Distribution of horses with days lost, and days-lost (DL) in 263 show-jumping horses, from 31 riders in four countries (NL; the Netherlands, SE; Sweden, CH; Switzerland, UK; United Kingdom), followed for 39,028 days-at-risk (DAR1).

Country	No. horses	Horses		Days-lost		Non-acute orthopaedic injuries			Acute orthopaedic injuries			Medical			Hoof			Undefined		
		Lost		No.	%		% of	% of		% of	% of		% of	% of		% of	% of		% of	% of
		No.	%			No.	DAR1	DL	No.	DAR1	DL	No.	DAR1	DL	No.	DAR1	DL	No.	DAR1	DL
NL	48	19	40	321	6	255	5	79	33	1	10	4	0	1	29	1	9	0	0	0
SE 2009	117	52	44	723	5	305	2	42	160	1	22	162	1	22	79	1	11	17	0	2
SE 2010	91	44	48	1005	10	590	6	59	230	2	23	80	1	8	52	0	5	53	1	5
CH	40	21	53	279	4	124	2	44	97	1	35	30	0	11	12	0	4	16	0	6
UK	30	7	23	29	2	29	2	100	0	0	0	0	0	0	0	0	0	0	0	0
Total	263	126	48	2357	6	1303	3	55	520	1	22	276	1	12	172	0	7	86	0	4

time-unit is presented in Table 6. Note that all sand-surfaces in the UK were waxed.

3.5. Modelling

None of the 120 rank correlations assessed for the continuous duration variables in the all-country data were >0.6 (absolute value). In the Swedish data of 351 correlations, nine were >0.7. Six of these nine by design represented collinear variables (e.g. duration for training and competing on sand was highly correlated to duration of training on sand). Two two-way interactions were significant in the all-country model (before age and month were added), though estimates and standard errors were highly inflated (between jumping duration and activity variation ($p = 0.01$), and jumping duration and previous orthopaedic problems ($p = 0.008$)). Adding month and age, mainly included to control for confounding, tended to make the estimates further differentiated from zero, especially in the all-country model. All previously significant effects remained. In the multivariable models (Table 7), the 95% CIs of the zero-inflation parameters did not include zero (indicating that zero-inflated models fit the data better than regular negative-binomial models). The 95% CIs of the alpha parameters did not include zero (which implies that the negative-binomial is preferred over the Poisson distribution).

In the all-country model, the variables included in the unreduced multivariable model were year, previous orthopaedic health problems, training variation, and country (forced). Duration variables were time used for jump training and training on a sand surface. In the reduced model significant negative-binomial/count variables were country with Switzerland and the UK having lower incidence-rate ratios (IR) compared to Sweden (IRs 0.02 and 0.03, respectively). Training in May was associated with a higher IR (4.5) and in August lower (IR 0.4). Age was not significant. Previous orthopaedic problems had almost a doubled IR (1.8) compared to baseline. If the horse had jumping training $\geq$1 min per DAR2, all categories showed IRs of 6.9–7.0 (compared to not $\geq$1 min). Variation in training was protective with a dose–response relationship; the highest variation category had an IR of 0.1.

In the Swedish model the variables included in the unreduced multivariable model were year, previous orthopaedic health problems, and rest. Duration variables were the time used for jump training, fitness work, training on a sand surface, training and competing on sand-wood surface, and competing on a sand-wood surface. In the final model, there was an association of year (IR 2.8 year 2010), if the horse rested >17–25% of the DAR2, or >33% of the DAR2 (IRS 3.5 and 3.0, compared to less time). Horses $\geq$6 years old had IRs of 1.8–2.0 compared to younger horses. For four months, IRs were different from 1; April and May were higher and both June and September were lower. A limited amount of training on sand was a risk factor (IR 2.2); in the higher-duration category, the IR was close to 1 (0.9) compared to not training on sand. Training/competing on sand-wood was a protective factor (IRs 0.4–0.5) compared to not using this surface.

Table 4
Percentile (%ile) distribution of mean duration (in minutes) per days-at-risk fit for training (DAR2) of ridden work by 31 professional show-jumping riders in four countries in 2009/2010 (NL; the Netherlands, SE; Sweden, CH; Switzerland, UK; United Kingdom).

	DAR2	Horses	Dressage			Hacking			Competition			Jumping		
	No.	No.	Total daily (min)		Horses in activity	Total daily (min)		Horses in activity	Total daily (min)		Horses in activity	Total daily (min)		Horses in activity
			75%ile	90%ile	%	75%ile	90%ile	%	75%ile	90%ile	%	75%ile	90%ile	%
NL	4881	48	30	35	96	0	0	73	0	0	85	0	0	100
SE 2009	14,124	117	30	45	100	0	30	97	0	0	97	0	0	100
SE 2010	9453	91	30	40	100	0	40	99	0	0	93	0	0	98
CH	6721	40	40	50	100	10	45	100	0	0	98	0	0	98
UK	1492	30	30	40	100	0	20	80	0	20	87	0	15	93

Table 5
Percentile (%ile) distribution of mean duration (in minutes) per days-at risk fit for training (DAR2) of unridden work by 31 professional show-jumping riders in four countries in 2009/2010 (NL; the Netherlands, SE; Sweden, CH; Switzerland, UK; United Kingdom).

	DAR2	Horses	Turnout			Walker			Led by hand			Lunging		
	No.	No.	Total daily (h)		Horses in activity	Total daily (min)		Horses in activity	Total daily (min)		Horses in activity	Total daily (min)		Horses in activity
			75%ile	90%ile	%	75%ile	90%ile	%	75%ile	90%ile	%	75%ile	90%ile	%
NL	4881	48	2	2	98	60	60	100	0	0	65	0	20	92
SE 2009	14,124	117	7	10	100	50	60	54	0	0	61	0	0	85
SE 2010	9453	91	7	8	100	55	60	59	0	0	55	0	0	80
CH	6721	40	1.5	3	100	45	45	93	0	0	85	0	0	95
UK	1492	30	0	2	63	60	60	90	0	0	50	0	0	17

4. Discussion

The fraction of days-lost differs considerably (by inspection) between riders. Each rider had only a few horses, so comparing directly between two riders was difficult. Some of the significant variables are likely contributors to the between-rider effect (e.g. amount and variation in training, for example relative to surface), but there seems to be a unique rider-effect as well. This is a cluster effect, which is often hypothesised to be related to undocumented management strategies based on experience or even ‘feel’. Equine orthopaedic medicine has evolved from being only

Table 6
Proportional use of training surfaces relative to surface type. Data are presented for surfaces used in competition and for external training (amalgamated) for Sweden only. In total, the riders trained 14,697 h on the training surfaces and competed (and trained externally) 2092 h on the Swedish surfaces (NL; the Netherlands, SE; Sweden, CH; Switzerland, UK; United Kingdom).

	Percent of the time surfaces were used							
	By country/year					By rider		
	NL	SE2009	SE 2010	CH	UK	Min	Median	Max
Training surfaces								
Sand[a]	11	33	21	0	23	0	14	80
Turf	6	9	4	1	20	0	2	39
Other	13	30	34	33	15	0	26	64
Sand/fibre	70	16	28	12	0	0	0	90
Sand/rubber	0	0	0	0	29	0	0	61
Sand/wood	0	13	14	0	0	0	0	43
Sand/fibre/rubber	0	0	0	55	13	0	0	76
Sand/fibre/wood	0	0	0	0	0	0	0	1
Competition and external training surfaces (only SE)								
Sand		35	13			1	29	51
Turf		43	15			6	35	79
Other		1	0			0	0	3
Sand/fibre		4	24			0	9	34
Sand/rubber		4	24			0	9	34
Sand/wood		14	9			0	11	31
Sand/fibre/rubber		0	0			0	0	0
Sand/fibre/wood		0	0			0	0	0
Sand/turf		0	13			0	4	20
Sand/fibre/turf		0	1			0	0	4
Rubber/turf		0	1			0	0	2

[a]The sand/sand combination surfaces in the UK are all waxed.

Table 7
Results from multivariable zero-inflated negative-binomial random-effects modelling of days-lost data from all four countries (31 riders; 263 horses) during 2009 and Sweden only (18 riders; 145 horses) during 2009/2010. The zero-inflation parameters and their 95% CIs were 0.34 (95% CI; 0.24–0.43) and 0.39 (95% CI; 0.30–0.48), and for the alpha parameters these were1.24 (95% CI; 0.62–1.85) and 1.92 (95% CI; 1.11–2.73).

Variable	Category/unit	All countries					Sweden				
		Estimate	SE[a]	*p*-value	IR[b]	95% CI	Estimate	SE	*p*-value	IR	95% CI
Age category (years)	≥8	0.22	0.29	0.44	1.2	0.7–2.2	0.69	0.26	0.008	2.0	1.2–3.3
	6 < 7	0.13	0.27	0.62	1.1	0.7–1.9	0.57	0.26	0.03	1.8	1.1–2.9
	≤5 (BL[c])	0					0				
Study year	2010						1.02	0.33	0.00	2.8	1.4–5.3
	2009 (BL)						0				
Previous locomotor problems	Yes	0.57	0.25	0.02	1.8	1.1–2.9					
	No (BL)	0									
Country	The Netherlands	−0.36	0.61	0.55	0.7	0.2–2.3					
	Switzerland	−1.82	0.80	0.02	0.2	0.0–0.8					
	The UK	−3.53	1.14	0.002	0.03	0.003–0.3					
	Sweden (BL)	0									
Rest	>33%						1.10	0.41	0.01	3.0	1.4–6.7
	>25–33%						0.62	0.44	0.16	1.9	0.8–4.4
	>17–25%						1.25	0.36	0.0005	3.5	1.7–7.1
	≤17%						0				
Jumping time (min/DAR2[d])	>5	1.93	0.83	0.021	6.9	1.3–35					
	>4 ≤5	1.94	0.77	0.01	6.9	1.5–31					
	>1 ≤4	1.94	0.72	0.007	7.0	1.7–28					
	≤1 (BL)	0									
Training variation[e]	Highest	−1.92	0.56	0.0006	0.1	0.0–0.4					
	High	−0.97	0.33	0.003	0.4	0.2–0.7					
	Medium	−0.19	0.27	0.48	0.8	0.5–1.4					
	Low (BL)	0									
Training time on sand (min/DAR2)	>12						−0.06	0.30	0.85	0.9	0.5–1.7
	>4 ≤ 12						0.79	0.30	0.01	2.2	1.2–4.0
	≤4 (BL)						0				
Training/competing time on sand-wood (min/DAR2)	>2						−0.67	0.34	0.05	0.5	0.3–1.0
	>0–2						−0.99	0.38	0.009	0.4	0.2–0.8
	0 (BL)						0				
Whether worked in[e]	April	−0.18	0.39	0.64	0.8	0.4–1.8	0.69	0.26	0.008	2.0	1.2–3.3
	May	1.50	0.58	0.01	4.5	1.4–14	0.57	0.26	0.03	1.8	1.1–2.9
	June	−1.11	0.87	0.20	0.3	0.1–1.8	−0.90	0.28	0.002	0.4	0.2–0.7
	July	1.25	0.77	0.11	3.5	0.8–16	0.74	0.66	0.26	2.1	0.6–7.6
	August	−0.90	0.40	0.03	0.4	0.2–0.9	1.10	0.90	0.22	3.0	0.5–18
	September	0.50	0.61	0.41	1.6	0.5–5.4	−1.40	0.69	0.04	0.2	0.1–1.0
	October	−0.26	0.46	0.58	0.8	0.3–1.9	−0.34	0.37	0.37	0.7	0.3–1.5
	November	1.59	1.00	0.11	4.9	0.7–35					
	December	1.83	1.05	0.08	6.2	0.8–49					

[a] SE-standard error.
[b] IR-incidence rate ratio.
[c] BL-baseline.
[d] DAR2-days at risk when perceived healthy.
[e] The activity variation categories were from low to high and they were > 50% of one type of training (of hacking, fitness work, flatwork, jumping and lunging), >40–50%, >30–40% and >20–30%; the baselines (IR = 1) are not given for each of the month variables.

curative to being more prophylactic, including treatment of mild orthopaedic disease (personal observation). That the data often included many short convalescence periods suggests to us that this was true for the orthopaedic conditions diagnosed in this study. This new strategy might in itself lead to an increased (or decreased) rider-effect on prevalence and on the nature of orthopaedic disorders.

Methodologically, the days-lost concept has advantages and disadvantages. The main problem is that many of the diagnoses were clinically mild, so it is unlikely that there would be much between-veterinarian agreement on the exact diagnosis that caused the problem. This can be compared to the poor between-veterinarian agreement on detection of the lame limb within a horse with mild clinical lameness (Keegan et al., 2010). It was therefore decided to not analyse more-exact diagnoses. In the same line, it is unlikely that all riders had the same threshold for deciding on when and how to handle mild clinical problems that 'could have' resulted in days-lost. This means that some days of reduced training, as described by the rider, might have been classified as days-lost by the authors and this could have 'punished' some riders more than others. However, this reflects the real-world situation and is a general problem in epidemiology, especially when mild disease is targeted. In cases with a very gradual progression from convalescence to ordinary training, the number of days-lost to a certain extent relied on the rider's subjective diagnosis. To ensure adherence to the same principles when dealing with whether a day was considered lost or not, the data were handled by one investigator and scrutinised by another and reviewed repetitively. A possible disadvantage in the current setting is that a horse could only be categorised into one subgroup each day. However, this was not a practical problem in the data, because there were few days-lost days where data suggested diagnoses in several subgroups.

Fixed effect zero-inflated negative-binomial models (with rider as a significant fixed effect) were initially tried in the Stata package, including covariates also in the inflated part. In general, the same effects were significant–but a few additional surface factors also emerged as significant (e.g. sand-fibre surface was a significant count risk-factor, limited usage of turf or turf/sand risk-factors–while sand was a protective factor). Because we reasoned that random-effects models in theory produced more reliable results (given the structure of our data), we chose the latter models and the effects disappeared. In this respect it should be realised that the glmmADMB procedure does not currently allow covariates or random-effects in the logit submodel (Atkins et al., 2013). In spite of multiple comparisons in this exploratory study, we decided not to do post hoc correction of *p*-values – but readers should attach the greatest significance to the variables with lowest *p*-values in the final models. Variables were only slightly correlated, but a few variables were likely eliminated because of collinearity (training, competing, and 'training and competing' on sand is an obvious example). Country, month and age were forced into the models. However, the small and very selected sample (possibly introducing some selection bias) and the poor compliance in some countries led to difficulties in interpreting country effects; therefore this variable mainly controls for confounding. One potential cause of selection bias was if riders prone to have physical-health problems in their horses were less likely to participate. Once recruited to the study, one reason for non-response bias across the four countries was approaching riders with frequent international travel–who also tended to hold the highest national rankings. Reasons given were logistic challenges of keeping protocols for travelling horses, confidentiality concerns regarding valuable horses and (for two approached riders) ambitions to provide more detailed information than the study protocol allowed. Age of the rider was also related to non–response bias; riders >23 years had a lower dropout rate. A probable reason was lack of experience or maturity, because the study demanded high commitment and daily discipline. In Sweden' electronic-software problems' was also a dropout reason.

We drew causal diagrams between the different training and exercise-management variables; most variables appeared related to each other. Riders whose planned training programs include variation of activity and who allot more time to training would be more likely to include more hacking in relation to dressage. Riders who allot less time to training could be more likely to give priority to dressage training (producing less variation). When not knowing which part of training was first on the causal pathway, the risk of including intervening variables was obvious but could not be prevented without assumptions.

There might be several reasons why rest was a risk factor. Sometimes rest was recorded when it seemed that horses were actually resting because of undocumented physical problems (i.e. suspected by the rider). In other instances, horses potentially rested too much to be able to achieve a good training effect – even though strategic rest is part of most training programmes for human athletes and is likely also beneficial (to some degree) in strategic horse training.

Though mainly included to control for confounding, the month variables indicate that participating the first spring months had significant IRs (April and May IR > 1, June < 1, lowest *p*-values). However, the dummies were constructed so that they indicated whether the horse participated that month more than the risk from a particular month, i.e. in general horses would participate several months and those estimates need to be combined to evaluate effects. However, from the raw data a rather limited 'but opposite' seasonal effect on the count of days-lost was less than statistically expected during April, May, and June and more than expected from July to September; we would explain this by the study design and the sport situation; riders tend to start a season with fresh horses. We also note that the competition frequency was even between the periods (results not shown). The Swedish model was controlled for year and year was significant. At the end of the study, we judged that the main interpretation of 'year' is to control for the possibility of improved data reporting the second year when riders were more experienced in reporting. Previous orthopaedic problems was a risk factor and the finding that older horses had an increased risk is in line with clinical experience and previous studies (Egenvall et al., 2008). It is possible that this relates to cumulative loading in older horses.

In the all-country model, jumping was a risk factor. However, such a conclusion is likely an artefact of our decision to use as baseline for a category that had the lowest amount of jumping—but only 16 horses. The IR are alike (from 6.9 to 7.0) in the rest of the categories (from horses training $\geq 1 < 4$ min/DAR2 to ≥ 4 min/DAR2). The 16 baseline horses were mostly non-Swedish with few days-lost (data not shown).

Activity variation was mainly a protective factor in the all-country model. We also modelled training variation without competition (data not shown) and results were similar but less linear, where the next-highest variation fared best. This is in line with experience and sports science; variation in activities will increase soundness, potentially reducing risk of repetitive overload injury (Bates, 2010). A main result from Lönnell et al. (2013) was the large variation in training (both relative to activity variation and to duration).

Table 6 shows that the between-rider variation relative to usage of various surface compositions was also substantial. We found that training on sand for a limited duration was a risk factor in the Swedish model. A UK study looking at risk factors for lameness in dressage horses found that a surface which had sand as the major component had the greatest risk for lameness (Murray et al., 2010a). However, there was also a reduction in risk of injury the more often a sand surface was used – suggesting a role of adaptation in protection from injury. Another study by the same group showed that wax-coated sand or sand and rubber surfaces were associated with a lower risk of injury for dressage horses than sand, sand and PVC, woodchip, or grass surfaces (Murray et al., 2010b).

It is important to remember that dressage competitions tend to be on artificial surfaces whereas show-jumping takes place on artificial surfaces during the indoor winter months and both grass and artificial surfaces during the outdoor summer months. When additionally trying to test interactions between waxed sands, and its combinations, and country or rider, waxed sands seemed to have a similar risk to other sand; however, because of the design, our models could not be made to account for this properly (data not shown). The five UK riders all trained a relatively substantial amount of time on waxed-sand arenas and they had few days-lost (three of them zero). From our current data, nothing suggests that waxed sands lead to additional days-lost (if anything, it is more the opposite).

One variable was related to competition surfaces (Swedish data). Training and competing on sand-wood (i.e. woodchips was protective for developing days-lost (negative-binomial part)), potentially related to lower impact on woodchip surfaces. It should be remembered that the time used competing was totally allocated to the competition arenas. Although as a general rule competitions and warm-up surfaces should be similar, this is often not the case during the summer outdoor season (where warm-up normally takes place on one surface type and the competition itself on turf). This could affect the risk of injury on the turf surface if the horse is not adapted to performing on that surface during warm-up. We also caution that the time used for competition was approximated in most cases; when more-exact data were available, the variation could be rather large (unpublished data). In summary, several surface top-layer variables were related to the outcome(s) in this limited dataset when the analysis ignored the detailed day-to-day registration (and each horse was represented by one row). We also stress that the mechanical properties of the surfaces can differ even if the components of the top-layer are similar (for example, depending on cushion depth and moisture condition) (Mahaffey et al., 2013) and that the deeper layers might also affect the functional characteristics. Several of the variables indicated that exposure to some variables for a limited duration was a risk factor, but that this effect disappeared when used more (which would support adaptation to a surface reducing risk of injury, similar to Murray et al., 2010a,b).

We designed this study to investigate the days-lost concept in elite show-jumpers. The concept of 'days-lost' has been used previously in human athletes and in Thoroughbred racing studies. An alternative to using all days-lost as outcome might have been to use only the orthopaedic days-lost as outcome. The characteristics and distribution of the outcome data do not allow many types of multivariable full data analyses. For example, a time-to-event analysis would have to concentrate on the first event or include multiple events, and both of those strategies would be problematic. We could control for rider, but only in the negative-binomial part. Further, to consider using the days-lost aggregated over training periods as the outcome, we needed to make a crucial 'biological' assumption: that training conditions were relatively stable within rider and horse, even from 'before', because days-lost accrues at the same time as the training. This is relatively likely, because riders can be imagined to follow a personal management/training strategy. However one should bear in mind that data on most variables (except for country, gender, breed, age, time at yard, previous orthopaedic problems, and perhaps study year) were assembled during the study period.

From a practical perspective, our results provide exciting new evidence supporting relevance of training regimens for orthopaedic health in show-jumpers. Variability of training for show – jumping horses as a protection against days-lost to injury agrees with similar findings in dressage horses, where different types of non-dressage training protected against lameness (Murray et al., 2010a). Repetitive-overload injury is a major problem for athletes from any discipline, and causes specific lesions for different equestrian sports (Murray et al., 2006). It makes biological sense that improving overall fitness, coordination, and strength using a variety of training types would be protective compared to repeating a limited number of movements for a large number of cycles without variation. This is particularly relevant where tendons and ligaments are repetitively loaded near their failure strains, as in the case in the show-jumping horse where the forelimb flexor tendons are at high risk of injury (Murray et al., 2006). The increased risk in older horses supports clinical impression and previous studies (Dyson, 2002; Murray et al., 2006). This could be attributed to the degeneration of tendons and ligaments with ageing (predisposing to injury) or to the cumulative cycles as a horse spends more years in work. In addition, because the strains on the flexor tendons increase with fence height, the older horses might be predisposed if they are competing over higher fences (which did tend to be the case in our study horses) (Meershoek et al., 2001a). To improve the understanding of orthopaedic injury in show-jumping horses, further steps in the 'sequence of prevention' (van Mechelen et al., 1992) would be valuable. This project has been one of the first attempts to identify incidence of orthopaedic injury and possible risk factors in elite show-jumping horses. A valuable next step would be to design training programs to test measures identified in this study as likely to reduce injury risk, such as been done in Thoroughbred racehorses (Boston and Nunamaker, 2000).

5. Conclusions

The occurrence of rider-perceived health problems varies between riders. A number of factors are associated with whether a horse develops any day-lost and with the number of days-lost. Caution in the interpretation of the results is advised due to the limited and selected dataset. Our results suggests that days-lost in show-jumping horses could be limited by selecting horses without previous orthopaedic problems, enhancing variation in training, and taking extra care to prevent injury in older horses.

Conflict of interest statement

None of the authors has any financial or personal relationships that could inappropriately influence or bias the content of the paper.

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