**A retrospective case-control study to investigate horse and jockey level risk factors associated with horse falls in Irish Point-to-Point races**

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**Abstract**

Horse racing as a high-risk sport can pose a significant risk to equine welfare. To date there have been limited epidemiological reviews of fall risk specific to point-to-point racing. This study aimed to identify horse and jockey level risk factors associated with horse falls and to compare these to published findings for Hurdle and Steeplechase racing. The study used a retrospective matched case-control design. Relevant variables were identified and information was collated for all races in the 2013/14 and 2014/15 seasons. Cases and controls were matched with a 1:3 ratio. Controls (n=2,547) were selected at random from all horses that completed in the same race (n=849). Horse and jockey level variables were analysed through univariable analysis to inform multivariable model building. A final matched case-control multivariable logistic regression model was refined, using fall/no fall as the dependent variable, through a backward stepwise process. Horse age was associated with an increased risk of horse falls. For every 1 unit increase in age there was a 1.2 times increased risk of falling. The overall number of races ran within 12 months was associated with a decreased risk of falling. The jockeys previous seasons percentage wins was associated with the risk of horse falls with jockeys who had 0-4% wins and 5-9% wins having an increase in risk compared to those who had over 20% wins/runs. The jockeys previous seasons percentage of falls (F) or unseating of the rider (UR) was associated with the risk of horse falls with jockeys who had over 20% F/UR having a 50% increased chance of falling compared to those who had 0-4% F/UR. Retrospective analysis of horse and jockey falls has exposed risk factors that have been previously identified in hurdle and steeplechase racing. The identification of risk factors is essential when considering future research and interventions aimed at improving horse and jockey safety.

**Introduction**

Point-to-point (PTP) racing is horseracing over jumps for amateur trainers and jockeys, overseen in Ireland by the Irish Turf Club, generally run over a distance of 24-32 furlongs (3-4 miles) and includes between 12-22 jumps. Previous research has investigated risk factors associated with horse falls in National Hunt (NH) racing (Pinchbeck *et al*., 2002b; Pinchbeck *et al*., 2004a, b, c; Williams *et al*., 2013a & b) however, there have been limited studies to investigate the risks associated with PTP racing (Smith *et al.,* 2018). Horseracing poses a risk to equine welfare with 42-60% of fatalities associated with horse falls (Bourke, 1995; Pinchbeck *et al*., 2002b) and fatality rates reported in UK hurdle (52/1,000 starts) and steeplechase racing (71/1,000 starts) higher than for flat racing (1/1,000 starts) (Wood *et al*., 2000). The rates of horse falls in steeplechase racing (32/1,000 starts) have also been found to be notably higher than in hurdle racing (11/1,000 starts) (Pinchbeck *et al*., 2004b). The higher mortality rates reported in steeplechase racing compared to hurdle racing have been associated with the increased race length and the size and positioning of the solid obstacles jumped (Boden *et al*., 2006). Hurdle races often run over 2-3 ½ miles and each hurdle is no more than 94 centimetres high whereas steeplechase racing includes fences of at least 1.4 metres and distances of 2-4 ½ miles. PTP racing shares more similarities with steeplechase

racing than hurdle racing, therefore it is relevant to consider that some of the risk factors noted within steeplechase racing and evaluate if these may also be present within PTP racing (Turner *et al*., 2002). It is important to note that there are however some key differences between steeplechase racing and PTP racing. Steeplechase racing involves professional jockeys and trainers, is run on professional racetracks and may involve a different demographic of horses being typically older and often having previously run in hurdle races. It is therefore also reasonable to consider that the risk of horse falls could differ between these two forms of racing. Analysis of jockey injury data has identified that PTP racing has a higher risk of jockey falls compared to professional jumps racing (Balendra *et al*., 2007; O'Connor *et al*., 2018) with 13% of rides resulting in a fall in Irish PTP racing compared to 5% of rides in Irish professional jumps racing. It should also be noted that Irish amateur jumps racing had the highest fall to ride rate when compared to both France and Great Britain (GB), which highlights the particular need to investigate risk factors relating to falls in amateur jump racing in Ireland (Forero Rueda *et al.,* 2010). Smith *et al.* (2018) previously found a 54% chance of an Irish PTP race including at least one horse fall which is higher than the 47% chance of falling noted in steeplechase races at Cheltenham racetrack (Williams *et al*., 2013b). In steeplechasing, a range of factors have previously been associated with an increased or decreased risk of horse falls including horse age (Pinchbeck *et al*., 2004b), equipment worn (Pinchbeck *et al.,* 2002b), frequency of racing (Pinchbeck et al., 2002b) and racing on the same track (Pinchbeck *et al.,* 2004a). Jockey experience has also been related to the risk of horse falls in the Grand National with a slightly reduced risk noted with greater experience (Williams *et al.,* 2013a). Accidents that occur during racing threaten the lives of horses and contribute to both horse and jockey injury (Turner *et al.,* 2002), therefore identification of risk factors that contribute to falls is key to devising strategies to reduce them and to enhance racehorse and jockey welfare. This study aimed to identify the main horse and jockey related risk factors associated with horse falls in Irish PTP racing.

## Materials and Methods

A retrospective case-control design identified the potential horse and jockey level risk factors associated with falls in PTP racing. Relevant factors were identified based on previous findings in horse sports which share similarities with PTP such as jumps racing and eventing (Singer *et al*., 2003; Williams *et al*., 2013b) (Table S1). Retrospective data for horse related variables were obtained from three sources: Irish Point to Point Services (Irish Point to Point Services, 2015) and The Racing Post (Racingpost.co.uk, 2015). A total of 5,259 starters racing in PTP races occurring between September 2013 and June 2015 were included in the study. Case races were races which included at least one horse fall unrelated to an unseated rider (UR) or a brought-down horse (including falls associated with interference from another horse) as both of these scenarios could cause the rider or horse to become unbalanced resulting in a fall, instead of the fall being related to the variables measured within the present study (Pinchbeck *et al*., 2003; Williams *et al*., 2013b). All starters in case races were recorded and the data were refined to exclude any horses that had not completed for any reason other than a fall (Smith *et al*., 2018). Within the study 1,190 fallers and 4,069 non-fallers were identified and recorded. These were refined to form matched data with fallers classified as cases (n=849) and non-fallers in the same race classified as non-cases (controls; n=2,547) (Williams *et al*., 2013b; Pinchbeck *et al*., 2004c).

### *Variables recorded*

A range of variables were recorded for each case and matching control horse (Table 1). Banks races, which consist of up to 22 fences including banks were excluded from the analysis due to the varying conditions and the small number of races held (12 in total out of 1,370 races) (Smith *et al*., 2018). Factors selected for analysis included horse age (Williams *et al*., 2013a; Pinchbeck *et al.,* 2002b), runs on the same course number of previous runs, number of falls to date, number of races within the previous three or 12 month period, number of wins/wins as a percentage of starts, previous type of race/raced over jumps previously, race number, (Pinchbeck *et al*., 2003 & 2004a), previous starts on the same course (Williams *et al*., 2013a; Proudman *et al.,* 2004), number of days since the last race/frequency of racing (Hernandez *et al*., 2001) and the jockeys previous number of starts/number of wins/number of falls or unseated (Parkin *et al.,* 2004b) (Table S1). The weight carried was included due to earlier research findings showing a significant link to increased horse injury rates when the weight carried was greater (Pinchbeck *et al.,* 2004d). Jockey sex has not previously been linked to an increased risk of horse falls but has been associated with an increased risk of jockey falls (Hitchens *et al.,* 2010) hence this variable was also included for analysis. Additionally, horse sex (Pinchbeck *et al,* 2004b) (Table S1) was included based on potential relevance and the biological plausibility that it could influence risk of horse falls.

**Table 1.** Definitions for independent predictor variable included within analysis. %: percentage

| **Factor** | **Description** |
|---|---|
| **Horse Factors** | |
| Horse name | Registered name |
| Case/control | Noted as a fall or non-fall |
| Horse age | Age at start |
| Horse sex | Male/Female |
| Weight carried | Total weight carried during the race |
| Change in weight carried | Increase or decrease in weight carried since last race |
| Race Outcome | Note whether the horse completed the race or not. Reasons for non-completion noted. |
| Total runs to date | Total number of starts |
| Total runs over jumps | Total number of starts over jumps |
| Previous starts on same course | Number of previous starts at same location |
| Number of falls | Total previous falls in jumps racing |
| Falls to date as % of runs | Percentage of previous races where falls have taken place |
| Number of races 3 months | Number of starts of any type race in the past 3 months |
| Number of races 12 months | Number of starts of any race type in the past 12 months |
| Number of wins | Total wins racing |
| Wins as percentage starts | Number of wins as a percentage of starts |
| Previous flat racing | Has the horse previously raced under rules in flat racing |
| National Hunt Flat (NHF) racing | Has the horse previously raced in NHF races |
| First race type | First race type of career |
| Last race type | Last recorded race type prior to the race currently being recorded |
| Raced over jumps previously | Has the horse raced over jumps |
| Days in racing | Total days since first race of career |
| Days in jumps racing | Total days since first jumps race of career |

| | |
|---|---|
| Days since last race | Number of days recorded since previous race regardless of type |
| Days since last jumps race – time frame recording | Notation used to categorise time period between jumps races |
| Frequency of racing | Number of races run divided by total years in racing |
| **Jockey Factors** | |
| Jockey name | Jockey riding named |
| Jockey sex | Male/Female |
| Number of races | Number of races run during previous seasons |
| Number of wins previously | Number of previous winners ridden until the current season |
| Percentage wins (jockey) | Percentage wins over career duration |
| Number of falls (F)[1] or UR[2] incidents | Number of previous F/UR until the current season |
| Percentage F/UR | Percentage F/UR over career duration |
| [1] **Number of jockey falls (F) in previous seasons**<br>[2] **Number of unseated rider (UR) incidents in previous seasons** | |

### *Selection of Cases and Controls*

Cases and controls were matched with a 1:3 ratio of cases to controls, this ratio was used to ensure maximum validity (Parkin *et al*., 2006). Three control horses were selected at random (n=2,547) from horses that did not fall in the same race as the fallers (n=849). Matching data allows potentially confounding effects to be controlled for i.e. effects of weather conditions and geographical location (Murray *et al.,* 2005; Rose and van der Laan, 2009) and ensures that valid comparisons can be made within the data (Murray *et al.,* 2005). Confounding occurs when a factor being considered is causally related to a predictor of interest and to the outcome that is being investigated (Dohoo *et al.,* 1996). Races were required to have three unique controls per case. In instances where three unique controls were unavailable the number of falls included for that race was reduced until the ratio of three controls per case could be met. The selection of horses to exclude was made using random number generation (openepi.com) to ensure no bias was present. These refinements lead to the exclusion of 28 races due to lack of available controls.

### *Descriptive analysis*

Descriptive analysis of the data was performed to establish the fall frequency within the variables recorded. A range of variables were investigated including: the percentage of falls linked to horse age, percentage of total jumping efforts completed when horse fell, horse gender, previous wins, wins as a percentage of starts, first and last race types, whether the horse had previously National Hunt Flat (NHF) raced, days since last jumps race, previous starts on the same course, frequency of racing per year, jockey percentage wins and jockey gender. For the purpose of identifying trends within the descriptive analysis age categories that included less than 20 horses were excluded (14-16 year olds) as these were considered of limited value.

### *Power of the study*

Power analysis for multivariable regression was conducted using a-priori sample size calculator (SPSS Sample Power 3.0) to determine the sufficient sample size required for the dichotomous variable using an alpha of 0.05 (95% confidence), power of 0.95 and a small

effect size (f2 =0.02). The sample size required to meet the aforementioned assumptions was 1,505. Under these assumptions the model produced was able to accurately calculate two-fold odds at 95±4% error.

### *Cluster analysis*

Due to the study including horses that had multiple starts over the two seasons recorded, clustering analysis was carried out to check for interaction between repeated variables. Clustering analysis identified if interaction occurred between repeated variables. Initial results indicated that the horse had little influence over the formation of clusters.

### *Univariate analysis*

The variables to be fitted in the multivariable model were first assessed using univariable analysis using the dependant variable 'fall to no fall' to establish potential risk and inform multivariable model building. A variable with an alpha value of <0.10 was considered eligible for use in building the multivariable model (Bailey *et al*., 1997).

### *Multivariate analysis*

A predictive multivariable logistic regression model was produced, using Statistical Package for the Social Sciences (SPSS) 22, for horse level data using the dichotomous variable: fall or no fall. The model was fitted using a backward stepwise process that excluded variables with a likelihood ratio test significance of P<0.05. Variables which had previously been found to exert a significant influence over fall risk or were biologically plausible risk factors for falling were also considered for inclusion (Parkin *et al.,* 2006). For each step in the multivariable model building process the effect of removal of variables was assessed using a likelihood ratio chi-square test of model coefficients (P<0.05) to check that the new model was an improvement over the baseline model. This was done to ensure that variables that had a significant impact on the model were not excluded from further analysis. A Hosmer-Lemeshow goodness of fit test (P>0.05) was used to evaluate the fit of the model produced. The predictive ability of the final model was investigated using receiver operating characteristic (ROC) curve analysis. The risk of a horse becoming a case was compared using the odds ratio (OR) and associated 95% confidence intervals (CI).

## Results

### *Descriptive analysis*

A total of 727 case races (54%) were identified from the 1,358 races recorded. To investigate specific horse and jockey related factors, horse and jockey details from all case races recorded were compiled. The data were refined to exclude any horses that had not completed for any reason other than a fall, which reduced the number of starters included to 5259 (1,190 cases and 4,069 controls). A range of variables were considered for descriptive analysis (Table 2).

**Table 2.** Descriptive statistics of the variables available for analysis in Ireland during the 2013/14 and 2014/15 PTP seasons

| Variables | Cases (falls) | | Controls | | Variables | Cases | | Controls | |
|---|---|---|---|---|---|---|---|---|---|
| | n | % | n | % | | N | % | n | % |
| **Horse sex** | | | | | **Days since last jumps race – time frame recording** | | | | |
| Male | 833 | 22 | 2,931 | 78 | 1-30 days | 468 | 20 | 1,887 | 80 |
| Female | 357 | 24 | 1,138 | 76 | 30-59 days | 107 | 18 | 489 | 82 |
| **Horse age** | | | | | 60-89 days | 47 | 25 | 143 | 75 |
| 4 | 180 | 23 | 589 | 77 | 90-119 days | 26 | 18 | 117 | 82 |
| 5 | 409 | 24 | 1,304 | 76 | 120-149 days | 18 | 17 | 91 | 83 |
| 6 | 298 | 23 | 994 | 77 | 150+ days | 160 | 21 | 598 | 79 |
| 7 | 153 | 22 | 541 | 78 | No previous jumps race | 364 | 33 | 744 | 67 |
| 8 | 64 | 20 | 249 | 80 | **Frequency of racing/year** | | | | |
| 9 | 34 | 17 | 166 | 83 | 0 - <5 | 325 | 20 | 1,312 | 80 |
| 10 | 22 | 19 | 92 | 81 | 5 - <10 | 163 | 15 | 904 | 85 |
| 11 | 11 | 16 | 70 | 84 | 10 + | 15 | 22 | 52 | 78 |
| 12 | 11 | 24 | 35 | 76 | Raced for under 6 months/not raced | 687 | 28 | 1801 | 72 |
| 13+ | 8 | 22 | 29 | 78 | **Previous starts same course** | | | | |
| **Previous wins** | | | | | Yes | 77 | 14 | 473 | 86 |
| Yes | 115 | 16 | 592 | 84 | No | 1,113 | 24 | 3,596 | 76 |
| No | 1075 | 24 | 3,477 | 76 | **Jockey sex** | | | | |
| **Wins as percentage starts** | | | | | Male | 1,141 | 23 | 3,919 | 77 |
| 0% | 709 | 21 | 2,733 | 79 | Female | 49 | 25 | 150 | 75 |
| >0 – 9% | 38 | 16 | 205 | 84 | **Jockey % wins** | | | | |
| 10 – 19% | 45 | 16 | 239 | 84 | 1-<10 | 763 | 25 | 2,250 | 75 |
| 20 – 29% | 19 | 17 | 92 | 83 | 10-<20 | 314 | 19 | 1,332 | 81 |
| 30% + | 13 | 19 | 55 | 81 | 20-<30 | 59 | 16 | 302 | 84 |
| Not raced previously | 366 | 34 | 745 | 66 | 30 + | 17 | 14 | 101 | 86 |
| **Previous National Hunt Flat[1] (NHF) racing** | | | | | No previous races | 37 | 32 | 79 | 68 |
| Yes | 148 | 20 | 587 | 80 | **Jockey % F[2]/UR[3]** | | | | |
| No | 1,042 | 23 | 3,482 | 77 | 1-<10 | 181 | 21 | 679 | 79 |
| **First race type** | | | | | 10-<20 | 890 | 22 | 3108 | 78 |
| PTP | 697 | 20 | 2,854 | 80 | 20-<30 | 62 | 28 | 161 | 72 |
| Chase | 0 | 0 | 1 | 100 | 30 + | 20 | 32 | 42 | 68 |
| Flat | 16 | 25 | 48 | 75 | No previous races | 37 | 32 | 79 | 68 |
| Hurdle | 37 | 24 | 120 | 76 | **No. previous races – jockey** | | | | |
| NHF | 94 | 21 | 344 | 79 | 0 | 37 | 31 | 81 | 69 |
| None | 346 | 33 | 702 | 67 | 1-<100 | 253 | 29 | 621 | 71 |
| **Last race type** | | | | | 100-<200 | 151 | 25 | 348 | 75 |
| PTP | 764 | 20 | 3,098 | 80 | 200-<300 | 133 | 22 | 484 | 78 |
| Chase | 13 | 13 | 90 | 87 | 300-<400 | 71 | 30 | 168 | 70 |
| Flat | 8 | 67 | 4 | 33 | 400+ | 545 | 19 | 2,267 | 81 |
| Hurdle | 31 | 24 | 98 | 76 | **Change in weight carried** | | | | |
| NHF | 28 | 27 | 77 | 73 | Less weight | 112 | 25 | 344 | 75 |
| None | 346 | 33 | 702 | 67 | More weight | 259 | 21 | 952 | 79 |
| **Raced over jumps previously** | | | | | Same weight | 473 | 19 | 2065 | 81 |
| Yes | 824 | 20 | 3,327 | 80 | No previous races | 346 | 33 | 708 | 67 |
| No | 366 | 33 | 742 | 67 | | | | | |

[1] **National Hunt Flat races are flat races run under National Hunt rules**
[2] **Number of jockey falls in previous seasons**
[3] **Number of unseated rider incidents in previous seasons**

The percentage of total horse falls that occurred within each category of jumping efforts is shown in Figure 1. Overall the highest proportion (34%) of falls occurred at 90-100% of jumping efforts. A higher proportion of falls occurred at 90-100% of jumping efforts when there were 12-14 fences (34%) compared to 80-89.9% of jumping efforts (19%) whereas there was a higher proportion of falls at both 80-89.9% (24%) and 90-100% (31%) of jumping efforts when there were 15-17 fences.

**Figure 1.** Percentage of total horse falls and percentage of total jumping efforts when races had 15-17 fences.

***Univariate analysis***

Univariable analysis identified 18 variables, which were taken forward to multivariable model building (Table S2): weight carried ($P \leq 0.001$), percentage wins jockey ($P \leq 0.001$), percentage F/UR jockey ($P=0.005$), runs to date ($P=0.001$), number of runs over jumps ($P \leq 0.001$), runs on same course ($P=0.004$), previous falls number ($P=0.056$), number of races within previous three months ($P \leq 0.001$), number of races within previous twelve months ($P \leq 0.001$), last race type ($P \leq 0.001$), first race type ($P \leq 0.001$), jumps raced previously ($P \leq 0.001$), days in racing ($P=0.003$), days in jumps racing ($P=0.001$), days since last jumps race ($P \leq 0.001$), wins as percentage of starts ($P \leq 0.001$), frequency of racing per year ($P \leq 0.001$) and previous jockey runs ($P \leq 0.001$). In addition to these variables, horse age was considered for inclusion in the model ($P=0.353$) based on previous research findings and biological plausibility (Pinchbeck *et al.,* 2002b; Pinchbeck *et al*., 2004b).

***Multivariate modelling***

Once controls were identified for each faller the data were refined to include 3,396 horses (849 controls and 2,547 cases) which were then taken forward for multivariable analysis. In the final model, eight variables were found to be significantly associated with horses falling: percentage of jockey wins, percentage of jockey falls/unseated rider, number of races within previous twelve months, horse age, days in jumps racing, last race type, wins as a percentage of starts and frequency of racing per year (Table 3). Hosmer Lemeshow goodness of fit statistics confirmed that the model showed a good fit ($P=0.173$) (Table S3). The likelihood ratio chi-square test of model coefficients reported a significance level of $P \leq 0.05$ at each step. ROC curve analysis indicated that the predictability of the final model was moderate (ROC: 0.651).

The results identified that the number of races the horse had run within the previous 12 months was associated with a decreased risk of falling. For each additional race ran, the chance of the horse falling decreased by 0.84 times. Horses that raced <5 times per year or

between 5-10 times per year were less likely to fall (26% and 31%, respectively) compared to those that raced 10 or more times a year (reference category).

Fall risk was also found to be associated with horses' performance, defined as wins as a percentage of starts, however none of the categories themselves were significantly linked to an increase or decrease in fall risk. Horse age did increase the risk of a horse experiencing a fall for every 1 unit (year) increase in age, horses were 1.2 times more likely to fall.

The number of days the horse had been in jumps racing was associated with a minor decrease in fall risk. However, the inclusion of this variable had a positive influence on model fit and predictability. Last race type was also included within the model to improve fit and predictability, but was not significantly associated with fall risk.

The jockeys previous seasons percentage wins was associated with the risk of horse falls with jockeys who had 0-4% wins and 5-9% wins having a significant increase in risk of 1.7 and 1.8 times respectively compared to those who had over 20% wins/runs. The jockeys previous seasons percentage of F/UR was associated with an increased risk of horse falls with jockeys who had over 20% F/UR having a 50% increased chance and those who had 15-19% F/UR having a 39% increased chance of falling compared to those who had 0-4% F/UR.

**Table 3.** Final multivariable model: horse and jockey level variables associated with the risk of horses falling whilst PTP racing in Ireland in 2013/14 & 2014/15 seasons (n=3396)

| **Backwards stepwise (LR)** | **Total (n=3,396)**<br><br>**n per category** | **Cases**<br><br>**(n=849, 25%)**<br><br>**n per category (%)** | **Controls (n=2,547, 75%)**<br><br>**n per category (%)** | **P-value[1]** | **Odds ratio** | **95% confidence interval** | **B-value[2]** |
|---|---|---|---|---|---|---|---|
| **Horse age** | 3,396 | 849 (25) | 2,547 (75) | 0.0001 | 1.209 | 1.112;1.314 | 0.190 |
| **Days in jumps racing** | 3,396 | 849 (25) | 2,547 (75) | 0.0001 | 0.999 | 0.999;1.000 | -0.001 |
| **Percentage wins jockey** | | | | 0.0001 | | | |
| 20+% | 314 | 52 (17) | 262 (83) | Ref[3] | | | |
| 0-4% | 942 | 274 (29) | 668 (71) | 0.004 | 1.718 | 1.190;2.482 | 0.541 |
| 5-9% | 1,020 | 275 (27) | 745 (73) | 0.001 | 1.794 | 1.266;2.541 | 0.584 |
| 10-14% | 783 | 162 (21) | 621 (79) | 0.253 | 1.233 | 0.861;1.767 | 0.210 |
| 15-19% | 271 | 59 (22) | 212 (78) | 0.063 | 1.500 | 0.978;2.301 | 0.405 |
| Not previously raced | 66 | 27 (41) | 39 (59) | 0.594 | 1.230 | 0.574;2.637 | 0.207 |
| **Percentage F/UR jockey** | | | | 0.0001 | | | |
| 0-4% | 72 | 31 (43) | 41(57) | Ref[3] | | | |
| Not previously raced | 66 | 27 (41) | 39 (59) | 0.563 | 0.815 | 0.408;1.628 | -0.204 |
| 20+% | 174 | 58 (33) | 116 (67) | 0.023 | 0.499 | 0.274;0.908 | -0.695 |
| 15-19% | 854 | 243 (28) | 611 (72) | 0.0001 | 0.389 | 0.229;0.659 | -0.945 |
| 10-14% | 1,751 | 396 (23) | 1,355 (77) | 0.0001 | 0.326 | 0.193;0.551 | -1.121 |
| 5-9% | 479 | 94 (20) | 385 (80) | 0.0001 | 0.291 | 0.166;0.509 | -1.235 |
| **Races 12 months** | 3,396 | 849 (25) | 2,547 (75) | 0.0001 | 0.841 | 0.792;0.893 | -0.173 |
| **Last race type** | | | | 0.888 | | | |
| PTP | 2,502 | 566 (23) | 1,932 (77) | Ref[3] | | | |
| Chase | 64 | 11 (17) | 53 (83) | 0.315 | 0.700 | 0.348;1.405 | -0.357 |
| Flat | 6 | 6 (100) | 0 (0) | 0.999 | $3.49 \times 10^{9}$ | 0.000 | 21.974 |
| Hurdle | 75 | 18 (24) | 57 (76) | 0.663 | 1.135 | 0.643;2.001 | 0.126 |
| NHF | 69 | 16 (23) | 53 (77) | 0.844 | 0.921 | 0.407;2.086 | -0.082 |
| None | 680 | 232 (34) | 448 (66) | 0.738 | 1.193 | 0.424;3.352 | 0.176 |
| **Wins percentage starts** | | | | 0.009 | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 30% + | 31 | 11 (35) | 20 (65) | Ref[3] | | | |
| Not previously raced | 724 | 245 (34) | 479 (66) | 0.324 | 0.535 | 0.154;1.857 | -0.626 |
| 0% | 2,259 | 500 (22) | 1,759 (78) | 0.140 | 0.565 | 0.265;1.205 | -0.571 |
| >0 – 9% | 162 | 38 (23) | 124 (77) | 0.975 | 1.014 | 0.418;2.464 | 0.014 |
| 10 – 19% | 159 | 38 (24) | 121 (76) | 0.759 | 1.146 | 0.480;2.738 | 0.136 |
| 20 – 29% | 61 | 17 (28) | 44 (72) | 0.676 | 1.227 | 0.470;3.203 | 0.205 |
| **Frequency of racing** | | | | 0.010 | | | |
| 10 + | 40 | 12 (30) | 28 (70) | Ref[3] | | | |
| Not previously raced/raced under 6 months | 1,626 | 483 (30) | 1137 (70) | 0.005 | 0.303 | 0.132;0.696 | -1.193 |
| 0 - <5 | 1,051 | 230 (22) | 795 (78) | 0.001 | 0.260 | 0.115;0.590 | -1.346 |
| 5 - <10 | 679 | 124 (18) | 547 (82) | 0.003 | 0.308 | 0.143;0.661 | -1.178 |
| **Model predictability**: area under receiver operating characteristic curve = 0.651 (CI: 0.630-0.673) | | | | | | | |
| **[1] P-value = probability**<br>**[2] B-value = bêta coefficient; estimated parameter representing change of 1n of odds in respect of the dependent variable**<br>**[3] Reference category** | | | | | | | |

## Discussion

The current study has identified a link between the risk of horse falls and horse experience with the risk decreasing when the horse had a greater number of starts within the previous 12 months. Further analysis of racing frequency found that the risk decreased when the horse had run less than five times or between five and ten times per year compared to over 10 times a year however caution should be taken with this result due to reduced numbers in the 10 times and over category. Links between horse experience and falls have also been identified in previous research (Pinchbeck *et al.,* 2002b; Pinchbeck *et al.*, 2004a; Williams *et al.,* 2013a; Pinchbeck *et al.,* 2003; Proudman *et al*., 2004). An 'over-racing' and fatigue effect has been previously suggested as a possible cause contributing to horses that had raced within the previous three months having an increased risk of falling (Pinchbeck et al., 2003). It has been previously noted that a high proportion of horses pull up in Irish PTP racing (30%) compared to the figure of 16.6% previously noted at Cheltenham racetrack (Mata *et al*., 2012; Smith *et al*., 2018) and it has been suggested that this high number may potentially be linked to fatigue as this has been noted as a valid factor within previous NH research (Ely *et al*., 2010). Horses that are raced more frequently may have increased levels of aerobic fitness which could increase their chances of completion. It would be of interest to further investigate the effect that racing frequency has on horse falls however this would require a very large data set due to the small number of horses, which race at high frequencies (>10 races per season) within PTP.

Days in jumps racing exerted minimal effect upon the risk of falls however the inclusion of this variable had a positive influence on model fit. Wins as a percentage of starts was also noted to be a significant variable however there was no notable significance found between each further sub category. One potential reason the percentage wins has an effect could be that the winning horses have better natural ability and/or greater fitness. Further work could investigate this potential link further through the use of a larger data set. There could also be a trainer effect however the current study did not investigate fall risk linked to individual trainers. The number of runs on the same course was significantly associated with a reduced risk of horse falls however this variable was not significant in the final model. Prior experience on the course being raced over would expose the horse to the terrain and layout of the course which could explain why these horses have a greater chance of successfully completing

subsequent races. Previous associations between prior runs on the same course and a reduced risk of falls have been noted (Pinchbeck *et al.,* 2004a; Proudman *et al.,* 2004; Williams et al., 2013a). Use of a larger data set may allow for this variable to be investigated further in future work.

Horse age was associated with an increased risk of horse falls. For every 1 unit increase in age there was a 1.2 times increased risk of falling however it should be noted that the largest proportion of horses were five year olds (32%) with horses between the ages of four and seven making up 85% of the racing starters recorded. Descriptive analysis showed that the percentage of horse falls declined from the age of four to 11 years, and then started showing an increase for horses aged 12 and 13 years and over. Point-to-point racing is often considered to be a starting place for potential top jump racing horses (ITM.ie. 2018) therefore an increase in the percentage of falls and decrease in the number of horses with increasing age could indicate that the more capable horses are progressing to other race types or alternatively could be leaving racing altogether. In a UK steeplechase study Pinchbeck *et al*. (2002b) found that there was a decreasing risk of horse falls with increasing age up to 12 years old followed by an increasing risk in older horses. It has been previously identified that race category is associated with the risk of falls in Irish PTP racing (Smith *et al*., 2018) with the highest risk of falls being noted in the six and seven year old maiden category races. It is interesting to note that the previous research has also identified that the risk of at least one fall occurring was not as high for the four and five year old maiden categories, compared to all other maiden races with the exception of maiden races for seven and eight year olds, seven year old and upwards and eight year old and upwards. Potentially this could be due to the restrictions in field size (maximum 17) in four-year-old races exerting an effect (Smith *et al*., 2018). Young horses are often less experienced which could account for the greater overall number of falls. It has been suggested that an increase in fall risk for older horses could be linked to sub clinical injury and fatigue (Pinchbeck *et al*., 2002b). Horse age and the link to race category as a risk factor warrants further research to identify whether there are any further modifications that can be made to improve racing safety.

Descriptive analysis showed that the highest proportion of falls occurred at 90-100% of jumping efforts. This is similar to findings by Pinchbeck *et al.* (2004a) who noted an initial increase in risk at the first fence was followed by a decline then by a steady increase in risk at later fences. A higher proportion of falls occurred at 90-100% of jumping efforts when there were 12-14 fences compared to 80-89.9% of jumping efforts whereas there was a higher proportion of falls at both 80-89.9% and 90-100% of jumping efforts when there were 15-17 fences. These findings could indicate that races with a larger number of fences cause an increased effect of fatigue. Further research that focuses on the potential relationship between number and type of obstacle, and racehorse fatigue is warranted.

Jockey experience had an impact on the risk of horse falls with an increase in risk noted when the jockey had a lower percentage of wins in previous seasons. This effect may be due to jockey skill however it is also possible that other factors, such as riding more experienced or capable mounts, could influence the decreased risk noted. Fall risk gradually reduced for horses from the age of four to 11 years, which could coincide with an increase in their race experience. It also seems likely that more capable jockeys would be matched with more capable mounts, perhaps due to working with better trainers who then retain them. However, work evaluating top jump jockeys in GB and Ireland found no significant difference in the fall/ride ratio when compared to 'non-elite' jockeys (Turner *et al*., 2002). The jockey's

previous season's percentage of F/UR was also associated with an increased risk of horse falls with jockeys who had high ratios of falls in previous seasons recording an increased risk in sequential seasons included within the current study. This effect could be due to the ability of the jockeys which could vary considerably depending on how much race riding and exercise riding experience these jockeys have, their natural ability, their physiological attributes (Hitchens *et al*., 2011b) and how much coaching they have had. It has been suggested by Connor *et al.* (2018) that larger numbers of jockeys in PTP racing and fewer racing opportunities could reduce the practice available for amateur jockeys. Further work could investigate these links further by focusing on more jockey details i.e. frequency of exercise riding, frequency of race riding, previous experience and fitness levels. The impact of quality of any training received by jockeys such as the Jockey Coaching Scheme implemented by the British Horseracing Authority and the Jockey Pathway offered by Work in Racing in Ireland, related to race performance is also warranted.

Overall there has been limited research investigating the link between jockey experience and horse falls. Pinchbeck *et al*. (2003) included previous jockey wins and fall rates in hurdle racing however these factors were not found to be significant. In contrast, Williams *et al*. (2013a) found that jockeys with reduced prior Grand National experience were associated with an increase in fall risk. Hitchens *et al*. (2011a) also found that in Australia provisionally licenced jockeys had a higher fall rate in both steeplechase and hurdle races. In Australian hurdle races a particularly higher fall rate was noted when riding in races with low prize money which could indicate that fall risk increases when inexperienced jockeys are placed on inexperienced horses. The results of the current study could be due to the amateur nature of PTP racing and jockeys racing with a wide range of prior experience. A more capable jockey would perhaps be more likely to make a correct judgement as to whether to pull up during the race which could aid in preventing falls from occurring (Williams *et al*., 2013b). Older jockeys (over 35 years) have been noted as having a higher fall rate if they had a previous ride earlier in the race meeting (Hitchens *et al.,* 2011a). Previous rides at the same meeting was a factor that the current study did not investigate however it would be of interest to investigate this further to establish whether there is a link between jockey fatigue and fall risk in P2P racing.

Although a range of factors were considered the current study did have some limitations. Retrospective data were recorded from online sources therefore the information available depended on what was available in the public sphere. Training methods have been noted to vary widely between trainers (Pinchbeck et al., 2004d) however no training data were included as obtaining these details were outside the scope of the current study.

**Recommendations**

The potential links between fall risk and horse fatigue warrant further investigation. Previous research has found that NH race performance may be improved through modification of training regimes (Ely *et al.,* 2010). Research which focuses on the preparation of horses for racing could identify factors that would enable horses to be better prepared for racing. Currently there are no qualification requirements for trainers within Irish PTP racing (Turfclub.ie, 2016) therefore the training of horses could be highly variable.

Horse experience has been found in the current research to potentially affect the risk of falling. The number of horses PU within PTP racing has been previously noted as being higher than in other racing types (Smith *et al*., 2018) indicating that horses could be underprepared for the challenges faced whilst racing. The inclusion of schooling races that allow horses to gain

jumping experience without added competitive pressures may help to reduce the risk of subsequent horse falls. Currently it is a requirement of jumps racing in Victoria (Australia) that horses are qualified to race. This qualification procedure requires that horses have schooled to the satisfaction of a steward over three approved hurdles (Racing Victoria, 2016). As a recommendation, similar measures could be employed within PTP racing to reduce the risk of horse falls. The inclusion of qualification procedures could result in horses which are less capable jumpers or that have been inadequately prepared being excluded from racing until a later date.

Jockey experience has also been indicated in the current study as influencing the risk of horses falling. Within PTP racing, jockeys may be linked to the individual trainer or secured for individual rides, resulting in a range of experience being present in races. It is possible that more inexperienced jockeys could tend to be placed on less accomplished or inexperienced horses in some instances, as suggested by Hitchens *et al.* (2011), which could further increase the risk of horse falls. Previous work has noted that jockey fall risk is particularly high in PTP racing compared to other forms of racing (Forero Rueda *et al.,* 2010). This is an area that warrants further research which hopefully would lead to the development of strategies to aid in reducing the risk of injury to the jockeys involved.

**Conclusion**

There are multiple factors which can affect the chances of a horse falling whilst PTP racing. there are some key associations that have been noted in the current research including the number of previous races run and jockeys experience. Further retrospective and prospective research is warranted in this area to provide more detail on each risk factor and its potential impact on the incidence of horse falls. Future research should look directly at the racing and training strategies utilised, for both the horse and jockey, within PTP racing. By increasing the understanding of why horses fall it should then be possible to consider modifications that could be made to improve safety whilst racing for both the horse and jockey.

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