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Fédération Equestre Internationale eventing: Risk factors for horse falls and unseated riders during the cross-country phase (2008-2018)

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Abstract

Background: Eventing is an equestrian sport that tests athletes' and horses' skill over three phases: dressage, jumping and cross-country. Falls during the cross-country phase can have very serious outcomes up to and including death for both horse and athlete. Therefore, understanding risk factors associated with falls is essential for improving equine and human welfare.

Objectives: To provide descriptive statistics and identify risk factors at the horse-, athlete- and course-level affecting horses competing in Fédération Equestre Internationale (FEI) events worldwide.

Study design: Retrospective cohort study.

Methods: Data collected by the FEI of every horse start worldwide in all international (CI), championship (CH), Olympics (OG) and World Equestrian Games (WEG) competitions between January 2008 and December 2018 were analysed. Descriptive statistics followed by univariable logistic regression to identify risk factor candidates for inclusion in the final multivariable logistic regression model. Models were constructed stepwise using a bi-directional process and assessed using the Akaike information criterion.

Results: Factors associated with increased risk of falls and or unseated rider included: higher event levels, longer course distances, more starters at cross-country phase and less experienced horses and athletes.

Main limitations: The data set is geographically comprehensive but covers only FEI competitions, not National Federation events, that is not every competition started by every individual horse. Nor does the data set include any prior veterinary information or data on training or schooling.

Conclusions: This is the first large-scale epidemiological study of cross-country falls in FEI eventing. Results suggest that a potential risk profile can be constructed for each horse-athlete combination prior to entering a given competition, based on individual histories and course-level factors. This could lead to interventions that can reduce the number of falls, thus protecting equine and human welfare.

KEYWORDS
falls, FEI, horse

1 | INTRODUCTION

The equestrian discipline of eventing is a challenging competition across three phases that examines multiple aspects of equine and human athletes' skills. The three phases of an event are dressage, jumping and cross-country. The Fédération Equestre Internationale (FEI) website states that 'The focus of the entire event is on the Cross-Country test, the objective of which is to test the ability of athletes and horses to adapt to different and variable conditions (weather, terrain, obstacles, footing, etc) and jumping ability of the horse, while at the same time demonstrating the athlete's knowledge of pace and the use of his/her horse'.[1]

In recent decades, most of the focus relating to safety in eventing has been on cross-country. More specifically, a major concern has been athlete and horse falls at jumps during cross-country which can potentially have very serious consequences for both horse and athlete.[2,3] Safety in eventing was subject to a major review following five high-profile athlete fatalities in the UK in 1999 alone,[4] and the following year the International Eventing Safety Committee (IESC) reported their findings, concluding that the primary focus of improving safety for both horses and athletes should be to 'prevent horses from falling'.[5]

In the two decades since the IESC report, there have been many rules revisions and developments in the sport.[2] There have also been at least 50 athlete fatalities and at least 109 horse fatalities worldwide at all levels of competition.[3] In the intervening years to today, there have only been a handful of academic studies published that attempted to quantify the risk factors associated with falls during cross-country: all those were published before 2009 and were based on data from the 2001/2002 season.[6-10] There is clearly a potential gap in evidence and evidence-based policy informed by academic study in the sport, compared with, for example horse racing, which has a much larger volume of academic literature over the past 20 years. Given this gap, it is difficult to say quantitatively, with peer-reviewed evidence, whether or not eventing has become safer since the IESC review.

The FEI publishes annual summary statistics of their competitions, which do give some indication of the state of the sport at international level.[11] The 2021 FEI publication reports an apparent reduction in the number of rotational falls between 2009 and 2019, but the number and incidence of athlete injuries has not followed suit. Rotational falls reduced from an incidence of 0.23% (n = 32) of starts in 2009 to 0.12% (n = 28) of starts in 2019. For slight injuries, the incidence was 0.52% (n = 74) of starts in 2009 and 0.41% (n = 86) of starts in 2019. For serious and fatal injuries, incidence was 0.18% (n = 25) of starts in 2009 and 0.17% (n = 35) of starts in 2019. None of the above changes in incidence were statistically significant. It is also possible that reporting methods and consistency of reporting have improved over the time frame, which adds to the difficulty in interpretation of these data.

This article presents the results of a global cohort multivariable model incorporating risk factors at the level of the horse, athlete and course. The goal of this work was to understand which risk factors contribute to increased odds of a horse/athlete combination falling 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 horse falls and athlete falls during the cross-country phase. Note that in this paper 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.

2 | MATERIALS AND METHODS

The data set used was the FEI's Global Eventing Database, which contains detailed records of every horse start in international-level eventing competition worldwide. A form of the database is publicly available online[12]—the authors were granted access to the complete data set for this study conducted in collaboration with the FEI. The unit of interest in this study was 'horse starts'—each individual horse start is one start made by one horse at one competition. The data used in this study relates to 202 771 horse starts between 1 January 2008 and 31 December 2018. The record for each horse start includes details about the horse and athlete, final scores, elimination codes, etc. The database could be further mined for individual histories using unique FEI ID numbers for each horse and athlete.

Eventing competitions have five potential outcomes: (a) Result—all three phases successfully completed; (b) Retired—the athlete voluntarily retired from the competition at any phase; (c) Disqualified—this can happen in the worst cases of horse abuse or athlete misbehaviour, both of which are defined in the FEI eventing rules[13]; (d) Withdrawn—the horse was not presented at the first horse inspection or did not show up to the event; (e) Eliminated—the horse and athlete were eliminated from the competition by the Ground Jury and/or Veterinary Delegate. Certain incidents incur an automatic elimination outcome, including falls or repeated refusals at obstacles during the cross-country or jumping phases of the event. The database recorded the furthest phase reached by each horse start as a means of identifying progress using a descriptor of the form 'started dressage', 'finished dressage', 'started cross-country' and so forth.

Falls are defined for the athlete as 'when he/she is separated from the horse in such a way as to necessitate remounting', and for the horse as 'when at the same time, both its shoulder and quarters have touched either the ground or the obstacle and the ground or when it is trapped in a fence in a way that it is unable to proceed without assistance or is liable to injure itself'.[12] In this study, both outcomes were investigated: henceforth they will be referred to as they are recorded in the FEI database, which is 'unseated rider' and 'horse fall' respectively.

The study cohort was selected to include all horses that started the cross-country phase of their competition. This reduced set of 187 602 horse starts was extracted from the full database of 202 771 starts as shown in Figure 1: first, 1848 horse starts (0.91% of the full database) had missing data at event-level in addition to the horse- and athlete-level—these were omitted from the analysis.

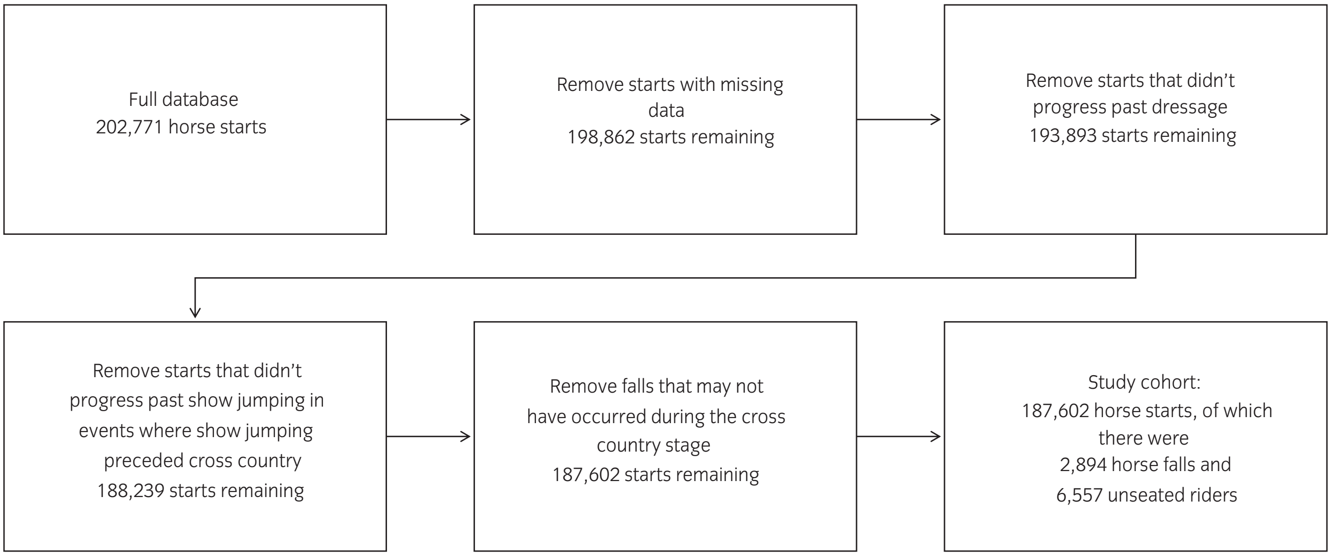

FIGURE 1 Flow chart showing the process of selecting the study cohort from the full FEI global eventing database

Second, 2061 horse starts (1.02%) with missing score data across all phases were omitted from the analysis. Third, horse starts whose maximum phase reached was recorded as 'Started Dressage' (6 starts [<0.01%]) or 'Finished Dressage' (4963 starts [2.45%]) were omitted from the study cohort. Fourth, horse starts whose competition was recorded with jumping scheduled before cross-country and whose maximum phase reached was recorded as 'Started Jumping' (1612 starts [0.79%]) or 'Finished Jumping' (4042 starts [1.99%]) were removed from the final cohort. Finally, 637 of the remaining horse starts (0.31% of the full database) were omitted because they resulted in a Fall outcome without a maximum phase reached recorded as 'Started Cross Country', For these 637 starts, there was no way to be sure of the location of these falls, so it was decided to omit these in order to achieve a consistent case definition.

Multivariable logistic regression models were constructed for each outcome in a bespoke code written in R (R Foundation for Statistical Computing). Potential risk factors included in this study, along with category definitions, can be found in Data S1. Risk factors included in continuous form were also tested in categorical form, with the best fitting form (as defined by Akaike information criterion AIC) included in the final model.[14,15]

The first stage of modelling examined each risk factor in turn in a univariable logistic regression model, with a maximum *P*-value of .20 used to select candidates for the final models. Multivariable models were constructed using a stepwise bi-directional (forwards-adding and backwards-removing) process with each step assessed using the AIC, until the best-fitting models were found. Risk factors rejected at the univariable and multivariable stages were subsequently tested for confounding in the final model.[16] Biologically plausible combinations of risk factors were tested for second-order interaction and included for assessment in the final model. The final models were tested for goodness-of-fit using the Hosmer-Lemeshow test.[15] The potential impact of horse- and athlete-level clustering was assessed by refitting the final multivariable models with horse and athlete as random effects together and separately. Post hoc power calculations indicated that for variables in continuous form, models for either outcome had at least 80% power to detect odds ratios of 1.06 or above, with 95% confidence. For variables in binary categorical form, models for either outcome had at least 80% power to detect odds ratios of 1.10 or above, with 95% confidence.

3 | RESULTS

Table 1 shows the descriptive statistics of the full cohort, in terms of the potential outcomes defined above. Of 202 771 horse starts between 1 January 2008 and 31 December 2018, 187 602 started the cross-country phase. Of these, 2894 (1.5%) had a horse fall recorded, and 6557 (3.5%) had an unseated rider recorded. Under the case definitions above, horse falls and unseated riders are mutually exclusive. The median number of jumping efforts per course during the cross-country phase was 30, and the interquartile range was four (mean 31.0, standard deviation 3.9). The mean number of horse falls per 10 000 jumping efforts was 5.1 (95% confidence interval 5.0-5.2). The mean number of unseated riders per 10 000 jumping efforts was 11.7 (95% CI 11.4-11.9).

Table 2 shows the final multivariable model for the outcome of horse falls, and Table 3 shows the results of the final multivariable model for the outcome of unseated riders.

3.1 | Horse falls

Compared with horses competing at 1* Level, horses competing at higher levels were all at increased odds of a horse fall. Horses

TABLE 1 Descriptive statistics for the possible outcomes of Eventing competitions, 2008-2018

Year	Starts	Results	Retired	Eliminated	Withdrawn/ disqualified	Horse falls	Unseated riders
2008	13 768	10 995 (79.6%)	712 (5.2%)	1699 (12.3%)	402 (2.9%)	212 (1.5%)	380 (2.8%)
2009	13 909	11 067 (79.6%)	613 (4.4%)	1813 (13.0%)	416 (3.0%)	221 (1.6%)	470 (3.4%)
2010	14 883	12 040 (80.9%)	526 (3.5%)	1873 (12.6%)	444 (3.0%)	235 (1.6%)	510 (3.4%)
2011	16 021	12 874 (80.4%)	551 (3.4%)	2207 (13.8%)	389 (2.4%)	267 (1.7%)	599 (3.7%)
2012	15 170	12 140 (80.0%)	591 (3.9%)	2094 (13.8%)	345 (2.3%)	269 (1.8%)	557 (3.7%)
2013	17 176	13 967 (81.3%)	819 (4.8%)	2061 (12.0%)	329 (1.9%)	275 (1.6%)	597 (3.5%)
2014	18 486	15 109 (81.7%)	869 (4.7%)	2151 (11.6%)	357 (1.9%)	304 (1.6%)	688 (3.7%)
2015	19 324	15 978 (82.7%)	893 (4.6%)	2071 (10.7%)	382 (2.0%)	274 (1.4%)	745 (3.9%)
2016	19 040	15 916 (83.6%)	875 (4.6%)	1871 (9.8%)	378 (2.0%)	268 (1.4%)	673 (3.5%)
2017	19 532	16 302 (83.5%)	898 (4.6%)	1913 (9.8%)	419 (2.1%)	268 (1.4%)	681 (3.5%)
2018	20 293	16 955 (83.6%)	961 (4.7%)	1981 (9.8%)	396 (2.0%)	301 (1.5%)	657 (3.2%)
Total	187 602	153 303 (81.7%)	8 308 (4.4%)	21 734 (11.6%)	4 257 (2.3%)	2 894 (1.5%)	6 557 (3.5%)

competing over longer cross-country course distances were at increased odds of falling. A higher number of starters at the cross-country phase were associated with increased odds, with those at and above the 75th percentile (65 starters) at odds ratio 1.08 (1.02-1.14) compared with those at or below the 25th percentile (27 starters).

At the horse level, mares were at increased odds compared with geldings. The odds of a stallion falling was not statistically significantly different from that of a gelding. Horses whose previous start was longer than 60 days ago were at reduced odds of falling compared with horses who had last started within the previous 60 days. Horses who had previously made more starts at the level of their current event were at reduced odds of falling compared with horses with fewer starts at that level. Horses at or above the 75th percentile (five previous starts at the current level) were at odds ratio 0.91 (0.87-0.95) compared with horses at or below the 25th percentile (one previous start at the current level). Horses with a previous fall in FEI events were at increased odds of falling again compared with horses that had never previously fallen.

At the human athlete level, male athletes were at increased odds of having a horse fall, compared with female athletes. Older athletes were at reduced odds compared with younger athletes: athletes at or above the 75th percentile of age (37 years) were at odds ratio 0.85 (0.78-0.92) compared with athletes at or below the 25th percentile (21 years). Athletes with more starts in their prior career were at reduced odds compared with relatively less experienced athletes: those at or above the 75th percentile (46 starts) were at odds ratio 0.92 (0.88-0.96) relative to those at or below the 25th percentile (four starts). Athletes whose previous start was more than 30 days ago were at increased odds compared with athletes who last started within 30 days. Athletes who did not finish their previous event, for any reason, were at increased odds compared with those who successfully finished their previous event. Horse-athlete combinations who recorded a score in the dressage phase that was higher than 50 were at increased odds of falling during the cross-country phase compared with combinations who recorded a dressage score of 50 or less.

No second-order interactions terms were retained in the final model for horse falls. No confounding was detected between retained risk factors and any risk factor rejected during univariable analysis. Random effects from the horse and athlete accounted for a total of 16% of the variance measured by R-squared in the mixed-effects model, altered the model estimate of one risk factor by more than 10%—'horse has fallen before', with the odds ratio for horses that had ever fallen before changing from 1.20 to 1.16. No evidence of a lack of fit was found with the Hosmer-Lemeshow goodness-of-fit test (P-value = .2).

3.2 | Unseated riders

Horse starts made in the years 2008-2015 were associated with reduced odds of an unseated rider compared with starts made in 2016-2018. Compared with horse starts made in 1* events, higher levels were associated with increased odds of unseated rider. In events where the cross-country phase was the final of the three phases, there was a lower odds of an unseated rider compared with events where the cross-country phase was the middle phase. Longer cross-country courses were associated with increased odds of unseated riders. Finally at course level, a higher number of starters at the cross-country phase was associated with reduced odds of unseated rider. Field sizes at or above the 75th percentile (65) were at odds ratio 0.96 (0.93-1.00) compared with field sizes in the 25th percentile (27).

At horse level, each additional previous career start reduced the odds of an unseated rider. Horses at or above the 75th percentile (11 previous career starts in the database) were at odds ratio 0.77 (0.69-0.86) compared with horses in the 25th percentile (one previous FEI start). Each additional start made by a horse in the previous 30-60, 60-90 and 90-180 days increased their odds of being involved in an unseated rider outcome. Horses with more previous starts at the present event level were at increased likelihood of an unseated rider, with horses at or above the 75th percentile (5) at odds ratio 1.08 (1.00-1.17) compared with horses in the 25th percentile (1

TABLE 2 Multivariable model results for horse falls in all FEI eventing competitions between 2009-2018. Cases were starts that recorded a horse fall during the cross-country phase. Risk factors with a *P*-value of less than .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

	Cases (%)	Controls (%)	Odds ratio	95% confidence interval	*P*-value
Course—Level					
1* Level*	934 (1%)	91 713 (99%)	1.00	–	–
2* Level	988 (1.6%)	59 666 (98.4%)	1.56	1.40-1.73	<.001
3* Level	762 (2.5%)	29 782 (97.5%)	2.53	2.25-2.84	<.001
4* Level	210 (5.6%)	3547 (94.4%)	4.48	3.73-5.38	<.001
Course—Cross-country course length					
Up to 3 km*	304 (0.8%)	36 292 (99.2%)	1.00	–	–
Over 3 km, up to 3.5 km	740 (1.3%)	57 084 (98.7%)	1.23	1.06-1.42	.006
Over 3.5 km, up to 4 km	848 (1.6%)	51 229 (98.4%)	1.36	1.18-1.57	<.001
Over 4 km	1002 (2.4%)	40 103 (97.6%)	1.80	1.55-2.08	<.001
Course—Number of starters at cross-country phase					
Per additional 20 horses	Median = 43	IQR = 38	1.04	1.01-1.07	.006
	Min = 1	Max = 142			
Horse—Sex					
Male*	2137 (1.5%)	139 546 (98.5%)	1.00	–	–
Female	757 (1.6%)	45 162 (98.4%)	1.24	1.14-1.35	<.001
Horse—Number of days since previous start					
Up to 60 days*	1582 (1.8%)	87 462 (98.2%)	1.00	–	–
Over 60 days	996 (1.4%)	70 310 (98.6%)	0.84	0.77-0.92	<.001
First start for this horse	316 (1.2%)	26 936 (98.8%)	0.98	0.84-1.15	.8
Horse—Number of prior starts at the current level					
Per additional 4 starts	Median = 2	IQR = 4	0.91	0.87-0.95	<.001
	Min = 0	Max = 60			
Horse—Has ever had a horse fall before					
No*	2540 (1.5%)	168 682 (98.5%)	1.00	–	–
Yes	354 (2.2%)	16 026 (97.8%)	1.20	1.06-1.35	.003
Athlete—Sex					
Female*	1567 (1.4%)	110 276 (98.6%)	1.00	–	–
Male	1327 (1.8%)	74 432 (98.2%)	1.27	1.17-1.37	<.001
Athlete—Age					
Per additional 4 years	Median = 28	IQR = 16	0.96	0.94-0.98	<.001
	Min = 10	Max = 73			
Athlete—Number of days since previous start					
Up to 30 days*	1541 (1.6%)	95 759 (98.4%)	1.00	–	–
Over 30 days	1203 (1.6%)	75 376 (98.4%)	1.13	1.03-1.23	.006
First start for this Athlete	150 (1.1%)	13 573 (98.9%)	0.82	0.66-1.02	.07
Athlete—Number of prior starts in career					
Per additional 10 starts	Median = 15	IQR = 42	0.98	0.97-0.99	<.001
	Min = 0	Max = 608			
Athlete—Outcome of previous start					
Finished*	2106 (1.5%)	134 307 (98.5%)	1.00	–	–
Did not finish	788 (1.5%)	50 401 (98.5%)	1.16	1.06-1.27	.001
Combination—Dressage Score					
Up to 50*	882 (1.4%)	62 806 (98.6%)	1.00	–	–
Over 50	2012 (1.6%)	121 902 (98.4%)	1.10	1.01-1.19	.04

TABLE 3 Multivariable model results for unseated riders in all FEI eventing competitions between 2009-2018. Cases were starts that recorded an unseated rider during the cross-country phase. Risk factors with a *P*-value of less than .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

	Cases (%)	Controls (%)	Odds ratio	95% confidence interval	*P*-value
Course—Year					
2008-2015	4546 (3.5%)	124 191 (96.5%)	0.87	0.82 - 0.93	<.001
2016-2018*	2011 (3.4%)	56 854 (96.6%)	1.00	–	–
Course—Level					
1* Level*	2882 (3.1%)	89 765 (96.9%)	1.00	–	–
2* Level	2124 (3.5%)	58 530 (96.5%)	1.21	1.12-1.31	<.001
3* Level	1296 (4.2%)	29 248 (95.8%)	1.63	1.47-1.81	<.001
4* Level	255 (6.8%)	3502 (93.2%)	2.37	1.98-2.84	<.001
Course—Cross-country phase was before jumping					
No*	4393 (3.7%)	114 697 (96.3%)	1.00	–	–
Yes	2164 (3.2%)	66 348 (96.8%)	0.82	0.76-0.90	<.001
Course—Cross-country course length					
Up to 4 km*	4778 (3.3%)	141 719 (96.7%)	1.00	–	–
Over 4 km	1779 (4.3%)	39 326 (95.7%)	1.21	1.13-1.29	<.001
Course—Number of starters at cross-country phase					
Per additional 20 horses	Median = 43	IQR = 38	0.98	0.96-1.00	.02
	Min = 1	Max = 142			
Horse—Number of prior starts in career					
Per additional 10 starts	Median = 5	IQR = 10	0.77	0.69-0.86	<.001
	Min = 0	Max = 71			
Horse—Number of starts in previous 30-60 days					
Per additional start	Median = 0	IQR = 1	1.05	1.01-1.11	.03
	Min = 0	Max = 4			
Horse—Number of starts in previous 60-90 days					
Per additional start	Median = 0	IQR = 0	1.14	1.08-1.20	<.001
	Min = 0	Max = 3			
Horse—Number of starts in previous 90-180 days					
Per additional start	Median = 0	IQR = 1	1.07	1.03-1.11	<.001
	Min = 0	Max = 7			
Horse—Number of prior starts at the current level					
Per additional four starts	Median = 2	IQR = 4	1.08	1.00-1.17	.06
	Min = 0	Max = 60			
Horse—Number of prior horse falls in career					
Per additional horse fall	Median = 0	IQR = 0	1.28	1.12-1.47	<.001
	Min = 0	Max = 4			
Horse—Number of prior unseated riders in career					
Per additional unseated rider	Median = 0	IQR = 0	1.24	1.19-1.30	<.001
	Min = 0	Max = 7			
Horse—Age at first FEI start					
Up to 6 years*	1702 (2.9%)	57 159 (97.1%)	1.00	–	–
Over 6 years	4855 (3.8%)	123 886 (96.2%)	1.10	1.03-1.18	.004
Athlete—Sex					
Female*	4290 (3.8%)	107 553 (96.2%)	1.00	–	–

TABLE 3 (Continued)

	Cases (%)	Controls (%)	Odds ratio	95% confidence interval	*P*-value
Male	2267 (3%)	73 492 (97%)	0.50	0.42-0.59	<.001
Athlete—Prior career length (years)					
Per additional year	Median = 3	IQR = 5	0.96	0.94-0.97	<.001
	Min = 0	Max = 10			
Athlete—Number of prior starts in career					
Per additional 10 starts	Median = 15	IQR = 42	0.97	0.96-0.99	<.001
	Min = 0	Max = 608			
Athlete—Number of starts in previous 30 days					
Per additional start	Median = 1	IQR = 2	0.97	0.95-0.99	<.001
	Min = 0	Max = 26			
Athlete—Number of starts in previous 90-180 days[a]					
Per additional start	Median = 0	IQR = 2	0.99	0.97-1.00	.057
	Min = 0	Max = 51			
Athlete—Has ever had an unseated rider before					
No*	4863 (3.7%)	125 284 (96.3%)	1.00	–	–
Yes	1694 (2.9%)	55 761 (97.1%)	0.87	0.79-0.95	.002
Athlete—Number of prior horse falls in career					
Per additional horse fall	Median = 0	IQR = 1	1.05	1.01-1.10	.021
	Min = 0	Max = 19			
Athlete—Outcome of previous start					
Finished*	4469 (3.3%)	131 944 (96.7%)	1.00	–	–
Did not finish	2088 (4.1%)	49 101 (95.9%)	1.22	1.16-1.29	<.001
Combination—Dressage score					
Up to 50*	1871 (2.9%)	61 817 (97.1%)	1.00	–	–
Over 50	4686 (3.8%)	119 228 (96.2%)	1.17	1.10-1.25	<.001
Combination—Number of prior starts in career					
Per additional four starts as this specific combination	Median = 3	IQR = 7	1.10	1.05-1.15	<.001
	Min = 0	Max = 69			
Combination—Number of prior starts at the current level					
Per additional four starts as this specific combination	Median = 2	IQR = 4	0.82	0.75-0.90	<.001
	Min = 0	Max = 56			
Combination—Number of prior horse falls in career					
Per additional horse fall	Median = 0	IQR = 0	0.81	0.68-0.96	.015
	Min = 0	Max = 4			
Second-order interactions terms					
3* Event Level × jumping before cross-country			1.25	1.08-1.44	.002
Athlete age × Male Athlete			1.05	1.04-1.07	<.001
Horse age × Gelding			1.06	1.01-1.11	.020
Horse age × Mare			1.09	1.03-1.15	.001
Horse age × Stallion			1.08	1.01-1.16	.024

[a]This result was borderline statistically significant at $P = .057$ but retaining it in the final model improved the overall fit.

start). Every additional horse fall in their career was associated with an increased odds of an unseated rider. Similarly, each additional unseated rider in a horse's history made another event more likely. Finally, at horse level, the age at which the horse made their first start in an FEI competition was significant. Compared with horses who first appeared aged 6 years or less (31% of horses), those who started their FEI career at older than 6 years were at increased odds of unseated rider with odds ratio 1.10 (1.03-1.18).

At athlete level, male athletes were less likely to be unseated than female athletes. More experienced athletes were at reduced odds of being unseated. Athletes at or above the 75th percentile of recorded career length (6-years of records in the FEI database) at odds ratio 0.82 (0.73-0.86) compared with athletes in the 25th percentile (1-year). Each additional FEI start in an athlete's previous career history also contributed to reduced odds of being unseated with athletes at or above the 75th percentile (46) at odds ratio 0.88 (0.84-0.96) compared with those in the 25th percentile (4). An increased number of recent starts for athletes was associated with reduced odds of being unseated, as each additional start in the previous 30 days reduced the odds. Similarly, each start in the previous 90-180 days reduced the odds of being unseated. Athletes who had ever been unseated before in their FEI career were at reduced odds of being unseated compared with those that had never been unseated. Each additional horse fall in an athlete's FEI career history increased the odds of an unseated rider. Athletes who did not finish their previous FEI competition start, for any reason, were at increased odds to be unseated in their current start.

At the combination level—that is specific combination of horse and athlete—those with high scores in the dressage phase were at increased odds of experiencing being unseated during the cross-country phase. Each additional career start as a specific combination increased the odds of the rider being unseated, combinations at or above the 75th percentile (eight prior starts) were at odds ratio 1.18 (1.09-1.28) compared with those in the 25th percentile (one prior start). However, additional starts as a specific combination at the current level of ride were associated with reduced odds of the rider being unseated—combinations at or above the 75th percentile (four prior starts) were at odds ratio 0.82 (0.75-0.90) compared with combinations in the 25th percentile (zero starts). Previous horse falls as a combination were associated with reduced odds of unseated rider, with each prior horse fall associated with an odds ratio of 0.81 (0.68-0.96).

Three second-order interactions terms were retained in the final model. Level 3 events at which show jumping was held before cross-country were at increased odds. The total impact of these event-level risk factors was that compared with a level 1 event at which cross-country was the second phase, starters in level 3 with cross-country as the final phase were at odds ratio 1.67 (1.21-2.35). Athlete age was not retained independently in the final model, but an interaction term containing it and athlete sex was present. Male athletes at or above the 75th percentile (age 37) were at odds ratio 0.61 (0.49-0.77) compared with female athletes at or below the 25th percentile (age 21). The final interaction term was horse age and horse sex—neither of which were retained independently in the final model. Age is associated with slightly different odds in geldings, mares and stallions compared with horses at or below the 25th percentile (aged 8-years), those at or above the 75th percentile (12-years) were at odds ratio 1.06 (1.01-1.11), 1.09 (1.03-1.15) and 1.08 (1.01-1.16) for geldings, mares and stallions respectively.

No confounding was detected between retained and risk factors rejected during univariable analysis. No evidence of a lack of fit was found with the Hosmer-Lemeshow goodness-of-fit test (*P*-value = .2). Horse and athlete were tested as random effects as part of the final multivariable model independently and simultaneously. Athlete as a random effect accounted for a significant amount—51%—of the variance measured by *R*-squared in the mixed model, and altered six model estimate values by between 10% and 25%, but all remained statistically significant with no changes in direction of association.

4 | DISCUSSION

Risk factors at the level of the course, the horse, the athlete and specific combination of horse and athlete were found to be significantly associated with increased odds of the horse falling or the athlete being unseated during the cross-country phase of an eventing competition.

Previous case-control studies[6-9] were primarily focussed on fence-level risk factors. In Singer et al,[6] risk factors reported as significant in univariable models, but not in the final multivariable models included athlete sex (same association as found here), horse sex (opposite association) and event level (same).

During courses over longer distances, horses spend a longer time at risk and have an increased exposure to jumping efforts. Fatigue is also likely to be a factor when competing over longer course distances. Associations between longer distances and deleterious outcomes have also been reported in Thoroughbred racing.[17-19] Higher event levels are required by the rules to have a more complex course design in order to challenge horses and athletes more than at lower event levels.[13]

Athletes were significantly less likely to be unseated in 2015 or earlier, compared with the time period 2016-2018. Given that the proportion of cases is slightly (though not significantly) lower in 2016-2018, this is likely due to some combination of other risk factors retained in the final model, which were more or less prevalent in the more recent 3-year period compared with earlier years. For example the prevalence of competitions in which the cross-country phase was second was significantly higher in 2016-2018 with 51.3% of horse starts in that period compared with 29.8% of horse starts in 2008-2015. This finding could also be the result of changes in reporting methods or consistency, for example in 2014 the current definition of an unseated rider was added to the rules.

Several risk factors identified are related to horse and athlete experience, including number of previous rides overall and at each level of competition (generally more experience means lower risk of deleterious outcomes), and number of previous falls (discussed below). These risk factors, in part at least, indirectly reflect horse and athlete skill—it can be concluded from these along with the risk factor of dressage score that less experienced/less skilled horses and athletes were more likely to fall/be unseated. Logically, those more skilled horses and athletes would go on to have longer careers—and compete at higher levels. However, higher levels in themselves carry increased risk to inexperienced and experienced combinations alike. This illustrates the importance of a qualification process that involves progressing gradually up through the levels. It has previously been reported that apprentice jockeys were more likely to experience a fall in racing.[20,21] It has also previously been reported that athletes who had taken cross-country lessons were at increased odds of falling during cross-country[8,9]—it could be speculated that this is consistent with the results here relating to experience level, but athletes who have lessons are not necessarily inexperienced. It is also important that athletes and coaches recognise the potential ceiling of ability of a horse or combination and these data could be used to identify factors that indicate a horse or combination has reached their optimal level of competition.

The risk factor related to whether or not an athlete finished their previous start reflected the athlete's most recent experience. It is possible that this could have been skewed by new athletes gradually increasing their experience—perhaps being more likely to retire partway through a cross-country phase as a stepping stone to fully competing. Further investigation into the specific reasons those athletes did not complete the whole event is required to understand why they were subsequently found to be at increased odds of being unseated.

Each additional horse fall or unseated rider event in a horse's individual history increased the likelihood of another horse fall or unseated rider. This could indicate that some horses continued to compete at a level above that for which they were suited and that certain horses are particularly prone to errors during the cross-country phase. Further modelling of potential interventions based on continued high frequency of falls or unseated rider may be considered prior to creating rules changes that may be related to advisory or enforced demotions.

Similarly, each horse fall in an athlete's individual history made it more likely that they would be unseated. Yet athletes who had been unseated before were less likely to have a subsequent event. This could be a result of the fact that athletes have much longer careers (median 15 starts) than horses (median 5 starts) and while unseated rider events are nearly twice as common as horse falls, it is simply more likely that an athlete with average experience has been unseated at least once before, compared with the equivalent for a horse with average experience. The picture is further complicated by the result that each horse fall in the history of a specific combination was associated with reduced odds of a subsequent unseated rider event. Perhaps these relate to combinations that stepped down a level of competition after experiencing a horse fall. It could be the case that horses appearing in the database in specific combination with their athlete might be more carefully managed since they could be the athlete's own horse, for example.

Several risk factors related to the recent experience of FEI competitions were retained in the final model, indicating that appropriate management of individuals' competition schedules is a key component of minimising risk. Horses with more starts in the recent past could end up being overworked and tired, and more likely to make a mistake, refuse at a fence or otherwise unseat their rider. Horses could also be experiencing sub-clinical injury which may affect their performance—it has previously been demonstrated that athletes do not always recognise when their horses are experiencing pain-related gait abnormalities.[22] Associations between a higher number of recent race starts and increased risk of deleterious outcomes have previously been demonstrated, linking the accumulation of high-speed exercise to increased risk of injury.[18,23] On the other hand, athletes with fewer recent starts were more likely to be unseated, indicating that for athletes it is more important to be well-practiced at competing. It is important to note here that athletes tend to have a higher number of competitions within the time periods investigated, since unlike horses, they can compete more than once per day, on several different horses.

The results presented here provide an overview of the data available in the FEI eventing database. The FEI database is comprehensive at international (FEI) level but contains no information about either national-level competition, or training. Another limitation of this study is that the FEI database does not contain any historical veterinary information.

5 | CONCLUSIONS

The study has identified risk factors for falls and unseated rider in eventing that could be modifiable through regulatory changes. For example in the form of evidence-based rules changes for horses' and athletes' qualification and progression to higher event levels (and potentially demotion to lower levels). Currently, qualification is based around combinations earning Minimum Eligibility Requirements (MER) in competition.[13] To earn an MER a combination must complete competition with fewer than the specified number of penalty points in each phase. Qualification up through National and International competition levels requires certain numbers of MERs to be earned at each stage of progression. There is scope within this system to alter either the number of MERs required at each level, or to alter the performance level required to earn an MER—or indeed some combination of the two, with variation from level to level. Furthermore, these results could be used to build a scientific, statistically validated risk profile for each horse which could inform athletes, trainers and governing bodies and contribute to data-driven decisions about whether individual horses or combinations are ready to step up to the next level of competition without exposing themselves or their horse to unnecessary risk. Data-driven rule changes have already been implemented for another FEI discipline (Endurance) and there is no reason to believe the same approach could not be used for Eventing. However, this type of work should not only be aimed at influencing regulation. Significant reductions in risk could be achieved by improved knowledge exchange, ensuring athletes are aware of how the history of their horse (ie their risk profile) contributes to the likelihood of a subsequent deleterious outcome such as a fall or unseated rider. This work presents a real opportunity to better inform or direct athletes to their appropriate level of competition using an evidence-based approach, driven by appropriate use of risk profiling analytics.

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CONFLICT OF INTERESTS

No competing interests have been declared.

AUTHOR CONTRIBUTIONS

E. Bennet contributed to study design, study execution, data analysis and interpretation, preparation of the manuscript and final approval of the manuscript. E. Bennet had full access to all the data in the study and is responsible for data integrity and accuracy of the analysis. H. Cameron-Whytock contributed to study execution, data analysis and interpretation, preparation of the manuscript and final approval of the manuscript. T. Parkin contributed to study design, data analysis and interpretation, preparation of the manuscript and final approval of the manuscript.

INFORMED CONSENT

Explicit owner informed consent for inclusion of animals in this study was not stated.

ETHICAL ANIMAL RESEARCH

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

PEER REVIEW

The peer review history for this article is available at https://publons.com/publon/10.1111/evj.13522.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the FEI. Restrictions apply to the availability of these data, which were used under license for this study. Data are available from the authors with the permission of the FEI.

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SUPPORTING INFORMATION

Additional supporting information may be found in the online version of the article at the publisher's website.

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