Received: 25 March 2023 | Accepted: 19 August 2023

DOI: 10.1111/evj.14002

ORIGINAL ARTICLE

Equine Veterinary Journal WILEY

Factors associated with safe completion of Fédération Equestre Internationale eventing cross-country (2008–2018)

Euan D. Bennet[1] | Heather Cameron-Whytock[2,3] | Tim D. H. Parkin[4]

[1]School of Biodiversity, One Health, and Veterinary Medicine, University of Glasgow, Garscube Campus, Glasgow, UK

[2]School of Animal Rural and Environmental Science, Nottingham Trent University, Brackenhurst Campus, Southwell, UK

[3]School of Veterinary Medicine, University of Central Lancashire, Lancashire, UK

[4]Bristol Veterinary School, University of Bristol, Bristol, UK

Correspondence
Euan D. Bennet, School of Biodiversity, One Health, and Veterinary Medicine, University of Glasgow, Garscube Campus, Glasgow, G61 1QH, UK.
Email: euan.bennet@glasgow.ac.uk

Funding information
Federation Equestre Internationale

Abstract

Background: Equestrian eventing involves competing in three phases: dressage, jumping, and cross-country. Competitors are ranked by number of penalties accrued—with those who have fewer penalties ranked higher. Completing the cross-country phase with zero obstacle penalties is commonly referred to as 'running clear'. Understanding factors associated with running clear can help athletes plan strategically for success, while also helping governing bodies to refine qualification criteria for elite levels.

Objectives: This study was carried out to identify factors associated with running clear in the cross-country phase of Fédération Equestre Internationale (FEI) eventing.

Study design: Retrospective cohort study of 107 348 horse starts worldwide in all FEI competitions between January 2008 and December 2018.

Methods: Multivariable logistic regression models constructed stepwise using a bi-directional process. Two study cohorts were assessed: a complete cohort that met all inclusion requirements and separately, a cohort that included only horses starting at the level above their previous start.

Results: Sixteen factors were associated with running clear. Factors associated with increased likelihood of doing so included lower event level, lower dressage score earlier in the event, fewer recent FEI event starts, and more clear runs in their previous three FEI events. For horses that had stepped up an event level, 14 of these factors were still associated with running clear.

Main limitations: Data available covered only FEI events, no national federation competitions were available for inclusion in horse histories. No prior veterinary information or data on training were available.

Conclusions: This study provides a framework that allows stakeholders to potentially better understand the appropriate level of competition for any particular horse/rider combination, given the combination's recent history. This could provide an additional direct benefit in terms of safety by reducing the likelihood of a combination falling during cross-country.

KEYWORDS
eventing, horse, performance, safety

1 | INTRODUCTION

Eventing is one of three Olympic equestrian disciplines, in which horse-rider combinations compete across three phases: dressage, jumping, and cross-country (XC). A full eventing 'triathlon' is designed to be a challenging test for both horse and rider in all aspects of horsemanship. Most recent literature about eventing has focussed on safety: following the International Eventing Safety Committee (IESC) review in 2000, several academic studies have been published examining risk factors associated with horse and rider falls during the cross-country phase.[1–9] This academic literature is supplemented in the public domain, but not in peer-reviewed journals, by audits and reports published by the Fédération Équestre Internationale (FEI), the international governing body.[10–12] Risk factors for XC falls that have been reported in peer-reviewed research and industry reports include: higher event levels, higher dressage scores earlier in the competition, less experienced athletes and horses (including experience at their current event level), number of recent competition starts, age/sex of horse/athlete, and if a horse or rider had any prior falls.[2,9] At course design level, factors including fence type, composition and setting have been demonstrated to be associated with falls.[1,3–5,7]

Much of the literature for other equestrian disciplines and for horse racing is also predominantly focussed on safety and welfare.[9,13–22] However, as an alternative to studying risk factors for deleterious outcomes, modelling positive outcomes—that is, factors associated with safe completion—has also been demonstrated in the equestrian discipline of endurance.[23] Separately, pacing strategy has been found to be a contributory aspect of successful completion in endurance.[24,25] In endurance, 'success' means to safely complete the course and pass the final veterinary examination. In comparison, in eventing, different stakeholders may have different definitions of 'success'. Horse-rider combinations are ranked in each phase according to penalty points accumulated in that phase.[26] The final score of a combination is the total of their penalty points across all three phases—the winner of the competition is therefore the combination that has the lowest total penalty points. Dressage is scored by a panel of judges, while both jumping and cross-country are scored in two parts: time and obstacle penalties. Jumping and cross-country courses each have an 'optimum time' that is outlined in the governing body rulebook. In cross-country, combinations which record a time exceeding the specified optimum time range (completing the course too slow) accumulate 0.4 penalty points per second. Obstacle penalties are awarded for faults at obstacles, including falls, unseated rider, refusals, dangerous riding, and knocking down part of an obstacle. Completing either the jumping or cross-country phase with a total of zero obstacle penalties—that is, no faults at obstacles—is commonly referred to as 'running clear'. While it is possible to incur some penalties and still be in contention to place well, athletes understand that in order to be competitive they must ideally 'run clear' in both jumping and cross-country. Falls—either horse falls or unseated riders—result in disqualification. Obstacle faults in cross-country are aligned with improving safety by essentially incentivising safer riding. For example, if a frangible device was activated, the horse must have touched the fence—in many cases they must have hit it fairly hard. Scoring rules incurring 11 penalty points (as of 2023) for frangible device activation act as a strong incentive to avoid hitting fences. Penalty points for refusals—and ultimately disqualification for a third refusal, as of 2023—also contribute to safety since refusals have been demonstrated to be associated with falls.[3,4,7] Penalties for knocking or missing the flags that demark a jump incentivise correct approach vectors and jump trajectories, both of which could help minimise the risk of falls. Thus, there is a link between safety and running clear. An additional potential benefit of identifying factors that are associated with successful completion of the cross-country phase is that these may be embraced more readily by riders compared to factors that are associated with falls. Every competitor wants to 'succeed', but most will not necessarily think about 'how not to fall' although the two outcomes are clearly closely linked.

In order to qualify to compete at higher event levels, both athletes and horses must achieve 'Minimum Eligibility Requirements' (MERs). The number and level of MERs is different for each level of competition, and at lower levels of international competition (1* and 2*) is determined by national federations. To achieve an MER in any given event, a combination must complete with the following minimum parameters: (1) a score of 45 or less in dressage; (2) incur 16 or fewer penalties at obstacles in jumping; (3) in cross-country, not exceed the optimum time by a certain amount (depending on competition level), and a 'clear round' at obstacles. In the FEI rules a clear round is defined as 'activating a maximum of one frangible device or having a maximum of one missing flag'.[26]

The present study examined factors associated with running clear in the cross-country phase of eventing. The goal of this work was to understand which factors contribute to increased or reduced odds of a horse/athlete combination running clear during the cross-country phase. The main hypothesis was that a combination of horse-, athlete-, and course-level factors (including factors relating to specific combinations of horse and athlete) would be associated with the overall likelihood of running clear. Two cohorts were studied: a general group of horses followed from the beginning of their international careers, and a subset of those horses observed when they stepped up to compete at a level higher than their previous FEI start.

2 | MATERIALS AND METHODS

The data available for this study were detailed records of 202 771 horse starts made in FEI eventing competitions—including all international (CI), championship (CH), Olympics (OG), and World Equestrian Games (WEG) events held between 1 January 2008 and 31 December 2018. One individual horse start was one start made by one horse at one competition. These data were extracted from the FEI's Global Eventing Database (GED). A complete version of the GED was made available to the authors in collaboration with the FEI. The GED could be used to extract and create variables relating to individual history of each horse, athlete, and specific horse-athlete combination. Note that in this study the risk factor 'event level' used the four star levels of the old system (1*, 2*, 3*, 4*) which was updated in 2019 to a five-level system. Table 1 shows both the old and new systems for comparison.

The inclusion criteria for this study were any horse start that at least started the cross-country phase of competition, and made by a horse for whom the study cohort includes their full recorded career in FEI competitions. The study cohort was selected as follows: first, 4157 horse starts (2.1% of the complete GED) with missing data at event-, horse-, and athlete-level were removed from the study cohort. Next, horse starts for which the recorded maximum phase reached was 'Started Dressage' (6 starts, <0.01%) or 'Finished Dressage' (4909 starts, 2.4%) were removed. Next, starts made in competitions which had jumping before cross-country and whose maximum phase reached was 'Started Jumping' (1609 starts, 0.8%) or 'Finished Jumping' (4032 starts, 2.0%) were excluded. Next, in order to ensure the study cohort contained the complete recorded FEI career of each individual horse in the cohort, starts made by horses born before 1 January 2003 were removed (80 687 starts, 39.8%). This ensured that the maximum age of any horse in the study cohort was 5-years at the beginning of the study period, thus any horse's first recorded start during the study period 2008–2018 was certain to be that horse's first FEI start according to the minimum age requirement for competing in an FEI event. Finally, a very small number of horse starts ($n = 23$, 0.1%) featuring a rider making their first recorded start in the GED were removed in order to avoid missing data in any variables related to rider history.

The final study cohort consisted of 107 348 horse starts made by 16 640 unique horses, and including the FEI competition history of each horse from their first FEI start up to the end of the study period. One model was constructed using this cohort to identify factors associated with running clear during cross-country. A second model was also built using a subset of the study cohort which contained only starts made by horses stepping up a level—that is, their current start was at least one event level higher than the level of their previous FEI competition start. The reduced cohort of the second model contained 15 691 starts made by 6926 unique horses. Note that this cohort included any time a horse started at a level higher than the level of their previous FEI start—it was not limited to just the first occasion that they stepped up to a new event level.

TABLE 1 The event level categorisations used in this study were replaced in 2019 when the FEI redesignated all event levels.

Categorisation 2018 and earlier	Categorisation 2019 onwards
Olympics and world equestrian games	Olympics and world equestrian games
Special category	Special category
CCI4*	CCI5*-L (long)
CCI3*	CCI4*-L (long)
CIC3*	CCI4*-S (short)
CCI2*	CCI3*-L (long)
CIC2*	CCI3*-S (short)
CCI*	CCI2*-L (long)
CIC*	CCI2*-S (short)
New introductory level	CCI* (unified) Not compulsory for qualifications

Note: The corresponding levels in both 'old' and 'new' formats are shown below. In both categorisations, CCI stands for 'Concours Complet International' and in the old format CIC stood for 'Concours International Combiné'.

Two options were considered when deciding on a consistent case definition. One was to apply the rules literally regarding obstacle penalties for MERs. In practice, this set a threshold of 15 obstacle penalty points as the maximum inclusion criteria. The second option was to use the colloquial interpretation of a 'clear' run to set a formal case definition for the study. In the eventing community, the phrase 'running clear' is commonly used to indicate successful completion of either cross-country or jumping with zero obstacle penalties incurred. It was decided to adopt the latter option as a case definition for this study, since the goal of the study was to identify factors associated with safely completing cross-country, as opposed to merely meeting MERs. A case definition that included cases where a combination activated a frangible device would not be consistent with a safety-focussed study goal.

Therefore, the case definition used for this study was 'horse starts that achieved zero obstacle penalties during cross-country'. All horse starts that reached a maximum step of 'started cross-country' or beyond but incurred one or more obstacle penalties during cross-country were included as controls.

R version 4.2.1 (R Foundation for Statistical Computing) and the Tidyverse package[27] was used for all data processing and modelling. Factors in continuous form, and their residuals, were assessed for normality using the Shapiro–Wilk test. Initial modelling examined each potential factor in turn, using univariable logistic regression. Individual factor p-values were calculated using log-likelihood-ratio tests. Those factors with a p-value of less than 0.20 were identified as candidates for the final models.[28] Factors in continuous form were also assessed in transformed forms including categorical forms, with the best fitting form as identified using the Akaike Information Criterion (AIC) selected.[29] Table 2 describes the variables which were included for consideration in the multivariable model.

A stepwise bi-directional process was then used to build multivariable logistic regression models, assessed for fit at each step using the AIC. Factors rejected from the final model were tested for confounding, and second-order interactions terms were assessed among pairs of biologically-plausible factors.[28] The impact of potential clustering at horse and athlete level was investigated with mixed-effects logistic regression models containing the final multivariable models along with horse and rider as random effects, together and separately. Post-hoc power calculations showed that for continuous variables, the full cohort model had at least 80% power to detect odds ratios of 1.02 or above with 95% confidence, while for the 'stepped-up' model the odds ratio threshold was 1.05. For binary categorical variables, the odds ratio thresholds were 1.04 and 1.10, respectively.

TABLE 2 Variables included for consideration in the two multivariable logistic regression models.

Variable	Categorisation	Notes
Course: year of competition	Grouped into two categories: 2008–2015, and 2016–2018	Univariable analysis determined the best categorical form
Course: event level	Star levels	The pre-2019 system with four levels was used
Combination: dressage score	Categorical	Univariable analysis determined the best categorical form
Horse: sex	Categorical	Levels used were Gelding, Stallion, and Female
Horse: age	Categorical	Univariable analysis determined the best categorical form
Athlete: gender	Binary	
Athlete: age	Categorical	Univariable analysis determined the best categorical form
Horse: age at first FEI start	Categorical	Univariable analysis determined the best categorical form
Horse: days since previous start	Categorical	Univariable analysis determined the best categorical form
Athlete: rode more than once today	Binary	Athletes can compete more than once per competition, on different horses
Athlete: days since previous start	Categorical	Univariable analysis determined the best categorical form
Horse: number of FEI starts in last 0–30 days	Continuous	
Horse: number of FEI starts in last 30–60 days	Continuous	
Horse: number of FEI starts in last 60–90 days	Continuous	Number of FEI starts in last x days variables were also tested in the form 0–30, 0–60, and 0–90 at the univariable modelling stage
Horse: change in event level since previous FEI start	Categorical	Three levels: no change, step down, and step up. Not included in the 'stepped up' model
Horse: ran clear in previous FEI start	Binary	
Horse: number of clear runs in previous three FEI starts	Categorical	
Horse: three clear runs in previous three FEI starts	Binary	Examined as an alternative form of the variable 'Horse: number of clear runs in previous three FEI starts'
Horse: career clear runs at the current level	Continuous	
Horse: career clear runs at the level below the current level	Continuous	
Athlete: ran clear in the previous FEI competition	Binary	
Horse: was involved in a fall during the previous FEI start	Binary	Either horse fall or unseated rider was a 'yes'

3 | RESULTS

3.1 | The full cohort model

Among the full study cohort of 107 348 horse starts, 76 883 (71.6%) resulted in a clear run during cross-country. Table 3 shows descriptive statistics of clear runs by event level in each year of the study cohort. Notice that because the study cohort was designed to include only horses for whom the beginning of their FEI career was included in the database, in the early years there were zero horse starts in higher event level competitions. Across all years, the incidences of clear runs were as follows: 73.0% at event level 1, 71.1% at level 2, 68.2% at level 3, and 58.0% at event level 4.

The univariable model results for the full study cohort are shown in Table S1. Table 4 shows the results of both the single-level multivariable model and the mixed-level model with horse ID and rider ID as random effects. The proportion of model variance explained by horse ID and rider ID—that is, how much of the variation in the model was attributable to clustering by the same individual horses or athletes appearing multiple times in the data—was 71%. The inclusion of horse ID and rider ID as random effects altered the odds ratios of three variables by more than 10%: 'event level', 'horse ran clear in previous FEI start', and 'horse number of clear runs in previous three FEI starts'. One variable changed significance between the single level and mixed-effects models: 'horse age at first FEI start' was significant ($p = 0.03$) in the mixed-effects model whereas including it in the single-level model it was not significant at the 95% level ($p = 0.2$).

Compared to 1* event level competitions, each increase in event level was associated with a reduction in likelihood of a combination running clear. Better performance (lower score) in the dressage phase of the same competition was associated with increased odds of running clear. At horse level, stallions were significantly less likely to run clear than geldings. Younger horses were associated with increased odds of running clear than older horses. Each additional FEI horse

TABLE 3 Descriptive statistics of the number and proportion of clear cross-country runs (scoring zero obstacle penalties) the study cohort recorded at each level of competition, 2008–2018.

Year	1* starts	1* clear runs (%)	2* starts	2* clear runs (%)	3* starts	3* clear runs (%)	4* starts	4* clear runs (%)
2008	18	8 (44.4%)	0	0	0	0	0	0
2009	805	600 (74.5%)	20	12 (60%)	0	0	0	0
2010	2171	1573 (72.5%)	520	362 (69.6%)	6	4 (66.7%)	0	0
2011	3337	2415 (72.4%)	1445	970 (67.1%)	212	141 (66.5%)	0	0
2012	4097	2896 (70.7%)	2133	1454 (68.2%)	545	365 (67%)	20	11 (55%)
2013	5809	4104 (70.6%)	3167	2187 (69.1%)	973	619 (63.6%)	47	24 (51.1%)
2014	7075	5050 (71.4%)	4300	2995 (69.7%)	1509	978 (64.8%)	111	62 (55.9%)
2015	7799	5641 (72.3%)	5265	3693 (70.1%)	2147	1447 (67.4%)	165	105 (63.6%)
2016	8557	6249 (73%)	5165	3641 (70.5%)	2526	1704 (67.5%)	228	126 (55.3%)
2017	9181	6707 (73.1%)	5760	4124 (71.6%)	2786	1817 (65.2%)	243	121 (49.8%)
2018	9578	7405 (77.3%)	6098	4649 (76.2%)	3181	2400 (75.4%)	345	224 (64.9%)

start in the periods 0–30, 31–60, and 61–90 days before competition was associated with a reduced likelihood of running clear. The third quartile for both 'horse FEI starts in last 0–30 days' and 'horse FEI starts in last 31–60 days' was 1, and the third quartile for 'horse FEI starts in last 61–90 days' was 0.

Compared to horses competing at the same level as their previous FEI competition, horses who stepped down in level were more likely to run clear, and those that stepped up a level were less likely to run clear. Horses with any number of clear runs in any of their three most recent FEI starts were more likely to run clear again compared to those who did not run clear in any of their last three starts. Each additional clear run at the current event level in a horse's prior career was associated with increased odds of running clear, with horses at or above the third quartile (3 clear runs) at odds ratio 1.16 (1.12–1.19) compared to horses at or below the first quartile (0 clear runs).

At rider level, men were more likely to run clear than women, and younger riders were more likely to run clear compared to those aged 51-years and older. Riders whose previous FEI competition was within the last 7 days were associated with increased odds of running clear. Riders who rode more than once at their current event (on different horses) were associated with increased odds of running clear. None of the variables rejected from the final model were confounded with any retained variables, and no second-order interactions terms were retained.

3.2 | The 'stepped up' cohort model

The reduced study cohort of starts made by horses who had stepped up a level since their last FEI start contained 15 691 horse starts, of which 10 386 (66.2%) resulted in a clear run during cross-country. Across all years, the incidences of clear runs among this cohort were 67.3% at level 2, 65.7% at level 3, and 58.1% at level 4. A total of 397 horse starts were made by horses stepping up a level despite having achieved zero MERs in their previous three FEI starts. Of these, 50.6% ($n = 201$) ran clear, compared to 71.1% of horses who stepped up following three MERs achieved in their previous three FEI starts.

The univariable model results for the 'stepped up' study cohort are shown in Table S2. The final multivariable model for this cohort is shown in Table 5. Both the single-level model, and the mixed-effects model including horse ID and rider ID as random effects are shown. The proportion of model variance explained by horse ID and rider ID was 59%. The inclusion of horse ID and rider ID as a random effect altered the odds ratios of two variables by more than 10%: 'event level', and 'horse number of clear runs in last three FEI starts'. No variables changed significance at the 95% level between the single level and mixed-effects models. Including the variable 'horse age at first FEI start' in the final 'stepped up' cohort model improved the overall fit according to AIC, despite the lack of statistical significance at the 95% level ($p = 0.07$ in the single-level model, and $p = 0.08$ in the mixed-effects model).

Higher event level was associated with reduced likelihood of running clear. As in the full cohort model, combinations with worse dressage performance, geldings/mares, and younger horses, were all more likely to run clear. Similarly to the full cohort model, each additional horse-level FEI competition in the periods 31–60 or 61–90 days was associated with reduced odds of running clear. Horses that ran clear in their previous FEI start were at increased odds of running clear again. Horses with three clear runs in their three previous FEI starts were at significantly increased odds of running clear compared to those with fewer clear runs, with progressively lower odds as the number of clear runs decreased. Each additional clear run at the level below the current event level was associated with increased odds of running clear at the new level, with horses at or above the third quartile (6 clears at the level below) at odds ratio 1.63 (1.17–2.22) compared to horses at or below the first quartile (2 clears).

At rider level, the same direction of association was found as for the full cohort model for the variables 'gender', 'age', 'days since last competed', and 'rode more than once at current event'. None of the variables rejected from the final model were confounded with any retained variables, and no second-order interactions terms were retained.

TABLE 4 Multivariable model results of factors associated with clear cross-country runs in all FEI eventing competitions between 2008 and 2018.

			Single level model			Mixed effects model			
Variable	Starts	Outcomes (%)	Odds ratio	95% confidence interval	*p*-value	Odds ratio	95% confidence interval	*p*-value	% difference in odds ratio
Course: event level									
1* level*	58 427	42 648 (73%)	1	–	–	1	–	–	
2* level	33 875	24 087 (71.1%)	0.94	0.91–0.98	0.004	0.76	0.72–0.79	<0.001	−19.1%
3* level	13 885	9475 (68.2%)	0.81	0.77–0.85	<0.001	0.51	0.48–0.55	<0.001	−37.0%
4* level	1161	673 (58%)	0.65	0.57–0.74	<0.001	0.31	0.26–0.35	<0.001	−52.3%
Combination: dressage score									
61+*	16 607	10 596 (63.8%)	1	–	–	1	–	–	
51–60	44 280	30 874 (69.7%)	1.24	1.19–1.29	<0.001	1.21	1.16–1.26	<0.001	−2.4%
41–50	27 788	20 897 (75.2%)	1.54	1.47–1.6	<0.001	1.45	1.38–1.52	<0.001	−5.8%
31–40	15 792	12 167 (77%)	1.73	1.64–1.82	<0.001	1.68	1.59–1.78	<0.001	−2.9%
0–30	2881	2349 (81.5%)	2.07	1.87–2.29	<0.001	1.94	1.74–2.17	<0.001	−6.3%
Horse: sex									
Gelding*	73 890	53 097 (71.9%)	1	–	–	1	–	–	
Mare	29 802	21 312 (71.5%)	0.99	0.96–1.02	0.4	0.98	0.94–1.02	0.4	−1.0%
Stallion	3656	2474 (67.7%)	0.76	0.71–0.82	<0.001	0.76	0.69–0.84	<0.001	0.0%
Horse: age (years)									
9 or older*	53 729	37 783 (70.3%)	1	–	–	1	–	–	
7 or 8	40 505	29 238 (72.2%)	1.16	1.12–1.2	<0.001	1.1	1.06–1.14	<0.001	−5.2%
Up to 6	13 114	9862 (75.2%)	1.36	1.3–1.44	<0.001	1.23	1.16–1.3	<0.001	−9.6%
Horse: age at first FEI start (years)									
12 or older*	1266	824 (65.1%)	1	–	–	1	–	–	
Up to 11	106 082	76 059 (71.7%)	1.09	0.97–1.23	0.2	1.17	1.02–1.35	0.03	7.3%
Horse: FEI starts in last 0–30 days									
	Median = 0	IQR = 1							
Per additional start	Min = 0	Max = 3	0.87	0.85–0.9	<0.001	0.91	0.88–0.94	<0.001	4.6%
Horse: FEI starts in last 30–60 days									
	Median = 0	IQR = 1							
Per additional start	Min = 0	Max = 4	0.89	0.87–0.92	<0.001	0.92	0.89–0.94	<0.001	3.4%
Horse: FEI starts in last 60–90 days									
	Median = 0	IQR = 0							
Per additional start	Min = 0	Max = 3	0.89	0.86–0.91	<0.001	0.91	0.88–0.94	<0.001	2.2%
Horse: change in level since previous FEI start									
No change*	82 998	59 482 (71.7%)	1	–	–	1	–	–	
Step down	8659	7015 (81%)	1.52	1.43–1.62	<0.001	1.39	1.3–1.48	<0.001	−8.6%
Step up	15 691	10 386 (66.2%)	0.84	0.8–0.87	<0.001	0.91	0.87–0.96	<0.001	8.3%

TABLE 4 (Continued)

Variable	Starts	Outcomes (%)	Single level model: Odds ratio	Single level model: 95% confidence interval	Single level model: p-value	Mixed effects model: Odds ratio	Mixed effects model: 95% confidence interval	Mixed effects model: p-value	% difference in odds ratio
Horse: ran clear in XC in previous FEI start									
No*	44 135	29 516 (66.9%)	1	–	–	1	–	–	
Yes	63 213	47 367 (74.9%)	1.48	1.44–1.53	<0.001	1.22	1.18–1.26	<0.001	−17.6%
Horse: number of clear XC runs in previous three FEI starts									
1–3 clear runs*	65 563	47 649 (72.7%)	1	–	–	1	–	–	
0 clear runs	2983	1632 (54.7%)	0.59	0.55–0.64	<0.001	0.83	0.76–0.9	<0.001	40.7%
Current start was one of horses' first three	38 802	27 602 (71.1%)	1.03	0.99–1.07	0.2	0.89	0.85–0.93	<0.001	−13.6%
Horse: previous XC clear runs at current level									
	Median = 1	IQR = 3							
Per additional clear run	Min = 0	Max = 27	1.07	1.06–1.08	<0.001	1.05	1.04–1.06	<0.001	−1.9%
Athlete: gender									
Female*	62 570	44 083 (70.5%)	1	–	–	1	–	–	
Male	44 778	32 800 (73.3%)	1.13	1.1–1.16	<0.001	1.13	1.08–1.19	<0.001	0.0%
Athlete: age (years)									
51+*	5705	3907 (68.5%)	1	–	–	1	–	–	
41–50	13 946	9993 (71.7%)	1.2	1.12–1.28	<0.001	1.16	1.06–1.28	0.002	−3.3%
26–40	47 343	34 566 (73%)	1.31	1.23–1.39	<0.001	1.29	1.18–1.42	<0.001	−1.5%
Up to 25	40 354	28 417 (70.4%)	1.21	1.14–1.29	<0.001	1.17	1.07–1.29	<0.001	−3.3%
Athlete: days since last competed									
Over 7 days ago*	100 882	72 024 (71.4%)	1	–	–	1	–	–	
Within 7 days	6466	4859 (75.1%)	1.16	1.1–1.24	<0.001	1.09	1.02–1.17	0.007	−6.0%
Athlete: rode more than once at current event									
No*	57 888	39 934 (69%)	1	–	–	1	–	–	
Yes	49 460	36 949 (74.7%)	1.21	1.17–1.24	<0.001	1.16	1.13–1.2	<0.001	−4.1%

Note: Cases were starts that scored zero obstacle penalty points during the cross-country (XC) phase. Risk factors with a *p*-value of less than 0.05 were retained in the final model. Among categorical variable levels, a * denotes the reference category. For continuous variables, the median, interquartile range, minimum and maximum are shown in place of the numbers of cases and controls. Both single-level and mixed effects models are shown, along with the percentage difference in odds ratios when comparing the results of the two models.

3.3 | Clustering

Tables 4 and 5 demonstrate that even when accounting for clustering by horse and rider, very few coefficients associated with final risk factors were significantly altered. Risk factors whose odds ratios changed by more than 10% were limited to 'Event level' and 'Number of clear XC runs in previous 3 FEI starts' in both models, and additionally 'Ran clear in XC in previous FEI start' for the full cohort model. Risk factors which changed statistical significance upon the inclusion of horse id and athlete id as random effects were limited to 'Horse age at first FEI start' in the full cohort model. In the 'stepped up cohort model', 'Horse age at first FEI

TABLE 5 Multivariable model results of factors associated with clear cross-country runs in all horse starts stepping up to a higher level in FEI eventing competitions between 2008 and 2018.

Variable	Starts	Outcomes (%)	Single level model			Mixed effects model			% difference in odds ratio
			Odds ratio	95% confidence interval	*p*-value	Odds ratio	95% confidence interval	*p*-value	
Course: event level									
2* level*	10 071	6774 (67.3%)	1	–	–	1	–	–	
3* level	4566	3000 (65.7%)	0.93	0.85–1.01	0.08	0.88	0.81–0.96	0.005	−5%
4* level	1054	612 (58.1%)	0.62	0.53–0.72	<0.001	0.53	0.45–0.62	<0.001	−15%
Combination: dressage score									
61+*	2931	1770 (60.4%)	1	–	–	1	–	–	
51–60	6347	4047 (63.8%)	1.14	1.04–1.25	0.006	1.13	1.03–1.24	0.01	−1%
41–50	3705	2589 (69.9%)	1.51	1.36–1.68	<0.001	1.46	1.31–1.63	<0.001	−3%
31–40	2344	1702 (72.6%)	1.76	1.56–1.99	<0.001	1.74	1.54–1.97	<0.001	−1%
0–30	364	278 (76.4%)	2.19	1.69–2.84	<0.001	2.02	1.54–2.64	<0.001	−8%
Horse: sex									
Gelding*	11 094	7358 (66.3%)	1	–	–	1	–	–	
Mare	4067	2704 (66.5%)	1	0.92–1.08	0.95	1	0.91–1.08	0.92	0%
Stallion	530	324 (61.1%)	0.76	0.63–0.91	0.003	0.74	0.6–0.9	0.003	−3%
Horse: age (years)									
9 or older*	9034	5774 (63.9%)	1	–	–	1	–	–	
7 or 8	6199	4295 (69.3%)	1.19	1.1–1.29	<0.001	1.17	1.08–1.27	<0.001	−2%
Up to 6	458	317 (69.2%)	1.16	0.94–1.43	0.2	1.13	0.91–1.41	0.3	−3%
Horse: age at first FEI start (years)									
12 or older*	75	42 (56%)	1	–	–	1	–	–	
Up to 11	15 616	10 344 (66.2%)	1.54	0.96–2.46	0.07	1.55	0.95–2.53	0.08	1%
Horse: FEI starts in last 30–60 days									
	Median = 0	IQR = 1	1	–	–	1	–	–	
Per additional start	Min = 0	Max = 3	0.91	0.86–0.97	0.005	0.92	0.86–0.98	0.007	1%
Horse: FEI starts in last 60–90 days									
	Median = 0	IQR = 1	1	–	–	1	–	–	
Per additional start	Min = 0	Max = 3	0.92	0.86–0.98	0.006	0.92	0.86–0.98	0.01	0%
Horse: ran clear in XC in previous FEI start									
No*	2130	1206 (56.6%)	1	–	–	1	–	–	
Yes	13 561	9180 (67.7%)	1.18	1.06–1.31	0.003	1.21	1.08–1.35	<0.001	3%
Horse: number of clear XC runs in previous three FEI starts									
3 clear runs*	5854	4124 (70.4%)	1	–	–	1	–	–	
2 clear runs	5129	3294 (64.2%)	0.81	0.74–0.88	<0.001	0.86	0.79–0.94	<0.001	6%
1 clear run	1715	977 (57%)	0.63	0.55–0.71	<0.001	0.71	0.62–0.8	<0.001	13%
0 clear runs	190	67 (35.3%)	0.29	0.21–0.4	<0.001	0.34	0.24–0.47	<0.001	17%

TABLE 5 (Continued)

			Single level model			Mixed effects model			
Variable	Starts	Outcomes (%)	Odds ratio	95% confidence interval	*p*-value	Odds ratio	95% confidence interval	*p*-value	% difference in odds ratio
Current start was one of horse's first three	2803	1924 (68.6%)	0.94	0.84–1.05	0.3	0.96	0.85–1.08	0.5	2%
Horse: previous XC clear runs at level below									
	Median = 4	IQR = 4	1	–	–	1	–	–	
Per additional clear run	Min = 0	Max = 27	1.03	1.01–1.04	<0.001	1.03	1.01–1.04	0.001	0%
Athlete: gender									
Female*	8380	5445 (65%)	1	–	–	1	–	–	
Male	7311	4941 (67.6%)	1.11	1.04–1.2	0.003	1.13	1.04–1.22	0.006	2%
Athlete: age (years)									
51+*	891	549 (61.6%)	1	–	–	1	–	–	
41–50	2279	1509 (66.2%)	1.28	1.08–1.5	0.004	1.29	1.07–1.55	0.009	1%
26–40	7652	5140 (67.2%)	1.34	1.15–1.55	<0.001	1.4	1.17–1.66	<0.001	4%
Up to 25	4869	3188 (65.5%)	1.31	1.12–1.53	<0.001	1.35	1.13–1.62	<0.001	3%
Athlete: days since last competed									
Over 7 days ago*	14 387	9466 (65.8%)	1	–	–	1	–	–	
Within 7 days	1304	920 (70.6%)	1.18	1.04–1.34	0.01	1.15	1–1.31	0.05	−3%
Athlete: rode more than once at current event									
No*	8025	5103 (63.6%)	1	–	–	1	–	–	
Yes	7666	5283 (68.9%)	1.16	1.08–1.24	<0.001	1.14	1.06–1.23	<0.001	−2%

Note: Cases were starts that scored zero obstacle penalty points during the cross-country (XC) phase. Risk factors with a *p*-value of less than 0.05 were retained in the final model. Among categorical variable levels, a * denotes the reference category. For continuous variables, the median, interquartile range, minimum and maximum are shown in place of the numbers of cases and controls. Both single-level and mixed effects models are shown, along with the percentage difference in odds ratios when comparing the results of the two models.

start' was not statistically significant, but in both models its inclusion improved the overall fit according to AIC.

4 | DISCUSSION

For the full cohort, 16 factors at the level of the event, the horse, the athlete, and specific combination of horse and athlete were found to be significantly associated with the odds of running clear. For the reduced cohort containing only horses who stepped up an event level, 14 factors were significantly associated with the odds of running clear. The factors retained in the 'stepped up' model were all a subset of the factors in the full cohort model. One factor present in the full cohort model—'horse FEI starts in last 0–30 days'—was not retained in the 'stepped up model'. The risk factor 'horse change in level since last FEI start' was not relevant for the 'stepped up model' and therefore was not a candidate variable.

Previous studies of eventing have identified risk factors for falls and unseated rider at the level of the event, course, fence, horse, and athlete.[1–8] The factors identified in this study are broadly consistent with those identified previously. While the outcome studied here is not exactly the opposite of the 'fall' outcome that has been investigated previously, throughout the study period a fall would either result in disqualification or many penalty points, depending on the rules in place at the time the fall occurred. Many of the factors in this study mirror those previously reported for falls, with associations in the opposite direction (increased odds of falls for the same factors that have reduced odds of running clear, and vice versa). For example: higher event levels; higher dressage score earlier in the competition; older horses and athletes; horses starting their career later; and horses with more frequent recent starts were associated with reduced odds of running clear. All of these factors have previously been demonstrated to be associated with increased risk of horse falls and unseated rider.[2,9] Among athletes, men are both at increased odds of running clear and of falling, previously, tentatively linked to either sex differences in risk taking behaviour or sex differences in body mass, with higher loads potentially affecting equine jumping kinematics.[9] It is critical to remember that although mutually exclusive these two outcomes are not diametrically opposed.

The form of the variable ‘horse age’ included in the final model was that determined by best fit and collapsed a 5-level categorical variable. However, it is clear that within levels 1–3 at least this relationship may not be clear cut with youngest and oldest horses being most likely to run clear and non-statistically significant differences in the likelihood of running clear for horses aged between 7 and 12 years (Table S3).

Very high dressage scores have previously been found to be associated with increased odds of falling during XC.[2,9] In this study, combinations scoring 30 or fewer dressage penalties were more than twice as likely to run clear during cross country, compared to those scoring over 60 in dressage. It should be noted here that a score above 60 is considered in the community to be a fairly poor performance, and above 70 would be exceptionally poor. Dressage scores in the range of 40–60 could be a horse/athlete combination having a ‘bad day’, but scoring above 60 indicates a consistently low-scoring round. One contribution to such performance could be the horse experiencing pain, stress, or subclinical injury.[9,30] Any of these potential contributions to high dressage score could naturally influence cross-country, both in terms of impacting performance and potentially increasing the risk of falls.

Year of event was not retained in either final model. The ‘best’ univariable form of this variable was collapsed into categories ‘2009–2015’ and ‘2016–2018’. This may be related to major rules reform in 2014 which featured, among other things, the widespread introduction of frangible devices. The categorical form of ‘horse age at first FEI start’ was the best fit (according to AIC) and is of similar form to the equivalent variable for Thoroughbred racing in North America.[21]

The mixed-effects models accounted for clustering at the level of the horse and the athlete by including both as random effects. Given the relatively large proportion of variance identified as being driven by horse id and rider id within these models, it is likely that a substantial source of this clustering was those individual horses and athletes who have had long, and in many cases very successful careers. This is reinforced by the retention of variables relating to athletes who competed within the previous 7 days, and those who competed more than once in the same event, both associated with increased odds of running clear. Only experienced or professional/elite athletes would follow such an intense competition schedule. Note that running order was not available in the data, so when an athlete competed more than once in the same event, it was not possible to identify which attempt happened first. Despite this clustering, very few model estimates in the final models were substantially altered by the inclusion of horse id and rider id. This indicates that while elite athletes and horses do influence the overall models, their influence is not accounted for by the variables included in the final models. It also indicates there are other, potentially significant, variables associated with horse and athlete which remain unmeasured and not yet available for inclusion in risk factor models.

The risk factors ‘Number of clear XC runs in previous 3 FEI starts’ and ‘Ran clear in XC in previous FEI start’ have some overlap in definition. A combination with ‘yes’ in the factor ‘Ran clear in XC in previous FEI start’ must also have had at least ‘1’ in ‘Number of clear XC runs in previous 3 FEI starts’. For this reason, particular attention was given to potential confounding between these factors. In the final model, both factors were retained because this combination and form of variables produced the best fit according to AIC. In addition, no confounding was detected using the definition applied throughout the modelling process: that is, the odds ratios did not alter by more than 20% and statistical significance did not change with the removal of either of the factors. The end result invites the conclusion that recent good performance over both the immediately previous start and the combination's previous three starts are important contributors to the likelihood of running clear in their next start.

One potential route to implementation of these results in the rules of the sport is in using them to inform future changes to MERs. This could include changing the requirements to achieve an MER in each event, as well as changing the MERs that must be achieved in order to qualify for higher event levels. Fewer than 0.5% ($n = 506$) of starts achieved an MER without also achieving a clear run of zero obstacle penalties. Governing bodies may wish to consider simplifying the requirements for MERs to match the colloquial definition of running clear (i.e., zero cross-country obstacle penalties).

At present, MER rules differ for each level of competition, and as such the flexibility to implement recommendations arising from this study already exists. For example, the results show that horses stepping up a level with three clear runs in their three previous FEI starts were significantly more likely to run clear again. A recommendation following this study could be the requirement that a horse must have achieved an MER in at least one of their previous three FEI starts before stepping up a level for the first time. If implemented during the study period (2008–2018) as a requirement for first qualification to event level 2, 8.7% of horses would have had slightly delayed progression. A stricter requirement of at least two MERs in the horses' previous three FEI starts before stepping up to either event level 3 or 4 for the first time would have affected 10.4% of horses.

Given the clear differences both in course design and in risk factors identified in this study, an additional recommendation could be made with regard to qualification requirements for the highest competition levels (4* and 5* in the star system implemented in 2019, 3* and 4* in the system used at the time of recording of all data used in this study). Horses competing at 3* and 4* levels were associated with significantly reduced odds of running clear compared to those competing at 2* level, therefore consideration could be given to stricter requirements of achieving MERs after the first time a horse steps up to one of the higher levels. An example recommendation here could be requiring horses stepping up to 4* level to achieve, perhaps, two MERs in their first four starts at 4* level in order to remain qualified for 4* competitions.

These results are based on a database that is complete at international (FEI) level but lacks any national-level competition data. Additional information that was unavailable at the time of the study included any training or veterinary records for horses. In other equestrian disciplines and horse racing these data sources have been shown to provide additional risk factors during analysis and would be of value for future studies in this area should they become routinely available.[31,32]

5 | CONCLUSIONS

Sixteen factors at the level of the horse, athlete, combination, and course were associated with running clear during cross-country. Fourteen of those factors were associated with running clear after stepping up an event level. These results can inform athletes and trainers about the readiness of horses and athletes to step up to higher competition level and compete safely. Modification of requirements for MERs in combination with data-driven evidence-based prediction of likely success on stepping up a level can help horse-rider combinations to be competitive, as well as improving safety by ensuring combinations are competing at an event level commensurate with their skill level. Many factors identified here have previously been demonstrated to be associated with falls, with the opposite direction of association. With appropriate validation, predictive modelling offers the potential for further evidence-based recommendations that recognise the links between good horsemanship, safety, and horse welfare.

AUTHOR CONTRIBUTIONS

Euan D. Bennet contributed to study design, and study execution. Heather Cameron-Whytock contributed to study execution. Tim D. H. Parkin contributed to study design. All authors contributed to data analysis and interpretation, preparation of the manuscript and gave their final approval of the manuscript. Euan D. Bennet had full access to all the data in the study and is responsible for data integrity and accuracy of the analysis.

ACKNOWLEDGEMENTS

We gratefully acknowledge the support of the Federation Equestre Internationale and in particular Göran Akerström and Caterina Termine for their help in interpretation of the database.

FUNDING INFORMATION

This research was funded by Federation Equestre Internationale.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

PEER REVIEW

The peer review history for this article is available at https://www.webofscience.com/api/gateway/wos/peer-review/10.1111/evj.14002.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study may be available from the FEI. A reduced form of the GED is in the public domain and is available on the FEI website. Restrictions apply to the availability of the complete data, which were used under licence for this study.

ETHICAL ANIMAL RESEARCH

Research ethics committee oversight not currently required by this journal: data provided by a sports regulator were analysed.

INFORMED CONSENT

Explicit owner informed consent for inclusion of animals in this study was not stated. Representatives of the FEI gave consent for use of their data.

ORCID

Euan D. Bennet https://orcid.org/0000-0001-9049-1920
Heather Cameron-Whytock https://orcid.org/0000-0003-0760-2584
Tim D. H. Parkin https://orcid.org/0000-0003-3566-9030

REFERENCES

1. Bennet ED, Cameron-Whytock H, Parkin TDH. Fédération Equestre Internationale eventing: fence-level risk factors for falls during the cross-country phase (2008–2018). Equine Vet J. 2023;55(3):463–73. https://doi.org/10.1111/evj.13863
2. Bennet ED, Cameron-Whytock H, Parkin TDH. Fédération Equestre Internationale eventing: risk factors for horse falls and unseated riders during the cross-country phase (2008–2018). Equine Vet J. 2022;54:885–94.
3. Murray JK, Singer ER, Morgan KL, Proudman CJ, French NP. The risk of a horse-and-rider partnership falling on the cross-country phase of eventing competitions. Equine Vet J. 2006;38:158–63.
4. Murray JK, Singer ER, Morgan KL, Proudman CJ, French NP. Risk factors for cross-country horse falls at one-day events and at two-/three-day events. Vet J. 2005;170:318–24.
5. Murray JK, Singer ER, Saxby F, French NP. Factors influencing risk of injury to horses failing during eventing. Vet Rec. 2004;154:207–8.
6. Singer ER, Barnes J, Saxby F, Murray JK. Injuries in the event horse: training versus competition. Vet J. 2008;175:76–81.
7. Singer ER, Saxby F, French NP. A retrospective case–control study of horse falls in the sport of horse trials and three-day eventing. Equine Vet J. 2003;35:139–45.
8. O'Brien D. Look before you leap: what are the obstacles to risk calculation in the equestrian sport of eventing? Animals. 2016;6:13.
9. Cameron-Whytock HA, Parkin TDH, Hobbs SJ, Brigden CV, Bennet ED. Towards a safer sport: risk factors for cross-country horse falls at British eventing competition. Equine Vet J. 2023. Epub ahead of print. https://doi.org/10.1111/evj.13934
10. 2000 Safety report.pdf. Accessed 27 July 2022. https://inside.fei.org/system/files/2000%20Safety%20report.pdf
11. 2021 Statistics 24.01.2022.pdf. Accessed 27 July 2022. https://inside.fei.org/system/files/2021%20Statistics%2024.01.2022.pdf
12. Eventing Audit—Charles Barnett—Final Report 26.07.16.pdf. Accessed 27 July 2022. https://inside.fei.org/system/files/Eventing%20Audit%20-%20Charles%20Barnett%20-%20Final%20Report%2026.07.16.pdf
13. Bennet ED, Parkin TDH. Federation Equestre Internationale endurance events: risk factors for failure to qualify outcomes at the level of the horse, ride and rider (2010-2015). Vet J. 2018;236:44–8.
14. Coombs SL, Fisher RJ. Endurance riding in 2012: too far too fast? Vet J. 2012;194:270–1.
15. Nagy A, Murray JK, Dyson SJ. Horse-, rider-, venue- and environment-related risk factors for elimination from Federation Equestre Internationale endurance rides due to lameness and metabolic reasons. Equine Vet J. 2014;46:294–9.

16. Boden LA, Anderson GA, Charles JA, Morgan KL, Morton JM, Parkin TDH, et al. Risk factors for Thoroughbred racehorse fatality in flat starts in Victoria, Australia (1989–2004). Equine Vet J. 2007;39:430–7.
17. Parkin TDH, Clegg PD, French NP, Proudman CJ, Riggs CM, Singer ER, et al. Race- and course-level risk factors for fatal distal limb fracture in racing Thoroughbreds. Equine Vet J. 2004;36:521–6.
18. Hitchens PL, Blizzard CL, Jones G, Day L, Fell J. Predictors of race-day jockey falls in flat racing in Australia. Occup Environ Med. 2010;67:693–8.
19. Estberg L, Stover SM, Gardner IA, Johnson BJ, Jack RA, Case JT, et al. Relationship between race start characteristics and risk of catastrophic injury in Thoroughbreds: 78 cases (1992). J Am Vet Med Assoc. 1998;212:544.
20. Estberg L, Stover SM, Gardner IA, Johnson BJ, Case JT, Ardans A, et al. Fatal musculoskeletal injuries incurred during racing and training in Thoroughbreds. J Am Vet Med Assoc. 1996;208:92–6.
21. Georgopoulos SP, Parkin TDH. Risk factors associated with fatal injuries in Thoroughbred racehorses competing in flat racing in the United States and Canada. J Am Vet Med Assoc. 2016;249:931–9.
22. Hitchens PL, Hill AE, Stover SM. The role of catastrophic injury or sudden death of the horse in race-day jockey falls and injuries in California, 2007–2012. Equine Vet J. 2016;48:50–6.
23. Zuffa T, Bennet ED, Parkin TDH. Factors associated with completion of Fédération Équestre Internationale endurance rides (2012–2019): modelling success to promote welfare-oriented decisions in the equestrian sport of endurance. Prev Vet Med. 2022;198:105534.
24. Marlin D, Williams J. Equine endurance race pacing strategy and performance in 120-km single-day races. J Equine Vet. 2018;67:87–90.
25. Marlin D, Williams J. Equine endurance race pacing strategy differs between finishers and non-finishers in 120 km single-day races. Comp Exerc Physiol. 2018;14:11–8.
26. FEI Eventing Rules (2012). *FEI*. Accessed 27 July 2022. https://inside.fei.org/fei/disc/eventing/rules
27. Wickham H, Averick M, Bryan J, Chang W, McGowan LD, François R, et al. Welcome to the Tidyverse. J Open Source Softw. 2019;4:1686.
28. Dohoo IR, Ducrot C, Fourichon C, Donald A, Hurnik D. An overview of techniques for dealing with large numbers of independent variables in epidemiologic studies. Prev Vet Med. 1997;29:221–39.
29. Akaike H. Information theory and an extension of the maximum likelihood principle. In: Petrov BN, Csaki F, editors. Second international symposium on information theory. Budapest, Hungary: Akademiai Kaido; 1992. p. 267–81. [Reprinted; In: Breakthroughs in Statistics, Volume I. Eds. Kotz, S. and Johnson, N.L. Springer, New York, USA. 1973; pp. 599–624].
30. Bennet ED, Parkin T, Cameron-Whytock H. We have demonstrated the potential to make eventing safer: what will happen next? Equine Vet J. 2023;55(5):723–6. https://doi.org/10.1111/evj.13963
31. Bennet ED, Hayes ME, Friend L, Parkin TDH. The association between clinical parameters recorded at vet gates during Federation Equestre Internationale endurance rides and the imminent risk of elimination. Equine Vet J. 2020;52:832–40.
32. Bennet ED, Parkin TDH. Fifteen risk factors associated with sudden death in Thoroughbred racehorses in North America (2009–2021). J Am Vet Med Assoc. 2022;260:1956–62.

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Bennet ED, Cameron-Whytock H, Parkin TDH. Factors associated with safe completion of Fédération Equestre Internationale eventing cross-country (2008–2018). Equine Vet J. 2023. https://doi.org/10.1111/evj.14002