DESCRIPTION OF VETERINARY EVENTS AND RISK FACTORS FOR FATALITY IN NATIONAL HUNT FLAT RACING THOROUGHBREDS IN GREAT BRITAIN (2000-2013)

SUMMARY

Background: No large-scale studies have described veterinary events occurring in National Hunt (NH) flat racing or investigated risk factors for fatality in this race type.

Objectives: To describe injuries and conditions requiring veterinary attendance on race-day and to determine risk factors for racehorse fatality in NH flat racing in Great Britain.

Study design: Retrospective cohort study (2000-2013)

Methods: Information from all NH flat races held over the study period, including horse, race and veterinary event report details, was combined. Veterinary events were described by type and anatomical structure(s) affected. Incidence per 1000 starts was calculated for all veterinary events and by event group, and stratified by certain horse- and race-level variables. Risk factors for fatality were determined using multivariable logistic regression modelling.

Results: Over the 14-year study period, 544 veterinary events were recorded, providing an overall incidence of 13.0 events per 1000 starts. The most common events were bone injuries (23.5%) and tendon or ligament injuries (16.4%). A fatal outcome was recorded for 117 horses (21.5% of all events), resulting in an incidence of 2.9 deaths per 1000 starts. Odds of fatality were 4.33 (95% CI = 1.59, 11.82, p=0.02) times higher in races restricted to conditional jockeys compared to those that were not. Horses starting in their first race experienced 1.44 (95% CI = 1.00, 2.08, p=0.05) times the odds of death compared to those that had raced before.

Main limitations: Classification of veterinary events frequently relied upon presumptive diagnosis.

Conclusion: This study provides a benchmark for the ongoing surveillance of veterinary events in NH flat racing. Results support the phasing out of NH flat races restricted to conditional jockeys and highlight the need for further work to establish why NH flat racing Thoroughbreds competing in their first race are at increased risk of death.

INTRODUCTION

National Hunt (NH) flat racing is an official form of jump racing in Great Britain (GB). NH flat races take place over a hurdle course that has been cleared of jumps, and offer novice jump horses the opportunity to gain racing experience before competing over obstacles. Horseracing carries an inherent risk of injury and death, and while jumping poses obvious additional risk, it is interesting that Thoroughbreds competing in NH flat races have repeatedly been shown to be at greater risk of injury and death compared to those in ordinary flat races. A 3-year survey, conducted in the late 1990s, of racehorse injures and clinical problems requiring veterinary attendance at British racecourses, determined a rate of 8.46 incidents per 1000 starts in NH flat races compared to 3.97 per 1000 starts for ordinary flat racing [1]. Reported fatality rates for NH flat racing vary from 3.8 – 4.7 deaths per 1000 starts, with the observed fatality rate for NH flat races consistently more than 4 times that of ordinary flat racing for the same study period [1-3]. In addition to all-cause mortality, NH flat racing Thoroughbreds have been found to be at substantially greater risk of fatal distal limb fracture [4] and sudden death [5] compared to those in ordinary flat racing.

It has been postulated that the increased risk of injury and death in NH flat racing may result from the fact that participating horses are typically older, competing over longer distances and are relatively inexperienced compared to their flat racing counterparts [1]. Increasing age and longer race distance are known risk factors for tendon injury [6], fatal distal limb fracture [7] and sudden death [5]. In terms of racing experience, Thoroughbreds competing in their first year of racing have been shown to be at increased risk of fatal distal limb fracture [8, 9], regardless of race type. A greater risk of fatality has also been demonstrated in horses starting in their first race of a new type; although NH flat racehorses were excluded from analysis in this study [3].

Further investigation is warranted to elucidate risk factors for all-cause fatality in NH flat racing so that potential incidence-reducing strategies can be developed and implemented. This study aims firstly to describe the events requiring veterinary attendance on race-day in NH flat racing, and secondly to identify risk factors for fatality in this race type.

MATERIALS AND METHODS

Study design and data collection

A retrospective cohort study of Thoroughbreds racing in NH flat races between 01 January 2000 and 31 December 2013 was conducted. Information for all events requiring veterinary attendance on race-day was extracted from the British Horseracing Authority (BHA) injury database. Additional data including horse demographics and race details were obtained from the Weatherbys racing database (www.weatherbys.co.uk).

Descriptive analysis of veterinary events

Definition of veterinary events

A veterinary event was defined as any event for which a horse required veterinary attendance on race-day and for which a clinical report was generated in the BHA injury database. A veterinary event could include more than one diagnosis and/or involve multiple body regions. Veterinary events were categorised into nine event groups using the definitions provided by Rosanowski *et al.* [10] (see Table 1 for a list of event categories).

All veterinary events were diagnosed by the attending racecourse veterinary surgeons and are primarily based on clinical examination alone. Fatality was defined as any veterinary event which resulted in the sudden death or euthanasia of a horse on race day.

Data analysis

Veterinary events and fatality were described as counts and percentages, by event group and by injury/condition within each event group. Veterinary events are also described by body area and anatomical structure(s) affected where appropriate.

Incidence rates were calculated as the number of veterinary events per 1000 starts, both overall and by event group. Incidence rates for select event groups were also stratified by age, sex, season, surface and going. A start was defined as a horse that crossed the starting tape, with all withdrawn horses excluded from incidence rate calculations. Confidence intervals for the rate estimates were not calculated, as the study population consisted of a consensus of all NH flat starts over the study period.

Risk factor analysis

Definition of case starts and non-case starts

Potential risk factors for fatality in NH flat racing were evaluated at the start level using univariable and multivariable logistic regression. A case start was defined as any start in a NH flat race that ended in fatality. All non-fatal starts were included as non-case starts. With horses competing on multiple occasions, a non-case start could reflect a case horse in a start prior to its death or a start made by a non-case horse.

Risk factors

A total of 42 risk factors (17 horse-related, 16-race related, 4 jockey-related and 5 trainer-related variables) were explored. Age variables were recorded in years and calculated using the convention in the northern hemisphere the official 'birth date' for all Thoroughbreds is 01 January. Sex was categorised as male or female. Number of starts was calculated from 01 January 2000. Average performance scores for horse, jockey and trainer, were calculated based on finishing position as described by Reardon *et al.* [6]. A conditional jockey was defined as an apprentice jump jockey under the age of 26 years who had won fewer than 75 races under Rules or whose 75th win occurred within the previous 6 months.

Details of all study starts and associated risk factor data were combined into an Excel spreadsheet (Microsoft 2013[a]). Prior to statistical analysis, the dataset was imported into STATA 14 I.C. (Statacorp[b]) and checked for internal validity. Quantitative variables were checked for outliers and related variables were cross-tabulated to check for consistency.

Study power

Based on the known number of fatalities within the dataset following descriptive analysis, a power calculation indicated the study would provide at least 80% power to detect an odds ratio of 2.4 or more, with 95% confidence, if the prevalence of exposure in the non-case population was between 7 and 82% (Epi-Info 7[c]).

Descriptive statistics

Descriptive statistics were produced for all categorical (proportion) and continuous variables (minimum and maximum values, median and interquartile range [IQR]).

Model building

Potential risk factors were screened using univariable logistic regression. Variables with a likelihood ratio test (LRT) P value ≤0.25 were considered for inclusion in a single-level, multivariable logistic regression model. Horse age and sex were considered for inclusion in the multivariable model as 'a priori' of interest.

To determine the 'best fit' for continuous variables, categories were generated using (rounded) quartile values and assessment of linearity made by comparing a model allowing for a non-linear relationship between the continuous variable and the log odds of death and a model assuming a linear trend. If there was no evidence of departure from linearity, visual assessment of the supported linear trend was made by plotting the log odds of death against the category mean. Quantitative variables were only modelled as continuous if both the LRT and graphical assessment supported linearity.

Pairwise correlation coefficients were calculated for all variables considered for inclusion in the multivariable model. To avoid issues of multi-collinearity, for highly correlated pairs of variables (P>0.9), the variable of least biological plausibility or interest was removed [11].

The Akaike Information Criterion and log likelihood values were used to rank the remaining variables and the model built using a forward selection process. Variables were retained in the multivariable model if the LRT P values were ≤0.05 [12]. The Wald test P value was used when comparing categories to the reference group.

Potential confounding was evaluated by resubmitting all of the variables from the univariable analysis, one at a time, into the final model and calculating the percentage change between the crude and adjusted odds ratios. Confounding was considered to be present if the addition of a variable altered the estimates by >10% [11], in which case confounding variables were retained. Biologically plausible interactions between variables in the final model and those taken forward to the multivariable analysis were assessed by comparing models including and excluding interaction terms using the LRT.

Adjustment for repeated horse starts and assessment of clustering within horse sire, jockey, trainer and racecourse was considered by adding each hierarchical level, individually, to all models as a random effect. Residual intraclass correlation coefficients (ρ) were assessed and an LRT comparing a model accounting for clustering with one that did not was performed.

Model fit and regression diagnostics

A summary measure describing the fit of the single-level multivariable model was produced by calculating the Hosmer-Lemeshow goodness-of-fit statistic and associated P value [12]. A receiver operating characteristic (ROC) curve was also produced to determine the predictive ability of the single-level multivariable model [13].

RESULTS

Descriptive results

During the study period, 40,770 NH flat race starts were made by 20,230 horses; 99 withdrawals, in which a horse that was intended to run did not start, were also observed. Horses made a median of two (IQR: 1–2) and a maximum of eight NH flat race starts. The median number of NH flat race starts per year was 3050 (range: 2184–3435). Races were held over 2416 days at 42 racecourses, with 3265 races run on turf surfaces and 143 races on all-weather tracks.

Table 1 summarises the number and incidence of veterinary events over the study period. A total of 530 veterinary events were reported for horses that started and 14 veterinary events for horses that were withdrawn. The overall incidence of veterinary events was 13.0 per 1000 starts. Further description of injuries/conditions by event group is given in Supplementary Item 1 – Table A.

Table 1: Number and incidence of veterinary events experienced by National Hunt flat racing Thoroughbreds in Great Britain as reported by race-day veterinarians (2000-2013).

Event Group	Total (% of total)[1]	Fatality (% of fatalities)	% Fatality within event group	Withdrawn prior to start (% within event group)	Incidence per 1000 starts	Incidence of fatality per 1000 starts
Total veterinary events	544	117	21.5	14 (2.6)	13.0	2.9
Bone injuries	128 (23.5)	90 (76.9)	70.3	0 (0.0)	3.1	2.2
Joint injuries	4 (0.7)	1 (0.9)	25.0	0 (0.0)	0.1	<0.1
Tendon and ligament injuries	89 (16.4)	9 (7.7)	10.1	0 (0.0)	2.2	0.2
Other soft tissue injuries	86 (15.8)	0 (0.0)	0.0	3 (3.5)	2.0	0.0
Gait observations	59 (10.8)	1 (0.9)	1.7	9 (15.3)	1.2	<0.1
Cardiac conditions	21 (3.9)	14 (12.0)	66.7	0 (0.0)	0.5	0.3
Respiratory conditions	72 (13.2)	1 (0.9)	1.3	0 (0.0)	1.8	<0.1
Metabolic or digestive conditions	63 (11.6)	1 (0.9)	1.6	1 (1.6)	1.5	<0.1
Miscellaneous conditions	31 (5.7)	0 (0.0)	0.0	1 (3.2)	0.7	0.0

[1]Totals will equal more than 100% as more than one type of injury or condition could be reported per veterinary event

Bone injuries

Bone injuries were the most common veterinary event observed on race-day (23.5%), with an overall incidence of 3.1 per 1000 starts. Most bone injuries were described as fracture or possible fracture (n=127; 99.2%). The majority of bone injuries involved the distal limb (n=88; 67.7%), within which the third metacarpus/metatarsus (MC3/MT3) was the most commonly affected structure (n=42; 47.7%). The pelvis (n=17; 44.7%) was the most common structure involved in bony injuries of the proximal limb. A summary of the location and outcome of bone injuries is shown in Supplementary Item 1 – Table B.

Tendon and Ligament Injuries

Tendon and ligament injuries were the second most common veterinary event observed on race-day (16.4%), with an overall incidence of 2.2 per 1000 starts. The extent of injury was recorded as moderate in 47.2% and severe in 32.6% of tendon and ligament events. The superficial digital flexor tendon (SDFT) was the most commonly affected structure (n=80; 89.9%). Injuries were also reported in the deep digital flexor tendon (DDFT; n=3; 3.4%), suspensory ligament (n=1; 1.1%), sesamoidean ligament (n=1; 1.1%), check ligament (n=1; 1.1%), plantar ligament (n=1; 1.1%) and stifle ligament (n=1; 1.1%).

Other soft tissue injuries

The incidence of other soft tissue injuries was 2.0 per 1000 starts; three horses with other soft tissue injuries were withdrawn before the start. The most common type of other soft tissue injuries were wounds and lacerations (n=60; 69.8%). Bruises or haematomas (n=11; 12.8%) and inflammation or soreness (n=10; 11.6%) were also reported.

Gait observations

Gait observations were recorded in 59 veterinary events. For nine (15.3%) of these events, the horse was withdrawn before the race, resulting in an incidence of 1.2 per 1000 starts. The majority of gait observations were reports of horses being lame, unlevel, stiff or poor movers (n=57; 96.6%).

Cardiac, respiratory, metabolic or digestive and miscellaneous conditions

The incidence of cardiac events was 0.5 per 1000 starts. Vascular catastrophe accounted for 66.7% (n=14) of cardiovascular events. There was a total of 72 respiratory events; most were episodes of epistaxis (n=29;

40.3%). Metabolic or digestive conditions were reported for 63 (11.4%) veterinary events; most were recorded as fatigue or heat exhaustion (n=48; 76.2%). The incidence of miscellaneous conditions was 0.7 per 1000 starts.

Fatality

A fatal outcome was recorded for 117 (21.5%) veterinary events resulting in an overall fatality incidence of 2.9 per 1000 starts. The majority of deaths resulted from injuries to bones (n=91; 77.8%). The third metacarpal or metatarsal bone was the most common site of catastrophic fracture (n=36; 85.7%). Nine tendon and ligament injuries were fatal; all involved the SDFT and were described as severe in eight cases (88.9%). One fatal SDFT injury also had a concurrent, unspecified bone injury. One fatal joint injury was recorded for a horse with a dislocated fetlock. All fatal cardiac events were the result of vascular catastrophe (n=14). Other reported causes of fatality include unspecified lameness (n=1), exhaustion (n=1) and epistaxis (n=1).

Stratified incidence rates

Figure 1 displays the distribution of incidence for each event group, all veterinary events and fatality over the study period. The rate of all veterinary events, event types and fatality varied over time, but without clear trends.

Figure 1: Incidence of race-day veterinary events as experienced by NH flat racing Thoroughbreds in GB (2000-2013), by year. (A) Total number of veterinary events, (B) fatality, bone, tendon or ligament injuries, (C) other soft tissue injuries, gait observations, cardiac conditions, (D) respiratory, metabolic and digestive and miscellaneous conditions.

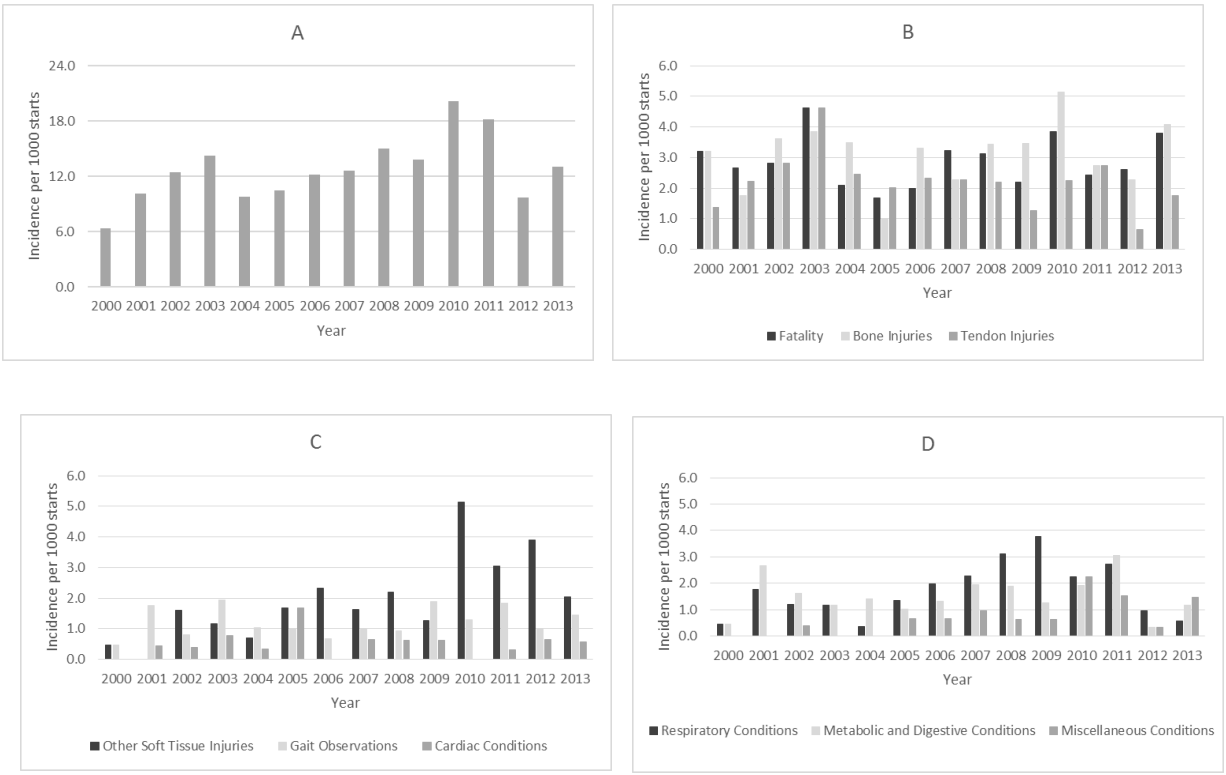

Table 2 summarises the overall incidence of veterinary events, and incidence of selected veterinary event groups, epistaxis and fatality, stratified by age, sex, season, surface and going.

Table 2: Incidence of race-day veterinary events as experienced by National Hunt flat racing Thoroughbreds in Great Britain (2000-2013), stratified by age, sex, season, surface and going.

Variable	No. of starts (%)	Incidence per 1000 starts (Number of Events)				
		All Veterinary Events	Bone injuries	Tendon and Ligament Injuries	Epistaxis	Fatality
Age (years)						
3	1663 (4.1)	9.02 (15)	1.80 (3)	0.00 (0)	0.60 (1)	1.80 (3)
4	14994 (36.8)	13.54 (206)	2.87 (43)	2.13 (32)	0.47 (7)	2.67 (40)
5	16601 (40.7)	13.13 (226)	3.55 (59)	2.29 (38)	0.96 (16)	2.95 (49)
6	7115 (17.5)	12.51 (92)	3.23 (23)	2.39 (17)	0.70 (5)	3.37 (24)
7+	397 (1.0)	12.59 (5)	0.00 (0)	5.04 (2)	0.00 (0)	2.52 (1)
Sex						
Male	27277 (66.9)	12.65 (352)	2.82 (77)	2.24 (61)	0.66 (18)	2.79 (76)
Female	13493 (33.1)	13.71 (192)	3.78 (51)	2.08 (28)	0.82 (11)	3.04 (41)
Season						
Spring	13811 (33.9)	13.97 (197)	2.97 (41)	1.81 (25)	0.72 (10)	2.39 (33)
Summer	3884 (9.5)	21.63 (84)	4.38 (17)	5.41 (21)	1.29 (5)	2.83 (11)
Autumn	9823 (24.1)	12.42 (126)	2.95 (29)	2.44 (24)	0.41 (4)	3.05 (30)
Winter	13252 (32.5)	9.89 (137)	3.09 (41)	1.43 (19)	0.75 (10)	3.24 (43)
Surface						
Turf	39261 (96.3)	12.86 (505)	3.01 (118)	2.14 (84)	0.71 (28)	2.80 (110)
All-weather	1509 (3.7)	16.57 (25)	6.63 (10)	3.31 (5)	0.66 (1)	4.64 (7)
Going						
On turf						
Heavy	3046 (7.5)	6.24 (19)	0.66 (2)	0.33 (1)	0.66 (2)	0.98 (3)
Soft	7833 (19.2)	9.96 (78)	1.91 (15)	0.77 (6)	0.51 (4)	2.30 (18)
Good to soft	8522 (20.9)	10.56 (90)	3.05 (26)	1.17 (10)	0.82 (7)	2.82 (24)
Good	13978 (34.3)	14.88 (208)	3.72 (52)	2.65 (37)	0.72 (10)	3.08 (43)
Good to firm	5674 (13.9)	18.51 (105)	3.70 (21)	5.29 (30)	0.70 (4)	3.70 (21)
Firm	197 (0.5)	25.38 (5)	10.15 (2)	0.00 (0)	0.00 (0)	5.08 (1)
Hard	11 (<0.1)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)
On all-weather						
Slow	62 (0.2)	48.39 (3)	16.13 (1)	0.00 (0)	0.00 (0)	16.13 (1)
Standard to slow	793 (1.9)	14.88 (11)	5.41 (4)	4.06 (3)	0.00 (0)	2.71 (2)
Standard	708 (1.7)	15.54 (11)	7.06 (5)	2.82 (2)	1.41 (1)	5.65 (4)

The overall incidence of veterinary events was lowest in 3-year-olds. The rate of tendon and ligament injuries increased with age. The incidence of fatality increased from 3 to 6 years of age but was lower again in horses aged 7 or older. The incidence of all veterinary events, bone injuries, tendon and ligament injuries and respiratory conditions was greatest in the summer, however rates of fatality were highest in winter. The highest incidence of veterinary events and fatality were recorded when the going was firm on turf surfaces and slow on all-weather tracks.

Risk factor analysis

Univariable analysis

The results of univariable analysis are presented in Supplementary Item 2: Tables A-D. Seventeen of the 42 risk factors screened at the univariable stage were put forward for consideration in the multivariable model. These included eight horse-level variables (age when entered training, age at first race, first start (yes/no), number of starts made and all race performance factors), 8 race-level variables (distance, surface, going, time of race, position on the race-card and races restricted to maidens, conditional jockeys and amateur jockeys) and the percentage of starts made by the jockey, since the start of the study period, where the horse failed to complete the race. Horse sex and age were carried forward as of a priori interest.

Multivariable analysis

The final model is presented in Table 3. Starts made in races restricted to conditional jockeys were 4.33 times more likely to end in fatality compared to starts in races not restricted to conditional jockeys. The odds of death in horses starting in their first race was 1.44 times greater than in those that had raced before. Age and sex were forced into the final multivariable model, however were removed as there was no apparent association with the risk of fatality. No significant interactions were identified.

Table 3: Results of multivariable logistic regression analysis investigating risk factors associated with fatality in Thoroughbred racehorses competing in National Hunt flat races in Great Britain (2000 – 2013). Horse is included as a random effect.

Risk factor for fatality	Odds ratio	95% confidence interval	LRT P value
First start			**0.05**
Yes	1.44	1.00 – 2.08	
No	1.00 (Ref)		
Restricted to conditional jockeys			**0.02**
Yes	4.33	1.59 – 11.82	
No	1.00 (Ref)		

Assessment of clustering

The addition of horse, horse sire, jockey, trainer or racecourse as a random effect to the single-level model resulted in a minimal change to the coefficient estimates and standard errors. Residual intra-class correlations coefficients (ρ) were estimated for horse (ρ=0.02), horse sire (ρ=0.05), jockey (ρ<0.01), trainer (ρ=0.07) and racecourse (ρ=0.03). Absence of clustering was also supported by the results of LRT.

Performance of the single-level model

The Hosmer-Lemeshow goodness-of-fit statistic was 0.15 (P=0.70), with an area under the ROC curve of 0.59.

DISCUSSION

This study has described the types and incidence of veterinary events reported in NH flat racing Thoroughbreds at GB racecourses and has, for the first time, identified risk factors specific for fatality in this type of racing. The overall incidence of veterinary events was 13.0 per 1000 NH flat starts. While this event rate cannot be directly compared to the 8.46 incidents per 1000 starts previously reported in NH flat racing as different event definitions were used [1], it is greater than the 9.4 events per 1000 flat starts observed for the same time period [10]. Injuries to bones, tendons and ligaments accounted for the majority of NH flat veterinary events. Similarly, a previous survey found that 81.0% of incidents requiring veterinary attention in NH flat racing resulted from musculoskeletal limb injury [1]. Bone and tendon or ligament injuries constitute a lower proportion (13.9%) of veterinary events in flat racing, with other soft tissue injuries the most common reason for veterinary attendance [10]. The higher rate of veterinary events recorded in NH flat racing

compared to flat racing is as previously described [1], however the differing distribution of event type is a novel finding. One possible explanation is that the risk factors, such as increasing horse age, longer race distances and relative inexperience, thought to predispose NH flat racing Thoroughbreds to increased risk of injury, may also render them more susceptible to more severe injuries. A fatal outcome was recorded for 70.3% of bone injuries and 66.7% of cardiac conditions in NH flat racing, compared to 43.7% of bone injuries and 22.6% of cardiac conditions in ordinary flat racing over the same time period [10]. Alternatively, this difference may reflect chronic under-reporting of other soft tissue injuries in NH flat racing.

The overall fatality rate was 2.9 per 1000 NH flat starts; lower than previously described rates of between 3.8 and 4.7 deaths per 1000 NH flat starts [1-3]. This may reflect the success of previously adopted risk-mitigating strategies, however sampling variation must also be considered; annual fatality rates for this study varied from 1.7 to 4.6 deaths per 1000 starts. The reported fatality rate is nearly 4 times greater than the 0.76 deaths per 1000 starts observed in flat racing over the same study period [10]; consistent with previous studies that have compared rates of death in the NH flat and ordinary flat racing [1-3]. More than 75% of fatalities resulted from catastrophic fracture, with most involving the MC3/MT3. Bone fatigue is a favoured mechanism for race-sustained fracture [14]. It is possible that as NH flat racehorses are typically older when entering training and are relatively inexperienced compared to their flat racing counterparts, that there has been limited opportunity for the bone to adapt to the stresses encountered during high-intensity exercise. Alternatively, older NH flat racing Thoroughbreds could be at increased risk of fracture as a longer life would provide greater opportunity for the accumulation of exercise-induced micro-damage [15].

Horses in races restricted to conditional jockeys were found to be at substantially greater risk of death. Similarly, the risk of fatal lateral condylar fracture of MC3/MT3 was found to be 3 times higher in horses competing in races restricted to non-professional jockeys [9]. Inexperienced jockeys may fail to detect the early signs of distress following injury, and continue to race, resulting in irreparable damage. Alternatively, conditional jockeys may be more likely to ride older or poorer quality horses, which may be more prone to injury. The proportion of NH flat events restricted to conditional jockeys has declined over the study period and these results support the continued reduction in races held under these conditions, although the overall impact on number of fatalities would be small.

Similar to our finding that horses competing in their first start were at increased risk of death, horses competing in their first race of a new type have previously been shown to experience a higher rate of fatality [3] and those in their first year of racing are at increased risk of fatal distal limb fracture [8]. This may result from inexperience of the racing environment, whereby the introduction of non-competitive 'practice' events may be of benefit. Alternatively, with increased risk of fatality observed early in a horse's career, consideration should be given to the potential impact of different training practices. Age at which the horse entered training was not found to be associated with risk of fatality in this study, however previous studies have documented the beneficial effects of early introduction of exercise in growing horses [16, 17]. Surface type and distance galloped in training have also been shown to be associated with risk of fatal distal limb fracture in racing Thoroughbreds [8]. Unfortunately, details of a horse's training regime were not available, as is usually the case in large studies such as this, which are based on retrospective data. Further investigations should seek to collect training information as well as veterinary histories for incorporation into a multivariable analysis of racing injuries, although the practicalities of gathering this additional information on a large scale may be challenging.

Although fatal race day events are likely to be well documented and less subject to misclassification, using such a broad case definition is not without limitation. It is possible that different types of fatal event have different risk factors and, indeed, a factor associated with increased risk for one type of event may be protective for another. It is difficult to determine what effect this would have on the results; however, a previous study that failed to determine unique risk factors for sudden death suggested a more generic approach was appropriate [5]. To investigate risk factors for specific causes of death in this population would require a considerably larger number of cases for each outcome.

No notable change in estimates was recognised following the inclusion of horse, horse sire, jockey, trainer or racecourse as a random effect to the final multivariable model. This likely reflects the low number of NH flat starts per horse during the study period (median = 2, IQR: 1-2). The area under the ROC curve suggested that the model's ability to discriminate between case and non-case starts is relatively poor [12]. This model should not be used for predictive purposes but is useful for generating hypotheses concerning fatality in NH flat racehorses. Within initial descriptive results, several of the known risk factors for injury and death demonstrated a similar pattern of effect to that reported in previous studies e.g. increased rate of fatality in

older horses and with firmer going. However, these variables were not identified as significant in the multivariable model, which may be due to the relative homogeneity of exposure status (e.g. limited variation in horse age) and limited number of observations and/or fatalities in certain variable categories.

Given that descriptions of veterinary events are frequently based on clinical examination alone, there is the potential that some of the reported injuries or conditions were misclassified. Bias may also have been introduced through the involvement of multiple parties in the management of case horses. It is possible that following severe but not fatal injury, a horse's representative might request euthanasia rather than treatment, especially in older, poorly performing or non-breeding animals. Recently it has become possible to identify, within the BHA database, whether fatal starts were subject to elective euthanasia or met with guidelines for immediate humane destruction. Future studies will need to consider whether elective euthanasia constitutes a racing fatality and the bias this might introduce.

Information regarding the number of race starts prior to 2000 was not available and therefore there is the potential that exposure status was underestimated for the horse performance variables, particularly at the beginning of the study. However, the impact of this is likely to be small given the relatively short length of a horse's NH flat racing career.

CONCLUSION

The descriptive information provided in this study is essential for monitoring trends in veterinary event occurrence in NH flat horses racing in GB and will serve as a reference for the continued assessment of racehorse safety and welfare by the BHA.

Results of risk factor analysis show that NH flat racing Thoroughbreds competing in races restricted to conditional jockeys and those at the very start of their race career are more prone to fatal injury. Consideration should be given to the continued phasing out of races restricted to conditional jockeys and further research is required to determine why the first start made poses additional risk of death. This has the potential to reduce the rate of fatality in NH flat racing.

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SUPPLEMENTARY ITEMS

Supplementary Item 1

Table A: The number and type of gait observations, cardiac, respiratory, metabolic or digestive and miscellaneous veterinary events experienced by NH flat racing Thoroughbreds in GB as reported by race-day veterinarians (2000-2013).

Event Group	Injury/Condition	Number	% of All Events	% of Injury/Condition Within Group
Bone Injury	Total	128	23.5	
	Fracture	100		78.1
	Possible fracture	27		21.1
	Unspecified	1		0.8
Joint Injury	Total	4	0.7	
	Sprain	1		25.0
	Effusion	2		50.0
	Dislocation	1		25.0
Tendon Injury	Total	89	16.4	
	Slight	16		18.0
	Moderate	42		47.2
	Severe	29		32.6
	Unspecified	2		2.2
Other Soft Tissue Injury	Total	86	15.8	
	Other	2		2.3
	Bruise/haematoma	11		12.8
	Laceration/wound/puncture	60		69.8
	Inflammation/sore	10		11.6
	Unspecified	3		3.5
Gait Observations	Total	59	10.8	
	Lame, unlevel, stiff, poor mover	57		96.6
	Stringhalt	2		3.4
Cardiac	Total	21	3.9	
	Vascular catastrophe	14		66.7
	Arrhythmia	6		28.6
	HR Raised	1		4.8
Respiratory	Total	72	13.2	
	Epistaxis	29		40.3
	Synchronous diaphragmatic flutter	2		2.8
	Scope – no abnormality detected	8		11.1
	Scope – mucopus	8		11.1
	Scope - other	3		4.2
	Whistling/roaring	4		5.6
	Gurgling	12		16.7
	Other	3		4.2
	Unspecified	3		4.2

Event Group	Injury/condition	Number	% of All Events	% of Injury/Condition Within Group
Metabolic and Digestive	Total	63	11.6	
	Choke	1		1.6
	Colic	1		1.6
	Fatigue, heat	48		76.2
	Mypoathic (tied up)	8		12.7
	Prolonged recovery	4		6.3
	Unspecified	1		1.6
Other	Total	31	5.7	
	Dermatitis, ringworm	14		45.2
	Urticaria or allergy	4		12.9
	Sarcoid	4		12.9
	Other	6		19.4
	Unspecified	3		9.7

[1] Gait observations included lame horses or those with poor/abnormal action but where no further diagnosis was made. [2] URT – upper respiratory tract.

Table B: Number and location of bone and tendon or ligament injuries experienced by NH flat racing Thoroughbreds in GB as reported by race-day veterinarians (2000-2013).

Region	Injury Location[2]	Number (%)[1]	Fatality (%)[1]	% Fatality in Anatomical Location
Bone Injuries				
Distal Limb	P1	12 (9.4)	10 (11.1)	83.3
	MC3 or MT3 condylar	15 (11.7)	12 (13.3)	80.0
	MC3 or MT3	27 (21.1)	24 (26.7)	88.9
	Sesamoid	4 (3.1)	3 (3.3)	75.0
	Carpal or tarsal	30 (23.4)	15 (16.7)	50.0
Proximal Limb	Radius or Ulna	3 (2.3)	3 (3.3)	100.0
	Scapula	2 (1.6)	1 (1.1)	50.0
	Tibia	12 (9.4)	11 (12.2)	91.7
	Patella	1 (0.8)	0 (0.0)	0.0
	Femur	3 (2.3)	2 (2.2)	66.7
	Pelvis	17 (13.3)	9 (10.0)	52.9
Other	Skull	1 (0.8)	0 (0.0)	0.0
	Unspecified	3 (2.3)	1 (1.1)	33.3
Tendon Injuries				
Distal Limb	SDFT	80 (89.9)	9 (100.0)	11.3
	DDFT	3 (3.4)	0 (0.0)	0.0
	Suspensory	1 (1.1)	0 (0.0)	0.0
	Sesamoidean	1 (1.1)	0 (0.0)	0.0
	Check	1 (1.1)	0 (0.0)	0.0
	Plantar	1 (1.1)	0 (0.0)	0.0
Proximal Limb	Stifle ligament	1 (1.1)	0 (0.0)	0.0
Other	Unspecified	1 (1.1)	0 (0.0)	0.0

[1]Within each event group [2] P1 = proximal phalanx, MC3/MT3 = third metacarpal/third metatarsal, SDFT = superficial digital flexor tendon, DDFT = deep digital flexor tendon

Supplementary Item 2

Table A: Univariable analysis results of horse-related risk factors[1] for fatality in Thoroughbred racehorses competing in NH flat races in GB (2000-2013). Horse included as a random effect.

Risk factor for fatality	Total number of starts n=40,770	Number of case starts (%) n = 117	Odds ratio	95% confidence interval	P value[2]
HORSE-RELATED VARIABLES					
Age at race (years)					**0.59**
3-4	16,657	43 (0.26)	1.00 (Ref)		
5	16,601	49 (0.30)	1.14	0.76 – 1.72	*0.52*
6-12	7,512	25 (0.33)	1.29	0.79 – 2.12	*0.31*
Sex					**0.65**
Male	27,277	76 (0.28)	1.00 (Ref)		
Female	13,493	41 (0.30)	1.09	0.75 – 1.60	*0.65*
Age entered training (years)					**0.24**
1-4	30,133	81 (0.27)	1.00 (Ref)		
5-7	10,570	36 (0.34)	1.27	0.86 – 1.88	*0.24*
Age at first race (years)					**0.19**
2-4	20,691	50 (0.24)	1.00 (Ref)		
5	15,040	52 (0.32)	1.43	0.97 – 2.11	0.07
6-8	5,039	15 (0.30)	1.23	0.69 – 2.20	0.48
Career length (years)					**0.30**
<1	33,332	100 (0.30)	1.00 (Ref)		
1+	7,438	17 (0.23)	0.76	0.46 – 1.28	*0.30*
First race start					**0.05**
Yes	20,002	68 (0.34)	1.44	1.00 – 2.08	0.05
No	20,768	49 (0.24)	1.00 (Ref)		
Number of starts made (all race types)					**0.14**
1	20,002	68 (0.34)	1.00 (Ref)		
2	12,329	28 (0.23)	0.67	0.43 – 1.04	*0.07*
3+	8,439	21 (0.25)	0.73	0.45 – 1.19	*0.21*
Average performance score					**0.10**
Previously unraced	20,002	68 (0.34)	1.00 (Ref)		
0-10	12,602	33 (0.26)	0.77	0.51 – 1.17	*0.22*
10-30	8,166	16 (0.20)	0.58	0.33 – 0.99	*0.05*
% wins to date					**0.13**
Previously unraced	20,002	68 (0.34)	1.00 (Ref)		
No prior win	17,637	43 (0.24)	0.72	0.49 – 1.05	*0.09*
Won at least once	3,131	6 (0.19)	0.56	0.24 – 1.30	*0.18*
% places to date					**0.10**
Previously unraced	20,002	68 (0.34)	1.00 (Ref)		
No prior places	12,513	33 (0.26)	0.78	0.51 – 1.18	*0.23*
Placed at least once	8,255	16 (0.19)	0.57	0.33 – 0.98	*0.04*
% fails to date					**0.13**
Previously unraced	20,002	68 (0.34)	1.00 (Ref)		
No prior fails	19,820	46 (0.23)	0.68	0.47 – 0.99	*0.05*
Failed at least once	948	3 (0.32)	0.93	0.29 – 2.96	*0.90*
Previous race type					**0.82**
Not NH flat	533	1 (0.19)	0.79	0.11 – 5.74	*0.82*
NH flat	20,235	48 (0.24)	1.00 (Ref)		
Change in run distance since last start of any race type					**0.48**
Decrease	4,454	8 (0.18)	0.62	0.28 – 1.41	*0.26*
Same	7,309	21 (0.29)	1.00 (Ref)		
Increase	9,005	20 (0.22)	0.77	0.42 – 1.43	*0.41*
Use of tongue strap					**0.26**
Yes	1,055	5 (0.47)	1.68	0.69 – 4.14	
No	39,715	112 (0.28)	1.00 (Ref)		*0.26*

[1]Results for first race type, use of eye wear and use of hood are not shown as no fatalities were observed in the exposed group. [2] Bold P values are based on the LRT and italicised P values the Wald test.

Table B: Univariable analysis results of race-related risk factors[1] for fatality in Thoroughbred racehorses competing in NH flat races in GB (2000-2013). Horse included as a random effect.

Risk factor for fatality	Total number of starts n=40,770	Number of case starts (%) n = 117	Odds ratio	95% confidence interval	P value[2]
RACE-RELATED VARIABLES					
Year					**0.80**
2000	2,184	7 (0.32)	1.00 (Ref)		
2001	2,262	6 (0.27)	0.83	0.28 – 2.47	*0.73*
2002	2,489	7 (0.28)	0.88	0.31 – 2.51	*0.81*
2003	2,593	12 (0.46)	1.45	0.57 – 3.69	*0.44*
2004	2,864	6 (0.21)	0.65	0.22 – 1.95	*0.44*
2005	2,961	5 (0.17)	0.53	0.17 – 1.66	*0.27*
2006	3,022	6 (0.20)	0.62	0.21 – 1.84	*0.39*
2007	3,086	10 (0.32)	1.01	0.38 – 2.66	*0.98*
2008	3,203	10 (0.31)	0.97	0.37 – 2.57	*0.96*
2009	3,184	7 (0.22)	0.68	0.24 – 1.96	*0.48*
2010	3,120	12 (0.38)	1.20	0.47 – 3.06	*0.70*
2011	3,290	8 (0.24)	0.76	0.27 – 2.10	*0.59*
2012	3,077	8 (0.26)	0.81	0.29 – 2.24	*0.69*
2013	3,435	13 (0.38)	1.18	0.47 – 2.97	*0.72*
Season					**0.60**
Spring	13,811	33 (0.24)	1.00 (Ref)		
Summer	3,884	11 (0.28)	1.19	0.60 – 2.35	*0.63*
Autumn	9,823	30 (0.31)	1.28	0.78 – 2.10	*0.33*
Winter	13,252	43 (0.32)	1.36	0.86 – 2.14	*0.19*
Time of race					**0.21**
Afternoon	38,106	106 (0.28)	1.00 (Ref)		
Morning/Evening	2,664	11 (0.41)	1.49	0.80 – 2.79	*0.21*
Race position in run sequence					**0.19**
Early and middle	1,258	1 (0.08)	1.00 (Ref)		
Late	39,512	116 (0.29)	3.71	0.52 – 26.56	*0.19*
Race distance (m)					**0.19**
2400-3200	20,338	55 (0.27)	1.00 (Ref)		
3300 - 3700	20,432	62 (0.30)	1.30	0.88 – 1.91	*0.19*
Number of runners					**0.61**
2 – 13	21,872	60 (0.27)	1.00 (Ref)		
14 – 25	18,898	57 (0.30)	1.10	0.76 – 1.58	*0.61*
Weight carried (lb)					**0.49**
130 - 153 lb	20,646	63 (0.31)	1.00 (Ref)		
153 - 168 lb	20,123	54 (0.27)	0.88	0.61 – 1.27	*0.49*
Value of race					**0.86**
2500 or less	25,471	74 (0.29)	1.00 (Ref)		
More than £2500	15,299	43 (0.28)	0.97	0.66 – 1.41	*0.86*
Listed race					**0.86**
Yes	789	2 (0.25)	0.88	0.22 – 3.58	*0.86*
No	39,981	115 (0.29)	1.00 (Ref)		
Restricted to maiden horses					**0.15**
Yes	6,514	13 (0.20)	0.66	0.37 – 1.17	*0.15*
No	34,256	104 (0.30)	1.00 (Ref)		
Restricted to conditional jockeys					**0.004**
Yes	332	4 (1.20)	4.36		
No	40,438	113 (0.28)	1.00 (Ref)	1.60 – 11.91	*0.004*
Restricted to amateur jockeys					**0.25**
Yes	4,549	17 (0.37)	1.36	0.81 – 2.27	*0.25*
No	36,221	100 (0.28)	1.00 (Ref)		
Surface					**0.20**
Turf	39,261	110 (0.28)	1.00 (Ref)		
All-weather	1,509	7 (0.46)	1.66	0.77 – 3.57	*0.20*
Going					**0.13**
Heavy, Soft, Good to Soft; Slow, Standard to Slow	20,202	48 (0.24)	0.71	0.46 – 1.11	*0.13*
Good; Standard	14,686	47 (0.32)	1.00 (Ref)		
Good to Firm, Firm, Hard	5,882	22 (0.37)	1.19	0.68 – 2.09	*0.62*

[1]Results for race class and selling/claiming race are not shown as no fatalities were observed in the exposed group [2] Bold P values are based on the LRT and italicised P values the Wald test

Table C: Univariable analysis results of jockey-related risk factors for fatality in Thoroughbred racehorses competing in NH flat races in GB (2000-2013). Horse included as a random effect.

Risk factor for fatality	Total number of starts n=40,770	Number of case starts (%) n = 117	Odds ratio	95% confidence interval	P value[1]
JOCKEY-RELATED VARIABLES					
Jockey performance score					**0.99**
0-12.25	22,459	66 (0.29)	1.00 (Ref)		
12.26-13.26	9,504	26 (0.27)	0.93	0.59 – 1.47	*0.76*
13.27-14.03	4,597	13 (0.28)	0.96	0.53 – 1.75	*0.90*
14.04-30	4,210	12 (0.29)	0.97	0.52 – 1.80	*0.92*
Jockey % win					**0.78**
0 -7.15	11,186	35 (0.31)	1.00 (Ref)		
7.16-9.37	8,178	20 (0.24)	0.78	0.45 – 1.35	*0.38*
9.38-11.69	8,921	28 (0.31)	1.00	0.61 – 1.65	*0.99*
11.7-100	12,485	34 (0.27)	0.87	0.54 – 1.40	*0.56*
Jockey % place					**0.85**
0-23.78	10,138	29 (0.29)	1.00 (Ref)		
23.79-28.85	8,602	25 (0.29)	1.01	0.59 – 1.74	*0.95*
28.86-33.33	8,539	21 (0.25)	0.86	0.49 – 1.51	*0.60*
33.33-100	13,491	42 (0.31)	1.09	0.68 – 1.75	*0.73*
Jockey % fail					**0.25**
0-0.47	1,043	4 (0.38)	1.00 (Ref)		
0.48-16.35	13,376	46 (0.34)	0.90	0.32 – 2.50	*0.84*
16.36-100	26,351	67 (0.25)	0.66	0.24 – 1.82	*0.42*

[1]Bold P values are based on the LRT and italicised P values the Wald test

Table D: Univariable analysis results of trainer-related risk factors for fatality in Thoroughbred racehorses competing in NH flat races in GB (2000-2013). Horse included as a random effect.

Risk factor for fatality	Total number of starts n=40,770	Number of case starts (%) n = 117	Odds ratio	95% confidence interval	P value[1]
TRAINER-RELATED VARIABLES					
Trainer performance score					**0.47**
0-12.17	17,234	56 (0.32)	1.00 (Ref)		
12.18-13.16	9,054	20 (0.22)	0.64	0.36 – 1.14	*0.13*
13.17-14.18	7,675	23 (0.30)	0.91	0.52 – 1.56	*0.72*
14.19-100	6,807	18 (0.26)	0.77	0.42 – 1.41	*0.40*
Trainer % win					**0.40**
0-6.52	11,596	41 (0.35)	1.00 (Ref)		
6.53-8.95	8,534	20 (0.23)	0.66	0.39 – 1.13	*0.13*
8.96-12.29	7,615	19 (0.25)	0.70	0.41 – 1.22	*0.21*
12.30-100	13,025	37 (0.28)	0.80	0.51 – 1.25	*0.33*
Trainer % place					**0.72**
0-22.86	11,076	36 (0.33)	1.00 (Ref)		
22.87-28.18	7,675	24 (0.31)	0.96	0.57 – 1.62	*0.88*
28.19-34.73	8,704	23 (0.26)	0.81	0.48 – 1.37	*0.44*
34.74-100	13,315	34 (0.26)	0.75	0.49 – 1.26	*0.31*
Trainer % fail					**0.45**
0-0.65	1,037	2 (0.19)	1.00 (Ref)		
0.66-3.16	2,267	10 (0.44)	2.80	0.49 – 15.89	*0.24*
3.17-14.29	14,364	38 (0.26)	1.49	0.30 – 7.46	*0.63*
14.30-100	23,102	67 (0.29)	1.68	0.34 – 8.24	*0.53*
Change of trainer[2]					**0.51**
Yes	1,005	4 (0.40)	1.40	0.52 – 3.82	*0.51*
No	39,765	113 (0.28)	1.00 (Ref)		

[1]Bold P values are based on the LRT and italicised P values the Wald test [2]Since last race start