



Research Article

Volume 11 Issue 4 - April 2026  
DOI: 10.19080/JPFMTS.2026.11.555825

J Phy Fit Treatment & Sports

Copyright © All rights are reserved by Lewis V

# Factors Influencing Frangible Device Activation and Fall Risk in Eventing Cross Country



Lewis V<sup>1</sup>, Taylor, S<sup>1</sup>, Dumbell L<sup>1</sup> and Cameron-Whytock H<sup>2</sup>

<sup>1</sup>Equine Science Department, School of Sport, Equine and Performance Sciences, Hartpury University, GL19 3BE, United Kingdom

<sup>2</sup>School of Veterinary Medicine, University of Lancashire, Preston, Lancashire, PR1 2HE, UK

Submission: April 09, 2026; Published: April 15, 2026

\*Corresponding author: Lewis V, Equine Science Department, School of Sport, Equine and Performance Sciences, Hartpury University, GL19, Email: Victoria.lewis@hartpury.ac.uk

## Abstract

Frangible devices are widely used in eventing cross country fences to reduce the risk of rotational falls, yet limited empirical evidence exists regarding the circumstances under which these devices activate and their relationship with fall outcomes. The aim of this study was to investigate factors influencing frangible pin activation during the cross-country phase of eventing and to examine associations between activation, fence characteristics, and horse–rider outcomes.

A retrospective observational study was conducted using video analysis of 500 horse–rider combinations competing at 16 FEI CCI2\*–CCI5\* events. Horse–fence contacts (n = 1,007) were analysed using notational analysis to record fence type, terrain gradient, water involvement, combination status, contact point, frangible pin presence, activation, and outcomes. Associations were assessed using Chi square tests and odds ratios (OR) with 95% confidence intervals (CI).

Most horse–fence contacts resulted in continuation of the round (96.7%), with falls occurring in 5.3% of contacts. Frangible devices were present on 15.45% of observable fences and activated in 11.56% of contacts at frangible fences. Pin activation was strongly associated with adverse outcomes, with significantly increased odds of any horse fall compared with no activation (OR = 22.64, 95% CI 3.42–150.70; p = 0.001). However, rotational falls were proportionally less common following activation than at non frangible fences.

Terrain gradient and water involvement were not significantly associated with collision outcomes. Combination fences carried significantly higher odds of a fall compared with single fences (OR = 5.59, 95% CI 1.83–17.07; p = 0.002). Forelimb and body impacts were significantly more likely to result in pin activation than hindlimb contact. Frangible pins activate primarily during high energy impacts and appear to reduce fall severity rather than prevent falls altogether. Strategic placement and continued refinement of frangible devices, particularly at higher risk fence configurations, may further enhance cross country safety.

**Keywords:** Eventing Frangible devices Rotational falls; Terrain gradient; Odds ratios; Confidence intervals; Cross-country

**Abbreviations:** CI: Confidence Intervals; OR: Odds Ratios;

## Introduction

Eventing is an Olympic equestrian discipline comprising three phases: dressage, show jumping, and cross country. The cross-country phase is a test of speed, endurance, and jumping ability, requiring horses to negotiate distances ranging from approximately 2,000 m at CCI1\* to 6,840 m at CCI5\*, the highest level of international competition [1]. During this phase, competitors jump between 20 and 45 solid natural obstacles, with maximum fence heights increasing from 1.05 m at CCI1\* Intro to

1.20 m at CCI5\* [1]. Courses are designed with an optimum time, incentivising competitors to maintain forward speed, which at the highest level reaches 570 m min<sup>-1</sup> [1].

Equestrian sport carries a comparatively high-risk profile, with higher hospital admission and mortality rates than many other high-risk sports, including rugby and motorsport [2]. Ensuring horse and rider safety is therefore critical to sustaining participation and growth. FEI Risk Management data indicate that

in 2025, 4.8% of international eventing starters experienced a fall, most of which (86.6%) did not result in injury [3]. However, 2.25% of these falls resulted in serious injury requiring hospital admission or fatality [3].

The FEI Risk Management Programme demonstrates that injury risk varies substantially according to the type of fall; between 2016 and 2025, unseated rider falls resulted in serious

injury in approximately one out of every 76 cases, whereas rotational horse falls resulted in serious injury in approximately one out of every five cases [4]. Horse falls also pose a significant risk to equine welfare, with 37.3% of equine fatalities in eventing associated with a reported horse fall during the cross-country phase [5]. Reducing fall risk is therefore essential for equine and rider welfare, mitigating negative media attention, and maintaining the sport's social licence to operate [6] (Figure 1).

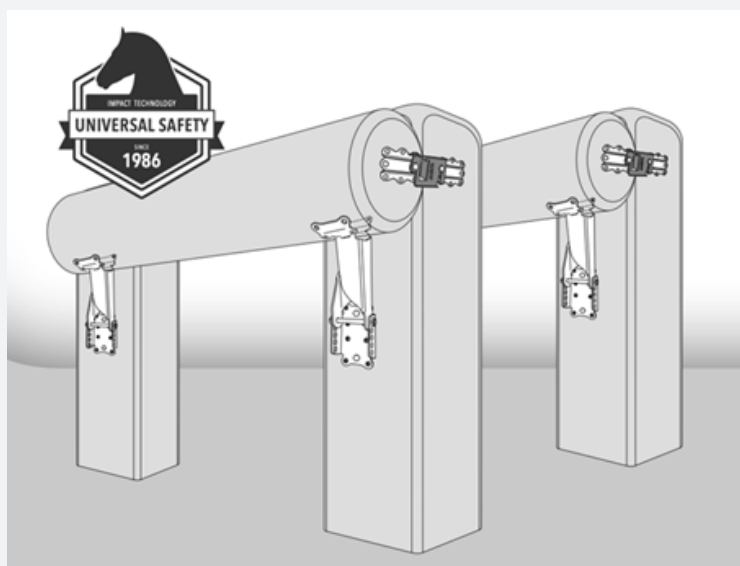


Figure 1: Example of MIM clips being use on an oxer made up of two post and rail fences( MIM 2026).

### Injury Risk and Rotational Falls

The inherent nature of solid cross-country fences contributes substantially to injury risk, with approximately 19.3% of riders experiencing a traumatic injury per year of competition, a higher rate than that reported in other equestrian disciplines [7,8]. Rotational falls occur when the horse contacts a fence with the forelimb, abruptly halting forward momentum and causing the hindquarters to rotate over the horse's centre of mass [9,10]. These events frequently result in the horse landing on its back, often with the rider trapped beneath [11].

Historically, rotational falls have been responsible for a disproportionate number of fatal injuries; of 25 rider fatalities occurring between 1997 and 2007, 18 resulted from rotational falls [12]. Multiple studies have identified course, fence, horse and rider related factors associated with falls, including water complexes, corner and drop fences, higher approach speed, rider experience, dressage performance, and previous cross-country penalties or falls [13-21]. Increased approach speed, identified as a risk factor in jump racing, is also likely to contribute to fall risk in eventing [13,22].

### Safety And Frangible Devices

Following a series of rider fatalities, the FEI initiated a comprehensive safety review of eventing, leading to the formation of the International Eventing Safety Committee and publication of the Hartington Report in 2000 [23]. Subsequent safety interventions included stricter qualification requirements, improved safety equipment standards, enhanced official training, and removal of the long format roads and tracks phases to reduce fatigue related risk [24,25]. Despite these advances, catastrophic and fatal injuries continue to occur [26,27]. Current FEI regulations mandate the use of approved frangible technology where appropriate across all international levels and apply a standardised 11 penalties when activation alters fence dimensions, reflecting a balance between incentivising safer outcomes and preserving competitive integrity [28,3].

FEI statistics demonstrate a substantial long-term reduction in rotational horse falls over the past two decades; however, recent large scale observational studies have reported higher overall fall risk at fences fitted with frangible devices, without distinguishing between rotational and non-rotational outcomes or whether device activation occurred [29,30]. Consequently, uncertainty

remains regarding the specific circumstances that lead to frangible device activation and the extent to which activation modifies fall severity rather than preventing falls. A clearer understanding of the fence, horse, rider, and impact related factors influencing frangible device activation is therefore required to refine evidence-based deployment of these technologies and optimise their effectiveness within FEI eventing.

### Aims and Objectives

The aim of this study was to investigate the factors influencing the likelihood of frangible pin activation on cross country fences in FEI eventing. The specific objectives were to: (1) examine the type and positioning of fences at which pin activation occurs; (2) identify common impact characteristics associated with frangible device activation; and (3) determine whether frangible pin activation is associated with a fall or allows continuation of the horse–rider combination.

### Methods

Following institutional ethical approval and in accordance with the Declaration of Helsinki, this retrospective observational study utilised video analysis of FEI eventing competitions. Retrospective video analysis is commonly employed in cross country eventing research, enabling the examination of large numbers of rounds without increasing risk to horse or rider [17]. Videos were sourced from live replays of events held between 2021 and 2023 using a publicly available subscription platform, providing a contemporary dataset following the FEI’s 2013 frangible device standardisation [9].

Sixteen FEI events across Europe, North America, and Asia were included, encompassing levels from CCI2\* to CCI5\*. For each starting combination, the available video footage was reviewed; however, not all fences in each round were necessarily visible. Only

rounds in which the horse made observable contact with at least one fence were included. In total, 500 horse–rider combinations were analysed. Notational analysis was used to record variables related to fence characteristics, including fence type, combination status, position within combinations, terrain gradient, water involvement, and the presence or activation of frangible devices.

Horse and rider demographic data were recorded where available, along with competition level and location. An adapted and validated video analysis protocol for cross country eventing falls was applied to classify outcomes and impact characteristics [31]. Outcomes were categorised as uninterrupted continuation, unbalanced continuation (“near miss”), unseated rider fall, non-rotational horse fall, or rotational horse fall. Horse falls were recorded at fences both with and without frangible devices.

### Data Analysis

Descriptive statistics summarised horse–fence contacts and outcomes. Associations between categorical variables were assessed using Chi square tests, with odds ratios (OR) and 95% confidence intervals (CI) calculated to quantify effect size. Data was not normally distributed; therefore, Spearman’s rho was used for correlation analysis. Statistical significance was set at  $p < 0.05$ .

### Results

1,007 incidences of horse contacts with fences (horse fence contact) were observed over the five hundred cross country rounds. Among rounds in which at least one horse–fence contact occurred, a mean of 2.01 contacts per round was observed. In 96.73% ( $n=974$ ) of horse fence contacts the horse and rider continued their round, 86.10% ( $n=867$ ) without interruption and 10.63% ( $n=107$ ) had a observable loss of balance but continued (Table 1). The rider fell in 3.28% of horse fence contacts and the horse fell in 1.79% of horse fence contacts (Table 1).

Table 1:

	Frequency of outcome	% of outcome
Continued Round (total)	974	96.73%
Continued without interruption	867	86.1
Continued with observable loss of balance	107	10.63
Rider fall	15	1.49
Non-rotational horse fall	11	1.09
Rotational horse fall	7	0.7

### Frangible Devices and Falls

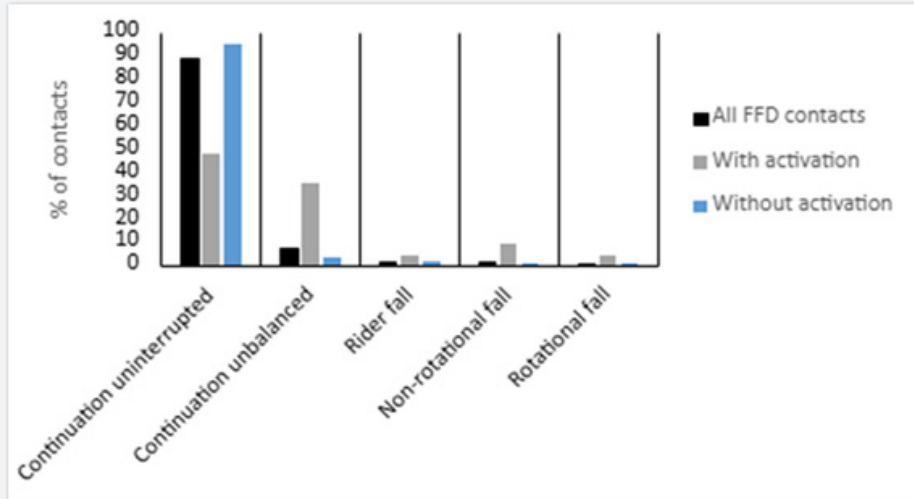
Frangible devices were present on an average of 15.45% of observable fences across levels 2\* to 5\*. Of all recorded horse–fence contacts, 9.76% occurred at fences fitted with a frangible device. Horses were not significantly more likely to contact a fence containing a frangible device compared with a fence without one

(OR = 1.30, 95% CI 0.65–2.80,  $p = 0.77$ ). Following contact with a fence fitted with a frangible device, the device did not activate in most cases (88.44%).

Activation of the frangible device occurred in 11.56% of contacts at frangible fences (Figure 2). Across all horse–fence contacts, regardless of fence type, the majority resulted in

continuation of the round (88.94%). Among contacts that resulted in a fall, non-rotational horse falls were most common (1.51%), followed by rider falls and rotational horse falls (both 1.01%). When a frangible device activated, the distribution of outcomes

changed markedly. The proportion of contacts resulting in continuation dropped to 47.83%, while the proportion of adverse outcomes increased.



**Figure 2:** The outcomes of horse fence contacts with fences containing frangible devices (FFDs). The non rotational fall and rotational fall involved a fall of horse and rider.

Non rotational horse falls accounted for 8.70% of contacts with pin activation, and rider falls and rotational horse falls each accounted for 4.35%. In contrast, when a frangible device did not act, the vast majority of contacts resulted in continuation (94.32%), and falls were rare, with non-rotational and rotational

horse falls each occurring in 0.57% of contacts. Horses were significantly more likely to fall when a frangible device activated compared with contacts where no activation occurred (OR = 22.64, 95% CI 3.42–150.70, p = 0.001; Table 2).

**Table 2:** Odds Ratios and P-values for Negative Outcomes of Frangible Fence Contacts, With and Without Pin Activation.

Outcome	Odds Ratio (OR)	95% Confidence Interval (CI)	P-value
Unbalanced horse and rider (near miss)	20.12	5.92 to 68.37	< 0.001
Rider Fall	7.55	0.63 to 89.84	0.11
Non-rotational horse fall	30.18	2.53 to 360.80	0.007
Rotational horse fall	15.09	0.88 to 257.80	0.06
All horse falls	22.64	3.42 to 150.70	<0.001

**Table 3:** Odds Ratios for Negative Outcomes by Gradient.

Outcome	Comparison	Odds Ratio (OR)	95% Confidence Interval (CI)	P-value
Unbalanced	Uphill vs. Level	0.68	0.30 to 1.54	0.11
	Downhill vs. Level	0.91	0.59 to 1.40	0.67
Rider Fall	Uphill vs. Level	0.88	0.08 to 9.21	0.92
	Downhill vs. Level	1.13	0.40 to 3.20	0.82
Non-rotational Horse Fall	Uphill vs. Level	0.88	0.08 to 9.21	0.92
	Downhill vs. Level	0.81	0.28 to 2.37	0.7
Rotational Horse Fall	Uphill vs. Level	2.05	0.20 to 20.84	0.53
	Downhill vs. Level	1.57	0.44 to 5.61	0.49

A Chi square test of independence demonstrated a significant association between frangible pin activation and the outcome of a horse–fence contact ( $\chi^2(4) = 118.9, p < 0.001$ ), indicating that the severity of outcomes differed depending on whether a frangible device activated. Table 2 presents odds ratios for individual adverse outcomes following contact with frangible fences, comparing contacts with and without pin activation. Activation was associated with significantly increased odds of an unbalanced continuation and non-rotational horse falls, while increased odds for rider falls and rotational horse falls did not reach statistical significance, likely due to low event frequencies Table 3.

### Impact of Gradient on Horse Fence Contacts and Fence Outcomes

Horse–fence contacts were analysed across three terrain gradients: uphill, downhill, and level. Most observable fences were situated on level ground (67.28%), with 22.29% located on a downhill gradient and 10.69% on an uphill gradient (Figure 3). Continuation following a horse–fence contact was the most common outcome across all gradients and occurred at broadly similar rates: 97.76% for uphill fences, 96.74% for level fences, and 96.45% for downhill fences. When uninterrupted continuation was considered specifically, this outcome was most

frequent at uphill fences (89.89%;).

Falls involving either the rider or horse were descriptively most common at downhill fences, where 3.55% of horse–fence contacts resulted in a fall. Combined horse–and–rider falls were also most frequent at downhill fences (1.91% of contacts), compared with level fences (1.81%) and uphill fences (1.12%). However, these differences were small. A Chi square test of independence was used to assess the association between terrain gradient and the outcome of a horse–fence contact. Analysis of the full outcome dataset showed no statistically significant association between gradient and contact outcome ( $\chi^2(8) = 1.64, p = 0.99$ ).

A second analysis using a condensed outcome dataset, in which all fall categories were combined, likewise showed no significant association ( $\chi^2(4) = 1.00, p = 0.91$ ). These findings indicate that the distribution of outcomes following horse–fence contact was statistically similar across uphill, downhill, and level terrain. Odds ratios for negative outcomes by gradient are presented in Table 5, using level fences as the reference category. All odds ratios for uphill and downhill fences were close to 1, with wide confidence intervals and non-significant p values, indicating no meaningful effect of terrain gradient on the likelihood of an unbalanced outcome or fall.

**Table 4:** Outcomes of Collisions with jumps into, in and out of water.

Comparison	Outcome	Odds Ratio (OR)	95% Confidence Interval (CI)	P-value
Jump in vs. Jump into	Unbalanced	1.62	0.44 to 5.92	0.47
	Falls	0.96	0.17 to 5.38	0.96
Jump out vs. Jump into	Unbalanced	0.81	0.22 to 2.97	0.75
	Falls	0.43	0.08 to 2.30	0.32

**Table 5:** Odds Ratio for Negative Outcomes Following Collisions at Combination Fences Compared with Single Fences.

Outcome	Odds Ratio (OR)	95% Confidence Interval (CI)	P-value
Unbalanced	3.51	0.69 - 17.80	0.13
Falls	5.59	1.83 - 17.07	0.002

### Impact of Type of Fence on Pin Activation and Falls

Horse–fence collision frequency, pin presence, and outcomes varied across fence types and water related obstacles (Figure 4). The highest number of collisions occurred at arrowhead/skinny (n = 199) and brush fences (n = 181), followed by roll top/ascending table (n = 135), table (square) fences (n = 128), and upright fences (n = 152). Frangible pins were most frequently present at table fences (n = 119), roll top/ascending table fences (n = 134), brush fences (n = 174), and arrowhead/skinny fences (n = 184), while no pins were present at open corners or water related fences. Across all fence types, most collisions resulted in continuation of the round, including 94.7% (136/152) at uprights and 88.9% (177/199) at arrowhead fences.

Pin activation following collision was uncommon across all fence types and most frequently observed at upright (n = 8), open corner (n = 8), table (square) (n = 2), and arrowhead fences (n = 1). Unbalanced horse and rider outcomes were observed most often at brush (n = 26) and arrowhead fences (n = 18), while rider falls were rare overall and primarily occurred at table, roll top/ascending table, and arrowhead fences. Horse falls were infrequent across all categories, with a small number occurring at upright, table, roll top, closed corner, brush, and arrowhead fences. No horse falls were recorded at water related fences involving jumps in, into, or out of water, and no frangible pin activations were observed at these fence types.

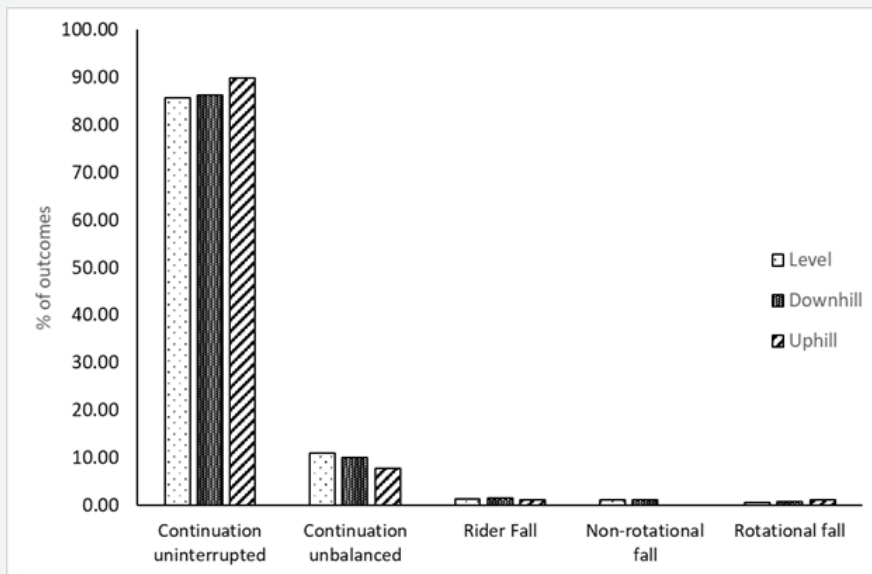


Figure 3: The proportion of each outcome seen at each gradient.

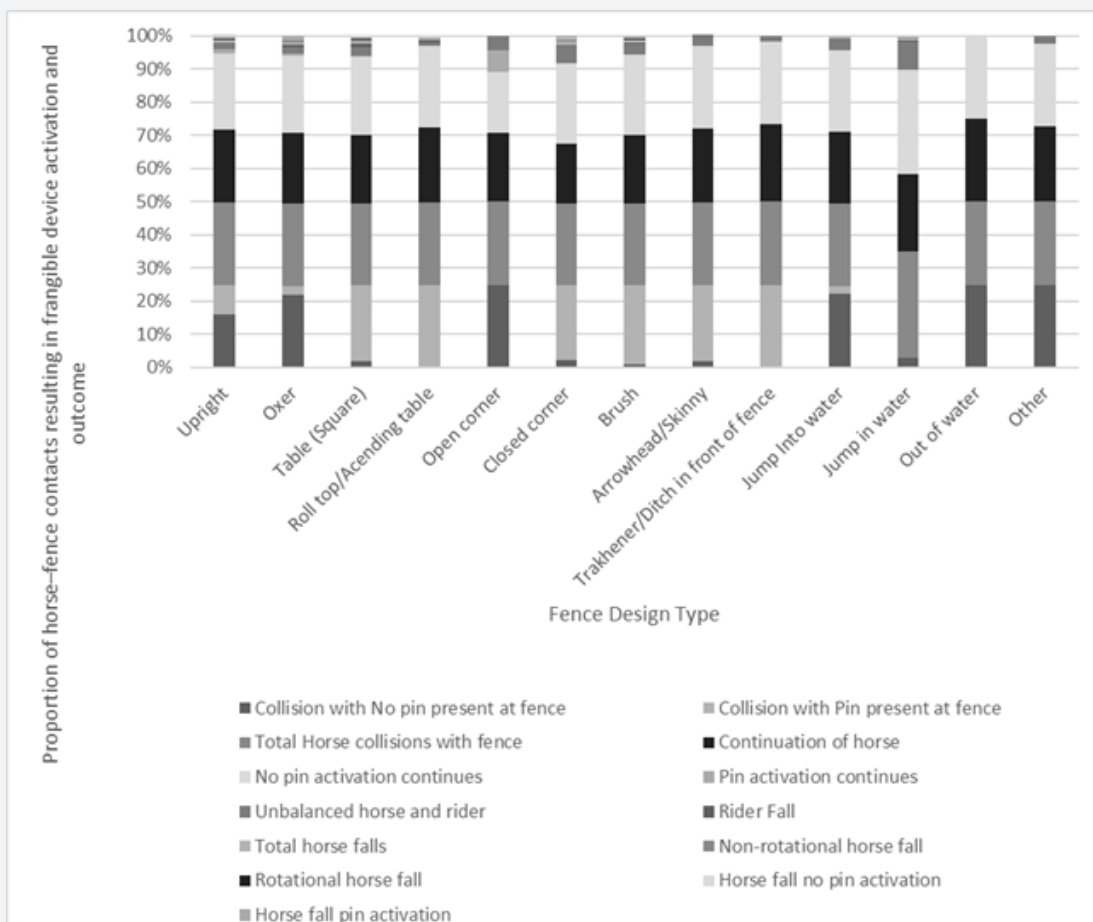


Figure 4: The distribution of frangible devices, pin activations, and collision outcomes varied across fence types.

**Impact of Water on Pin Activation and Falls**

Horses were more likely to collide with fences jumping into and within water than fences not associated with water, when the percentage of each of these types of fences is considered. However, rotational falls did not occur at fences involving water as shown in figure 5. The data was non-parametric (Kolmogorov-Smirnov significance value = 0 (<0.05)) for all factors suggesting data was not normally distributed. A Spearmans rho reported significant correlation  $p= 0.08$  ( $rs=0.83$ ,  $p>0.05$ ) between water being present at a fence and a fall occurring. There were no frangible activations at fences involving water.

The odds ratio analysis shows no statistically significant association between the type of water jump and the odds of a negative outcome. For all comparisons, the 95% confidence intervals include 1, and the p-values are all above 0.05. This

indicates that, based on this data, the odds of an unbalanced outcome or a fall are not meaningfully different for a horse on a jump in water or jump out of water fence compared to a jump into water (see table 4).

**Impact of Combination Fences on Pin Activation and Falls**

When collision frequency was considered relative to fence type, collisions, rider falls, and non-rotational horse falls occurred proportionally more often at combination fences than at single fences. Figure 6 illustrates the proportion of falls and frangible pin activations associated with combinations, stratified by the number of elements within each combination. Outcomes of collisions at single fences and combination fences are shown in Figure 7. Single fences accounted for most recorded collisions (74%; 173/234), while combination fences (elements one to four) accounted for 26% (61/234).

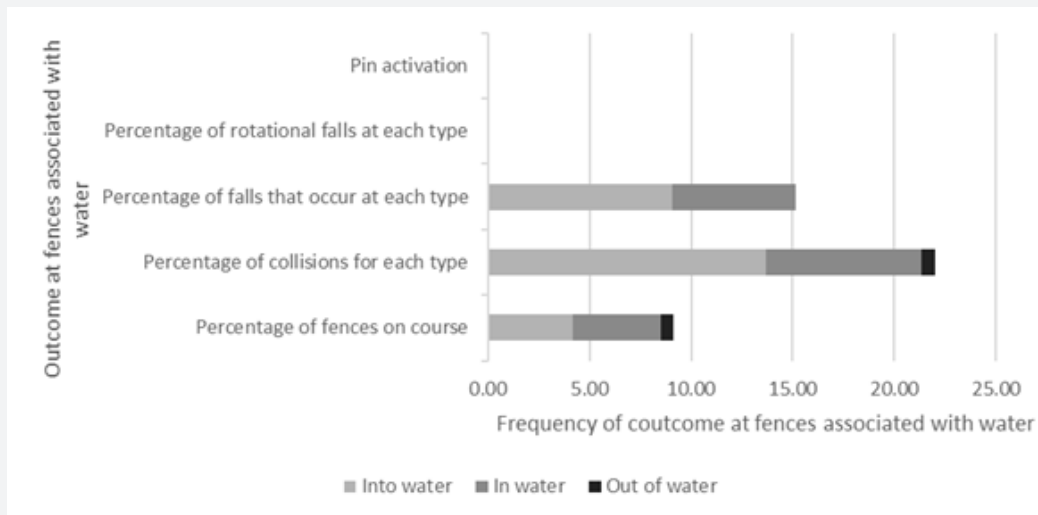


Figure 5: The outcome of fences involving water.

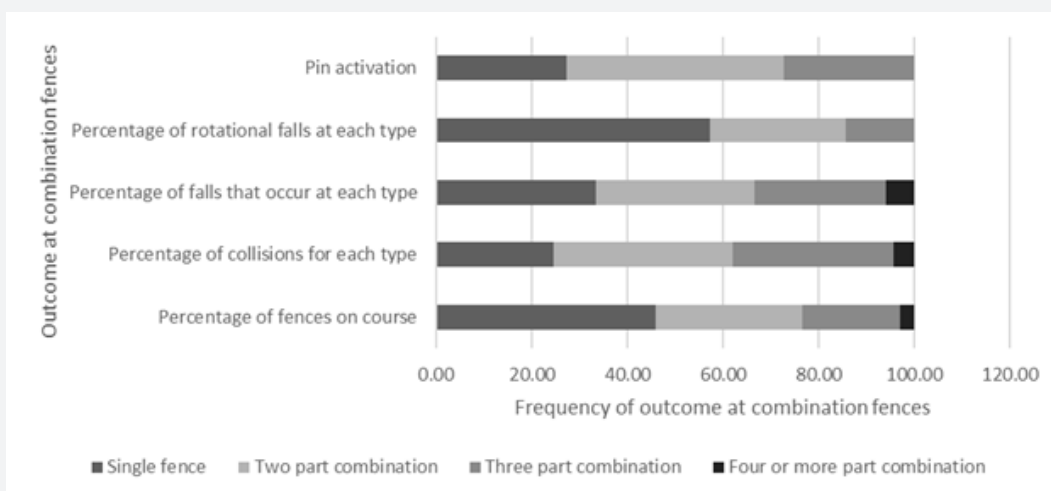


Figure 6:

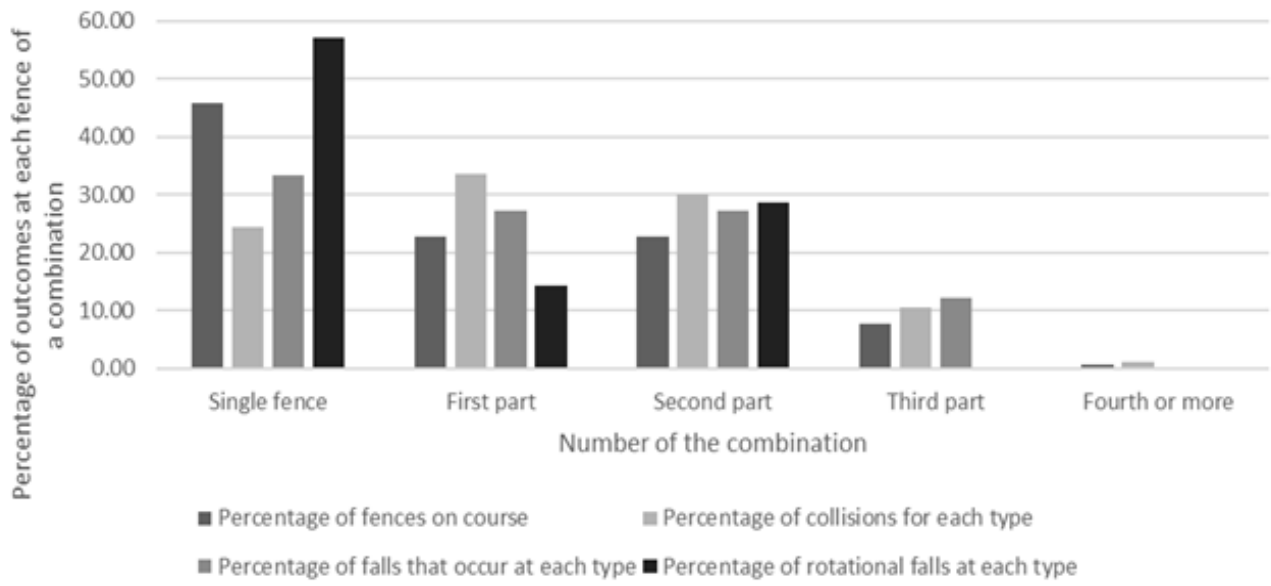


Figure 7: Percentage of collisions and falls at combination fences

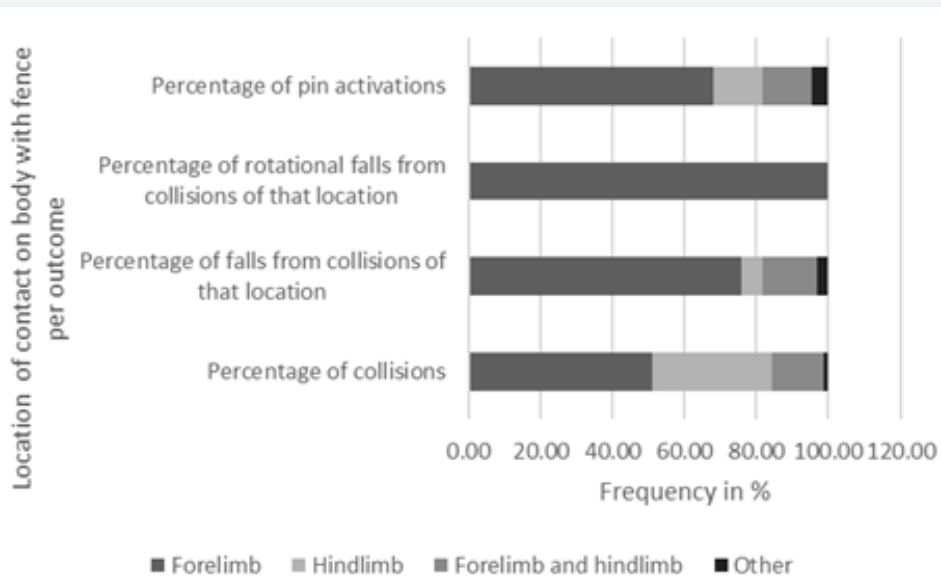


Figure 8: The outcome of the fence and the percentage of them that come from each type of collision.

Despite this absolute lower number of collisions, combination fences were associated with a disproportionately higher number of negative outcomes. Specifically, collisions at combination fences accounted for 4 out of 5 rider falls, 2 out of 4 rotational horse falls, and 6 out of 8 unbalanced outcomes. In contrast, although single fences were involved in more total collisions, outcomes were predominantly favourable. Of the collisions at single fences,

153 resulted in an uninterrupted continuation, compared with 61 such outcomes at combination fences. These findings indicate that while single fences are involved in more incidents overall, collisions occurring at combination fences are more likely to result in an adverse outcome.

A Chi-square test demonstrated a significant association between fence type and collision outcome ( $\chi^2 = 23.51$ ,  $df = 2$ ,  $p$

< 0.001), indicating that the distribution of outcomes differs significantly between single and combination fences. Table 5, using single fences as the reference category, odds ratio analysis showed that horses colliding with a combination fence had 5.59 times greater odds of falling (OR = 5.59, 95% CI 1.83–17.07, p

= 0.002). Although the odds of an unbalanced outcome were higher for combination fences (OR = 3.51, 95% CI 0.69–17.80), this association was not statistically significant (p = 0.130), likely reflecting the low number of unbalanced outcomes observed at single fences.

**Table 6:** Relative ratios of activations from contact points of the horse with the fence.

Body Part in Contact	Activations/100 Collisions	Odds Ratio	95% Confidence Interval (CI)	P-value
Forelimb	17.6	4.4	1.83 - 10.59	<0.001
Hindlimb	4	1	N/A	N/A
Both forelimb and hindlimb	18.7	4.6	1.70 - 12.33	0.003
Other part of body	50	12.3	4.48 - 33.74	<0.001

### Body Part Impact with Fence

Contact with the fence was most made with the forelimbs. Figure 8, illustrates the distribution of collisions, falls, and rotational falls according to the initial body part contacting the fence. Spearman’s rho analysis indicated no statistically significant correlation between the body part initially contacting the fence and the overall outcome of the contact ( $r_s = 0.083$ ,  $p = 0.08$ ). However, odds ratio analysis (Table 6) identified a significant association between the body part that first contacted a frangible fence and the likelihood of frangible pin activation. Hindlimb-only contacts resulted in 3 pin activations from 75 collisions and were used as the reference category.

Forelimb contacts were associated with a 4.4-fold increase in the odds of pin activation, with 23 activations from 131 collisions ( $p < 0.001$ ). Similarly, contacts involving both forelimbs and hindlimbs showed a 4.6-fold increase in the odds of activation, based on 3 activations from 16 collisions ( $p = 0.003$ ). The highest likelihood of activation was observed when contact occurred with another part of the body (e.g. chest or shoulder), which resulted in 5 activations from just 10 collisions and a 12.3-fold increase in odds compared with hindlimb contact ( $p < 0.001$ ). Overall, these findings indicate that any form of contact other than a hindlimb-first strike is substantially more likely to result in frangible pin activation, with the strength of association increasing markedly when impacts involve the forelimbs or other parts of the body.

### Discussion

#### Frangible Devices and Falls

This study demonstrates that frangible devices rarely activate during horse–fence contacts and that activation does not necessarily prevent a fall. These findings reinforce previous research suggesting that frangible devices primarily function to reduce fall severity rather than eliminate fall risk entirely [18]. The markedly increased likelihood of a fall following activation reflects that these devices are triggering during high energy impacts that

may otherwise result in more catastrophic outcomes, including rotational falls. The significant increase in the odds of any horse fall when a frangible device activated (OR = 22.64) highlights that activation is strongly associated with adverse events.

However, despite this increased fall likelihood, rotational falls were proportionally less common following activation than at non frangible fences. The FEI reports a decrease in rotational falls at international competition decreasing by 50% from 30 in 2016, to 15 in 2025, citing the increased use and technical development of the frangible devices for this reduction [4]. This supports biomechanical modelling indicating that energy dissipation through fence deformation can reduce the rotational moment acting on the horse during impact [11]. Together, these findings suggest that frangible devices may mitigate fall severity even when a fall still occurs.

Frangible device activation following hindlimb contact was observed without corresponding falls, highlighting concerns regarding unintended activation and the subsequent application of penalties. Overly sensitive activation mechanisms may risk altering the traditional character of cross country by blurring distinctions with show jumping, potentially undermining the traditional character of the phase [32]. As perceived risk remains a motivating factor for participation in eventing [8,33], inappropriate activation thresholds may influence rider behaviour and participation, with broader implications for the sport’s sustainability [34].

The proportion of fences fitted with frangible devices has increased substantially since 2013 [17]. However, many fences associated with falls in the present study still lacked frangible technology. While course authenticity may partially explain this limited uptake, failure to deploy safety technologies where appropriate has implications for welfare and the sport’s social licence to operate [19]. Strategic expansion of frangible devices used at higher risk fences may therefore yield additional safety benefits [20,21].

## Gradient

Previous research has identified downhill gradients as a risk factor for rotational falls [19,16,13]. Although descriptive trends in the present study suggested slightly higher fall frequencies at downhill fences, statistical analysis indicated no significant association between gradient and collision outcome. This likely reflects limited statistical power due to the low frequency of falls relative to total contact.

Despite this, the observation that frangible devices were less likely to activate on downhill fences, where falls were descriptively more common, is noteworthy. Downhill approaches alter the horse's centre of mass and momentum vectors, potentially reducing vertical force transmission and therefore the likelihood of activation [13,11]. This mismatch between fall risk and activation observed in this study highlights the need for further biomechanical research into gradient specific impact forces.

## Fence Type

Fence type influenced both collision frequency and collision outcomes. Brush fences were associated with a higher number of contacts but comparatively fewer falls than more upright profiles, which may reflect their softer visual and physical profile. Brush fences may permit horses to better interpret the jumping effort and maintain momentum without excessive elevation, thereby reducing the likelihood of destabilising impacts [35]. However, the stiffness of the brush material remains an important consideration, as firmer brush may still disrupt momentum sufficiently to contribute to rotational falls [11].

Jump biomechanics provide further insight into these findings. Upright fences require greater vertical impulse and a more upright trunk angle at take-off, whereas wider fences demand greater horizontal projection of the centre of mass [36-38]. The present results suggest that upright fences are more frequently associated with pin activation and rotational falls, likely due to increased trunk angle and forelimb loading at impact. This supports the importance of rider training focusing on collection, hindlimb engagement, and lumbosacral flexion at takeoff, strategies commonly seen in successful show jumping horses [39].

## Water Fences

Contrary to previous studies identifying water as a prominent fall risk [20,30,16], this study found no rotational falls and no frangible pin activations at fences involving water. While collision frequency was higher at water fences relative to their occurrence on course, these collisions were not associated with increased fall risk. Reduced approach velocity caused by water resistance may decrease impact forces and rotational momentum [16,11,40]. Additionally, altered ground reaction forces and limb kinematics in water may increase collision frequency without proportionally increasing fall severity [41,42]. These findings should be interpreted cautiously given sampling limitations and recent serious incidents at water complexes.

## Combination Fences

Combination fences presented a disproportionate risk of adverse outcomes relative to their frequency. Horses colliding with a combination fence had significantly greater odds of falling compared with single fences. Although rotational falls were fewer at combinations, non-rotational falls were more prevalent, representing a potential reduction in injury severity.

Rotational falls carry a substantially higher risk of serious injury or fatality [12,11]. The relatively greater frequency of non-rotational falls at combinations may therefore represent a meaningful safety benefit. Frangible activation occurred most frequently at the second element of combinations, suggesting concentrated impact forces at these points. This observation aligns with prior work identifying later elements as higher risk components of combinations [15].

## Limitations

Weather and ground conditions have also been suggested to impact fall risk [13,14,15,16] but could not be measured objectively using these retrospective videos so this may impact the results found. The approach speed also could not be measured easily which could impact the fall risk as increasing speed can increase the chances of a fall occurring [13,14,15,16] due to the increased momentum and forward energy the fence is collided with [11].

The videos also did not show every fence on the course which could have biased the results. The videos more commonly showed more technical or difficult fences, due to this increasing interest to spectators. This could mean that relatively more activations and falls may have occurred. The distance of the courses was not recorded and therefore the impact of fatigue was beyond the scope of this study.

## Conclusion

This study provides insight into the factors influencing frangible device activation and fall outcomes during the cross-country phase of eventing. Frangible devices were infrequently activated and were strongly associated with high energy horse-fence contacts; however, their activation appeared to reduce fall severity by limiting the occurrence of rotational falls rather than preventing falls altogether. Collision outcomes varied according to fence configuration, with combination fences and upright profiles presenting a higher risk of adverse outcomes when contact occurred, while brush fences were associated with frequent contacts but comparatively fewer falls.

No rotational falls or frangible activations were observed at water related fences, although these findings contrast with previous literature and should be interpreted cautiously. Collectively, the results suggest that strategic placement and continued refinement of frangible devices particularly at higher risk fence elements may enhance safety outcomes without compromising the essential

characteristics of the traditional cross-country phase. Further research incorporating biomechanical analysis of horse–fence interactions is warranted to optimise device responsiveness and inform evidence-based course design.

## References

1. Federation Equestre Internationale (FEI) FEI Eventing Rules. 27th ed. Lausanne: FEI; 2026.) 2026 FEI Eventing Rules\_Clean.
2. Scott L Zuckerman, Clinton D Morgan, Stephen Burks, Jonathan A Forbes, Lola B Chambless, et al. (2015) Functional and structural traumatic brain injury in equestrian sports: a review of the literature. *World Neurosurgery* 84(6): 1098-1113.
3. Federation Equestre Internationale (FEI) (2026) Risk management data: Highlights of international statistics FEI Online Eventing Seminar 31 January 2026 FEI Risk Management Programme (2024–2025) PowerPoint Presentation
4. O'Connor D, Buntine S (2026) FEI Risk Management Seminar 2025-2026. 31st January, 2026. Eventing Seminars 2025 - 2026 | FEI.
5. Cameron Whytock HA, O'Brien D, Lewis V, Parkin T, Bennet ED (2025) Equine fatalities in equestrian eventing. *Equine Veterinary Journal* 57(5):1387-1394.
6. C Navas de Solis, F Althaus, N Basieux, D Burger (2018) Sudden death in sport and riding horses during and immediately after exercise: a case series. *Equine Veterinary Journal* 50(5): 644-648.
7. Joakim Ekberg, Toomas Timpka, Henrik Ramel, Lars Valter (2011) Injury rates and risk factors associated with eventing: a total cohort study of injury events among adult Swedish eventing athletes. *International Journal of Injury Control and Safety Promotion* 18(4): 261-267.
8. Thompson K, Nesci C (2016) Over riding concerns: developing safe relations in the high risk interspecies sport of eventing. *International Review for the Sociology of Sport* 51(1): 97-113.
9. Vega GR (2017) Simulation of horse–fence contact and interaction affecting rotational falls in the sport of eventing. University of Kentucky.
10. Wood S (2020) Safety concepts for every ride: a statistical ensemble simulation to mitigate rotational falls in eventing cross country. University of Tennessee.
11. Foreman MH, Engsborg JR, Foreman JH (2019) Point mass impulse momentum model of the equine rotational fall. *Comparative Exercise Physiology* 15(3): 157-165.
12. O'Brien D (2016) Look before you leap: what are the obstacles to risk calculation in the equestrian sport of eventing?. *Animals* 6(2): 13.
13. Singer ER, Saxby F, French NP (2003) A retrospective case control study of horse falls in the sport of horse trials and three day eventing. *Equine Veterinary Journal* 35(2): 139-145.
14. Murray JK () An Epidemiological study of the risk factors associated with falls of horses and riders in the sport of eventing (Doctoral dissertation, University of Liverpool).
15. Murray JK, Singer ER, Morgan KL, Proudman CJ, French NP (2005) Risk factors for cross-country horse falls at one-day events and at two-/three-day events. *The Veterinary Journal* 170(3): 318-324.
16. Murray JK, Singer ER, Morgan KL, Proudman CJ, French NP (2006) The risk of a horse-and-rider partnership falling on the crosscountry phase of eventing competitions. *Equine veterinary journal* 38(2): 158-163.
17. Hennessy KD (2017) Profiling fallers in national eventing competition. *Journal of Human Sport and Exercise* 12(Proc2).
18. O'Brien D (2016) Look before you leap: what are the obstacles to risk calculation in the equestrian sport of eventing? *Animals* 6(2): 13.
19. Bennet ED, Cameron-Whytock H, Parkin TD (2022) Fédération Equestre Internationale eventing: Risk factors for horse falls and unseated riders during the cross-country phase (2008-2018). *Equine veterinary journal* 54(5): 885-894.
20. Bennet ED, Cameron-Whytock H, Parkin TD (2023) Fédération Equestre Internationale eventing: Fence-level risk factors for falls during the cross-country phase (2008–2018). *Equine veterinary journal* 55(3): 463-473.
21. Cameron-Whytock HA, Parkin TD, Hobbs SJ, Brigden CV, Bennet ED (2024) Towards a safer sport: Risk factors for cross-country horse falls at British Eventing competition. *Equine veterinary journal* 56(1): 137-146.
22. Williams JM, Marlin DM, Langley N, Parkin TD, Randle H (2013) The Grand National: factors associated with non completion and horse falls, 1990–2012. *Comparative Exercise Physiology* 9(3-4): 131-146.
23. International Eventing Safety Committee (2000) The International Eventing Safety Committee Report (Hartington Report).
24. Kahmann KM (2010) Engineering sport safety: a study of equestrian cross country eventing. University of Kentucky; 2010. "ENGINEERING SPORT SAFETY: A STUDY OF EQUESTRIAN CROSS COUNTRY EVENTING" by Katherine M. Kahmann
25. Federation Equestre Internationale (FEI) FEI Risk Management Policy and Action Plan.
26. BBC Sport (2024) British event rider Campbell dies after fall from horse.
27. Jones E (2023) European young rider champion in intensive care and horse put down after fall. *Horse & Hound*. 5 June 2023. A young eventing star in intensive care, and other things the horse world is talking about - *Horse & Hound*
28. Sinclair G, Ethington-Smith M, Vos D, Evand D, Bjornetun M (2021) Online Frangible Device Information Session, 30 March 2021 Frangible Devices Presentation 27.03.2021 C.pptx
29. Barnett C (2016) An audit into eventing incorporating an analysis of risk factors for cross country horse falls at FEI eventing competitions. FEI; 2016. Eventing Audit - Charles Barnett - Final Report 26.07.16.pdf
30. O'Brien D (2016) Risk perception and safety interventions in eventing. *Animals*.
31. Lindsay E Nylund, Peter J Sinclair, Andrew N McLean, Stephen Copley (2021) Development of a video analysis protocol and assessment of fall characteristics in equestrian cross country eventing. *Scandinavian Journal of Medicine & Science in Sports* 31(12): 2187-2197.
32. De Haan D, Dumbell LC (2016) Equestrian sport at the Olympic Games from 1900 to 1948. *Sport in History* 33(6-7):648-665.
33. Lamperd W, Clarke D, Wolfram, Inga A, Williams Jane (2016) What makes an elite equestrian rider? *Comparative Exercise Physiology* 12(3): 105-118.
34. Elder L (2024) Rising costs and late entries among complex factors that make greenfield events harder than ever to run. *Horse & Hound*. 14 February 2024. Rising costs among complex factors behind changing eventing calendar
35. A Egenvall, CA Tranquille, AC Lönnell, C Bitschnau, A Oomen, et al. (2013) Days lost to training and competition in relation to workload in elite show jumping horses. *Preventive Veterinary Medicine* 112(3-4): 387-400.

36. Clayton HM, G Colborne, TE Burns (1996) Linear kinematics of water jumping in Olympic show jumpers. *Pferdeheilkunde* 12(4): 657-660.
37. Hilary M Clayton, Lindsay St George, Jonathan Sinclair, Sarah Jane Hobbs (2021) Characteristics of the flight arc in horses jumping three different types of fences in Olympic competition. *Journal of Equine Veterinary Science* 104: 103698.
38. G Cassiat, P Pourcelot, L Tavernier, D Geiger, JM Denoix, et al. (2004) Influence of individual competition level on back kinematics of horses jumping a vertical fence. *Equine Veterinary Journal* 36(8): 748-753.
39. Fercher C (2017) The biomechanics of movement of horses engaged in jumping over different obstacles in competition and training. *Journal of Equine Veterinary Science* 49: 69-80.
40. Ana Muñoz, Aritz Saitua, Mireya Becero, Cristina Riber, Katy Satué, et al. (2019) The use of the water treadmill for the rehabilitation of musculoskeletal injuries in the sport horse. *Journal of Veterinary Research* 63(3): 439-445.
41. Gustås P, Johnston C, Drevemo S (2006) Ground reaction force and hoof deceleration patterns on two different surfaces at the trot. *Equine and Comparative Exercise Physiology* 3(4): 209-216.
42. N Crevier-Denoix, S Falala, L Holden-Douilly, M Camus, J Martino, et al. (2013) Comparative kinematic analysis of the leading and trailing forelimbs of horses cantering on different surfaces. *Equine Veterinary Journal* (S45): 54-61.



This work is licensed under Creative Commons Attribution 4.0 License  
DOI: [10.19080/JPFMTS.2026.11.555825](https://doi.org/10.19080/JPFMTS.2026.11.555825)

### Your next submission with Juniper Publishers

will reach you the below assets

- Quality Editorial service
- Swift Peer Review
- Reprints availability
- E-prints Service
- Manuscript Podcast for convenient understanding
- Global attainment for your research
- Manuscript accessibility in different formats  
( Pdf, E-pub, Full Text, Audio)
- Unceasing customer service

Track the below URL for one-step submission

<https://juniperpublishers.com/online-submission.php>