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Original Article

Application of a Ridden Horse Pain Ethogram to horses competing at 5-star three-day-events: Comparison with performance

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Summary

A Ridden Horse Pain Ethogram (RHpE) was previously developed to facilitate the detection of musculoskeletal pain. The objectives were to apply the RHpE during warm-up for the dressage phase of two 5* three-day events and to correlate the RHpE scores with subsequent performance. It was hypothesised that there would be a higher rate of failure to complete the cross-country phase in horses which exhibited ≥7 behaviours compared with those showing <7 behaviours. The RHpE, comprising 24 behaviours, was applied for 10–12 min during warm-up. Gait abnormalities in trot and canter were recorded. Dressage penalties, cross-country performance, showjumping penalties and final placings were documented. Horses were categorised as those which completed cross-country, or those which did not complete because of elimination or retirement. RHpE scores (n = 137) ranged from 0 to 9/24 (median 3 [range 0–9] for nonlame horses; median 5 [range 1–9] for horses with gait abnormalities in trot or canter). There was a moderate correlation between dressage penalty scores and the RHpE score (rho = 0.4, P<0.001, Spearman rank). Fifty-nine per cent of horses (n = 10/17) with a RHpE score ≥7 failed to complete cross-country, compared with 33% (n = 39/117) with a score <7. Horses that failed to complete the cross-country phase had higher RHpE scores compared with those that completed (P = 0.04, *W* = 8.3, Kruskal–Wallis; pairwise comparison Bonferroni, P = 0.06). There was a significant (rho = 0.3) relationship between total RHpE score and final horse placings (n = 80, P<0.01, Spearman rank). Horses with lameness or gait abnormalities in canter had significantly higher RHpE scores (P<0.01, $\chi^2 = 35$, chi-square test) compared with other horses. There was a strong correlation between the RHpE scores for horses which competed at both events (P<0.001, rho = 0.6, Spearman rank). The RHpE should facilitate earlier identification of horses which may benefit from diagnosis and treatment, resulting in improvement in both performance and equine welfare.

Introduction

There has been considerable debate in recent years about what constitutes lameness (van Weeren *et al*. 2018; Bathe *et al*. 2018; Adair *et al*. 2018, 2019; Dyson 2019a; van Weeren 2019). It is clear that there are some horses which exhibit measurable asymmetry in gait which may not influence performance (Greve and Dyson 2016). There is a growing body of evidence that approximately 50% of the sports horse population which are in regular work have subjectively assessed (Greve and Dyson 2014; Dyson and Greve 2016; Dittman *et al*. 2020) or objectively assessed (Rhodin *et al*. 2016; Wilson *et al*. 2016) gait abnormalities that are likely to reflect musculoskeletal pain. The failure of a systemic nonsteroidal anti-inflammatory drug (meloxicam) to influence measurable gait asymmetries (Persson-Sjodin *et al*. 2019) does not preclude the presence of underlying pain. The response to diagnostic anaesthesia is a more reliable means of determining the presence or absence of pain (Dyson 2016b). It has been observed that lameness which is not visible in hand may be detectable during ridden exercise and that subtle gait abnormalities in hand may be accentuated with a rider (Licka *et al*. 2004; Dyson and Greve 2016). Moreover, some horses do not show asymmetries of gait in trot but show pain-related gait abnormalities in canter (Greve and Dyson 2014; Dyson 2016a; Greve and Dyson 2020).

In order to aid the recognition of horses showing pain-related body language, caused by musculoskeletal pain, a Ridden Horse Pain Ethogram (RHpE) was developed in studies which compared nonlame and lame horses (Dyson *et al*. 2018a). The RHpE comprised 24 behaviours, the majority of which were at least 10 times more likely to be seen in a horse with musculoskeletal pain compared with a nonlame horse. Nonlame horses demonstrated a median of 2/24 behaviours (range 0–6), whereas lame horses exhibited a median of 9/24 behaviours (range 4–14), although some lame horses scored <8. It was concluded that the presence of ≥8/24 behaviours was a good indicator of musculoskeletal pain, and this was verified in further studies (Dyson *et al*. 2018b, 2020; Dyson and van Dijk, 2020). However, the RHpE cannot rule out other causes of discomfort, such as gastric ulceration. This RHpE now needs to be tested further to assess its reliability and usefulness in the field, for example at competitions.

Three-day events comprise dressage, cross-country and showjumping. Horses at Fédération Equestre Internationale (FEI) Concours Complet International (CCI) events undergo a public inspection by the Ground Jury (the dressage judges) and a veterinarian, in hand at trot, 1 or 2 days prior to performing a dressage test, to determine fitness to compete. Horses with overt lameness are eliminated. Prior to the dressage phase of the competition, the competitors warm-up on a grass surface, performing a variety of movements in walk, trot and canter. In the cross-country phase, a fall of horse or rider, four cumulative refusals, or three refusals at a single fence result in elimination. A rider may elect to retire a horse if it is jumping poorly. On the final day of competition, horses undergo a second public inspection prior to the showjumping phase, and horses with overt lameness are eliminated.

The aims of the study were to: (i) describe gait abnormalities in horses warming up for the dressage phase at two CCI 5* events; (ii) apply the RHpE during the dressage warm-up phase of these two events; and (iii) correlate the RHpE scores with subsequent performance. It was hypothesised that there would be a higher rate of failure to complete the cross-country phase in horses which exhibited ≥7 behaviours compared with those showing <7 behaviours.

Materials and methods

Pilot study

Pilot data were acquired at Burghley CCI 4* (now 5*) event in 2018 (Dyson 2019b). A convenience sample of 35 horses, competing in consecutive order on the second day of dressage, was each assessed for a minimum of 10 min during trot and canter in the late stages of warm-up. The RHpE was applied by a trained assessor (S.D., a Diplomate of the European College of Veterinary Sports Medicine and Rehabilitation). Cross-country performance was obtained from the competition website; horses were classified as completing, eliminated or retired. Twenty-seven nonlame horses scored 0–4/24 behaviours (mean and median 2/24, standard deviation [s.d.] ±2; interquartile range [IQR] 0,3); the most frequently observed behaviours were head behind the vertical ≥10 s; mouth open ≥10 s. Eight horses with gait abnormalities scored 3–9/24 (median 7.5, IQR 4,8; mean 6, s.d. ± 2); the most frequently observed behaviours were head behind the vertical ≥10 s; mouth open ≥10 s; an intense stare ≥5 s; and repeated head tilt. Thirty-four horses started cross-country of which 35% were eliminated or retired. Only four horses scored ≥8. The proportion of horses failing to complete was significantly higher for RHpE scores ≥7, compared with <7. Of 28 horses which scored <7/24 behaviours, eight (29%) were eliminated or retired. Of six horses which scored ≥7/24 behaviours, four (67%) were eliminated or retired.

The pilot study highlighted that in a cohort of highly trained horses competing at 5* level, it may be useful to use a slightly lower total RHpE score as an indicator of possible influence on performance, rather than the score of 8/24, previously identified as a reliable score for differentiating sports horses competing at a variety of levels, from unaffiliated to elite, with and without musculoskeletal pain (Dyson *et al*. 2018a,b, 2020; Dyson and Van Dijk 2020).

Main study

This was a prospective cohort study which involved all horses (n = 137) warming up for the dressage phase of a CCI 5* event (Badminton May 2019, n = 70; Burghley September 2019, n = 67).

Observations

Each horse was observed for 10–12 min immediately prior to the scheduled dressage test. At each venue, the warm-up facilities were identical for all competitors. This was a grass area approximately 80 × 80 m within which was a 20 × 60 m boarded arena; the area was flat at Burghley and on an incline at Badminton. The majority of horses were observed in medium walk, working and medium trot, shoulder-in, half pass, working canter and simple flying changes. Two horses did not perform flying changes. Most riders were receiving guidance from professional coaches.

The 24 behaviour RHpE (**Table 1**; Dyson *et al*. 2018a) was applied by an observer (S.D.) extensively trained in its application, from the same vantage points for all horses, so that horses could be observed from behind, in front and the side on both the left and right reins. The ethogram was applied in binary fashion (yes/no), with a potential total score of 24.

In addition, the horses were assessed subjectively by the same observer for the presence of lameness, gait abnormalities in canter which are not included in the ethogram (stiff, stilted canter; canter lacking a suspension phase; close temporal and spatial placement of the hindlimbs [Dyson 2016a; Greve and Dyson 2020]), saddle slip (Greve and Dyson 2013), teeth grinding, excessive blinking and other potentially relevant observations, which were recorded in note form. Gait abnormalities were subsequently classified as follows: 0 – absent; 1 – occasionally observed; 2 – recurring, but inconsistent; 3 – consistent abnormality in

TABLE 1: The 24 behaviour Ridden Horse Pain Ethogram (Dyson *et al*. 2018a), which was applied in binary fashion (a behaviour was present or absent) during observation for 10–12 min

1.	Repeated changes of head position (up/down), not in rhythm with the trot
2.	Head tilted or tilting repeatedly
3.	Head in front of vertical (>30°) for ≥10 s
4.	Head behind vertical for (>10°) ≥10 s
5.	Head position changes regularly, tossed or twisted from side to side, corrected constantly
6.	Ears rotated back behind vertical or flat (both or one only) ≥5 s; repeatedly lay flat
7.	Eye lids closed or half closed for 2–5 s
8.	Sclera exposed repeatedly
9.	Intense stare (glazed expression, 'zoned out') for ≥5 s
10.	Mouth opening ± shutting repeatedly with separation of teeth, for ≥10 s
11.	Tongue exposed, protruding or hanging out, and/or moving in and out repeatedly
12.	Bit pulled through the mouth on one side (left or right), repeatedly
13.	Tail clamped tightly to middle or held to one side
14.	Tail swishing large movements: repeatedly up and down/ side to side/ circular; repeatedly during transitions
15.	A rushed gait (frequency of trot steps >40/15 s); irregular rhythm in trot or canter; repeated changes of speed in trot or canter
16.	Gait too slow (frequency of trot steps <35/15 s); passage-like trot
17.	Hindlimbs do not follow tracks of forelimbs but repeatedly deviated to left or right; on 3 tracks in trot or canter
18.	Canter repeated leg changes in front and/or behind; repeated strike off wrong leg; disunited
19.	Spontaneous changes in gait (e.g. breaks from canter to trot or trot to canter)
20.	Stumbles or trips more than once; repeated bilateral hindlimb toe drag
21.	Sudden change of direction, against rider direction; spooking
22.	Reluctance to move forwards (has to be kicked ± verbal encouragement), stops spontaneously
23.	Rearing (both forelimbs off the ground)
24.	Bucking or kicking backwards (one or both hindlimbs)

canter; 4 – consistent abnormality in canter and occasional lameness; and 5 – continuous lameness.

Dressage penalties, cross-country performance, showjumping penalties, and final placings were collected from the respective event web site. Horses were categorised as those which completed cross-country, or those which did not complete because of elimination or retirement. Additional data concerning the reason for elimination were obtained from the British Eventing website. Horses which were withdrawn before the cross-country phase were recorded.

Data analysis

The results for cross-country performance are presented independently for each event because the influence of the cross-country course varied between competitions. However, the data for completion placings and RHpE score, as well as field observations, were analysed combined. Data were mostly nonparametric and analysed using Kruskal–Wallis (Bonferroni, multivariate tests, e.g. RHpE scores between eliminated, retired and noncompletions), Mann–Whitney (RHpE scores between events, between independent groups), Wilcoxon sign-test (e.g. completion/noncompletion, same horses) and Spearman rank correlations (correlations between RHpE and performance factors) (JASP, 0.1.11, 2019). The significance level was set at $P<0.05$. A preliminary principal component analysis was carried out using parallel component loadings with 20 of the behaviours (excluding three nonoccurring and one with low correlation). An oblique promax applied rotation method was used with parallel analysis highlighting three components in a Scree plot. This was done in order to highlight clusters of behaviours likely to occur together, rather than to reduce variables.

Results

Comparison between Badminton and Burghley 2019

Horse starts and status by the end of the cross-country phase

At Badminton 2019, 70 horses started, two withdrew after the dressage phase and 16/68 cross-country starters (24%) failed to complete the cross-country phase. Forty-nine horses (70%) completed the event. At Burghley 2019, from 67 starters, three withdrew after dressage, and 31/64 (48%) cross-country starters failed to complete the cross-country phase. Thirty-three horses (52%) completed the event. The median RHpE score was 4 and 3, respectively, for Badminton and Burghley (Mann–Whitney, $P = 0.09$, $W = 0.95$). Data for completion of cross-country are summarised in **Table 2**, in relation to the RHpE scores. Forty-four per cent of horses which started cross-country at Badminton with an ethogram score of ≥7 were retired or eliminated, compared with 20% of horses with a RHpE score of <7. At Burghley, 71% of horses which started cross-country with a RHpE score of ≥7 failed to complete cross-country, compared with 46% of horses with a RHpE score of <7. At Badminton eliminations comprised 1/68 (1.5%) horse fall, 2/68 (2.9%) unseated riders and 1/68 (1.5%) three refusals; whereas at Burghley, there were 2/64 (3.1%) horse falls, 10/64 (15.6%) unseated riders and 3/64 (4.7%) accumulated refusals.

Ridden Horse Pain Ethogram scores

Ridden Horse Pain Ethogram scores ranged from 0 to 9 (**Fig 1**). Only 10/137 horses scored ≥ 8. The median score for horses with neither lameness nor gait abnormalities in canter was 3 (range 0–9), compared with a median score of 5 (range 1–9) for horses with observed gait abnormalities.

The occurrence of different behaviours was similar at each event (**Fig 2**), with the most frequent observations being *front of the head behind a vertical position >10^0 for ≥10 s, repeated head tilt, mouth open with separation of the teeth for ≥10 s, an intense stare for ≥5 s* and *repeated tail swishing*. In total, 457 behaviours were recorded. The behaviours *slow rhythm, repeated stumble or toe drag,* and *eye lids partially closed for 2–5 s* were not observed; *head in front of vertical >30^0 for ≥10 s* and *rearing* were only observed once.

Similar proportions of horses with gait abnormalities were seen at each event. At Badminton, 27/70 horses (38.6%) showed lameness or gait abnormalities in canter (forelimb or hindlimb lameness n = 6, including three with abnormal canter; gait abnormalities in canter n = 14, poor hindlimb impulsion n = 7). At Burghley, 28/67 horses (41.8%) showed lameness or gait abnormalities in canter (forelimb or hindlimb lameness n = 12, including three with abnormal canter; gait abnormalities in canter n = 14, poor hindlimb impulsion n = 2).

Performance and the Ridden Horse Pain Ethogram scores

There was a moderate positive correlation between dressage penalty scores and the RHpE score (rho = 0.4, $P<0.001$, Spearman rank). There was no relationship between the RHpE score and cross-country time penalties or total showjumping penalties. There was a significant but weak (rho = 0.3) relationship between total RHpE score and final horse placings (n = 70, $P<0.01$, Spearman rank; **Fig 3**, **Table 3**). There was no difference between events for these results (Kruskal–Wallis).

The median RHpE score for the five horses withdrawn before cross-country was relatively low (median 2), although one horse had a RHpE score of 8. There was a strong trend towards a higher RHpE score for horses that did not complete (median 4) compared with those that did complete (median 3) the cross-country phase ($P = 0.06$; $W = 1788$, Mann–Whitney). There was a higher RHpE score for horses that retired during the cross-country phase compared with those that completed (**Fig 4**, $P = 0.04$, $W = 8.3$, Kruskal–Wallis, pairwise comparison Bonferroni, $P = 0.05$), but no difference between eliminations and retirements (**Fig 4**).

Repeat performances

In total, 25 horses participated both at Badminton and Burghley 2019. There was no significant difference between those attending one event or both events in final placing, dressage penalties and showjumping penalties. Horses that attended both events tended to be placed higher at Burghley ($P = 0.08$, $t = 1.8$, independent t-test), partially because of a lower overall completion rate (46%). The completion rate of horses attending both events was significantly higher at Badminton than Burghley ($P < 0.05$, $\chi^2 = 6.7$, chi-square test; **Table 4**).

Pairwise comparison of total RHpE scores for horses which competed at both three-day events showed that there was no significant difference, with 19/25 horses having a difference in score ≤2 (Wilcoxon sign-test; **Fig 5a**). There was a good correlation between the RHpE scores between the two events ($P<0.001$, rho = 0.6, Spearman rank correlation; **Fig 5b**). There was a mean agreement of 65% (s.d. ± 16) between occurrences of individual behaviours.

TABLE 2: Descriptive overview of data in relation to all entry starts and Ridden Horse Pain Ethogram score (RHpES) (Dyson *et al*. 2018a) by the end of the cross-country phase at two 5* three-day events

Venue	Starts	RHpES median (range) after dressage	DNC* cross-country	Completed with RHpES ≥7	E or R with RHpES ≥7	Total of horses starting cross-country with RHpES <7	Total of horses starting cross-country with RHpES ≥7
Badminton 2019	70	4 (0–9)	16/68[W(2)] E or R (24%)	n = 4/52 (10% of completions)	n = 5/16 (31% of eliminations)	n = 59 of which 12 (20%) E or R	n = 9 of which 4 (44%) E or R
Burghley 2019	67	3 (0–9)	31/64 [W(3)] E or R (48%)	n = 2/33 (6% of completions)	n = 5/31 (16% of eliminations)	n = 57 of which 26 (46%) E or R	n = 7 of which 5 (71%) E or R

* Did not complete: DNC = withdrawn (W) after dressage, E, eliminated during cross-country, R, retired during cross-country

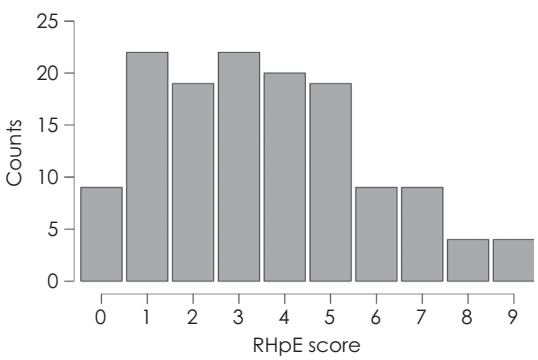

Fig 1: Frequencies of Ridden Horse Pain Ethogram (RHpE) scores (from Dyson et al. 2018a) for horses assessed for 10–12 min during warm-up prior to their dressage test at Badminton (n = 70) and Burghley (n = 67) 2019. Counts = number of horses with each score.

Horses with RHpE scores 9 (n = 1), 8 (n = 1) and 7 (n = 2) at Badminton scored 6, 5, 6 and 4, respectively, at Burghley. However, despite these reductions in RHpE scores, the horses showed major gait abnormalities in canter at both events. Comments included stiff, stilted canter; canter lacked suspension; croup high in flying changes; and bucked in flying changes. In addition, one of these horses had developed a forelimb lameness in lateral work, despite an improvement in the RHpE score, and was eliminated in the cross-country phase at Burghley. One of these horses was retired in the cross-country phase at both events, and one was eliminated in the cross-country phase at Badminton.

Other observations in relation to Ridden Horse Pain Ethogram scores

Horses with lameness or gait abnormalities in canter had a significantly higher RHpE score ($P<0.01$, $\chi^2 = 35$, chi-square test; **Fig 6**) compared with other horses. The RHpE score was significantly lower for horses without additional noted observations in comparison with those with a gait irregularity score higher than 2 ($P<0.001$, Kruskal–Wallis; **Table 5**); there was a strong correlation between gait abnormalities and the RHpE score (rho = 0.44, $P<0.001$, Spearman). There was a weak negative correlation between the gait score and the final placing (the lower the score, the higher placing; rho = 0.3, $P<.05$, Spearman). There was a stronger positive correlation between the gait score and dressage penalties (rho = 0.4, $P<0.001$, Spearman).

Preliminary principal component analysis of the RHpE behaviours exhibited by all horses combined highlighted three distinct groupings of behaviours which were likely to occur together (**Fig 7**). Other observations included teeth grinding (n = 4; 2% of horses without gait abnormalities, 6% of horses with gait abnormalities), teeth chomping (n = 2) and continuous 'tension' (n = 2). Tension was shown by one horse with no detectable gait abnormality, but a RHpE score of 9.

Discussion

This study aimed to compare and relate the RHpE score to performance parameters in an applied field study. It was not within the scope of this to establish causes for any observed relationships. The RHpE was initially developed by the comparison of nonlame and lame horses (Dyson *et al*. 2017, 2018a) and was tested by the comparison of horses before and after resolution of lameness by diagnostic anaesthesia (Dyson *et al*. 2018b; Dyson and Van Dijk 2020). In these studies, a RHpE score of ≥8 was a strong indicator of the presence of musculoskeletal pain. In the current study, the application of the RHpE was explored in relatively fit and healthy high-level performance horses, to test whether the ethogram may be useful in predicting some aspects of performance. As would be expected from this sample population, and based on the pilot data, only a small proportion of horses showed evidence of discomfort when ridden, and therefore, a cut-off score of seven behaviours was selected for assessment. There are a number of factors with the potential to influence the RHpE score, including the influence of the rider and their application of the aids, as discussed below with respect to mouth opening. However, previous studies comparing the RHpE scores of lame horses before and after relief of musculoskeletal pain by diagnostic anaesthesia indicate that discomfort is of major importance (Dyson *et al*. 2018b; Dyson and Van Dijk 2020). When ridden horses exhibit conflict behaviour (Górecka-Bruzda *et al*. 2015) or behaviour related to stress (Hall *et al*. 2014), we need to try to understand why.

In accordance with our hypothesis, the proportion of horses failing to complete the cross-country phase was higher for horses with a RHpE score ≥7 (mean 59%) compared with horses with a score <7 (mean 33%). The reason for failure to complete the cross-country phase could not be investigated. In addition to musculoskeletal discomfort compromising performance, other factors have to be considered, such as rider or horse error, rider skill, lack of athletic ability required to

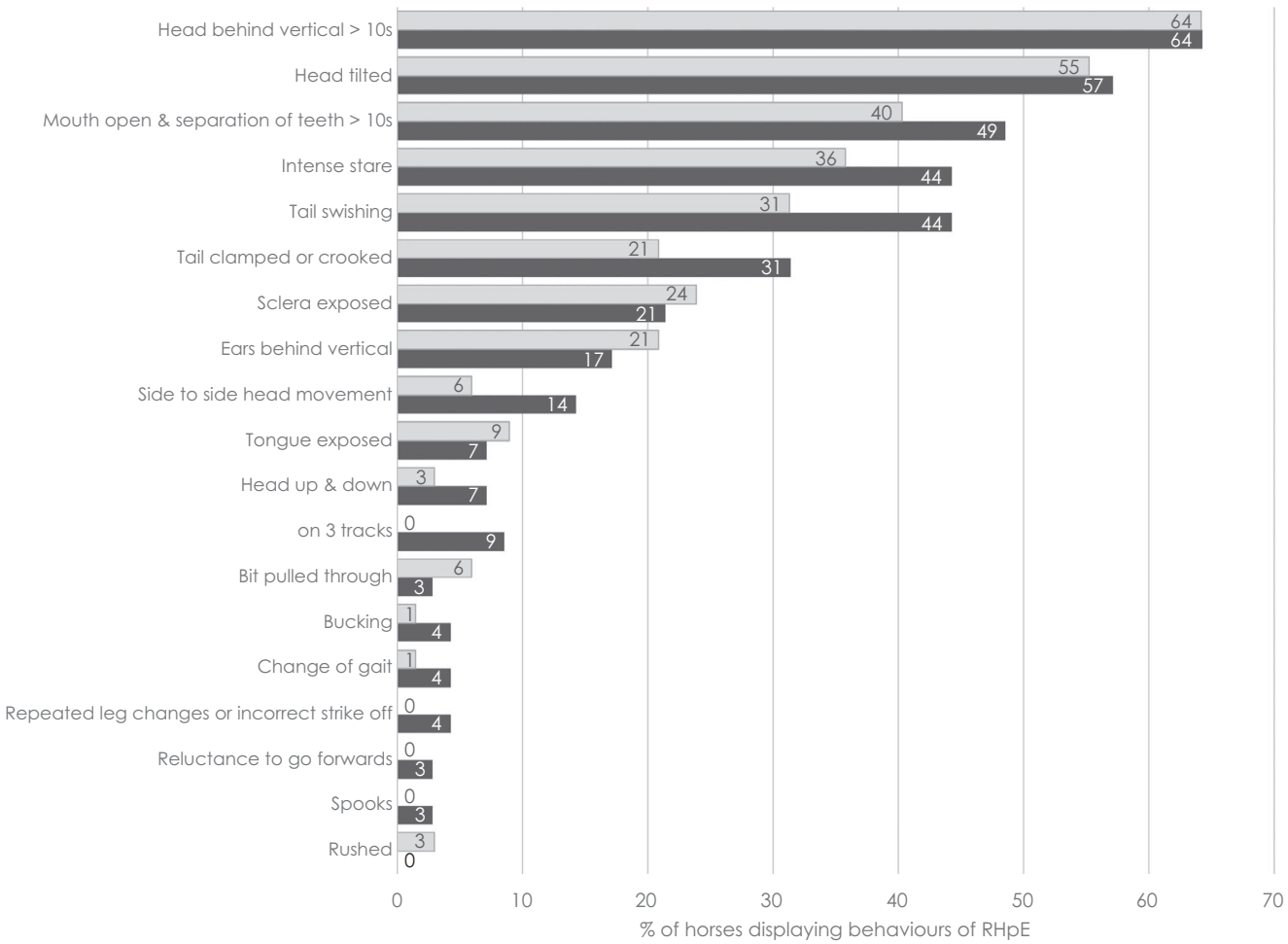

Fig 2: Percentage of horses (x-axis) displaying behaviours from the Ridden Horse Pain Ethogram (RHpE; Dyson et al. 2018a), assessed for 10–12 min during the dressage warm-up, according to event (Badminton 2019, n = 70 [dark bars]; Burghley 2019 n = 67 [light bars]).

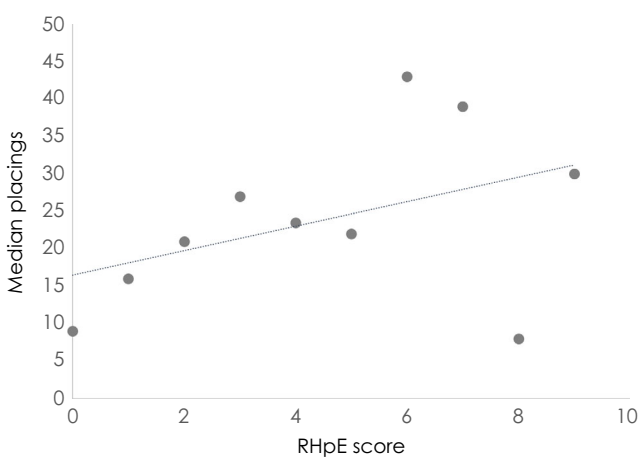

Fig 3: Relationship between final placing and Ridden Horse Pain Ethogram (RHpE) score recorded during warm-up for dressage from horses competing at Badminton 2019 and Burghley 2019 (n = 70, P<0.01, rho = 0.3, Spearman Rank).

compete at 5* level, the footing, or loss of a shoe(s), but it is notable that two horses assessed at each event with RHpE scores ≥7 failed to complete on both occasions. During the cross-country a high level of adrenaline and release of endorphins (Ferlazzo *et al*. 2012; Micalos 2014) may overcome musculoskeletal pain, enabling horses to jump well despite the presence of discomfort. In the pilot study, one horse had a RHpE score of 9, ground its teeth incessantly and had a stiff, stilted hindlimb gait, and finished 7th; in the main study, one horse scored 8, lacked a suspension phase in the canter on the left and right reins and bucked in flying changes, and finished 8th. Some horses are supremely talented and are competing well within their athletic capabilities; others are maximally stretched and if jumping errors are repeated may be less willing to keep trying, especially if there is underlying discomfort (Górecka-Bruzda *et al*. 2013, 2015). In addition, it has previously been documented that behavioural signs of discomfort may be related to ill-fitting tack (Peham *et al*. 2004). Despite the higher elimination or retirement rate at Burghley 2019, because of the difficulty of the course, compared with Burghley 2018 and Badminton 2019 (Phillips 2019), the proportion of horses failing to complete cross-country remained higher for those with RHpE scores ≥7 (71%) compared with the proportion with a score <7 (46%).

There was also a negative relationship between the RHpE score and both the performance in the dressage phase and the final placing. The dressage scores are related to the

TABLE 3: Final placings of horses that completed at Badminton 2019 (n = 70) and Burghley 2019 (n = 67) related to the Ridden Horse Pain Ethogram score (Dyson *et al*. 2018a), recorded during warm-up for dressage

	Ridden Horse Pain Ethogram score									
Placing	0	1	2	3	4	5	6	7	8	9
n	5	18	8	15	12	11	4	4	1	2
Mean place	19.8	16.2	25.4	30.3	27.4	23.3	42.7	36.0	8.0	30.0
Median	9.0	16.0	21.0	27.0	23.5	22.0	43.0	39.0	8.0	30.0
SD	19.5	10.7	18.4	18.5	17.4	14.2	12.6	21.5		15.6
Minimum	4	1	5	2	2	3	30	10	8	19
Maximum	50	38	53	84	54	48	55	56	8	41

n, number; s.d., standard deviation.

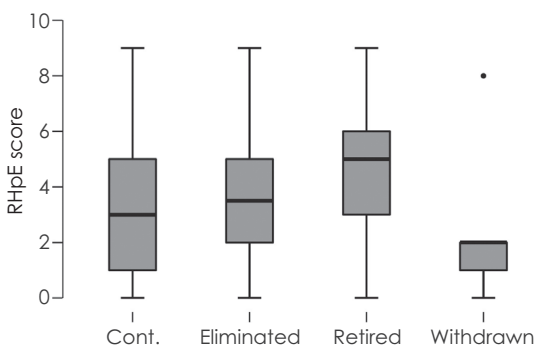

Fig 4: Distribution and median Ridden Horse Pain Ethogram (RHpE) scores (Dyson et al. 2018a) in relation to the outcome of the cross-country phase (Cont. – continued to showjumping; Eliminated – during cross-country; Retired – during cross-country; Withdrawn – before cross-country).

quality of the paces, obedience and compliance. The FEI Rules for Dressage (2019) use terms such as 'rhythm, harmony and lightness'. The rules specifically indicate that 'behind the bit' (the front of the head being behind a vertical position), putting the tongue out and 'agitation of the tail' are signs of lack of submission. The term 'accepting the bridle with a light and consistent soft submissive contact' is also used by the FEI, which is interpreted as the mouth being closed. Within the RHpE, the front of the head being behind the vertical>10° for ≥10 s, the mouth being open exposing the teeth for ≥10 s, the tongue being out and the tail swishing were previously correlated with an increased risk of musculoskeletal pain (Dyson *et al*. 2018a,b; Dyson *et al*. 2020; Dyson and Van Dijk 2020).

It is notable that the front of the head being behind a vertical position >10° for ≥10 s and the mouth being open with separation of the teeth for ≥10 s, were common features, observed in 64% and 45% of horses, respectively. These features were observed in both nonlame horses with no abnormalities of canter and horses with gait abnormalities. Some riders are able to alter a horse's head and neck position and may ride the horse with the front of the head vertical during the test, while warming up with the front of the head behind a vertical position (Hall *et al*. 2014; Toft *et al*. 2020). A study that evaluated horses performing a standard exercise test on a treadmill in walk, trot and canter, with variable head and neck positions, showed that with the front of the head in a vertical position, there was evidence of stress, manifest by increased heart rate variability and cortisol concentrations, and more conflict behaviour, compared with other head and neck positions (Smiet *et al*. 2014). Mouth opening may represent an evasion or conflict behaviour (Górecka-Bruzda *et al*. 2015), or reflect discomfort associated with head position (Eisersiö *et al*. 2013), or the bit or bridle (Cook and Mills 2009). The principal component analysis grouped this behaviour with most other head behaviours indicating discomfort, and also together with repeated tail swishing. Mouth opening was previously shown to be related to the presence of a rider (Dyson *et al*. 2017), and an increase in rein tension (Manfredi *et al*. 2009). Increase in rein tension has been measured as a proxy for forces applied in the mouth. However, rein tension can be related to the horse, rider or equipment and current methods of reporting

TABLE 4: Final placings for horses competing at either one or both of two 5* three-day events in 2019

Horses competing at	Single event	Both events	Both events Badminton 2019	Both events Burghley 2019
Number	87	25	25	25
Completion rate	59%	58%	70%	46%
Mean placing ± s.e.	26 ± 2.1	23 ± 2.3	27 ± 4.1	17 ± 2.3
Minimum placing	2	1	1	3
Maximum placing	56	55	55	25
Mean penalties ± s.e.	71 ± 3.3	66 ± 4.6	65 ± 6.5	67 ± 5.6
Minimum penalties	31	27	27	28
Maximum penalties	143	125	125	87
Mean RHpES ± s.e.	3.5 ± 0.3	3.9 ± 0.3	3.8 ± 0.5	4.0 ± 0.3

s.e., standard error; RHpES, Ridden Horse Pain Ethogram score.

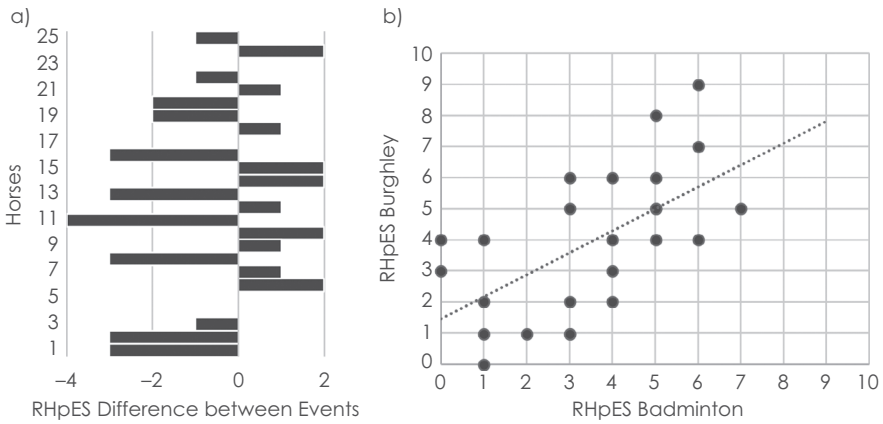

Fig 5: a) The difference (Burghley minus Badminton) in Ridden Horse Pain Ethogram (Dyson et al. 2018a) scores (RHpES Points Difference) for 25 horses competing at two 5* three-day events, assessed during the warm-up for dressage. b) Correlation of the RHpE scores between Badminton and Burghley, 2019.

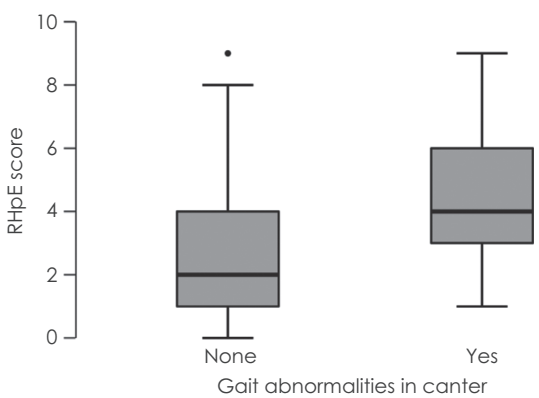

Fig 6: Distribution and median scores for the Ridden Horse Pain Ethogram scores (RHpES; Dyson et al. 2018a), comparing those horses without gait abnormalities (0) and those with lameness or gait abnormalities in canter (1), assessed during warm-up for dressage at two 5* three-day events.

TABLE 5: Comparison of subjective gait evaluation with the Ridden Horse Pain Ethogram (RHpE) (Dyson *et al*. 2018a) scores (mean, minimum and maximum) for 137 horses during warm-up for dressage at two 5* three-day events

	Gait observations*					
RHpE Score	0	1	2	3	4	5
Mean†	2.35[a]	4.09[ab]	3.72[ab]	5.06[b]	4.67[b]	4.43[ab]
SD	2.15	2.27	1.70	2.18	1.87	2.23
Minimum	0.00	1.00	1.00	1.00	1.00	2.00
Maximum	9.00	9.00	7.00	9.00	7.00	9.00

s.d., standard deviation.
*Gait observations: 0 – absent; 1 – occasionally observed; 2 – recurring, but inconsistent; 3 – consistent abnormality in canter; 4 – consistent abnormality in canter and occasional lameness; 5 – continuous lameness
† Significance indicated between values not sharing a superscript P<0.01, Kruskal–Wallis, Bonferroni pairwise comparison

have been inconsistent (Dumbell *et al*. 2019). In a small study (n = 7) of upper-level, Warmblood dressage horses, ridden in sitting trot on a treadmill, with a snaffle bridle and with an appropriately fitted noseband, the mouth was open with separation of the teeth for a longer period of the recorded time (23% ± 13) when horses were ridden 'on the bit', compared with loose reins (1%±2) (Eisersiö *et al*. 2013). It would be interesting to compare application of the RHpE during warm-up for cross-country, when head and neck positions may be different.

There was a strong relationship between the presence of gait abnormalities and the RHpE score in both the pilot study (Dyson 2019b) and the main study. Lameness, when observed, was generally low-grade (≤2/8, Dyson 2011) and often only seen in specific movements, for example, 10-m-diameter circles, shoulder-in and half pass. There was a higher frequency of occurrence of abnormalities of canter (25%) compared with lameness (13%). Flying changes are included in the dressage test and were frequently practised during the warm-up period. In horses with gait abnormalities in canter, performance of flying changes often provoked more behaviours included in the RHpE. Not surprisingly, there was a strong negative correlation between gait abnormalities and the dressage performance (P<0.001). Overall gait abnormalities were observed in 40% of horses, less than in the general sports horse population (reported as ranging from 47% to 65% [Greve and Dyson 2014; Dyson and Greve 2016; Rhodin *et al*. 2016; Wilson *et al*. 2016]), as one might expect at high-level competitions.

We acknowledge that it is likely that a proportion of horses would have previously undergone symptomatic treatment, for example, physiotherapy. This may have been without addressing the primary problem, for example, the cause of gait abnormalities in canter. This was a first 'look and see' study to determine whether RHpE scores can tell us something about the performance in a field setting. Given the relationship between RHpE scores, gait abnormalities and performance, it seems reasonable to assume that if the primary problems causing gait abnormalities are diagnosed and treated, then performance, and possibly RHpE score, may be improved. This justifies future field studies in closer collaboration with horse owners and more controlled

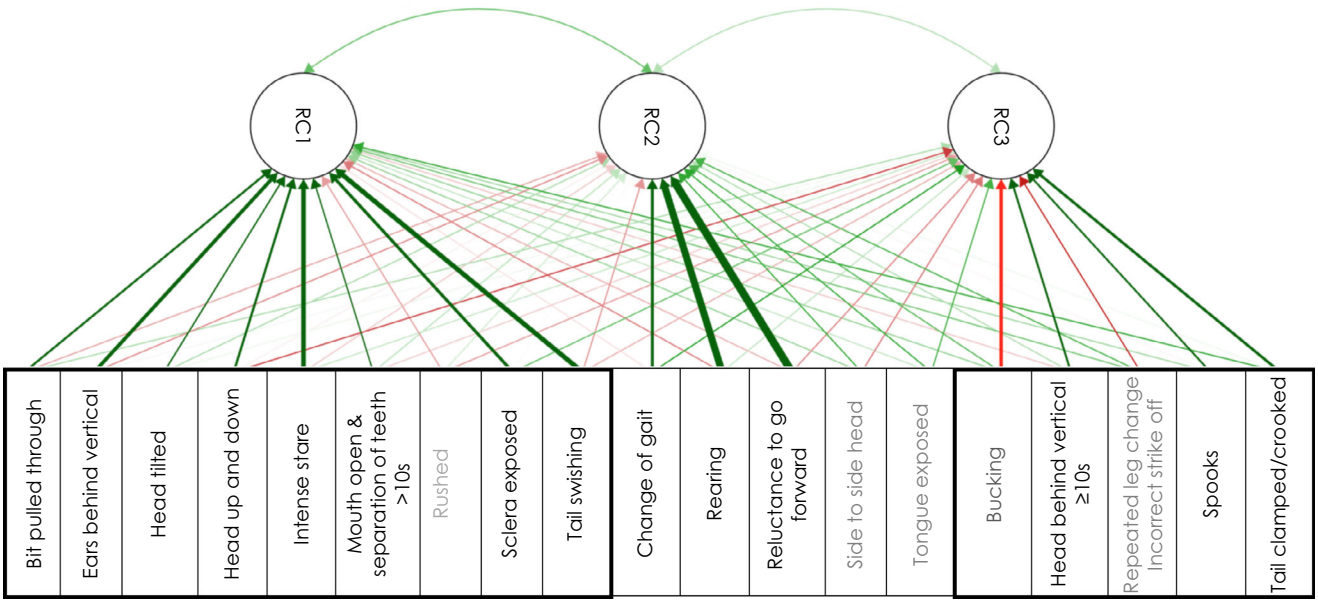

Fig 7: Path diagram of principal component analysis highlighting three distinct clusters (RC1, RC2 and RC3) of behaviours likely to occur together from the Ridden Horse Pain Ethogram behaviours (Dyson et al. 2018a), observed at two CCI 5* Events (Burghley and Badminton, 2019, n = 137) during warm-up for dressage. The technique is used to capture strong patterns in a data set. Green arrows indicate positive correlations; red arrows indicate negative correlations. Line thickness reflects the strength of associations.

lameness assessments. The principle of marginal gains in other sports is well-recognised (Hall *et al*. 2012; Ingham *et al*. 2013; Robertson *et al*. 2020); for example, a minor alteration in technique may make a substantial improvement in relative performance. Resolution of low-grade pain would also enhance equine welfare. Application of the RHpE should facilitate the recognition of horses which may benefit most from further investigation and appropriate treatment.

There was good consistency of the RHpE score for individual horses assessed at more than one event. Of the horses in which there was a difference of three or more behaviours at Badminton 2019 vs. Burghley 2019 (n = 6), all but one improved at Burghley. The exception was a horse with RHpE score of 3 at Badminton, which showed left forelimb lameness and completed the event in the third quartile. At the later event, Burghley, the horse had an ethogram score of 7, again showed left forelimb lameness and underwent compulsory reinspection after the dressage phase; it was allowed to continue, but then retired during the cross-country phase. This highlights that the first horse inspection (the 'Trot up'), and any subsequent in-hand inspection, may miss some lame horses, or those with canter abnormalities which are only apparent when ridden.

We have previously observed that different horses display different behaviours as a manifestation of the presence of musculoskeletal pain (Dyson *et al*. 2018a,b; Dyson 2019a,b Dyson and Van Dijk 2020) and this was verified in the current study using principal component analysis. We have not previously identified particular behaviours of the RHpE associated with specific sources of pain. The PCA carried out in this study was for observational purposes and seems to suggest that certain RHpE parameters cluster together. Future controlled studies could be performed to test whether there is a link to specific causes of musculoskeletal pain or whether it reflects individual responses to discomfort.

This field study had some limitations. There is no set pattern of warm-up, so not all horses performed all movements that they would in the test; for example, a minority of horses did not perform flying changes. This may have influenced the ethogram score; for example, one horse, which ground its teeth incessantly during the warm-up, did not perform flying changes; the RHpE score was only 2. In the test, the horse performed flying changes badly and repeatedly became disunited and displayed other behaviours, which would have resulted in a higher RHpE score, if seen during the warm-up. The RHpE assessor could not be blinded to lameness status. The same person applied the RHpE and assessed the gait, which could provide unconscious bias. Evaluation of the gait was of necessity subjective; however, similar observations were made in those horses evaluated at more than one event. The same assessor evaluated the horses at all events and blinding of the horses was not possible, although each horse was identified by number. Future studies should ideally include additional observers. When a large number of horses underwent sequential assessment, extreme focus on the live events was required, although it is acknowledged that repeated observations of the same horses could be influenced by recall bias. Although the data were obtained at 5* three-day events, the rider skill level and experience were variable, which may influence overall performance. Ground conditions and atmosphere were similar, but weather conditions varied. Data were only acquired from three events; we had originally intended to collect data at events in 2020, but this was prevented by the COVID-19 pandemic. Despite this, the consistency of the observations from three events highlights the potential usefulness of the application of the RHpE as a tool to identify horses which may benefit from management changes. We have described a relationship between the RHpE scores and performance, but causality cannot be proven. However, there was a positive relationship

between RHpE scores and the presence of gait abnormalities.

It is concluded that horses can pass an in-hand inspection, but show gait abnormalities when ridden, highlighted by behavioural changes. Gait abnormalities may compromise dressage and cross-country performance in some horses and influence the final placing. The RHpE could facilitate identification of horses which may benefit from veterinary investigation and treatment, potentially resulting in improvement in both performance and equine welfare.

Authors' declaration of interests

No conflicts of interest have been declared.

Ethical animal research

The study was approved by the Clinical Ethical Review Committee of the Animal Health Trust. Data were collected at a public venue, and informed rider consent was not required.

Authorship

S. Dyson was responsible for the study design and study execution. S. Dyson and A. Ellis were responsible for data analysis and interpretation, and preparation of the manuscript. Both authors gave their final approval of the manuscript.

References

Adair, S., Baus, M., Belknap, J., Bell, R., Boero, M., Bussy, C., Cardenas, F., Casey, T., Castro, J., Davis, W. and Erskine, M. (2018) Response to letter to the editor: do we have to redefine lameness in the era of quantitative gait analysis? *Equine Vet. J.* **50**, 415-417.

Adair, S., Baus, M., Bell, R., Erskine, M., Farr, R., Fischer, A. Jr, Forbes, B., Ford, T., Genovese, R., Gottschalk, R., Hoge, M., Honnas, C., Hunter, G., Joyce, J., Kaneps, A., Keegan, K., Kramer, J., Labens, R., Lischer, C., Marshall, J., Oosterlinck, M., Radue, P., Redding, R., Reed, S., Rick, M., Santschi, E., Schoonover, M., Schramme, M., Schumacher, J., Stephenson, R., Thaler, R., Nielsen, J. and Wilson, D. (2019) Letter to the Editor: A response to 'What is lameness and what (or who) is the gold standard to detect it?' *Equine Vet. J.* **51**, 270-272.

Bathe, A., Judy, C. and Dyson, S. (2018) Do we have to redefine lameness in the era of quantitative gait analysis? *Equine Vet. J.* **50**, 273.

Cook, W. and Mills, D. (2009) Preliminary study of jointed snaffle vs crossunder bitless bridles: quantified comparison of behaviour in four horses. *Equine Vet. J.* **41**, 827-830.

Dittman, M., Latif, S., Hefti, R., Hartnack, S., Hungerbühler, V. and Weishaupt, M. (2020) Husbandry, use, and orthopedic health of horses owned by competitive and leisure riders in Switzerland. *J. Equine Vet. Sci.* **91**, 103107.

Dumbell, L., Lemon, C. and Williams, J. (2019) A systematic literature review to evaluate the tools and methods used to measure rein tension. *J. Vet. Behav. Clin. Appl. Res.* **29**, 77-87.

Dyson, S. (2011) Can lameness be reliably graded? *Equine Vet. J.* **43**, 379-382.

Dyson, S. (2016a) Evaluation of poor performance in competition horses: a musculoskeletal perspective. Part 1 Clinical assessment. *Equine Vet. Educ.* **28**, 284-293.

Dyson, S. (2016b) Evaluation of poor performance in competition horses: a musculoskeletal perspective. Part 2 Further investigation. *Equine Vet. Educ.* **28**, 379-387.

Dyson, S. (2019) Letter to the Editor: continued debate about what constitutes lameness. *Equine Vet. J.* **51**, 556.

Dyson, S. (2019) Application of a ridden horse ethogram to horses competing at a 4-star three-day-event: comparison with cross-country performance. *Equine Vet. J.* **51**, *Suppl*. **53**, 11.

Dyson, S., Berger, J., Ellis, A. and Mullard, J. (2017) Can the presence of musculoskeletal pain be determined from the facial expressions of ridden horses (FEReq)? *J. Vet. Behav. Clin. Appl. Res.* **19**, 78-89.

Dyson, S., Berger, J., Ellis, A. and Mullard, J. (2018a) Development of an ethogram for a pain scoring system in ridden horses and its application to determine the presence of musculoskeletal pain. *J. Vet. Behav. Clin. Appl. Res.* **23**, 47-57.

Dyson, S., Berger, J., Ellis, A. and Mullard, J. (2018b) Behavioural observations and comparisons of non-lame horses and lame horses before and after resolution of lameness by diagnostic analgesia. *J. Vet. Behav.: Clin. Appl. Res.* **26**, 64-70.

Dyson, S. and Greve, L. (2016) Subjective gait assessment of 57 sports horses in normal work: a comparison of the response to flexion tests, movement in hand, on the lunge and ridden. *J. Equine Vet. Sci.* **38**, 1-7.

Dyson, S., Thomson, K., Quiney, L., Bondi, A. and Ellis, A. (2020) Can veterinarians reliably apply a whole horse ridden ethogram to differentiate non-lame and lame horses based on live horse assessment of behaviour? *Equine Vet. Educ.* **32**(**S10**), 112-120.

Dyson, S. and Van Dijk, J. (2020) Application of a ridden horse ethogram to video recordings of 21 horses before and after diagnostic analgesia: reduction in behaviour scores. *Equine Vet. Educ.* **32**(**S10**), 104-111.

Eisersiö, M., Roepstorff, L., Weishaupt, M. and Egenvall, A. (2013) Movements of the horse's mouth in relation to horse–rider kinematic variables. *Vet. J.* **198**, e33-e38.

Fédération Equestre Internationale. www.fei.org/fei/regulations/dressage Accessed 23.11.2019

Ferlazzo, A., Melica, P., Cravana, C. and Fazio, E. (2012) Circulating β-endorphin, adrenocorticotropin, and cortisol concentrations of horses before and after competitive show jumping with different fence heights. *J. Equine Vet. Sci.* **32**, 740-746.

Górecka-Bruzda, A., Jastrzebska, E., Muszyńska, A., Jedrzejewska, E., Jaworski, Z., Jezierski, T. and Murphy, J. (2013) To jump or not to jump? Strategies employed by leisure and sport horses. *J. Vet. Behav. Clin. Appl. Res.* **8**, 253-260.

Górecka-Bruzda, A., Kosińska, I., Jaworski, Z., Jezierski, T. and Murphy, J. (2015) Conflict behavior in elite show jumping and dressage horses. *J. Vet. Behav. Clin. Appl. Res.* **10**, 137-146.

Greve, L. and Dyson, S. (2013) An investigation of the relationship between hindlimb lameness and saddle slip. *Equine Vet. J.* **45**, 570-577.

Greve, L. and Dyson, S. (2014) The interrelationship of lameness, saddle slip and back shape in the general sports horse population. *Equine Vet. J.* **46**, 687-694.

Greve, L. and Dyson, S. (2016) Body lean angle in sound dressage horses in-hand, on the lunge and ridden. *Vet. J.* **217**, 52-57.

Greve, L. and Dyson, S. (2020) What can we learn from visual and objective assessment of non-lame and lame horses in straight lines, on the lunge and ridden? *Equine Vet. Educ.* **32**(**9**), 479-491.

Hall, D., James, D. and Marsden, N. (2012) Marginal gains: Olympic lessons in high performance for organisations. *HR Bull. Res. Pract.* **7**, 9-13.

Hall, C., Kay, R. and Yarnell, K. (2014) Assessing ridden horse behaviour: professional judgement and physiological measures. *J. Vet. Behav. Clin. Appl. Res.* **9**, 22-29.

Ingham, S., Fudge, B., Pringle, J. and Jones, A. (2013) Improvement of 800-m running performance with prior high-intensity exercise. *Int. J. Sports Physiol. Perform.* **8**, 77-83.

Licka, T., Kapaun, M. and Peham, C. (2004) Influence of rider on lameness in trotting horses. *Equine Vet. J.* **36**, *Suppl*. **8**, 734-736.

Manfredi, J., Rosenstein, D., Lanovaz, J., Nauwelaerts, S. and Clayton, H. (2009) Fluoroscopic study of oral behaviours in response to the

presence of a bit and the effects of rein tension. *J. Comp. Exercise Phys.* **6**, 143-148.

Micalos, P.S. (2014) Perspectives on biochemical and neurosensory mechanisms for exercise-induced pain inhibition. *Fatigue* **2**(**4**), 219-230.

Peham, C., Licka, T., Schobesberger, H. and Meschan, E. (2004) Influence of the rider on the variability of the equine gait. *Hum. Movement Sci.* **23**, 663-671.

Persson-Sjodin, E., Hernlund, E., Pfau, T., Haubro Andersen, P., Holm Forsström, K. and Rhodin, M. (2019) Effect of meloxicam treatment on movement asymmetry in riding horses in training. *PLoS One* **14** (**8**), e0221117.

Phillips, M. (2019) HorseandHound.co.uk/plus/mark-phillips-burghley-learning-curve-hh-vip-696758 Accessed 26.03.2020.

Rhodin, M., Roepstorff, L., French, A., Keegan, K.G., Pfau, T. and Egenvall, A. (2016) Head and pelvic movement asymmetry during lungeing in horses showing symmetrical movement on the straight. *Equine Vet. J.* **48**, 315-320.

Robertson, C., Lodin-Sundström, A., O'Hara, J., King, R., Wainwright, B. and Barlow, M. (2020) Effects of pre-race apneas on 400-m freestyle swimming performance. *J. Strength Condition. Res.* **34**, 828-837.

Smiet, E., Van Dierendonck, M., Sleutjens, J., Menheere, P., van Breda, E., de Boer, D., Back, W., Wijnberg, I. and van der Kolk, J. (2014) Effect of different head and neck positions on behaviour, heart rate variability and cortisol levels in lunged Royal Dutch Sport horses. *Vet. J.* **202**, 26-32.

Toft, K., Kjeldsen, S.T., Otten, N.D., van Galen, G., Fjeldborg, J., Sinding, M. and Hansen, S. (2020) Evaluation of dynamic structural disorders in the upper airways and applied rein tension in healthy dressage horses during riding in different gaits and head-neck positions. *J. Equine Vet. Sci.* **87**, 102934.

van Weeren, P.R. (2019) Letter to the Editor: On the origin of lameness – do opinions differ less than it might appear at first glance? *Equine Vet. J.* **51**, 557.

van Weeren, P.R., Pfau, T., Rhodin, M., Roepstorff, L., Bragança, F.S. and Weishaupt, M.A. (2018) What is lameness and what (or who) is the gold standard to detect it? *Equine Vet. J.* **50**, 549-551.

Wilson, A., Agass, R., Vaux, S., Sherlock, E., Pfau, T. and Weller, R. (2016) Foot placement of the equine forelimb: relationship between foot conformation, foot placement and movement asymmetry. *Equine Vet. J.* **48**, 90-96.