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Whip use and race progress are associated with horse falls in hurdle and steeplechase racing in the UK

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Summary

Reasons for performing study: **Falls during racing present a risk of injury to both horse and jockey and a risk of fatality to horses.**

Objectives: **To use video recordings of races to describe the circumstances surrounding horse falls at hurdle and steeplechase fences and to identify and quantify within-race risk factors for horse falls in National Hunt racing in the UK.**

Methods: **A retrospective, matched, nested case-control study using video recordings of races was conducted on 6 UK racecourses. Cases and controls were matched on both race type and jump number at which the fall occurred. Conditional logistic regression analysis was used to examine the univariable and multivariable relationship between predictor variables and the risk of falling.**

Results: **The risk of falling was significantly associated with whip use and race progress. Horses which were being whipped and progressing through the race were at greater than 7 times the risk of falling compared to horses which were not being whipped and which had no change in position or lost position through the field.**

Conclusions: **This study has identified whip use and the position of the horse with respect to others in the field as potential risk factors for horse falls.**

Potential relevance: **If these findings are confirmed by the use of intervention trials (e.g. with whip-free or restricted whip use races), modifications could be introduced which would reduce the frequency of horse falls, leading to improved equine welfare.**

Introduction

Accidents during racing, such as falling at a fence or colliding with another horse, threaten the lives of horses and contribute to horse and jockey injury (Turner *et al*. 2002).

In 2 descriptive studies of fatalities in National Hunt racing, 50% (McKee 1995) and 60% (Bourke 1995) of all fatalities in jump racing were associated with falls. In an earlier study by Vaughan and Mason (1975), 55% of reported racecourse fatalities were associated with a fall and 22% of these injuries were vertebral fractures. Furthermore, 90% of these were associated with a fall at a fence. The majority of these horses died instantly or were quadriplegic immediately after falling, and injuries such as these are likely to have a very negative impact on the public's perception of animal welfare in horse racing.

A workshop of the Horserace Betting Levy Board in 1996 identified the need to quantify risk factors for racing injuries in the UK (Mellor and Newton 1997). Subsequently there have been various studies in the UK conducted on racecourse fatalities and injuries (Wood *et al*. 2000; Williams *et al*. 2001; Verheyen *et al*. 2001; Parkin *et al*. 2002). In a retrospective study of death on UK racecourses, Wood *et al*. (2001) showed that much of the variation in the risk of death in hurdling was at the level of the start. Although readily available, there has been limited use made of video recordings of races. Previous analysis of accidents in horse racing utilising video recordings have been limited to racing accidents in Japan and flat racing accidents in the USA (Ueda *et al*. 1993; Cohen *et al*. 1997) and to the study of fatal distal limb fractures in the UK (Parkin *et al*. 2002). As many jump racing deaths are associated with falls, video analysis was used to identify and quantify start level risk factors, using recording of races to report descriptive data and risk factors for horse falls on 6 UK racetracks.

Materials and methods

Study design

A nested, matched case-control study was conducted with cases and controls being selected from a previous cohort study of falling in hurdle and steeplechase racing on 6 UK racetracks during 2000 and 2001 (Pinchbeck *et al*. 2004). One hundred and nineteen cases were selected during this cohort study and power calculations estimated that 2 controls selected per case would give an estimated power of 85% to detect odds ratios of 2 or more with an exposure of 50% in the controls. It was assumed that matching would increase study power. A nested case-control study was selected due to the difficulties involved and time required to follow large numbers of horses on video. The study was matched on race type and sequential jump number in the race, as these have previously been shown to be associated with risk of falling (Pinchbeck *et al*. 2002a, 2003).

Identification and selection of cases and controls

Cases were defined as any horse from the prospective cohort study (Pinchbeck *et al*. 2004) on the 6 UK racecourses that suffered a fall at a steeplechase fence or hurdle. Cases were identified by

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TABLE 1: Descriptive statistics and univariable conditional logistic regression analyses of categorical variables investigated during video analysis for association with falling in hurdle and steeplechase racing on 6 UK racetracks between February 2000 and November 2001

Variable	% Controls (n)	% Cases (n)	Conditional unadjusted odds ratio	95% Confidence intervals of odds ratio (OR)	LRS P value
Position start					
Front third	76 (81)	24 (26)	1.0		
Middle third	63 (88)	37 (51)	1.8		
Back third	60 (45)	40 (31)	1.9		0.04
Position start					
Inside	70 (84)	30 (36)	1.0		
Middle	66 (74)	34 (38)	1.2	0.7–2.0	
Outside	63 (56)	37 (33)	1.3	0.8–2.3	0.5
Position first fence					
Front third	75 (77)	25 (26)	1.0		
Middle third	67 (99)	33 (49)	1.5	0.8–2.7	
Back third	54 (38)	46 (32)	2.3	1.2–4.2	0.02
Position first fence					
Inside	67 (64)	33 (31)	1.0		
Middle	65 (49)	35 (49)	1.3	0.7–2.2	
Outside	68 (57)	32 (27)	1.0	0.5–2.0	0.9
Position 2 fences previous					
Front third	68 (69)	31 (32)	1.0		
Middle third	63 (80)	37 (47)	1.2	0.7–2.2	
Back third	68 (41)	32 (19)	1.0	0.5–1.9	0.7
Position 2 fences previous					
Inside	58 (44)	42 (32)	1.0		
Middle	68 (122)	32 (58)	0.6	0.4–1.2	
Outside	71 (50)	29 (20)	0.6	0.3–1.1	0.2
Position 1 fence previous					
Front third	67 (59)	33 (29)	1.0		
Middle third	64 (80)	36 (45)	1.2	0.7–2.2	
Back third	69 (48)	31 (22)	1.0	0.5–2.0	0.8
Position 1 fence previous					
Inside	65 (44)	35 (24)	1.0		
Middle	65 (94)	35 (51)	1.1	0.6–1.9	
Outside	70 (49)	30 (21)	0.8	0.4–1.6	0.8
Position at fence					
Front third	67 (70)	33 (34)	1.0		
Middle third	64 (86)	36 (49)	1.2	0.7–2.0	
Back third	70 (48)	30 (21)	1.0	0.5–1.9	0.9
Position at fence					
Inside	66 (44)	34 (23)	1.0		
Middle	67 (101)	33 (50)	0.9	0.5–1.9	
Outside	67 (62)	33 (30)	0.9	0.5–1.9	0.9
Horse immediately beside					
No	69 (180)	31 (83)	1.0		
Yes	58 (38)	42 (27)	1.8	0.9–3.5	0.09
Horse immediately in front					
No	69 (200)	31 (91)	1.0		
Yes	49 (18)	51 (19)	3.5	1.4–8.8	0.006
Previously brushed fence					
None	68 (107)	32 (51)	1.0		
Once	66 (57	34 (30)	1.1	0.6–2.0	
Twice	62 (29)	38 (18)	1.4	0.7–2.8	
Three times	74 (14)	26 (5)	0.6	0.2–2.2	
Four times	70 (7)	30 (3)	0.9	0.2–4.8	
Five times	57 (4)	43 (3)	1.7	0.3–9.7	0.8
Previous mistakes					
None	66 (165)	34 (86)	1.0		
One	70 (44)	30 (19)	0.8	0.4–1.5	
Two	64 (7)	36 (4)	1.1	0.3–3.7	
Three	67 (2)	33 (1)	0.9	0.1–10.7	0.9
Previous jumping direction					
Straight	65 (179)	35 (95)	1.0		
Left	60 (9)	40 (6)	1.2	0.4–3.3	
Right	93 (14)	7 (1)	0.1	0.02–1.00	0.1
TABLE 1 continued					
Whip use: 2 fences previous					
None	68 (207)	32 (103)	1.0		
One	58 (7)	42 (5)	1.4	0.3–6.2	
Two	67 (4)	33 (2)	1.0	0.2–5.6	0.9
Whip use: 1 fence previous					
None	66 (183)	34 (95)	1.0		
One	79 (23)	21 (6)	0.5	0.2–1.3	
Two	57 (12)	43 (9)	1.4	0.5–3.6	0.2
Whip use: at fence					
No	69 (188)	31 (84)	1.0		
Yes	54 (30)	46 (26)	2.7	1.3–5.7	0.02
Whip use: number of times					
None	69 (188)	31 (84)	1.0		
One	57 (17)	43 (13)	2.2	0.9–5.3	
Two	50 (9)	50 (9)	3.7	1.1–11.8	
Three	50 (4)	50 (4)	3.6	0.7–11.9	0.05
Position change from 1st fence					
None	71 (66)	29 (28)	1.0		
Forward	59 (80)	41 (56)	2.3	1.1–4.8	
Back	73 (72)	27 (26)	1.2	0.6–2.7	0.02

LRS = Likelihood ratio test statistic P value for change in deviance.

author attendance at the racecourses and verified against an independent data source and subsequently during video observation. Horses that unseated the rider or were brought down by another horse were not included in the case definition. Two controls per case were selected randomly using random number generation (Epi-Info 6.04)[1] from all horses in the same race that reached the jump number at which the case occurred. In 2 races, only one other horse reached the same point in the race as the case horse; these 2 cases therefore had only one matched control.

After the cases and controls had been identified, a spreadsheet was created identifying the cases and controls by number and racing colours only. This enabled the observer to be blinded with respect to which was a case or control horse up to the point of the fall.

Data collection

Videos on all races containing cases and controls were obtained from Racetech Ltd (Raynes Park, London, UK). At least 3 views were available on all races and some had up to 5 views. Four television screens and videos were set up with synchronised freeze frame which enabled slow-motion viewing of up to 4 views simultaneously, enabling all horses to be followed at every point in the race. One observer followed all cases and controls and recorded information relating to the horse's position, jumping mistakes and jockey's use of the whip throughout the race up to the point of the fall. The categorical variables recorded are shown in Table 1. Observational data on the cases were also recorded. These data were recorded directly onto a data sheet designed for use with a data entry scanner (Fujitsu fi-4110CU image scanner)[2] and software (Teleform Elite v 7.0)[3]. Ten percent (33) of these data sheets were randomly selected using random number generation (Epi Info 6 Version 6.04)[1] for double-checking of the data entry manually by the author (G.L.P.). The error rate was 0.1% (1 error in 968 entries).

Statistical analysis

Due to the presence of potentially correlated independent variables, simple correlation analysis was performed prior to analysis to avoid multicollinearity (Dohoo *et al*. 1997). If correlated variables were found (Pearson correlation coefficient >0.8), only the variable that

TABLE 2: Causes of fatality and description of the falls in the 8 fatal cases of falling on 6 UK racecourses

Injury	Race type	Description of fall
Shoulder fracture*	Steeplechase	Took off too early, extended front limbs into fence
Shoulder injury*	Steeplechase	Very fatigued, failed to take off, hit fence hard
Shoulder fracture*	Steeplechase	Misjudged take-off, put forelimbs in ditch, hit fence with chest and shoulders
Cervical fracture	Steeplechase	Took off too early, extended front limbs into fence, somersaulted
Cervical fracture	Hurdle	Caught front limbs on hurdle, somersaulted
Cervical fracture	National steeplechase	Ploughed through the fence and was catapulted
Third metacarpal fracture	Steeplechase	Took off too early, extended forelimbs into fence
Fetlock dislocation	Steeplechase	Hit fence, fell awkwardly on landing; lame on landing, ran on then completely dislocated fetlock

*No *post mortem* report available.

explained most of the residual deviance was included in the final model. The dependent variable for all analyses was the case horse that fell and the control horses that successfully jumped the fence. To take account of the matching conditional logistic regression methods using maximum likelihood estimation were used for both univariable and multivariable analyses (Hosmer and Lemeshow 2000). Continuous variables were considered first as linear in their relationship with the outcome and then as categorical variables. Variables relating to changes in position throughout the race were categorised to describe whether the horse moved forward in position, remained unchanged or had fallen back in position. Effect modification terms between the matching variables (race type and jump number of fall) and explanatory variables were tested to see whether there was any significant difference between race type and jump number and the risk associated with a particular variable. Effect modification terms were subsequently tested between all biologically plausible terms with a particular hypothesis that interactions between whip use and changes in position may exist. Following univariable analysis, variables with a likelihood ratio test statistic P<0.25 were considered for inclusion in a multivariable model. The critical probability throughout was 0.05. The stability of the model was assessed by examining the delta-betas (approximation of the amount an estimated regression coefficient would change if a given observation were omitted from the regression fit) (Pregibon 1981), and variable fit was reassessed by removal of matched sets containing data observations with the largest delta-betas. All analyses were performed in EGRET (Egret Application 2.0)[4].

Results

Descriptive statistics

One hundred and nineteen cases were available for analysis, of which 9 were excluded due to inability to visualise the case and control horses properly in any of the views; 31 cases were in hurdle races, 73 in steeplechase races and 6 were over the Aintree National steeplechase racecourse. There were 8 fatal cases of falling; Table 2 shows the causes of fatality and describes the associated falls.

Satisfactory observation of the fall was obtained in 106/110 cases. None of the falls were due to an obvious problem such as limb fracture or cardiovascular problem before take-off at the fence. In 97/106 (91%) cases, the fall was associated with the horse hitting the fence or hurdle; of these, 6/97 (6%) appeared to hit the guardrail on the take off side of the fence first, 10/97 (10%) took off too early (extended the front legs into the fence or hurdle) and 8/97 (8%) took off too late (hit the fence or hurdle before gaining enough height to clear the fence). Eleven of the 97 (11%) caught the forelimbs only, 9 (9%) the hindlimbs only and 44 (45%) hit the fence with fore- and hindlimbs. Horses that caught the hindlimbs were often somersaulted (landing on dorsal aspect of neck or back) over the fence. Four horses jumping an open ditch attempted to put in an extra stride with the forelegs in the ditch of the fence. All 4 of these then hit the fence hard; one suffered a fractured shoulder and was subjected to euthanasia. In 8/97 (8%), fatigue was the most likely reason for the fall. Only horses that were observably fatigued, as defined by laboured cantering, falling back in position and being heavily encouraged by the jockey, were classified as fatigued.

Of 31 hurdle cases, 9/31 (29%) horses appeared to canter into the hurdle flight with no attempt to jump the obstacle and 5 (60%) of these cases occurred when there was a field size greater than 12 horses in close proximity to each other.

While the majority of horses fell due to hitting the fence, 9/106 (8%) cleared the fence and then fell on landing. Two of these falls appeared to be due to interference from another horse on landing and the remaining horses seemed to lose their forelimb footing on landing. After the falls, all horses lost their riders and 69/106 (65%) horses continued to run without the rider.

Univariable and multivariable logistic regression

The results of the univariable conditional logistic regression analyses of categorical variables are shown in Table 1. Effect modification terms between the jump number of the fall, race type and other variables were not significant (P>0.3) and all data were therefore analysed together. The final multivariable model is shown in Table 3. Examination of the delta-betas showed this model to be stable and removal of matched sets containing the observations with the largest delta-betas had little effect on size of the odds ratio or significance of individual variables.

Horse immediately in front

A case or control was defined as having a horse in front at take-off at the fence if another horse was directly in front and this horse had not landed before the case or control horse took off at the jump. This variable was significant in the final multivariable model with increased odds of falling of 3.3 (95% CI = 1.3, 8.6).

Use of the whip

Use of the whip by the jockey was measured leading up to both 2 fences and one fence previous to the fall, as well as leading up to the fall fence. Any use, plus the number of strikes the horse received, was recorded. In the final multivariable model, use of the whip leading up to the fall fence was assessed with a binary yes/no outcome and an effect modification term between whip use and change in position from 2 fences previously was significant. This is illustrated in Figure 1 (using re-categorised variables to represent the

TABLE 3: Model development using conditional logistic regression methods of risk factors associated with horse falls on 6 UK racecourses identified from video recordings. The final row shows the likelihood ratio P value for the addition of variables to the model. The final column represents the final multivariable model

Variable added to model	Odds ratio (95% CI) for each variable in each successive model			
Horse in front = Yes	3.3 (1.3, 8.2)	3.6 (1.4, 9.2)	3.3 (1.3, 8.5)	3.3 (1.3, 8.6)
Whip use = Yes		2.9 (1.3, 6.4)	3.1 (1.4, 6.9)	1.8 (0.7, 4.5)
Position change from 1st fence = Forwards			1.9 (1.2, 3.2)	2.6 (1.4, 4.9)
Position change from 2 fences previous = Forward				0.4 (0.2, 0.9)
Interaction term†: Whip use * position change 2 fences = Forward				8.9 (1.6, 49.6)
Change in likelihood ratio (df) for addition of variable	7.00 (1)	7.3 (1)	6.1 (1)	8.1 (2)
LRS P value	0.008	0.007	0.01	0.02

†Estimated odds ratio for a horse that was had progressed forwards from 2 fences previously and was being whipped compared to a horse that had not progressed and was not being whipped was estimated to be 1.8 x 0.4 x 8.9 = 6.4.

effect modification term), which shows the relationship between the odds ratios for change in position, with and without whip use, and the outcome of falling. In univariable analysis, and after adjusting for position change from 2 fences previously and horse in front, there appeared to be a dose-response relationship with 2 and 3 strikes of the whip associated with an even greater chance of falling (Fig 2).

Change in position from 2 fences prior to fall fence

Neither the position at the fence nor at 1 and 2 fences previously were significant in univariable analysis. However, the change in position from 2 fences prior to the fall fence had a significant interaction with whip use, as shown in Figure 1. Horses which were being whipped and progressing in the field were most at risk, followed by horses being whipped and not changing position. Horses not being whipped, especially when progressing forwards, were at the lowest risk.

Change in position from the first fence

Although the position in the field at the first fence was significant in univariable analysis, the change in position from the first fence to the fall fence explained more of the residual deviance and was significant in the final model. Horses that had progressed in position from the first fence to the fall fence were significantly more likely to fall than those that had not changed position or lost position (odds ratio [OR] 2.6, 95% CI 1.4, 4.8).

Discussion

This study has provided information regarding the circumstances surrounding horse falls on 6 UK National Hunt racecourses. In 2 retrospective studies of horse falls in hurdling and steeplechasing (Pinchbeck *et al*. 2002a,b), most variation in risk was at the level of the start, and this study has identified and quantified some start level risk factors.

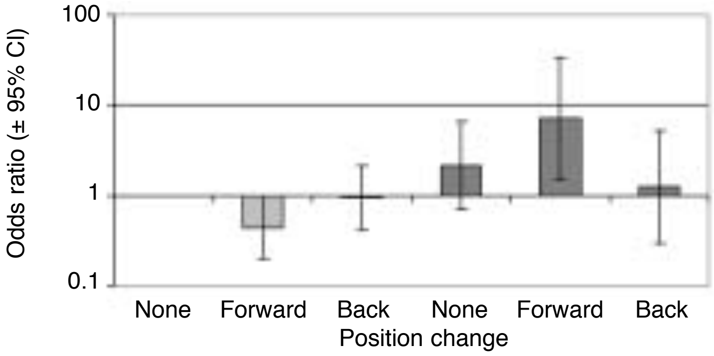

Fig 1: The relationship between risk of falling and change in position from 2 fences previously, with (■) and without (■) whip use in hurdle and steeplechase races on 6 UK racecourses. The model was adjusted for other variables in the multivariable model (Table 3).

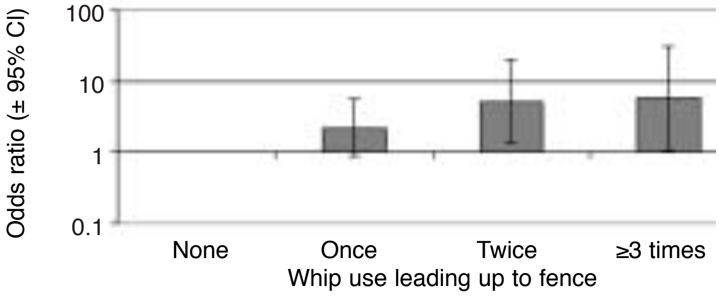

Fig 2: The relationship between risk of falling and whip use, adjusted for the position of the horse 2 fences previously and a horse in front in hurdle and steeplechase races on 6 UK racecourses.

In this study, the majority of falls (91.5%) were due to collision with the fence. The reasons for hitting the fence varied, but were most commonly due to inaccurate approach strides (e.g. taking off too early or late) and fatigue (8%). Only horses that were obviously very fatigued were classed as fatigued (possible observation inaccuracies may have occurred if we had tried to assess mild fatigue) and this may therefore be an underestimation. Previous studies have observed that the risk of falling increases at later hurdles in a race (Pinchbeck *et al*. 2003) and the risk of distal limb fracture increases in the later part of races in National Hunt racing (Parkin *et al*. 2002). Rooney (1982) showed that race length was a factor in causing fatigue and lameness, although other studies have shown that the risk of severe musculoskeletal injury is increased in the early part of flat races (Mohammed *et al*. 1992) and in shorter distance races (Cohen *et al*. 1999a). However, these studies were in flat racing only and considered a very different outcome to that used here. In an earlier study by Vaughan and Mason (1975) that described some of the aspects of fatal falls on UK racecourses from 1970–1973, the authors observed that 9 of 29 horses that suffered vertebral fractures were near the end of the race when the accident happened.

Four horses jumping open ditches in our study appeared to misjudge the take-off. The one fatal case at an open ditch had a diagnosis of shoulder fracture that was based on clinical examination on the racecourse. Vaughan and Mason (1975) also described one case of scapula fracture and 2 cases of humeral fracture where horses had misjudged an open ditch and hit the fence. Vaughan and Mason (1975) observed that 13 horses somersaulted after hitting the fence with their fore- or hindlimbs. The nature of the fall may be important with respect to injuries. In the current study, there were 3 cases of vertebral fracture and these were all somersaulted at the time of the fall. Vaughan and Mason (1975) also observed that 13/14 cases of cervical vertebral fracture occurred due to a fall at a fence and that all of these were subjected to trauma about the head or neck. Other than fatigue, the reasons for the inaccurate approaches and hitting the fence are unclear. They may have been due to rider error, poor visibility of the fence, the presence of other horses or it may have been that some horses were inherently poor jumpers. Barrey and Galloux (1997) showed that, in an accelerometry study of 8 horses all ridden by instructor grade riders, there was a significant horse effect on most of the parameters. A study by Powers and Harrison (2000) on the techniques used by untrained horses during loose jumping showed that horses in a 'poor' jumping group, that consistently hit or knocked the fence, had a significantly increased approach horizontal velocity compared to a 'good jumping group'. The authors hypothesised that this higher speed may affect the horse's judgement of approach speed and distance from the fence. This study also showed that the angles created by flexion of the carpi at take off were smaller in the 'good' jumpers and it may be that some horses are better at lifting the forelimbs during the jump. Our study showed that horses that had previously brushed fences during the race, or those that made mistakes, did not seem to be at significantly greater risk of falling and that the numbers of mistakes and fence contact made by both cases and controls was high (Table 1).

In our study, having a horse directly in front at the point of take-off increased the risk of falling (OR 2.9, 95% CI 1.1, 7.9) and 2 of the horses that fell after clearing a fence did so because of physical contact with the horse in front. There may be some misclassification of horse falls and being brought down by another horse. However, these 2 cases were left in the analysis as there was no error by the horses in front. Two other falling horses appeared to collide with another horse at their side at the point of take-off, although having a horse beside was not significantly associated with falling in the final multivariable model. Physical contact between horses during the race was associated with the risk of overall and catastrophic injuries in a matched study of 216 cases of musculoskeletal injury in flat racing on 4 US racecourses (Cohen *et al*. 1997). In the study by Ueda *et al*. (1993), accidents resulting from a collision with another horse were excluded from analysis and details of these were not published.

Univariable analysis in our study showed that horses positioned in the middle or at the back of the field at the start or at the first fence were associated with a greater risk of falling than those in the front third of the field. This is similar to findings by Peloso *et al*. (1994) in a study on musculoskeletal racing injuries. However, this study was in flat racing only and the aetiology of musculoskeletal injuries on the flat and injuries due to falling in jump racing are likely to be very different. In the final multivariable analysis, the position at the start was confounded by the change in position from the first fence to the fall fence and horse in front and horse beside, and these variables were retained in the model. Horses that had progressed in the race were at greater risk of falling; however, the position of the horse at the time of the fall, relative to others in the field, was not significantly associated with the risk of falling.

Whip use leading up to the fall fence was associated with falling in this study and there was a relationship between the number of times a horse was whipped and falling. Whip use by the jockeys appeared to be used primarily for increasing the speed of the horse. Horses going forward and being whipped were at the most risk of falling. This may be because these horses are very extended and do not reduce their velocity in approach strides sufficiently before take-off and therefore have a weak acceleration impulse by the fore- and hindlimbs at take-off (Barrey and Galloux 1997). Horses with no change in position from 2 fences previous were also more at risk if the whip was used. Another possible explanation is that whip use unbalances the horse on the approach to the jump. Very few jockeys used the whip at the actual point of take-off at the fence. It is possible that these horses were going to fall anyway and the relationship between whip use and falling was confounded by an unmeasured variable (e.g. fatigue). However, the finding that the risk was greater in horses improving in position suggests that this was not the case. In 2 studies by Cohen *et al*. (1997, 1999b), a protective effect of use of the whip was found for musculoskeletal injuries. However, the earlier study recorded whip use from only 12 secs before the injury and, as the authors suggested, it is possible that the jockey had already recognised a problem and was reluctant to use the whip. In the later study, whip use was not significantly associated with injury in the final model after allowing for other variables. In the study in Japan (Ueda *et al*. 1993), it was suggested that whip use was associated with racing accidents, excluding those associated with a fence, but this study did not use control horses. In a study by Parkin *et al*. (2002), horses receiving encouragement in the final 10 secs before time of fracture were at greater risk of suffering a fatal distal limb fracture.

In conclusion, this study has described some of the circumstances surrounding horse falls in National Hunt racing and has identified whip use, race progress and the horse's position relative to other horses as risk factors for these falls. Horses are obviously racing to progress through the field and win races, and this is therefore not modifiable. However, horses that were improving in position and not being whipped had a much lower risk of falling compared to those progressing and being whipped. Whip use is a potentially modifiable intervention via the introduction of restricted whip or whip-free races. Jockey education regarding use of the whip and positioning at fences relative to other horses may also be useful.

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Manufacturers' addresses

[1]CDC, Atlanta, Georgia, USA.
[2]Fujitsu, Tokyo, Japan.
[3]Cardiff Software Inc., Middlesex, UK.
[4]Cytel Software Corporation, Cambridge, Mssachusetts, USA.

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