An epidemiological study of the risk factors associated with falls of horses and riders in the sport of eventing.

Thesis submitted in accordance with the requirements of the University of Liverpool for the degree of Doctor in Philosophy

by

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ABSTRACT

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Eventing is an equestrian sport that appeals to amateur and professional riders across the world. A total of six riders died in the United Kingdom as a result of horse and rider falls during the cross-country phase of eventing competitions during 1999 and 2000. These fatalities raised concerns about the safety of this sport and initiated an epidemiological investigation aimed at reducing the risk of injury to horse and rider.

The objective of this study was to identify variables that increased or decreased the risk of a horse fall during the cross-country phase of an eventing competition. A matched prospective case-control design with a ratio of 3 controls per case was used to test associations between potential risk factors and horse falls. Data were collected for 180 cases and 540 controls. Cases were jumping efforts that resulted in a fall of the horse. Controls were matched by day and competition and were selected randomly from jumping efforts that did not result in a horse fall. Multivariable conditional logistic regression models were used to explain the association between variables and the risk of a horse fall. The data were analysed initially as a complete dataset. Subsequently the dataset was split and analysed on the basis of event type (one- and two-/three-day events) and fall type (rotational and non-rotational).

Two variables were present in four of the five models (fences requiring a landing in water and the combined variable of the angle and spread of the fence). The variables identified in two or more multivariable models as being associated with an increased risk of a horse fall can be separated into two groups. Firstly, there were the variables associated with the competitive nature of the rider. These included: the rider's knowledge of their position within the competition, their opinion of their speed of approach to the fence, previous refusals on the cross-country course by the partnership and cross-country tuition received by the rider (presumably in an effort to improve performance). Secondly, a group of variables relating to the fence and ground were identified as increasing the risk of a horse fall. These variables included: fences with a take-off or landing in water, non-angled fences with a spread of two metres or greater, angled fences and fences with a drop landing.

The data were examined for evidence of reporting bias. No evidence was found for response bias when the reporting of dressage and cross-country scores were analysed as a function of respondent category (case/control). The lack of response bias to the selected variables meant that it could be assumed that minimal reporting bias existed in the responses to similar areas of the questionnaire.

This study has identified a number of variables that were associated with an increased or decreased risk of a horse fall on the cross-country course of eventing competitions in Great Britain. Many of the course-/fence-level variables are modifiable and we have recommended changes in course design that should reduce the risk of horse falls and the associated risk of injury to horse and rider.

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CHAPTER ONE:

Introduction

INTRODUCTION

The aim of this chapter is to provide the reader with an overview of the sport of eventing and in particular, the risks that horses and riders incur whilst competing on the cross-country course. A brief history of the sport is provided, together with a summary of the format, competitor requirements and scoring of eventing competitions. Recent rule changes are discussed in the context of safety within the sport. Finally, the risks associated with horse falls, horse and rider injuries and fatalities are discussed with reference to the published literature.

The sport of eventing

Eventing is an equestrian sport consisting of three stages: dressage, cross-country and show jumping. The sport was first introduced at the Olympic Games in 1912 and was open only to army officers, to test the aptitude of military horses. The rules were altered in 1924 to allow civilians to compete in the sport. Eventing is currently one of few Olympic events in which men and women compete against each other on equal terms.

Eventing is a popular sport appealing to both amateur and professional riders, with 8,283 riders and 10,513 horses registered with British Eventing in 2003. The sport received much negative media coverage during 1999 and 2000, as a result of six rider fatalities at eventing competitions within the United Kingdom (U.K.). All six fatalities are believed to have resulted from a horse falling over a cross-country fence and landing on the rider. Compared with other equine competitions, the cross-country phase of eventing is considered to be a relatively high-risk activity (Dyson, 1996). Rodeo riders are stated to be the only equestrians with a higher risk of injury than event riders (Paix, 1999).

National sport

In Great Britain eventing is classified according to whether or not the competition is affiliated with the national governing body of the sport (British Eventing). Unaffiliated competitions can vary greatly in terms of the standards of cross-country fence design, medical cover and the ability of horses and riders that they attract. British Eventing (B.E.) officials run affiliated events according to the rules and regulations of the governing body. As a result, affiliated competitions tend to be of a more consistent standard than unaffiliated events, with strict guidelines regulating the conduct of events. Affiliated eventing competitions are held in Great Britain (G.B.) between March and October, dependent on weather and ground conditions.

International governing body of eventing

The Federation Equestre Internationale (F.E.I.) was founded in 1921. The F.E.I. is the international governing body of the sport of eventing recognised by the International Olympic Committee. The F.E.I. governs the rules and regulations that control International eventing competitions. International events are open to competitors from countries affiliated with the F.E.I., providing that they meet the qualification requirements of the competition. Currently, 130 countries are members of the F.E.I. with 22 countries hosting International three-day events.

This thesis refers to a study during which data were collected at affiliated events held in Great Britain. The following description of the sport of eventing refers only to G.B. affiliated events (although many factors may also apply to unaffiliated events).

Types and levels of eventing competitions

An eventing competition may be run over one, two or three days and is classified according to the level of difficulty of the cross-country course. There are 5 one-day event levels (in ascending order of difficulty): Intro, Pre-novice, Novice, Intermediate and Advanced. Two-day events are held at Novice and Intermediate levels with the aim of providing competitors with an introductory experience of the four cross-country phases required for a three-day event. Three-day events are also knows as Concours Complet Internationale (CCI) competitions, with the difficulty increasing from 1-star (1*) to 4-star (4*) level. All three-day events held in Great Britain are International competitions, and thus are run under the rules of the F.E.I.. The stages of a one-day event are run in the order of: dressage, show jumping and cross-country. Two-day events have dressage and show jumping on the first day and speed and endurance (incorporating the cross-country phase) on the second day. Three-day events have dressage on the first day, speed and endurance on the second day and show jumping on the final day. The speed and endurance day consists of four phases, Phases A, B, C and D (these are described in more detail below). Phase D is equivalent to the cross-country course at one-day events.

Three-day events begin with a veterinary inspection, to ensure that all horses are sound to compete. Two- and three-day events include a veterinary check of horses during the 10-minute rest prior to Phase D (the cross-country course). A panel consisting of a veterinary surgeon and two event officials has the authority to prevent horses from participating in the competition if they are considered unfit to continue. A veterinary inspection does not take place during one-day eventing competitions.

The three disciplines of eventing

Dressage

Each competitor is required to complete a dressage test of set movements. The level of difficulty and length (approximately 4 – 9 minutes) varies according to the level of the competition (B.E. rules, 2001). The purpose of the dressage test is to assess the horse's training and obedience as well as the ability of the rider. Event officials have the authority to prevent a combination from continuing in the competition if the safety of the horse and/or rider is believed to be at risk as a result of a lack of ability or training. At one- and two-day events (which do not have a veterinary inspection prior to the start of the competition), the dressage test also enables officials to detect lame horses and prevent them from starting the cross-country course.

Show jumping

The show jumping course consists of 8-12 obstacles constructed from lightweight poles resting in shallow cups. The number of fences, their maximum height and spread, and the speed at which the course should be completed varies according to the level of the competition (B.E. rules, 2001). At one-day events the show jumping phase tests the carefulness of the horse and, in the interests of safety, also prevents poor jumpers (eliminated for 3 refusals) from starting the cross-country course. The purpose of the show jumping phase at three-day events is to assess the horse's carefulness, fitness and agility following the rigours of the previous cross-country day. The origin of the show jumping phase at three-day events was to assess the military horse's ability to return to the battlefield following the exertions of the previous day.

Cross-country

One-day events

At one-day events the cross-country phase has course distances of 1,600-4,000 metres incorporating 18-40 jumping efforts. The maximum height and spread of the fences are similar to those permitted for the show jumping and vary according to the level of the competition.

Two-day events

The cross-country requirements of a two-day event represent a shortened version of the three-day event requirements. The cross-country stage of two- and three-day events incorporates four phases (A, B, C and D) that are completed in alphabetical order, with a 10-minute rest prior to starting phase D. Phases A and C (also known as 'roads and tracks'), require the horse to cover a total distance of 6,600-13,200 metres at average speeds of 160-220 metres per minute (m/min) along country lanes and through fields with no jumping efforts required. Phase B (also known as 'the steeplechase'), consists of a 1,280-2,310 metre length course of 4-7 steeplechase fences that are negotiated at racing pace (640-660 m/min). Phase D is equivalent to the cross-country course of one-day events, with course distances ranging from 2,200 to 4,200 metres incorporating 22 to 36 jumping efforts.

Three-day events

The cross-country stage of three-day events is similar to that of two-day events; however, the endurance requirements are greater, as indicated by the greater distances that are covered by the horse and rider. Phases A and C cover a combined distance of 10,120-14,300 metres. Phase B is a course of 5-10 steeplechase fences over a distance of 1,920-3,105 metres, which is required to be negotiated at a speed of 640-690 m/min.

The cross-country stage (Phase D) of three-day events is substantially longer than that of the one- and the two-day events, covering a distance of 3,900-7,980 metres including a maximum of 30-45 jumping efforts over solid obstacles.

A summary of the cross-country requirements for the different types and levels of eventing competitions is provided in the Appendix to this Chapter.

Cross-country course and fence design

Cross-country courses

Cross-country courses include a wide variety of obstacles. Each obstacle on the course is defined as such if it is numbered and its extremities are marked with red and white flags. The majority of obstacles consist of one fence (or element), requiring a single jumping effort. However, some obstacles consist of two or more elements situated in close proximity. The number of jumping efforts on a cross-country course is defined as the number of fences (or elements) on the course. Throughout this study the term 'fence' refers to a single element on a cross-country course and a 'jumping effort' is defined as the effort required to negotiate an element.

Fence construction

Cross-country fences are usually built from solid material that does not dislodge if the horse hits the fence. Exceptions include hedges and steeplechase fences that are designed to allow the horse to 'brush through' the top and frangible fences (discussed below). Common materials include timber and stone, whereas more 'artificial' fences may be constructed from plastic poles and even cars.

Frangible fences

In 2000, the International Eventing Safety Committee recommended that research was needed into the construction of deformable structures that could be incorporated into course design with the aim of reducing the incidence of horse falls. Recent research conducted by the Transport Research Laboratory (TRL) has led to the construction of 'knock-down' (frangible) fences that incorporate frangible pins that will break on impact, allowing a rail to drop. The pins have been designed to break only under 1530 kg vertical loading and in a downward direction, (variables that were identified by TRL to be associated with rotational falls). The breaking of a pin allows the rail to drop 20 centimetres at the centre of the fence, allowing the horse to lift its legs sufficiently to prevent a rotational fall. Twenty-nine frangible fences were tested at nine events in 2002, and a further twelve events included frangible fences in 2003. British Eventing plans to extend the use of frangible fences for all appropriate existing fences by the beginning of 2006 (Walcott, 2003). Any horse that hits a frangible fence hard enough to cause the pins to break incurs compulsory retirement under the rules of B.E., with the assumption that the horse would have fallen had the pins not broken.

Fence siting

The siting of fences is at the discretion of the course designer and is dependent on the amount and topography of land available and the level of difficulty required for the class. Fences may be built in open fields, in the hedge lines of fields, in woods, or at the edge or within man-made or natural water features. Fences may also be positioned to test the horse's ability to jump uphill or downhill. A course builder may also position fences within close proximity to each other as a test of the horse's athleticism, obedience and training.

Scoring of event competitions

The competition is won by the horse and rider combination with the lowest total penalty score obtained from the three tests of dressage, show jumping and cross-country. Scoring of the three stages has been designed so that each stage exerts a different influence on the overall competition result. The relative influence exerted by the dressage should be slightly more than that exerted by the show jumping, but considerably less than that exerted by the cross-country.

Dressage

Marks are awarded as integers on a scale between 0 and 10 for each specified set of movements that the horse is required to complete. The total marks awarded for the test are then subtracted from the maximum marks available to give the combination's penalty score. Dressage scores are awarded in penalty points, therefore; the lower the penalty point score, the better the performance. One-day event dressage tests are marked by a single judge and therefore result in penalty scores that are integers. Three judges are used to mark three-day event dressage tests. The average mark awarded by the judges for a three-day event competitor is rounded to two decimal places and then used to calculate their dressage penalty score.

In order that the dressage exerts the correct influence on the overall competition, a coefficient of 0.5 (0.4 for advanced tests) is used to multiply one-day event dressage penalty scores. International events run under F.E.I. rules use a coefficient of 1.5 to calculate the final dressage penalty scores.

Cross-country

During the cross-country phase of eventing, the criteria on which horses and riders are judged include: time, refusals, rider falls and horse falls. A rider fall incurs a penalty if the rider becomes separated from his/her horse in such a way as to necessitate remounting. A horse fall is recorded if the shoulders and quarters of the horse touch either the ground or the obstacle and the ground at the same time (B.E. rules, 2001). A horse fall usually leads to a fall of the rider and is therefore also known as a 'horse and rider fall'. A horse fall on the cross-country course incurs compulsory retirement whilst the second fall of a rider leads to elimination of the partnership. Rider falls and horse falls are only penalised if they occur as a result of attempting a numbered obstacle on the course.

Show jumping

Penalty points are awarded for: exceeding the optimum time, knocking fences down, refusals, rider falls and horse falls.

Grading of horses

Horses are graded according to the number of points that they have won in eventing competitions. Points are awarded to the top eight or more horses in a class, according to their final placing in the competition and the number of competitors in the class. In addition, points are awarded to unplaced horses that complete both show jumping and cross-country phases without jumping penalties. The number of points awarded varies according to the level of the competition and the placing achieved (B.E. rules, 2001). Horses with 20 points or less are classified as Grade 3, Grade 2 horses have 21-60 points and Grade 1 horses have more than 60 points.

For one- and three-day event competitions the grade of a horse and/or the number of points that it has won are used to restrict and permit access to certain levels of competition.

Recent rule changes

British Eventing publishes a rulebook on an annual basis that evolves in line with changes in the sport and recommendations from bodies such as the B.E. Rules Committee, B.E. Safety Committee and the F.E.I. Eventing Committee. Outlined below are some of the key rule changes that have been made in recent years, in an effort to improve horse and rider safety following the five rider fatalities in 1999 and one rider fatality in 2000. Some of these changes arose directly from recommendations made by the F.E.I. Eventing Committee (2001) and the International Eventing Safety Committee (2000).

Cross-country speed

In 2001, cross-country speeds were reduced for many of the classes run by British Eventing. The cross-country speeds of 600 m/min for Advanced classes, 570 m/min for Intermediate classes and 490 m/min for Pre-novice classes (rule 85, B.E. rules, 2000) were reduced to 570 m/min, 550 m/min and 450 m/min respectively (rule 85, B.E. rules, 2001).

Number of horses ridden per day

Prior to 2001, a rider was permitted to compete as many horses at an event as he/she wished. From 2001, riders were restricted to competing a maximum of five horses in the cross-country test in one day (rule 27, B.E. rules, 2001). Benefits of this rule change would be expected to include a reduction in rider fatigue, as well as helping the organisers allocate staggered starting times to riders who are competing many horses.

Stopwatches

Prior to 2000, riders were permitted to use stopwatches at all levels of competition as an aid to completing the cross-country course within the optimum time. From the beginning of 2000, the use of stopwatches has been banned at one-day event competitions of novice level and below, (B.E. rules, 2000). The rationale for the banning of stopwatches at the lower levels was to encourage riders to develop a 'feel' for their cross-country speed, rather than to rely on a stopwatch and perhaps try to go faster than was safe for their ability or their horse's fitness and / or level of training. This rule is a little controversial, as it could be argued that riders at all levels of competition should be riding without a stopwatch. Indeed, the pressure to go faster increases as the optimum cross-country speed increases with the level of the class.

Jumping from a standstill

The F.E.I. Eventing Committee produced a more rigorous definition of a refusal in 2001, which meant that jumping from a standstill would be penalised with a refusal. British Eventing already had rules in place to prevent a rider from trying to avoid incurring a refusal by encouraging their horse to jump from a standstill. (One of the high profile fatalities in 1999 anecdotally resulted from a horse trying to jump a fence from a standstill, somersaulting over the fence and landing on the rider.) The British Eventing rule referring to refusals was made more stringent, as the maximum fence height permitted to be jumped from a standstill was reduced from 50 cm to 30 cm in 2001 (rule 89a, B.E. rules, 2001).

Maximum number of cross-country refusals permitted

The F.E.I. Eventing Committee reduced the maximum permitted number of cumulative refusals on the cross-country course from five to four (F.E.I. Eventing Committee, 2001). In line with the F.E.I., British Eventing changed the rule referring to the maximum permitted number of refusals in 2002, so that any horse and rider combination incurring their fourth cumulative refusal on the cross-country course would be eliminated from the competition (rule 89, B.E. rules, 2002). It is logical to assume that this rule is designed to prevent horse and rider partnerships that are struggling to complete the course from continuing on the course and perhaps risking a fall.

Fall of horse

In 2001, British Eventing revised its rules on horse falls and stipulated that a horse fall would incur immediate compulsory retirement of the partnership from the cross-country course. This rule was also enforced by the F.E.I. in 2002 (F.E.I. Eventing Committee, 2001). Prior to the introduction of these rules, horses were eliminated only for their second fall on the cross-country course. The change to this rule was controversial, as some riders believed that if a horse was fit to continue then to do so would restore confidence to the partnership. However, others were concerned that a horse that had fallen might be injured, even if this was not immediately apparent. This rule prevents horses that have fallen from continuing and possibly risking further injury, or perhaps an additional fall through reduced performance.

Fall of rider

The British Eventing rule stating that a rider would be eliminated for a second rider fall on the cross-country course (rule 88, B.E. rules, 2001) was adopted by the F.E.I. in 2002 (F.E.I. Eventing Committee, 2001). The rationale for this rule is expected to be similar to the decisions discussed above for elimination of a partnership for their fourth cumulative refusal.

Alternative fences

From 2002, cross-country fences that were designed to give riders a choice of two or more routes through the obstacle, need no longer be limited by the routes having to be sited between a single set of flags. Two separate obstacles could now be built that were identified by flags marked with a black line (B.E. rules, 2002; F.E.I. Eventing Committee, 2001). The F.E.I. stated that the introduction of this rule should avoid the construction of twisty, time-consuming routes through an obstacle, which break the flow of the course and cause "dangerous and unnecessary strain on the lesser horses" (F.E.I. Eventing Committee, 2001).

Dangerous riding

In 2001, dangerous riding was defined as "any rider who affects the safety of any horse, rider or third party will be considered to have acted dangerously and will be penalised accordingly" (F.E.I. Eventing Committee, 2001). Penalties varied from 25 penalties added to the score to elimination. This definition of dangerous riding was included in the B.E. rulebook in 2002, although dangerous riding with a similar definition was also penalised during 2001, (B.E. rules, 2001).

Qualifications

The horse and rider qualification requirements for three-day event eligibility have been made more stringent over recent years in an effort to ensure that combinations are sufficiently experienced for the competitions they enter.

Safety equipment

British Eventing and the F.E.I. specify that riders must wear hats and body protectors whilst competing on the cross-country phase of eventing competitions. Hats must meet the current specified safety standards outlined in the rules. The hats believed to offer the greatest protection to riders are: PAS 015 and ASTM F1163, although others are also permitted (B.E. rules, 2001, 2002). Whilst the use of a body protector is mandatory, no safety standard is specified as compulsory, although Class 2 and 3 body protectors are advised to give more protection than Class 1 body protectors (B.E. rules, 2001, 2002). Body protectors cover the rider's torso with optional shoulder protection. Their function is to reduce soft tissue injury to the upper body and reduce injuries to the chest and spine in the event of a fall or a kick (Whitlock, 1999).

The risk of a horse fall

The risk of a horse fall during the cross-country phase of an eventing competition has been shown to be considerably less than the risk of a fall incurred by racehorses taking part in steeplechase or hurdle races. A retrospective study of eventing competitions by Singer et al. (2003) showed an incidence of one horse fall per 1,160 cross-country jumping efforts. Studies of National Hunt racehorses have reported falling rates of one fall per 447 jumping efforts in hurdle races (Pinchbeck et al., 2003) and one fall per 254 jumping efforts in steeplechase races (Pinchbeck et al., 2004b, *in press*). The risk of falling has also been expressed as the rate per 'start' (i.e. every time a horse starts a race or cross-country event course). The risk of a horse fall during the cross-country phase of an eventing competition was calculated in a retrospective study as 0.9 falls per 100 starts (Murray et al., unpublished data). Pinchbeck et al. (2002a) reported a risk of 2.1 horse falls per 100 starts in National Hunt hurdle races, whilst a risk of 5.6 horse falls per 100 starts was observed for steeplechase races (Pinchbeck et al., 2002b).

Risk of injury to event horses and riders on the cross-country course

Horse injury

Common injuries to event horses are reported to include: cuts, superficial digital flexor tendonitis, suspensory ligament desmitis and stifle trauma, with neck trauma and fractures associated with horse falls (Dyson, 1996). Recent work by Singer et al. (unpublished research) has shown an injury rate of 0.66% for competing event horses, with 0.45% of cross-country starters suffering an injury on the cross-country phase. The reported risk of injury to event horses is considerably lower than the risk of injury to National Hunt racehorses (2.8% of starters) reported by Pinchbeck et al. (2004a). A retrospective study of horses that fell during the cross-country phase of events during 2000 showed that 32% of horses that fell were injured (Murray et al., 2004a). Most of the injuries (83%) sustained were minor requiring no recuperation period. The prevalence of injury amongst fallers was not significantly associated with fence design or class of competition at one-day events ($P>0.05$). Univariable analysis showed an increased risk of injury to be associated with combination fences (OR=1.7, 95% confidence intervals (C.I.) 1.1, 2.9, $P=0.02$) and falls in which the horse landed in water (OR=2.1, 95% C.I. 1.1, 3.7, $P=0.01$) compared to single fences and falls on land respectively. The majority of water fences were also combination fences, meaning that the independent effects of the two variables could not be estimated by multivariable analysis, due to the strong confounding that was present. Horses falling in water were shown to be at a higher risk of incurring cuts from their fall as compared to horses that fell on land (OR=3.9, 95% C.I. 2.0, 7.4, $P<0.001$). The authors suggested that the higher risk of incurring cuts might be due to the gravel footing frequently used to provide a secure landing in water, as opposed to the grass or sand that surrounds fences 'on land'.

Unpublished statistics produced by British Eventing for the years 1996-1999 showed an incidence of 2.3 horse fatalities per 10,000 cross-country rounds (B.E., unpublished data). More recently, data collected retrospectively showed an incidence of 1.1 horse fatalities per 10,000 cross-country rounds and a fatality rate of 1.5% for event horses that fell (Murray et al., 2004a). Data available for the fatalities showed the reported cause of death or euthanasia to be fractures of the distal forelimb, neck or pelvis. The reduction in horse fatalities may be a reflection of the progression in course design in recent years. For example, it has anecdotally been noted that course designers have increased the use of fences with rounded profiles with the aim of decreasing the risk of injury to horse and rider in the event of a mistake. Higher fatality rates have been reported for racehorses at 29 fatalities per 10,000 flat or National Hunt race starts (Williams et al., 2001). Wood et al. (2000) reported an overall fatality rate of 28 per 10,000 racing starts, with rates for steeplechase, hurdle and flat races of 67, 49 and 9 fatalities per 10,000 starts respectively. Pinchbeck et al., (2002b) reported a fatality rate of 3.7% for horses that fell during steeplechase races in the U.K. and 7% for hurdle race fallers selected for inclusion in a case-control study (Pinchbeck et al., 2003). Recent research has therefore shown horse fatality rates expressed per start and per fall to be considerably higher for racehorses than for event horses. Suggested explanations for the higher fatality rates of racehorses when compared with event horses include the additional risk that falling racehorses have of being injured by other horses in the race, the greater speed at which they are travelling at the time of the fall and the high incidence (>75%) of non-jumping related fractures observed in racing Thoroughbreds (Parkin et al., 2003).

Rider injury

Five riders died in the U.K. as a result of horse and rider falls during the cross-country (XC) phase of eventing competitions during 1999. More recently, a rider died during 2000 and another in 2003 from injuries sustained following horse falls in B.E. eventing competitions. These fatalities raised concerns about the safety of this sport and initiated investigations aimed at reducing the risk of injury to horse and rider. Thus, the International Eventing Safety Committee was formed by the British Horse Trials Association (now British Eventing) and the F.E.I. to review the sport. They concluded in their report that "everything should be done to prevent horses from falling" (International Eventing Safety Committee, 2000).

Horse falls have a high potential for rider injury, particularly if the horse lands or rolls on the rider. A horse fall that occurs as a consequence of a failed jumping effort may cause the rider's head to hit the ground from a height of approximately three metres (Silver and Lloyd Parry, 1991). Additionally, the horse with a mean bodyweight of approximately 511 kg (Ellis et al., 2002) may then land on the rider. Whitlock (1999) showed a rider injury rate of 1.1% and a fatality rate of 0.12 rider fatalities per 1000 cross-country rides (2/16940) from data obtained from 54 days of XC competition that took place between 1992 and 1997 in the U.K.. Both of the rider fatalities resulted from the horse falling and landing on the rider.

Paix (1999) collected data from 35 non-randomly selected events in South Australia between 1990-1998. The reported rate for riders seeking medical treatment for injuries was 0.88% (37/4220) per competitor per event. All recorded injuries occurred during the cross-country phase, usually as a result of a horse and/or rider fall at an obstacle. Head and neck injuries accounted for 51.4% of all recorded injuries. Seventy percent (26/37) of injured riders were referred to hospital, of which 46% (12/26) were admitted. One fatal and one life threatening injury were recorded, both of which resulted from a horse somersaulting over a fence and landing on the rider. The rider fatality rate was 0.24 fatalities per 1000 competitors. Paix (1999) noted a trend between the level of the event and rider injury, with higher injury rates being observed at the more advanced level of events, although no statistical analysis of the data was conducted.

General horse falls as a cause of rider injury

The following literature refers to horse falls in general, some of which may not have occurred as a result of a failed jumping attempt. Unfortunately, information as to the exact nature of the horse falls was omitted from many of the papers. The falls are likely to have included two additional types of horse falls. Firstly, horse falls that were not associated with a jumping effort, but were caused by the horse stumbling or slipping. Secondly, falls of rearing horses (i.e. a horse that was standing on its hindlegs only), which lost balance and fell over backwards.

Crushing of the rider, as a result of a horse fall, has been attributed to 6.3% (Edixhoven et al., 1981), 7% (Hobbs et al., 1994) and 14% (Chitnavis et al., 1996) of equestrian-related injuries recorded in hospitals or accident service centres. Eleven percent (2/18) of all horse-related deaths that occurred in South Australia during an eleven-year period were reported to have occurred as a result of the rider being crushed by the horse following a fall (Pounder, 1984). A study of horse shows by Bernhang and Winslett (1983) revealed that 22% of reported rider injuries were caused by horses falling or slipping.

Hobbs et al. (1994) observed that horse falls were associated with the more serious rider injuries, whilst commonly identified injuries including fractures to the pelvic ring and ribs as well as major ligament injuries to the knee were noted by Edixhoven et al. (1981). Barone and Rodgers (1989) conducted a 14-year review of paediatric equestrian injuries and reported that horse falls were responsible for all five pelvic fractures recorded and 10% of all injuries were as a result of either a horse fall or the horse stepping on the rider.

Horse and/or rider falls as a cause of rider injury

Much of the published research on falls experienced by riders does not distinguish between rider only falls and horse and rider falls. In addition, many of the studies refer to horse-related injuries, which will include injuries sustained by horse-handlers as well as riders. A review of the literature indicates that falls in general (horse and/or rider falls), have been associated with high rates of human injury. A summary of research that is of particular relevance to this study is provided below.

Falls have been associated with between 64% and 84% of horse-related injuries sustained by riders or horse handlers recorded by accident and emergency departments of a hospital or by accident services (Gierup et al., 1976; Barber, 1973; Lloyd, 1987; Moss et al., 2002). Data collected at a specialist Head Injury Unit revealed that that 90% (53/59) of injuries were due to falls and severe head injuries were observed in 5% of the patients (McGhee et al., 1987). Kriss and Kriss (1997) studied 30 patients with equine-related neurosurgical trauma and noted that falls were responsible for the majority of injuries (60%) and crushing by the horse was responsible for 13% (4/30) of injuries. Geirup et al. (1976) reported compression resulting from the rider being trapped between the horse and the ground or a fixed object to account for 5% (8/174) of accidents, with 38% (3/8) of these injuries being classified as severe.

Moss et al. (2002) reported that of the 78.8% of injuries attributable to falls, isolated upper limb injuries were identified in 31.7% of cases and isolated head injuries were diagnosed in 17.6% of cases. Moss et al. (2002) concluded that a comparison between their data and previously published work (Whitlock, 1999) indicated that the number of upper limb injuries and in particular wrist injuries as a proportion of all injuries were increasing, perhaps as a result of decreasing head injuries due to increased use of head protection.

Horse and/or rider falls as a cause of rider fatality

Ingemarson et al. (1989) analysed 53 trauma-related fatal riding injuries that took place in Sweden between 1969 and 1982. Thirty-eight of the fatalities occurred whilst riding a horse. Rider falls were stated to be responsible for 53% (28/53) of all fatalities whilst horse falls caused 11% (6/53) of the fatalities, one of which occurred during a cross-country event. This gives an overall rate of 64% (34/53) of horse-related fatalities and 89% (34/38) of riding fatalities that were caused by a fall. Only two mounted riders were considered to be using adequate helmets. Aronson and Tough (1993) who collected data on all horse-related fatalities that took place in Alberta (1975-1990) reported similar figures. They also found the majority of fatalities (65.8%) to be caused either by a rider fall or by the horse falling and crushing the rider. They stated that the use of protective headgear was minimal with only one rider in the study using an approved helmet.

Buckley et al. (1993) reported the incidence of hospitalisation and fatality rates related to falls from horses in New Zealand of 23.7 and 0.17 respectively, per 100,000 people per year. Head injuries were the most common cause of fatality (61%) and hospitalisation (36%).

The risk of injury to event riders compared with the risk of injury in other sports

Comparisons of the rate of injury to riders participating in different sports are difficult as the definition of 'injury' may vary between studies. For instance, Paix (1999) stated that any rider requiring medical treatment for a horse-related injury at an event would be classified as injured (0.88%), but did not specify that their injury should prevent them from continuing in the competition. Whitlock (1999) defined injury as having occurred if 'the rider required medical assistance and was considered unfit to continue riding that day'. The injury rate of 1.1% reported by Whitlock (1999) was thus higher than the rate reported by Paix (1999), despite the stricter definition used. Turner et al. (2002) compared rider injury rates for flat and jump racing in Great Britain and Ireland, defining injuries as those that were recorded in writing by the medical officer at the racecourse. Data collected for the period 1992-2000 showed an overall incidence rate of falls per ride to be 0.41% for flat racing and 6.1% for jump racing. Injury rates per fall were approximately 40% for flat racing (G.B. and Ireland) and ranged from 12.3% for jump racing in Ireland to 17.7% for jump racing in G.B.. Fatal injuries were very uncommon in race riding, the reported rate for 1975-2000 being 4.2 fatalities per million flat racing rides and 6.5 fatalities per million jump racing rides. The risk of injury has therefore been shown to be much higher for jump race jockeys than for event riders whilst the risk of fatality is lower for jump race jockeys than for event riders. An explanation for the increased risk of a fatality for event riders when compared to jump race jockeys may be related to the difference in stirrup length. Jockeys ride with a shorter stirrup length than event riders, thus giving jockeys less stability in the saddle. Therefore, jockeys are more likely than event riders to be thrown clear in the event of a horse fall, thus reducing their chances of being crushed by the horse.

Paix (1999) states that professional rodeo riders are the only equestrians with a higher rate of injury than event riders (0.88% per competitor per eventing competition). Indeed, Griffin et al. (1987) reported horse riding rodeo events (saddle bronc and bareback competitions) to have an overall injury rate of 30% (24/80). A larger study by Butterwick et al. (1996) reported an injury rate of 2.4 per 100 competitor exposures (94/3882) for all types of rodeo competition, and 2.9 injuries per 100 competitor exposures (41/1420) in saddle bronc and bareback riding rodeo competitions. The risk of injury that has been reported for horse riding rodeo riders is thus far greater than for event riders.

When making comparisons of injury rates between riders in different studies it is important to consider two points. Firstly, the proportion of riders' using protective helmets and/or body protectors has increased over recent years (Chitnavis et al., 1996). Secondly, whilst some leisure riders may choose not to use a protective helmet, riders competing in disciplines such as racing or the cross country phase of eventing are required to use an approved helmet and body protector. For example, in the study by Grossman et al. (1978) of equestrians seen at an American hospital, fewer than 20% of the 110 injured riders had been using a protective helmet at the time of the accident. In contrast, all the event riders included in Whitlock's (1999) study were using approved hats and body protectors.

The incidence rate for rider injury (0.88%) observed by Paix (1999) was considerably higher than the injury incidence rates recorded by Chapman and Oni (1991) at a U.K. Grand Prix circuit for motorcycle racing (0.24%) and car racing (0.14%). Paix (1999) estimated that cross-country riding had an injury rate of one per 14 hours and was therefore more than 70 times as dangerous as all other forms of horse riding combined.

Avery et al. (1990) analysed fatalities that occurred in England and Wales as a result of sporting and leisure activities during 1982-1988. Horse riding was associated with the third highest fatality rate with a mean death rate of 0.58 per one million adult participations per annum. Mountaineering/potholing and motor sports were the only activities with higher fatality rates than riding with 2.31 and 1.00 deaths per million adult participations per annum respectively. Horse riding, and in particular eventing, should therefore be considered as a sport with one of the highest fatality rates in the U.K..

Epidemiological research

To date, much of the scientific research related specifically to eventing has focussed on the frequency and nature of injuries sustained by riders (Whitlock, 1999; Paix, 1999), or the physiological responses of horses during cross-country courses (Kohn et al., 1995; Munoz et al., 1999; Andrews et al., 1995; Ecker and Lindinger, 1995; Kohn and Hinchcliff, 1995; Schroter et al., 1996). To our knowledge, the study by Singer et al. (2003) was the first epidemiological study conducted within the sport of eventing. Prior to the publication by Singer et al. (2003), epidemiological research relating to the sport of eventing had been conducted only as part of larger studies. For example, Nicholl et al. (1995) compared the risk of injury for horse riding (including cross-country trials, general riding, polo, dressage, etc.) with other sports, in a study of sports and exercise-related injury in the U.K..

Epidemiological studies have been used to investigate risk factors associated with falls, injuries and fatalities of racehorses. Prospective cohort studies of racehorses have been used to identify risk factors associated with horse falls in steeplechase races (Pinchbeck et al., 2002b) and musculoskeletal injuries sustained in training (Cogger et al., 2003). Case-control studies have enabled the investigation of the risk factors associated with: fatal distal limb fractures occurring during racing (Parkin et al., 2003), training injuries of Thoroughbred racehorses (Verheyen et al., 2003) and horse falls in hurdle races (Pinchbeck et al., 2003).

A case-control study design was used by Singer et al. (2003) for their retrospective study of horse falls during the cross-country phase of eventing competitions. Fifty cases and 150 unmatched controls were selected from B.E. eventing competitions in 1999 and data were analysed for risk factors associated with horse falls during the cross-country phase. Multivariable analysis revealed that the risk of falling was significantly associated with variables associated with the fence, event and rider (Table 1).

Table 1. Multivariable conditional logistic model of risk factors associated with falls of horses in the XC phase of eventing competitions (Singer et al., 2003).

Variable	Description	Odds ratio	95% C.I.	P-value
Total number of jumping efforts per course	Increase of one jumping effort	0.81	0.67-0.97	0.01
Total number of jumps per course	Increase of one jump	1.56	1.21-2.02	<0.001
Number of the jumping effort (after effort number 20)	Increase of one jumping effort	1.20	1.02-1.42	0.02
Cross-country start order	Increase of one in start order	0.98	0.96-0.99	0.002
Ascending spread	Ascending spread vs. not ascending spread	0.25	0.08-0.76	0.01
Ditch in front	Ditch in front vs. no ditch in front	5.77	1.09-30.68	0.04
Siting	Flat	Ref.		
	Up	2.48	0.61-10.05	
	Down	8.41	2.46-28.78	0.001
Rider occupation	Full-time eventer	Ref.		
	Full-time horses other	10.20	1.08-96.67	
	Full-time job not horses	19.41	2.01-187.41	
	Student	19.75	2.00-194.61	
	Unknown	22.88	2.37-220.61	0.01

In addition to providing useful information on risk factors for horse falls, the study by Singer et al. (2003) provided an important test of the compliance of British Eventing staff, event officials and riders during data collection. The F.E.I. Veterinary Committee funded the retrospective study, thereby giving their crucial support for data collection at international eventing competitions in Great Britain. The support of British Eventing and the F.E.I. was fundamental to the success of the work reported in this thesis.

Previous studies have identified variables that were associated with an increased or decreased risk of a fall of horse occurring whilst jumping cross-country fences (Singer et al., 2003) or National Hunt hurdle and steeplechase fences (Pinchbeck et al., 2003; Pinchbeck et al. 2002b). The retrospective study by Singer et al. (2003) was based on a sample of 50 cases and 150 controls selected from a three-week period in 1999. The results reported in this thesis are based on data obtained from 180 cases and 540 controls recruited during the 2001 and 2002 B.E. eventing seasons. The large sample size and prospective nature of the study reported in this thesis will further the knowledge of risk factors that increase or decrease the risk of a horse fall on the cross-country course of eventing competitions in Great Britain. Based on the findings of the study, logical strategies can be designed which aim to reduce the risk of horse falls and thus the risk of injury to both horse and rider.

APPENDIX: CHAPTER ONE

Table 1. Cross-country speeds, times, distances and number of jumping efforts used in eventing competitions during 2001 and 2002. (B.E. rules, 2001, 2002).

Class	Course length (m)	Speed (m/min)	Number of jumping efforts	Maximum fence height (m)	Maximum base spread (m) (fences with height)
One-day events					
Intro	1600-2800	450	18-25	0.90	1.50
Pre-novice	1600-2800	450	18-25	1.00	1.80
Novice	1600-2800	520	18-28	1.10	2.10
Intermediate	2400-3620	550	22-32	1.15	2.45
Advanced	3250-4000	570	25-40	1.20	2.80
Two-day events (Phase D)					
Novice	2200-3200	520	22-32	1.10	2.10
Intermediate	3200-4200	550	24-36	1.15	2.45
Three-day events (Phase D)					
CCI 1*	3900-4940	520	30 (max.)	1.10	2.10
CCI 2*	4950-6050	550	35 (max.)	1.15	2.40
CCI 3*	5700-6840	570	40 (max.)	1.20	2.70
CCI 4*	6840-7980	570	45 (max.)	1.20	3.00

Table 2. Cross-country speeds, times, distances and number of jumping efforts used in phases A, B and C of two- and three-day eventing competitions during 2001 and 2002. (B.E. rules, 2001, 2002).

	Phase A (roads and tracks)	Phase B (steeplechase)	Phase C (roads and tracks)
Two-day events			
Novice	220 m/min 2200-4400 metres No jumping efforts	640 m/min 1280-1600 metres 4-5 jumping efforts	220 m/min 4400-7700 metres No jumping efforts
Intermediate	220 m/min 2200-4400 metres No jumping efforts	660 m/min 1980-2310 metres 6-7 jumping efforts	220 m/min 4400-8800 metres No jumping efforts
Three-day events			
CCI 1*	220 m/min 3960-5060 metres No jumping efforts	640 m/min 1920 metres 5-7 jumping efforts	220 m/min 6160-7700 metres No jumping efforts
CCI 2*	220 m/min 3960-5060 metres No jumping efforts	660 m/min 2310 metres 6-8 jumping efforts	220 m/min 6160-7700 metres No jumping efforts
CCI 3*	220 m/min 4400-5500 metres No jumping efforts	690 m/min 2760 metres 6-8 jumping efforts	220 m/min 6600-8800 metres No jumping efforts
CCI 4*	220 m/min 4400-5500 metres No jumping efforts	690 m/min 3105 metres 8-10 jumping efforts	220 m/min 6600-8800 metres No jumping efforts

CHAPTER TWO:

Why do horses fall whilst competing in eventing competitions?

Analysis of course-level and event-level variables.

Abstract

Eventing is a popular international equestrian sport which has Olympic status. In 1999 five riders died in eventing competitions in the United Kingdom as a result of horse falls on the cross-country course. In an effort to decrease the risk of human and equine death or injury, a case-control study was carried out to identify variables that increased or decreased the risk of a horse fall on the cross-country phase of an eventing competition. Data were collected for 180 cases (horse falls) and 540 controls (1:3 ratio). Cases were jumping efforts that resulted in a fall of the horse. Controls were matched by competition and day (but not class) and were selected randomly from all jumping efforts that did not result in a horse fall. Data related to course- and fence-level variables, which might be associated with horse falls, were collected on the day of the event.

Conditional logistic regression was used to analyse the data. Risk factors for horse falls in the final multivariable model were: jumps which involved taking off or landing in water (OR=17.7, 95% confidence intervals (C.I.) 5.5, 56.6, $P<0.001$) and (OR=3.2, 95% C.I. 1.5, 6.9, $P<0.01$) respectively, the presence of a drop landing (OR=2.9, 95% C.I. 1.6, 5.5, $P<0.001$), angled fences (OR=3.8, 95% C.I. 1.9, 7.5, $P<0.001$), non-angled fences that had a spread of two metres or greater (OR=3.8, 95% C.I. 2.2, 6.7, $P<0.001$) and good to soft, soft or heavy take-off ground (OR=9.2, 95% C.I. 2.4, 35.7, $P=0.001$). Risk factors which were not significantly associated with the risk of falling included: fence type (e.g. upright or ascending spread), the presence of a ditch, gradients of approach and landing, the number of separate elements or components at a fence and the position of the fence in the total sequence of jumps (jumping effort number).

This study identified course- and fence-level variables that were significantly associated with the risk of a horse fall during the cross-country phase of eventing competitions.

Introduction

Eventing is an equestrian sport enjoyed by amateur and professional riders. In 1999 five riders died in the United Kingdom (U.K.) as a result of horse and rider falls on the cross-country phase of eventing competitions. These fatalities raised concerns about the safety of the sport and initiated an epidemiological investigation aimed at reducing the risk of injury to horse and rider.

Data suggest that the rate of rider injury at eventing competitions is much greater than the rate of injury for competitors participating in motorcycle or car racing. The rate of eventing injuries to riders has been reported as 0.88% (Paix, 1999) and 1.1% (Whitlock, 1999), compared with 0.24% and 0.14% for motorcycle and car racing competitors respectively at U.K. Grand Prix circuits (Chapman and Oni, 1991). Horses are also frequently injured in falls. We recently reported that 32% of horses that fell were injured, with 1.5% of fallers euthanased as a result of their injuries (Murray et al., 2004a). Horse falls occurring during the cross-country phase of events present a risk of injury and fatality to horses and riders and it is important to measure this risk, and to identify the factors that might be manipulated to decrease the risk.

Eventing consists of three stages: dressage, cross-country and show jumping. Events may be run over one, two or three days and are classified according to the level of difficulty of the cross-country course. There are 5 one-day event levels (in ascending order of difficulty): Intro, Pre-novice, Novice, Intermediate and Advanced. Three-day events are also known as Concours Complet Internationale (CCI) competitions, with the difficulty increasing from 1-star (1*) to 4-star (4*) level.

The stages of a one-day event are run in the order of dressage, show jumping, and cross-country. Two-day events have dressage and show jumping on the first day and speed and endurance (incorporating the cross-country phase) on the second day. Three-day events have dressage on the first day, speed and endurance on the second day and show jumping on the final day. The speed and endurance day consists of four phases, (A, B, C and D). Phase D is equivalent to the cross-country course at one-day events.

The cross-country stage (phase D) of three-day events covers a distance of 3,900–7,980 metres and includes solid obstacles that should be completed by horses in 30-45 jumping efforts. The cross-country phase of one-day events is shorter with course distances of 1,600-4,000 metres incorporating 18-40 jumping efforts.

During the cross-country phase of eventing, the criteria on which horses and riders are judged include: time, refusals, rider falls and horse falls. A rider fall is penalised if a rider becomes separated from his/her horse in such a way to necessitate remounting. A horse fall, which incurs compulsory retirement, is recorded if the shoulders and quarters of the horse touch either the ground or the obstacle and the ground at the same time (British Eventing (B.E.) rules, 2001). A horse fall usually leads to a fall of the rider, and is therefore also known as a 'horse and rider fall'.

Analysis of retrospective data, using a case-control study design, suggested an increased risk of falling associated with fences sited on a downhill slope (OR=8.4, 95% C.I. 2.5, 28.8, P=0.001) or with a ditch in front (OR=5.8, 95% C.I. 1.1, 30.7, P=0.04) when compared with fences sited on flat ground and without a ditch in front respectively (Singer et al., 2003). The risk of falling also rose as the number of fences on a course increased (OR=1.6, 95% C.I. 1.2, 2.0, P<0.001); however, the risk associated with each additional jumping effort on the course decreased (OR=0.8, 95% C.I. 0.7, 1.0, P=0.01).

To our knowledge, the study reported here is the first large-scale prospective study conducted to investigate potential risk factors for eventing horse falls. The aim of the current study was to identify course- and fence-level variables that increased or decreased the risk of horse falls during the cross-country phase of eventing competitions.

Materials and Methods

Study Design

A matched prospective case-control design with a ratio of 3 controls per case was used to test associations between course and fence, horse, rider and event related variables and horse falls. The course- and fence-level variables are reported here. One- and two-day eventing competitions were selected randomly during the 2001 and 2002 British Eventing (B.E.) seasons. Only sixteen three-day event competitions were scheduled for the study period and all were selected for inclusion, to maximise data collection from these competitions. Data were obtained for 180 cases and 540 controls. Controls were matched by venue and by day of cross-country competition.

Case Definition

A case was a jumping effort that resulted in a horse fall on the cross-country phase of an event. A jumping effort was defined as having occurred if the horse attempted to negotiate a numbered obstacle on the cross-country course. A horse fall was defined as follows: the horse's shoulders and quarters touched either the ground or the obstacle and the ground at the same time. Falls that occurred on the approach to the fence, as a result of a horse attempting to refuse or run past the fence, were not classified as cases. Falls were defined as cases if the horse fell as a direct result of an attempted jumping effort. The horse was not required to fall within a set distance of the fence in order to be classified as a case; however; most horses fell within a few metres of the fence. Cases were identified by fence judges positioned by each obstacle to record any penalties incurred by each competitor. Fence judges were briefed at the beginning of the competition on the definition of a horse fall.

Control definition and selection

A control was a jumping effort that did not result in a horse fall. Three controls were selected randomly from all successful jumping efforts that took place on the same day and at the same competition from which their case was selected. Matching was used to control for the potentially confounding effects of month, weather conditions and geographical location.

In order to facilitate the random selection of control jumping efforts, every fence on the course was numbered consecutively. In some situations it was not possible to calculate the exact number of jumping efforts taken by a horse and rider combination, because competitors were given the choice between a shorter, technically difficult route, and an easier, but longer alternative with more elements. In situations where the exact number of jumping efforts was unknown, the minimum possible number of the jumping effort was used.

Description of fences

Cross-country courses include between 16 and 42 numbered obstacles requiring a maximum of 18 to 45 jumping efforts. The majority of obstacles consist of one fence, requiring a single jumping effort. However, some obstacles require multiple jumping efforts as they consist of two or more elements situated in close proximity. These obstacles are known as combination fences. For the purposes of this study, two fences were defined as part of a combination fence if they were positioned so that the average horse would take four or fewer strides between the two fences. (A four-stride distance between fences was equivalent to a mean distance of 16.8 (SD 1.6) metres in this study).

Risk of a horse fall

The risk of a horse fall was calculated by dividing the number of horse falls by the total number of jumping efforts, and was expressed as the risk per 1000 jumping efforts. The risk was calculated as a function of the level of difficulty of the cross-country course and the type of event (one-, two- or three-day event).

Data collection

Data were recorded on the day of the competition for the variables listed in Table 1 of the Appendix to this chapter. The ground conditions were categorised subjectively by visual assessment and by digging a heel into the ground to assess the firmness of the ground. Assessments were made by one of two observers (JKM, ERS) who worked together at the beginning of the data collection period to standardise interpretation of the six main categories of 'going' (firm, good-firm, good, good-soft, soft, heavy). Ground was considered to be slippery if the footwear of the observer could slide easily along the surface of the ground. Periodically, during the duration of the study, the two observers compared their assessment of ground conditions at events, to maintain consistency and to reduce observer bias. On average, ground conditions were recorded at each fence every 3-4 hours during the day of competition to document any changes that occurred as a result of weather conditions, drainage and soil type. The ground conditions recorded for each case or control were those observed closest to the time of the competitor's cross-country round.

The gradients of the ground on the approach and landing of the selected fences were measured using levelling techniques with a surveyor's staff and level (Nikon Automatic Level AC-2, Nikon, Inc. Instrument Group, Melville, USA). Measurements were recorded from the base of the fence (take-off and landing side), to 20 metres (m), 10m, 5m and 2m on the approach to the fence and to 10m, 5m and 2m on the landing side of the fence (Appendix, Figure 1). The gradient between two points was calculated as the difference in height (centimetres) between the points divided by the distance (metres) between the points. Measurements were not made at 20 metres from the fence on the landing side, since a horse fall at a distance of more than 10 metres from the fence on the landing side would be unlikely to be associated with the fence. For combination fences, the gradient measurements were taken for available distances between elements. Measurements were taken at the right and left of the fence in order that the camber of the fence could be calculated. The jumpable width of the fence was recorded as the distance between the flags that were attached to the left and right limits of all fences, indicating the two points between which the horse must jump.

Data Analysis

Categorical variables with few observations in one or more categories were recoded to create fewer categories with more observations. In addition, a new variable of 'changing light conditions' was formed from the combination of the variables of 'light to dark' and 'dark to light' conditions.

All variables were tested for association with falling using univariable conditional logistic regression models. The statistical packages R (www.r-project.org) and Egret (Cytel Software Corporation, USA) were used for data analysis. Continuous variables were also categorised into quintiles in the univariable analysis. The fit of the categorical variables in the model were compared to the fit of the continuous variables by assessing the change in deviance, (assuming the change in deviance follows a chi-squared distribution with n degrees of freedom, where n is the number of extra parameters fitted). To reduce the effects of collinearity, continuous variables were centred by subtracting the mean of the variable from all recorded observations (Kleinbaum et al., 1988).

Variables with a P-value <0.2 were considered for inclusion in a multivariable model, which was built using the technique of backward elimination. The variables: ditch in front, downhill approach, total number of jumps and jumping efforts on the course, and jumping effort number were also considered for inclusion in the multivariable model as a result of *a priori* evidence of an association identified by Singer et al. (2003). The effect of biologically plausible interactions between variables was also tested for in the model. The level of the event (Intro/Pre-novice, Novice, Intermediate or Advanced) and event type (one- or two-/three-day event) were evaluated as potential confounders. A change in the regression parameters of >25% was considered to be indicative of confounding. The fit of the model was assessed by examination of the sensitivity and specificity of the model at cut-off points ranging from 0.2 to 0.6. Model stability was assessed by examination of the delta betas. The model was considered to be stable if removal of individual cases or controls altered the odds ratio by <25% and did not affect the significance of individual variables.

Population Proportional Attributable Risk

The population attributable risk (PAR) provides a measure of the impact that a variable has on a population, whilst the population proportional attributable risk

(PPAR) represents the fraction of cases that would not have occurred if they had not been exposed to the risk factor (Kirkwood, 1988). The PPARs were calculated for each of the explanatory variables included in the final multivariable model by the method outlined by Bruzzi et al. (1985). Categorical variables were ordered by ascending odds ratios so that the PPAR could be calculated for each variable associated with an increased risk of a horse fall.

Results

The overall risk of a horse fall was 0.35 per 1000 jumping efforts (C.I. 0.30, 0.41) (Table 1). The risk appeared to increase as the level of difficulty of the event increased. Three-day events and one-day event championships were noted to be associated with a higher risk of a horse falling compared to one-day events.

Table 1. A summary of the number of falls per 1000 jumping efforts (j.e.) recorded at randomly selected eventing competitions in Great Britain during 2001-2002.

Class	No. of falls	No. of j.e.	No. of falls per 1000 j.e.	95% Confidence Intervals
One-day events				
Intro	2	18,988	0.11	0.00, 0.38
Pre-novice	20	131,026	0.15	0.00, 0.24
Novice	42	178,106	0.24	0.17, 0.32
Intermediate	37	68,044	0.54	0.38, 0.75
Advanced	14	24,841	0.56	0.31, 0.95
CIC 1*	1	6,383	0.16	0.00, 0.87
CIC 2*	1	9,529	0.10	0.00, 0.58
CIC 3*	0	4,537	0.00	0.00, 0.81
Novice Championships	2	1,373	1.45	0.18, 5.24
Intermediate Championships	2	1,778	1.12	0.14, 4.05
One-day event total	*121*	*444,605*	*0.27*	*0.23, 0.33*
Two-day events				
Novice two-day event	1	2,847	0.35	0.00, 1.96
Three-day events				
CCI 1*	16	24,049	0.66	0.38, 1.08
CCI 2*	15	14,950	1.00	0.56, 1.65
CCI 3*	9	12,346	0.73	0.33, 1.38
CCI 4*	18	10,563	1.70	1.01, 2.69
Three-day event total	*59*	*61,908*	*0.95*	*0.73, 1.23*
Overall total	**180**	**50,9360**	**0.35**	**0.30, 0.41**

CIC = Concours Internationale Combined, (International one-day event).

CCI = Concours Complet Internationale, (International three-day event).

The variables which were considered for inclusion in the final multivariable model are shown in Tables 2 and 3. In all instances where a continuous variable was also analysed as a categorical variable, the continuous variable resulted in a better fit.

Table 2. Continuous variables with a P-value of <0.2 (in descending order of P-value) in the univariable analysis of potential risk factors for cross-country horse falls at event competitions in Great Britain (2001-2002). Variables were centred to reduce the effects of collinearity.

Variable*	Coefficient	Standard Error	OR	P-value
Landing gradient: 0m to 5m (linear fit)	-0.02	0.02	0.98	0.19
Course length (metres) (linear fit)	0.001	0.0004	1.00	0.18
Total number of jumping efforts (linear fit)	0.06	0.05	1.06	0.16
Camber (linear fit)	-0.08	0.04	0.93	0.05
Approach gradient: 5m to 0m	-0.04	0.02	0.96	0.03
Approach gradient: 20m to 0m	-0.07	0.03	0.94	0.01
Landing gradient (quadratic fit)	-0.0001	0.0000	1.00	0.01
Spread of fence (metres) (quadratic fit)	0.62	0.16	1.85	<0.01
Element number (linear fit)	0.52	0.13	1.67	<0.01
Number of elements at fence (linear fit)	0.30	0.09	1.35	<0.01
Approach gradient: 10m to 0m	-0.06	0.02	0.94	<0.01

*A description of the variables is provided in Table 1 of the Appendix to this chapter.

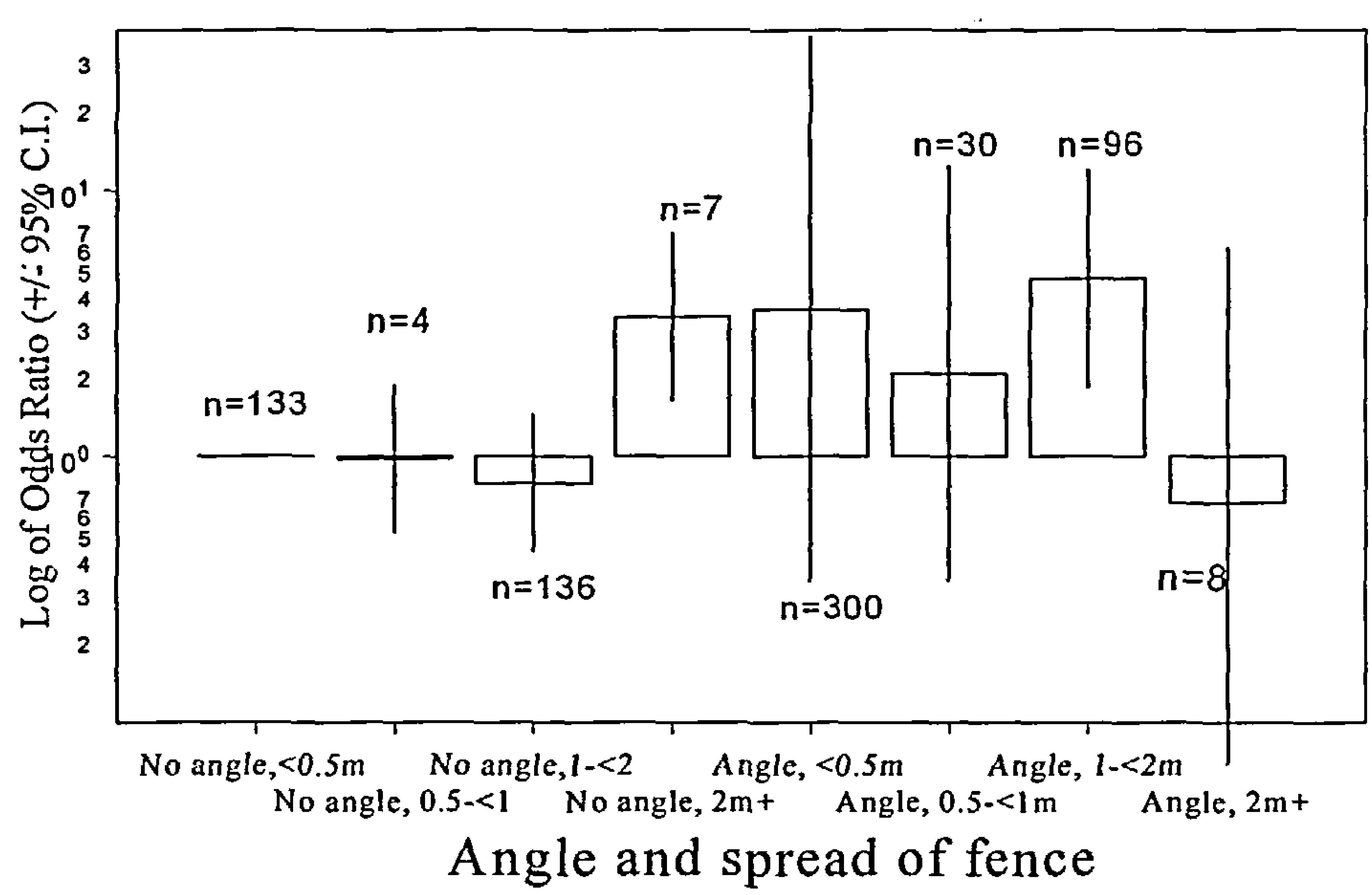
Gradients were calculated as the mean loss of ground level height (centimetres (cm) per metre (m))

Table 3. Categorical variables with a P-value of <0.2 (in descending order of P-value) in the univariable analysis of potential risk factors for cross-country horse falls at event competitions in Great Britain (2001-2002).

Variable		Number of controls (%)	Number of cases (%)	Odds ratio (95% C.I.)	P-value
Corner					
	No	527 (98)	172 (96)	Ref.	
	Yes	13 (2)	8 (4)	1.9 (0.8, 4.7)	0.17
Turn after	No	408 (76)	145 (81)	Ref.	
	Yes	132 (24)	35 (19)	0.7 (0.5, 1.1)	0.15
Fence type					
	Upright	35 (6)	9 (5)	Ref.	
	Ascending slope	176 (33)	55 (31)	1.1 (0.5, 2.9)	
	Ascending spread	174 (32)	47 (26)	1.0 (0.4, 2.4)	
	Square spread	76 (14)	33 (18)	1.7 (0.7, 4.0)	
	Step up	39 (7)	24 (13)	2.4 (0.9, 6.3)	
	Step down	23 (4)	8 (4)	1.2 (0.5, 4.5)	
	Other	17 (3)	4 (2)	0.9 (0.2, 3.6)	0.13
Wings					
	No	260 (48)	74 (41)	Ref.	
	Yes	280 (52)	106 (59)	1.3 (0.9, 1.9)	0.10
Slippery take-off					
	No	485 (90)	168 (93)	Ref.	
	Yes	55 (10)	12 (7)	0.5 (0.2, 1.5)	0.09
Combination					
	No	320 (59)	92 (51)	Ref.	
	Yes	220 (41)	88 (49)	1.4 (1.0, 2.0)	0.05
Fence angle					
	No	509 (94)	161 (89)	Ref.	
	Yes	31 (6)	19 (11)	2.0 (1.1, 3.6)	0.03
Shadows					
	No	465 (86)	143 (79)	Ref.	
	Yes	75 (14)	37 (21)	1.7 (1.1, 2.8)	0.02
Number of elements at fence					
	One	319 (59)	92 (51)	Ref.	
	Two	129 (24)	41 (23)	1.3 (0.7, 1.7)	
	Three	71 (13)	28 (16)	1.4 (0.8, 2.4)	
	Four or more	21 (4)	19 (11)	3.7 (1.8, 7.8)	0.005
Ground surface at take-off					
	Firm / Good to firm	270 (50)	73 (41)	Ref.	
	Good	250 (46)	84 (47)	1.7 (1.1, 2.8)	
	Good to soft / Soft / Heavy	13 (2)	10 (6)	5.6 (1.9, 16.6)	
	Water	23 (4)	13 (7)	8.3 (3.1, 22.0)	<0.001
Ground surface at landing					
	Firm / Good to firm	249 (46)	70 (39)	Ref.	
	Good	255 (47)	72 (40)	1.0 (0.6, 1.7)	
	Good to soft / Soft / Heavy	13 (2)	6 (3)	1.9 (0.6, 5.8)	
	Water	23 (4)	32 (18)	5.0 (2.7, 9.5)	<0.001
Angle and spread					
	No angle, <2m spread	443 (83)	120 (68)	Ref.	
	No angle, ≥2m spread	59 (11)	37 (21)	2.6 (1.6, 4.3)	
	Angled fences	30 (6)	19 (11)	2.6 (1.4, 4.8)	<0.001
Drop landing					
	No	494 (91)	147 (82)	Ref.	
	Yes	46 (9)	33 (18)	2.8 (1.7, 4.9)	<0.001

In the initial multivariable model, variables that were shown to be related to the risk of a fall were: take-off and landing ground surface, drop landing, the angle of the fence and the spread of the fence. Interaction was found between the explanatory variables of fence angle and spread. The relationship between the angle and spread of the fence and the risk of falling is illustrated in Figure 1. The separate categories for angled fences (base spread <0.5 metres, 0.5<1.0 metres, 1.0<2.0 metres, ≥2.0 metres) were combined into a single category due to the wide confidence intervals present when the categories were considered separately. Non-angled fences were split into two categories to allow for the apparent increased risk associated with fences with a spread of 2 metres or greater (Figure 1). No evidence was found to support the hypothesis that the risk of a fall increased as the spread of the fence increased beyond two metres (P=0.5). A new variable was created that combined the variables of fence angle and spread, which was biologically plausible and improved the fit of the model. The new variable was created with three categories (non-angled fence with a spread of <2 metres, non-angled fence with a spread of ≥2 metres and angled fences of any spread).

Figure 1: Relationship between angle and spread of fence and the risk of cross-country horse falls at eventing competitions in Great Britain (2001-2002).



n = The total number of cases and controls in this category

Angle = Fences that were jumped on an angle
No angle = Fences that were not jumped on an angle

<0.5m, 0.5<1m, 1<2m, 2m+ = The spread of the fence (metres), measured at the base of the fence, at the point at which the horse is expected to jump the fence.

None of the variables considered for inclusion in the multivariable model, as a result of *a priori* evidence of an association identified by Singer et al. (2003) improved model fit and they were excluded from the final model. The variables of a downhill approach to the fence (OR=0.93, 95% C.I. 0.56, 1.53, P=0.76), ditch in front (OR=0.65, 95% C.I. 0.31, 1.36, P=0.25), jumping effort number (OR=1.00, 95% C.I. 0.98, 1.02, P=0.88), total number of jumping efforts on the course (OR=1.05, 95% C.I. 0.94, 1.16, P=0.39) and total number of obstacles on the course (OR=1.07, 95% C.I. 0.92, 1.24, P=0.39) were not significantly associated with the risk of a horse fall in the multivariable model. Biologically plausible interactions between variables were tested for, none were found to be significant. There was no evidence of confounding by the variables of event level and event type (Table 2, Appendix). The final model is shown in Table 4.

Table 4. Multivariable conditional logistic regression model for risk factors for cross-country horse falls at eventing competitions in Great Britain (2001-2002).

	Coefficient	Standard Error	P-value	Odds Ratio (95% C.I.)
Take-off surface				
Firm / Good-Firm	Ref.			1.00
Good	0.66	0.32	0.04	1.93 (1.03, 3.61)
Good-Soft / Soft / Heavy	2.22	0.69	0.001	9.19 (2.37, 35.67)
Water	2.87	0.59	<0.001	17.69 (5.53, 56.56)
Landing surface				
Firm / Good-Firm	Ref.			1.00
Good	-0.46	0.33	0.17	0.63 (0.33,1.21)
Good-Soft / Soft / Heavy	-0.52	0.68	0.45	0.60 (0.16, 2.27)
Water	1.15	0.40	<0.01	3.16 (1.46, 6.85)
Drop landing				
No	Ref.			1.00
Yes	1.07	0.32	<0.001	2.91 (1.55, 5.47)
Angle and spread of fence				
No angle, < 2m spread	Ref.			1.00
No angle, ≥ 2m spread	1.35	0.28	<0.001	3.84 (2.22, 6.66)
All angled fences	1.34	0.35	<0.001	3.80 (1.93, 7.52)

The fit of the model was assessed by examination of the delta betas. Individual cases and controls with delta betas greater than 0.2 and less than –0.2 were removed from the dataset and the model was rerun. The variables of landing ground surface, drop landing and angle and width of the fence were considered to be stable, as rerunning the model altered the odds ratios by <25% and the significance of the variables remained unchanged. The variable of take-off ground surface appeared to be less stable because the individual removal of the six cases and six controls with large delta betas, either altered the odds ratio by >25% or altered the significance of the variable. Examination of these cases and controls revealed no unusual conditions and the individuals were therefore retained in the dataset.

The predictive capacity of the model was assessed by calculating the sensitivity and specificity of the model at various cut-off points (Table 5). The specificity of the model was shown to be good, although the sensitivity was poor at cut-off values of 0.3 and above. Thus, the model was able to predict controls better than cases when the cut-off value was 0.3 or higher.

Table 5. Sensitivity and specificity of the multivariable conditional logistic regression model shown in Table 4 at cut-off points 0.2 to 0.6

Cut-off point	Sensitivity (% of cases predicted)	Specificity (% of controls predicted)
0.2	78.4	58.1
0.3	58.5	82.7
0.4	40.9	90.4
0.5	33.5	94.5
0.6	22.2	98.3

Population Proportional Attributable Risk

The population proportional attributable risks (PPAR) were calculated for each of the explanatory variables included in the final multivariable model (Table 6). The largest PPAR was associated with good take-off ground, therefore, exposure to this risk factor was associated with the highest proportion of falls of horse and rider combinations investigated in this study. The variables of non-angled fences with a spread of two metres or more, landing in water and drop landings were all associated with a high proportion of the horse falls recorded. The PPAR was derived from multiple logistic regression and therefore was not additive.

Table 6. Population proportional attributable risk values of explanatory variables for risk factors for cross-country horse falls at eventing competitions in Great Britain (2001-2002).

Explanatory Variable	Population Proportional Attributable Risk (PPAR)
Take-off surface	
Firm / Good to firm ground	0.00
Good ground	0.21
Good to soft / Soft / Heavy ground	0.05
Water	0.07
Landing surface	
Good to soft / Soft / Heavy ground	0.00
Good ground	0.03
Firm / Good to firm ground	0.01
Water	0.13
Drop landing	
No	0.00
Yes	0.12
Angle and spread of fence	
Non-angled, <2m spread	0.00
Non-angled, ≥2m spread	0.15
All angled fences	0.08

Discussion

This study has identified a number of risk factors for cross-country horse falls that were associated with the course and the fence. In addition, the study provided no evidence for an association between the risk of a horse fall and variables previously hypothesised to be associated with the risk of falling, such as combination fences. However, a potential limitation of the study was due to the matching that was used to select controls. Whilst matching on the variables of day and venue of competition had the advantages of controlling for the potential confounding effects of month, weather and geographical location of the event, disadvantages existed. In particular, if the matching variables were confounders in the source population, then the observed effects in the sampled data may have been biased towards the null (Rothman and Greenland, 1998). In addition, if the matching variables were not confounders in the source population, but were associated with the exposure, then the observed exposure effect would again be biased towards the null. These biases could have the effect of causing variables that were significantly associated with the risk of falling in the population to be non-significant in the analysis of the sampled data. Caution must therefore be taken when interpreting the results of non-significant findings in a matched study, such as the study presented here. Due to potential bias from matching, further research is needed to investigate the lack of an association identified between variables investigated in this study and the risk of falling.

Risk factors significantly associated with an increased risk of a horse fall included the ground surface at the approach and landing areas of the fence. Fences into and out of water were associated with the greatest risks of a horse fall, increasing the risk by 3.2 times and 17.7 times respectively, compared to fences with a firm or good to firm take-off ($P<0.01$). Fences requiring a take-off out of water were usually sited so that horses would take at least one stride in water before jumping. Fences rarely had both the take-off and landing in water; only 3% (2/75) of 'water fences' included in this study fitted this description. The increased risk of falling at fences with a take-off in water may have been attributable to miscalculation of the jump height and take-off point by the horse and rider due to the base of the fence being obscured under water, and / or the drag of the water unbalancing the horse. The increased risk of falling at fences with a landing in water may also have been due to the drag of the water, or as a result of reflections or shadows on the water surface that impaired the horse's ability to judge the presence or depth of water. Fences that required the horse to take-off on dry ground and land in water usually included a drop landing, as the water was at a lower level than the take-off area. However, the variable of drop landing was also in the final model and was thus adjusted for in the odds ratio calculated for the landing ground surface. No significant interaction (P=0.40) was found between the variables of drop landing and landing ground surface and the model fit was not improved by adding the interaction term.

The evidence from this and an earlier study (Murray et al., 2004a), suggest that water fences should be considered as an important area of risk on cross-country courses. Our earlier findings showed an increased risk of injury to horses for falls in water compared to falls on land (OR=2.1, 95% C.I. 1.1, 3.7, P=0.01). Whilst jumping into water is an important test of the horse's 'bravery' and obedience, jumping out of water is thought to be an easier test for the horse. A comparison of the proportion of refusals at the two types of fences showed that a higher number were recorded at fences jumped into water (10.15 per 1000 jumping efforts), as opposed to fences jumped out of water (0.45 per 1000 jumping efforts), (Murray et al., unpublished data). Results from the study reported here suggest that fewer horse falls would be anticipated if competitors exited water complexes by cantering up a slope rather than by jumping out of the water.

The risk of falling appeared to increase as the take-off ground conditions became softer. Good to soft, soft and heavy ground were associated with a higher risk of falling (OR=9.2) than good ground (OR=1.9) when compared to firm and good to firm take-off ground. Human long jump and high jump athletes use a firm take-off surface to aid performance and land on a soft surface to help minimise the risk of injury (Fukuda, 1988). It is therefore logical that equine jumping performance might be enhanced and the risk of falling reduced, by the provision of good to firm take-off surfaces at cross-country fences.

Singer et al. (2003) found no association between course distance and the risk of falling for event horses, but the risk of falling was shown to increase as the number of fences on a cross-country course increased. Course length and the number of fences on a course will be correlated, since the maximums permitted for the two variables increase with the level of the event; however, neither variable was found to have a significant effect on the risk of falling in the study presented here. The reason for the contradictory findings is unclear, as the retrospective nature of Singer's study should not have affected the accuracy of the data collected for the variables of course length and number of fences on a course. However, Singer used unmatched controls, in contrast to the individually matched controls that were selected in our study. As a result of the matching used in this study, the cases selected from classes with the longest course distances (CCI 3* and CCI 4*) were matched to controls competing over the same course distance, as these were the only classes held at their respective venues. Therefore, the influence of the variable of course length could not be adequately evaluated in this study. Further research that does not match on day of event and competition venue is needed to explore the potential effects of course distance on the risk of falling.

The width of the fence and the angle of approach were identified as significant risk factors for horse falls. The increased risk of a fall associated with non-angled fences with a spread of two metres or more, compared with those with a spread of less than 2 metres, may be due to the horse having insufficient impulsion to clear the spread of the fence. The maximum permitted spread was 3.0 metres for a fence that also required vertical clearance and 4.0 metres for an open ditch (B.E. rules, 2001). No relationship was found to exist between the risk of falling and the spread of the fence for fences with a spread of 2 metres or more (P=0.5). No horse falls were recorded at open ditches within this study. These results suggest that reducing the maximum permitted spread for fences with height may reduce the risk of a fall, whilst the PPAR of 0.15 indicates that this would be a useful intervention strategy.

Angled fences included corner fences and those positioned in such a way that horses were required to jump the fence at an angle. Due to the angle of the fence, horses can 'run past' rather then jump the fence with relative ease, thus making these fences a useful test of the horse's obedience. A logical explanation for the increased risk of falling associated with angled fences is that the horse needs to make additional adjustments at take-off, to ensure that both front legs are raised sufficiently to clear the angled fence.

Population proportional attributable risks (PPARs) calculated for non-angled fences with a spread of 2 metres or greater (PPAR = 0.15) and fences with a landing in water (PPAR=0.13) indicate that these variables should be considered as important areas for the focus of future intervention studies. The high PPAR associated with good take-off ground (PPAR=0.21) needs to be considered in conjunction with the effect of ground surface on equine injury, before changes are implemented. For example, a study of Thoroughbred racehorses competing in steeplechase or hurdle races reported a decreased rate of musculoskeletal injuries and tendon and suspensory ligament injuries as the racing surface became softer (Williams et al., 2001). Conversely, surfaces that are too soft may lead to a premature onset of fatigue in the horse and a risk of soft tissue strain (Clayton, 2002). Suggested strategies to minimise the number of horse falls include reducing the number of fences jumped out of water and increasing the use of good to firm 'all-weather' surfaces before fences.

Other risk factors identified for horse falls included fences with drop landings (i.e. the ground level at landing was lower than the ground level at take-off). The association between drop landings and an increased risk of a horse fall (OR=2.9) is a logical association that may be explained by a loss of balance of the horse on landing. In contrast with the findings of Singer et al. (2003), no association was found with fences sited downhill or with fences with a ditch in front. The contradictory findings may be explained by the different case definitions and different methods of data collection that were used in the two studies. Singer et al. (2003) included falls that resulted from a refusal. These were excluded from our study, as our case and control definitions did not include attempted jumping efforts that resulted in refusals. Our study excluded six falls that occurred as a result of a refusal, three of which were at fences with a ditch in front and another at a fence with a downhill approach. Horse falls following a refusal may be more likely to occur at fences that have a ditch in front, since the forward momentum of the horse can carry it into the ditch, thus causing a fall. The differing case definitions of the retrospective study (Singer et al., 2003) and our prospective study may thus explain the different conclusions regarding the risk associated with fences with a ditch in front. The conflicting findings attributed to fences with a downhill approach are more likely to be as a result of the different methods of data collection. Singer et al.

(2003) collected data retrospectively, which may have led to inaccuracies in the recall of the gradient of the approach to the fence, and in the misclassification of cases.

This prospective study has identified a number of risk factors for horse falls that are associated with the course and the fence. It is encouraging for the sport of eventing that this study showed no significant association between the risk of a horse fall and variables such as combination fences, narrow fences and ditches.

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APPENDIX: CHAPTER TWO

Table 1. Description of course- and fence-level variables recorded during the day of competition for a study of risk factors for cross-country horse falls in eventing competitions in Great Britain (2001-2002).

Course- and fence-level variables	Description
XC level	One-day events: Intro/Pre-novice, Novice, Intermediate, Advanced Two-/three-day events: Novice/CCI 1*, Intermediate/CCI 2*, CCI 3*, CCI 4*
Speed	Official speed required for course (metres per minute)
Distance	Official course distance (metres)
Jumping effort number	Jumping effort number of selected fence
Total jumping efforts	Total number of jumping efforts on the course
Total number of jumps	Total number of obstacles on the course
Element number	Continuous variable of element number of selected fence, (single fences coded as one).
Number of elements	Number of elements at selected fence, (single fences coded as one).
Combination	Two or more fences with ≤ 4 strides between each element
Approach	Approach to fence (flat, uphill, downhill, water)
Flat approach	Flat approach to fence (yes/no)
Uphill approach	Uphill approach to fence (yes/no)
Downhill approach	Downhill approach to fence (yes/no)
Water approach	Water approach to fence (yes/no)
Take off going	Ground surface at approach to fence (firm, good to firm, good, good to soft, soft, heavy, water)
Slippery take off	Slippery ground at take off area (yes/no)
Rutted take off	Rutted ground at take off (yes/no)
Landing	Landing of fence (flat, uphill, downhill, water)
Flat landing	Flat landing after fence (yes/no)
Uphill landing	Uphill landing after fence (yes/no)
Downhill landing	Downhill landing after fence (yes/no)
Water landing	Water landing after fence (yes/no)
Landing going	Ground surface at landing of fence (firm, good to firm, good, good to soft, soft, heavy, water)
Slippery landing	Slippery ground at landing area (yes/no)
Rutted landing	Rutted ground at landing (yes/no)
Camber	Fence is positioned on a camber (yes/no)
Fence in open	Fence is sited in the open (yes/no)
Changing light	Fence is jumped from a light to a dark area or *vice versa* (yes/no)
Fence in dark	Fence is sited in a dark area (yes/no)
Shadows	Shadows on fence (yes/no)
Wings	The presence or absence of barriers attached to the left and right of a jump that guide the horse to the fence
Turn before	The approach to the fence involved a turn ≤5 strides before fence (yes/no)

Course- and fence-level variables	Description
Turn after	After jumping the fence a turn is required ≤5 strides later (yes/no)
Horse angle	Horses jump fence at an angle. Assessed by watching horses jump the fence and studying hoof prints around the fence.
Fence angle	Fence is positioned at an angle to the line of approach, (e.g. corner fence, angled rails)
Groundline	Use of material (e.g. pole or bark) to help prevent the horse from taking off too close to the fence (yes/no)
Groundline type	Type of groundline (none, true groundline (away from base of fence), filled base of fence, incomplete groundline (eg logs placed in front of fence), incomplete fill of base of fence (eg sharks teeth fence), log, false groundline).
True groundline	True groundline, placed infront of base of fence (yes/no)
No groundline	False or no groundline present (yes/no)
Log	Positioned on ground or suspended (e.g. 'hanging' log)
Ground log	Log placed on ground (yes/no)
Hanging log	Log suspended above the ground (yes/no)
Fence type	Upright, ascending slope, ascending spread, square spread, step up, step down, other (e.g. open ditch)
Upright	Upright fence (yes/no)
Ascending slope	Ascending slope, fence <1m spread, (yes/no)
Ascending spread	Ascending spread, fence ≥1m spread (yes/no)
Square spread	Square spread/parallel fence. Fence ≥1m spread. Flat top to fence (yes/no)
Step up	Step up: the landing ground is at the same height as the top of the fence (yes/no)
Step down	Step down: the fence involves no height to be cleared, - but a loss in height from the take off to the landing ground (yes/no)
Ditch	Open, sited in front, under and / or behind fence, trakehner fence (Trakehner fences have a log or rail suspended over a ditch)
Ditch type	Type of ditch (none, ditch in front of fence or in front and under fence, ditch behind fence or behind and under, trakehner, open ditch).
Ditch in front	Ditch in front of fence (yes/no)
Ditch under	Ditch under fence (yes/no)
Ditch behind	Ditch behind fence (yes/no)
Open ditch	Open ditch: no height clearance required, (yes/no)
Trakehner	Log/rail suspended over a ditch (yes/no)
Bounce	Two elements sited so that the horse lands and immediately takes off, without taking a stride in between the elements (yes/no)

Course- and fence-level variables	Description
Drop landing	Landing is on lower ground than the take-off to the fence (yes/no)
High landing	Landing is on higher ground than the take-off to the fence (yes/no)
Corner	Left or right pointed corner (< or >), (yes/no)
Brush through	Highest point of fence is not rigid, but formed of spruce, hedge etc that the horse can brush through (yes/no)
Narrow	Front face of fence is visibly narrower than the majority of fences found on a cross-country course (yes/no)
Frangible	Fence is constructed with frangible pins (yes/no)
Owlhole	Fence requires the horse to jump underneath a solid structure, i.e. to jump through a 'hole' (yes/no)
Filled front	Front face of fence is solid, i.e. it is not possible to see through the fence (yes/no)
Filled top	Top of a spread fence is solid, i.e. from above the fence, it is not possible to see the ground underneath the fence (yes/no)
Front fill	Material from which the solid front of the fence is constructed (open, wood, brush, other)
Top fill	Material from which the solid top of the fence is constructed (open, wood, brush, other)
Fence height	Measured as the distance from the ground to the highest (lowest for steps down) solid point of the fence that the horse is expected to jump (metres)
Fence spread	Measured at the base of the fence, at the point at which the horse is expected to jump the fence (metres)
Angle width combined	Combined variable of the fence angle and the spread of the fence, (Non-angled, <2m spread, non-angled, ≥2m spread, All angled fences of any spread width)
Jumpable width	The shortest distance between the flags attached to the left and right of the fence (metres). Jumpable width was therefore measured in a straight line for all fences, including U-shaped fences.
Strides from	Number of strides from previous jumping effort to the fence (0, 1, 2, 3, 4, 5 or more)
Strides to	Number of strides from the fence to the next jumping effort (0, 1, 2, 3, 4, 5 or more)
Gradient measurements (see Fig. 1 below for diagram)	

Course- and fence-level variables	Description
Approach: 20m to 10m	Gain or loss in height (cm) over the distance measured from 20m from the fence to 10m from the base of the fence on the approach side. Expressed as the difference in height (cm), divided by the distance covered (10m)
Approach: 10m to 5m	Gain or loss in height (cm) over the distance measured from 10m from the fence to 5m from the base of the fence on the approach side. Expressed as the difference in height (cm), divided by the distance covered (5m)
Approach: 5m to 2m	Gain or loss in height (cm) over the distance measured from 5m from the fence to 2m from the base of the fence on the approach side. Expressed as the difference in height (cm), divided by the distance covered (3m)
Approach: 2m to 0m	Gain or loss in height (cm) over the distance measured from 2m from the fence to 0m from the base of the fence on the approach side. Expressed as the difference in height (cm), divided by the distance covered (2m)
Approach: 5m to 0m	Gain or loss in height (cm) over the distance measured from 5m from the fence to 0m from the base of the fence on the approach side. Expressed as the difference in height (cm), divided by the distance covered (5m)
Approach: 10m to 0m	Gain or loss in height (cm) over the distance measured from 10m from the fence to 0m from the base of the fence on the approach side. Expressed as the difference in height (cm), divided by the distance covered (10m)
Approach: 20m to 0m	Gain or loss in height (cm) over the distance measured from 20m from the fence to 0m from the base of the fence on the approach side. Expressed as the difference in height (cm), divided by the distance covered (20m)
Approach: 10m to 2m	Gain or loss in height (cm) over the distance measured from 10m from the fence to 2m from the base of the fence on the approach side. Expressed as the difference in height (cm), divided by the distance covered (8m)
Approach: 20m to 2m	Gain or loss in height (cm) over the distance measured from 20m from the fence to 2m from the base of the fence on the approach side. Expressed as the difference in height (cm), divided by the distance covered (18m)

Course- and fence-level variables	Description
Landing gradient	Gain or loss in height (cm) over the distance measured from from the base of the fence on the approach side to the base of the fence on the landing side. Expressed as the difference in height (cm), divided by the spread of the fence (m)
Landing: 0m to 2m	Gain or loss in height (cm) over the distance measured from 0m to 2m from the base of the fence on the landing side. Expressed as the difference in height (cm), divided by the distance covered (2m)
Landing: 2m to 5m	Gain or loss in height (cm) over the distance measured from 2m to 5m from the base of the fence on the landing side. Expressed as the difference in height (cm), divided by the distance covered (3m)
Landing: 5m to 10m	Gain or loss in height (cm) over the distance measured from 5m to 10m from the base of the fence on the landing side. Expressed as the difference in height (cm), divided by the distance covered (5m)
Landing: 0m to 5m	Gain or loss in height (cm) over the distance measured from 0m to 5m from the base of the fence on the landing side. Expressed as the difference in height (cm), divided by the distance covered (5m)
Landing: 0m to 10m	Gain or loss in height (cm) over the distance measured from 0m to 10m from the base of the fence on the landing side. Expressed as the difference in height (cm), divided by the distance covered (10m)
Landing: 2m to 10m	Gain or loss in height (cm) over the distance measured from 2m to 10m from the base of the fence on the landing side. Expressed as the difference in height (cm), divided by the distance covered (8m)
Camber	Difference between the height of the ground at the base of the fence at the right and left flags. Expressed as the difference in centimetres, divided by the distance (m) between the flags.

Figure 1: Schematic representation of the location of gradient measurements in metres (m) for a cross-country fence, (not to scale).

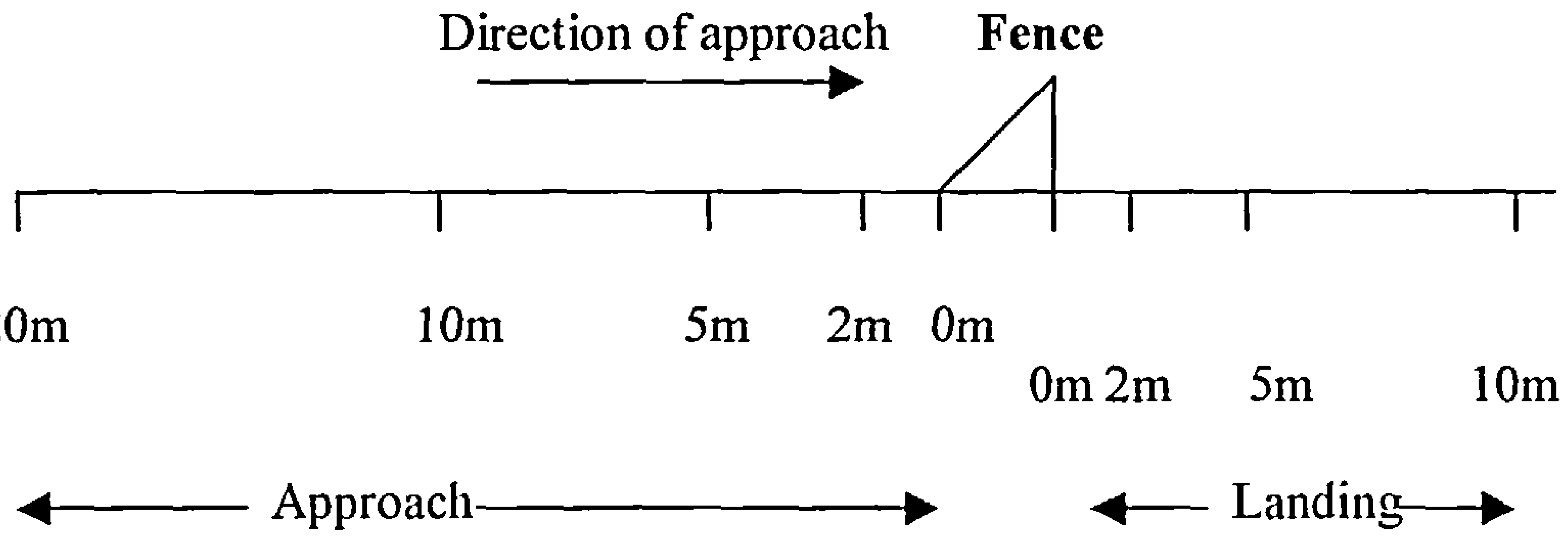


Table 2. A summary of the effect of adding the variables; event level and event type into the model of course- and fence-level risk factors for horse falls during the cross-country phase of eventing competitions presented in Table 4 of Chapter 2.

	Original model (A)	Model A plus event level	Model A plus event type
Variable	Odds Ratio	Odds Ratio	Odds Ratio
Take-off surface			
Firm / good-firm	1.00	1.00	1.00
Good	1.93*	1.92*	1.92*
Good-soft / soft / heavy	9.19*	9.21*	9.17*
Water	17.69*	17.64*	17.63*
Landing surface			
Firm / good-firm	1.00	1.00	1.00
Good	0.63	0.64	0.65
Good-soft / soft / heavy	0.60	0.59	0.61
Water	3.16*	3.12*	3.23*
Drop landing			
No	1.00	1.00	1.00
Yes	2.91*	2.95*	3.00*
Angle and spread of fence			
No angle, <2m spread	1.00	1.00	1.00
No angle, ≥2m spread	3.84*	3.78*	3.85*
All angled fences	3.80*	3.76*	3.82*
Event level			
Intro / Pre-novice		1.00	
Novice		1.15	
Intermediate		1.24	
Advanced		1.63	
Event type			
One-day event			1.00
Two-/three-day event			0.41

* P-value <0.05

CHAPTER THREE:

Towards reducing injury to horse and rider in eventing: A case-control study.

Abstract

The objective of this study was to identify variables that increased or decreased the risk of a horse fall during the cross-country phase of an eventing competition. Data were collected for 180 cases and 540 controls. Cases were jumping efforts that resulted in a fall of the horse. Controls were matched by day and competition and were selected randomly from jumping efforts that did not result in a horse fall. The course and fence-related risk factors for horse falls in the final multivariable model were: jumping into or out of water, taking off from good, good to soft, soft or heavy ground, fences with a drop landing, non-angled fences with a spread greater than or equal to two metres and angled fences. Other risk factors for horse falls were; the rider's knowledge of their position within the competition before the cross-country phase, speed of approach to the fence, no refusals at earlier fences, and cross-country lessons taken by the rider.

Introduction

Eventing is an equestrian sport enjoyed by amateur and professional riders, with 8,106 riders registered with British Eventing in 2002. Five riders died in the United Kingdom (U.K.) as a result of horse and rider falls during the cross-country (XC) phase of eventing competitions during 1999. These fatalities raised concerns about the safety of this sport and initiated epidemiological investigations aimed at reducing the risk of injury to horse and rider.

Apart from these high profile deaths, the incidence rate for rider injury at event competitions has been reported as 0.88% (Paix, 1999). This rate is considerably higher than the injury incidence rates recorded by Chapman and Oni (1991) at a U.K. Grand Prix circuit for motorcycle racing (0.24%) and car racing (0.14%). Whitlock (1999) showed a rider injury incidence rate of 1.1% from data obtained from 54 days of XC competition in the U.K. including two fatalities, which resulted from the horses falling and landing on the riders. Previously, we reported that 32% of horses that fell were injured, with 1.5% being euthanased as a result of the injuries sustained (Murray et al., 2004a). Horse falls occurring during the cross-country phase of events have thus been associated with injuries and fatalities to horses and riders.

Eventing consists of three stages: dressage, cross-country and show jumping. Events may be run over one, two or three days and are classified according to the level of difficulty of the cross-country course. There are 5 one-day event levels (in ascending order of difficulty): Intro, Pre-novice, Novice, Intermediate and Advanced. Three-day events are also knows as Concours Complet Internationale (CCI) competitions, with the difficulty increasing from 1-star (1*) to 4-star (4*) level. The stages of a one-day event are run in the order of: dressage, show jumping and cross-country. Two-day events have dressage and show jumping on the first day and speed and endurance (incorporating the cross-country phase) on the second day. Three-day events have dressage on the first day, speed and endurance on the second day and show jumping on the final day. The speed and endurance day consists of four phases, (phases A, B, C and D). Phase D is equivalent to the cross-country course at one-day events.

The cross-country stage (phase D) of three-day events covers a distance of 3,900-7,980 metres including a maximum of 30-45 jumping efforts over solid obstacles. Phase D requirements vary according to the level of the event (British Eventing (B.E.) rules, 2001). The cross-country phase of one-day events is shorter with course distances of 1,600-4,000 metres incorporating 18-40 jumping efforts. During the cross-country phase of eventing, the criteria on which horses and riders are judged include: time, refusals, rider falls and horse falls. A rider fall incurs a penalty if the rider becomes separated from his/her horse in such a way to necessitate remounting. A horse fall is recorded if the shoulders and quarters of the horse touch either the ground or the obstacle and the ground at the same time (B.E. rules, 2001). A horse fall, which incurs compulsory retirement, usually leads to a fall of the rider, and is therefore also known as a 'horse and rider fall'.

Analysis of retrospective data, using a case-control design, suggested an increased risk of falling associated with fences sited on a downhill slope (OR=8.4, 95% confidence interval (C.I.) 2.5, 28.8, P=0.001) or with a ditch in front (OR=5.8, 95% C.I. 1.1, 30.7, P=0.04) when compared with fences sited on flat ground and without a ditch in front (Singer et al., 2003). The risk of falling also rose as the number of fences on a course increased (OR=1.6, 95% C.I. 1.2, 2.0, P<0.001); however, the risk associated with each additional jumping effort on the course decreased (OR=0.8, 95% C.I. 0.7, 1.0, P=0.01).

In this paper we report a large-scale prospective study conducted to investigate potential risk factors for eventing horse falls. Its aims were to identify variables that increased or decreased the risk of horse falls during the cross-country phase of eventing competitions. The risk factors will be reported to the sport's governing body so that intervention studies can be designed to reduce the risk of horse falls.

Materials and Methods

Study design

A matched prospective case-control design with a ratio of 3 controls per case was used to test associations between course and fence, horse, rider and event related variables and horse falls. One- and two-day eventing competitions were randomly selected during the 2001 and 2002 British Eventing seasons. Only sixteen three-day event competitions were scheduled to take place during the study period and all sixteen were selected for inclusion, to maximise data collection from three-day event competitions. Data were obtained for 180 cases and 540 controls. Controls were individually matched by venue and day of cross-country competition, but not by class.

Case definition

A case was a jumping effort that resulted in a horse fall on the cross-country phase of an event. A jumping effort was defined as having occurred if the horse attempted to negotiate the obstacle. A horse fall was defined by B.E. rules (2001) as: the horse's shoulders and quarters touched either the ground or the obstacle and the ground at the same time. In this study falls were identified and recorded by fence judges, who were positioned by each fence to record penalties incurred by each competitor. The fence judges were briefed before the competition on the definition of a horse fall, in order to maximise the probability of correct identification. Falls that occurred on the approach to the fence, as a result of the horse attempting to run out or refuse the fence, were not classified as cases.

Control definition and selection

A control was a jumping effort that did not result in a horse fall. Three controls were selected randomly from all successful jumping efforts that took place on the same day and at the same competition from which their case was selected. Matching was used to control for the potentially confounding effects of month, weather conditions and geographical location of the event.

Misclassification of the response variable was assessed by video analysis. Video footage was available for a total of 42 cases and 122 controls from three sources (Television in Europe Ltd.[1], Total Recall Videos[2] and Lucid Dreams Media[3]).

Data collection

Cross-country courses consist of between 16 and 42 numbered obstacles. The majority of obstacles consist of one fence, requiring a single jumping effort. However, some obstacles require multiple jumping efforts as they consist of two or more fences (also known as elements), situated in close proximity. These obstacles are known as combination fences. For the purposes of this study, two fences were defined as part of a combination fence if they were positioned so that the average horse would take four or fewer strides between the two fences. (A four-stride distance between fences was equivalent to a mean (s.d.) distance of 16.8 (1.6) metres in this study).

For this study, every fence on the course was numbered consecutively and defined as a jumping effort. The order in which the riders started the cross-country course was used to identify in sequence, all jumping efforts that had been completed during the day. Thus, each jumping effort during the competition could be identified for the random selection of controls. In some situations it was not possible to calculate the exact number of jumping efforts taken by a horse and rider combination, because competitors were given the choice between a shorter, technically difficult route, and an easier, but longer alternative with more elements. In situations where the exact number of jumping efforts was unknown, the minimum possible number of the jumping effort was used. Data were recorded on the day of the competition for

[1] Television in Europe Ltd., London.
[2] Total Recall Videos, Northants.
[3] Lucid Dreams Media, Northern Ireland.

course- and fence-level variables. The ground conditions were assessed subjectively by one of two observers (JKM, ERS) who worked together at the beginning of the data collection period in an attempt to standardise interpretation of the six main categories of 'going' (firm, good-firm, good, good-soft, soft, heavy). The two observers also compared their assessment of ground conditions at events over the duration of the study, to maintain consistency and to reduce any effects of observer bias. On average, ground conditions were recorded at each fence every 3-4 hours. This enabled the conditions encountered by each horse in the study to be recorded as accurately as possible, by matching the time that each horse started the cross-country course to the nearest recorded ground conditions.

A fence was classified as having a drop landing if the ground level at landing was obviously lower than the ground level at take-off. Fences were also classified as being angled or non-angled; angled fences were those positioned at an angle to the horse's line of approach. Angled fences may consist of a single or double set of rails (Figure 1). Angled fences constructed from a single set of rails (Figure 1A) require minimal width clearance from the horse, whereas 'corner' fences (Figure 1B) require the horse to clear the width between both sets of rails (B) in one jumping effort. The spread of the fence was defined as the distance (metres) that the horse would be required to clear, measured at the base of the fence. Fences were measured after the competition, so that hoofprints could be used to indicate where the majority of horses jumped the fence. The variables of fence angle and spread were shown to interact, so a new variable was created that combined the two variables. The new variable was assigned three categories (non-angled fence with a spread of <2 metres, non-angled fence with a spread of $\geq$2 metres and angled fences of any spread).

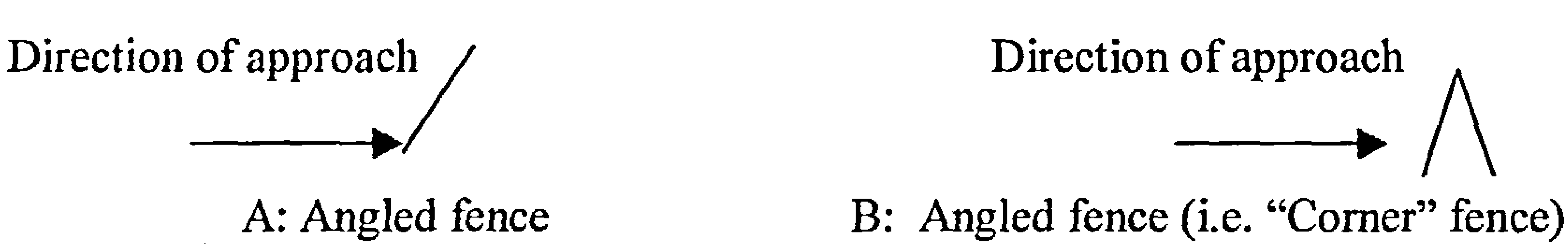


Figure 1. Schematic representation of the two main types of angled fences

A letter explaining the study was sent to all case and control riders within 3 days of the event. The letter informed the riders of imminent contact by telephone to complete a questionnaire relating to the event and additional areas such as horse and rider training. The telephone questionnaires were administered as soon as possible to each rider selected as a case or control. Questionnaires were completed by 173 case riders (96.1%) and 503 control riders (93.1%).

Risk of a horse fall

The risk of a horse fall was calculated by dividing the number of horse falls by the total number of jumping efforts, and was expressed as the risk per 1000 jumping efforts. The risk was calculated as a function of the level of difficulty of the cross-country course and the type of event (one-, two- or three-day event).

Data analysis

All variables were tested for association with falling using univariable conditional logistic regression models. The statistical packages R (www.r-project.org) and Egret (Cytel Software Corporation, USA) were used for data analysis. Continuous variables were also categorised into quintiles in the univariable analysis. The fit of the categorical variables in the model were compared to the fit of the continuous variables by assessing the change in deviance, (assuming the change in deviance follows a chi-squared distribution with n degrees of freedom, where n is the number of extra parameters fitted). To reduce the effects of collinearity, continuous variables were centred by subtracting the mean of the variable from all recorded observations (Kleinbaum et al., 1988).

Variables with a P-value <0.2 were considered for inclusion in a multivariable model, which was built using the technique of backward elimination. The variables: total number of jumps and jumping efforts on the course, ditch in front, downhill approach and jumping effort number were also considered for inclusion in the multivariable model as a result of *a priori* evidence of an association identified by Singer et al. (2003). The effect of biologically plausible interactions between variables was also tested for in the model. Rider status (professional or amateur event rider), event type (one- or two-/three-day event) and level of the event (Intro/Pre-novice, Novice, Intermediate or Advanced) were evaluated as potential confounders. A change in the regression parameters of $\geq$25% was considered to be indicative of confounding. The fit of the model was assessed by examination of the sensitivity and specificity of the model at cut-off points ranging from 0.2 to 0.6. Model stability was assessed by examination of the delta betas. The model was considered to be stable if removal of individual cases or controls altered the odds ratio by <25% and did not affect the significance of individual variables.

Analysis of potential recall bias

In order to investigate the potential presence of recall bias, the dressage score reported by each rider during the telephone interview was compared with that officially recorded at the event. Recall accuracy was classified as a binary variable (accurate=0, inaccurate=1) rather than as a continuous variable as the data were not normally distributed and could not be transformed to a normal distribution. Dressage scores were awarded in penalty points, therefore, the lower the penalty point score, the better the performance. One-day event dressage tests are marked by a single judge and therefore result in penalty scores that are integers. Three judges are used to mark three-day event dressage tests. The average mark awarded by the judges for a three-day event competitor, rounded to two decimal places, is used to calculate their dressage penalty score. To allow for differences in reporting style between riders (integers or decimals), a recalled score was considered accurate if it was within 0.5 penalty points of the B.E. database score.

The effect of case-control status of the respondent and time between questionnaire and event was investigated by including these as explanatory variables in generalised linear mixed models. Case-control status and time since the event were introduced as fixed effects into the model. The potential confounding effects of rider status (professional or amateur event rider) and event type (one- or two-/three-day event) were also considered. Generalised linear mixed models were fitted to the data using the function glmmPQL in the statistical package R (www.r-project.org), with the matching variable as the random effect (Armitage et al., 2002). Variables with $P \leq 0.05$ were considered to be statistically significant.

Results

The overall risk of a horse fall was 0.35 falls per 1000 jumping efforts (95% C.I. 0.30-0.41). The risk appeared to increase as the level of difficulty and duration of the event increased (Table 1). Three-day events and one-day event championships were noted to be associated with a higher risk of a horse falling compared to one-day events.

All the variables considered for inclusion in the multivariable model, as a result of *a priori* evidence of an association identified by Singer et al. (2003) were excluded from the final model, as their inclusion did not improve the fit of the model (P>0.05). These were: a downhill approach to the fence (P=0.42), ditch in front (P=0.10), jumping effort number (P=0.97), total number of jumping efforts on the course (P=0.19) and total number of obstacles on the course (P=0.25). The final model is shown in Table 2. The relationships between the categorical variables of take-off and landing surface and the risk of a horse fall are shown in Figures 2 and 3. No interaction was found between variables in the model and there was no evidence of confounding by the variables of rider status, event type and event level.

Table 1. A summary of the number of falls per 1000 jumping efforts recorded at randomly selected eventing competitions in Great Britain during 2001-2002.

Class	No. of falls	No. of jumping efforts	No. of falls per 1000 jumping efforts (95% C.I.)
One-day events			
Intro	2	18,988	0.11 (0.00, 0.38)
Pre-novice	20	131,026	0.15 (0.00, 0.24)
Novice	42	178,106	0.24 (0.17, 0.32)
Intermediate	37	68,044	0.54 (0.38, 0.75)
Advanced	14	24,841	0.56 (0.31, 0.95)
CIC 1*	1	6,383	0.16 (0.00, 0.87)
CIC 2*	1	9,529	0.10 (0.00, 0.58)
CIC 3*	0	4,537	0.00 (0.00, 0.81)
Novice Championships	2	1,373	1.45 (0.18, 5.24)
Intermediate Championships	2	1,778	1.12 (0.14, 4.05)
One-day event total	121	444,605	0.27 (0.23, 0.33)
Novice two-day event	1	2,847	0.35 (0.00, 1.96)
Three-day events			
CCI 1*	16	24,049	0.66 (0.38, 1.08)
CCI 2*	15	14,950	1.00 (0.56, 1.65)
CCI 3*	9	12,346	0.73 (0.33, 1.38)
CCI 4*	18	10,563	1.70 (1.01, 2.69)
Three-day event total	59	61,908	0.95 (0.73, 1.23)
Overall total	180	509,360	0.35 (0.30, 0.41)

CIC = Concours Internationale Combined, (International one-day event)

CCI= Concours Complet Internationale, (International three-day event)

Table 2. Multivariable conditional logistic regression model for risk factors for cross-country horse falls at eventing competitions in Great Britain (2001-2002).

Variable	Coefficient	Standard Error	Odds Ratio	95% C.I.	LRT P-value
Take-off surface					
Firm / Good-firm	Ref.		1.00		
Good	0.83	0.38	2.29	1.09, 4.82	
Good-soft/Soft/Heavy	2.74	0.93	15.56	2.54, 95.45	
Water	3.91	0.80	49.80	10.38, 238.99	<0.001
Landing surface					
Firm / Good-firm	Ref.		1.00		
Good	-0.47	0.40	0.63	0.28, 1.38	
Good-soft/Soft/Heavy	-0.51	0.94	0.60	0.09, 3.83	
Water	1.74	0.51	5.72	2.12, 15.45	<0.001
Drop Landing					
No	Ref.		1.00		
Yes	1.23	0.38	3.41	1.60, 7.25	0.001
Angle and spread of fence					
No angle, <2m spread	Ref.		1.00		
No angle, ≥2m spread	1.18	0.33	3.24	1.71, 6.16	
All angled fences	1.57	0.43	4.83	2.09, 11.16	<0.001
Position before XC					
Didn't know position	Ref.		1.00		
First	1.48	0.57	4.39	1.44, 13.43	
Second or lower	-0.81	0.35	0.45	0.22, 0.89	0.001
Approach speed					
Appropriate	Ref.		1.00		
Too slow	1.61	0.49	5.00	1.90, 13.14	
Too fast	1.84	0.44	6.30	2.64, 15.02	<0.001
Previous XC refusals on the course incurred by the horse and rider					
Yes	Ref.		1.00		
No	3.14	1.04	23.02	2.98, 178.12	0.003
Rider has XC lessons					
No	Ref.		1.00		
Yes	0.66	0.24	1.94	1.21, 3.09	0.006

Figure 2. The relationship between take-off surface and the risk of a horse fall during the cross-country phase of eventing competitions in Great Britain (2001-2002).

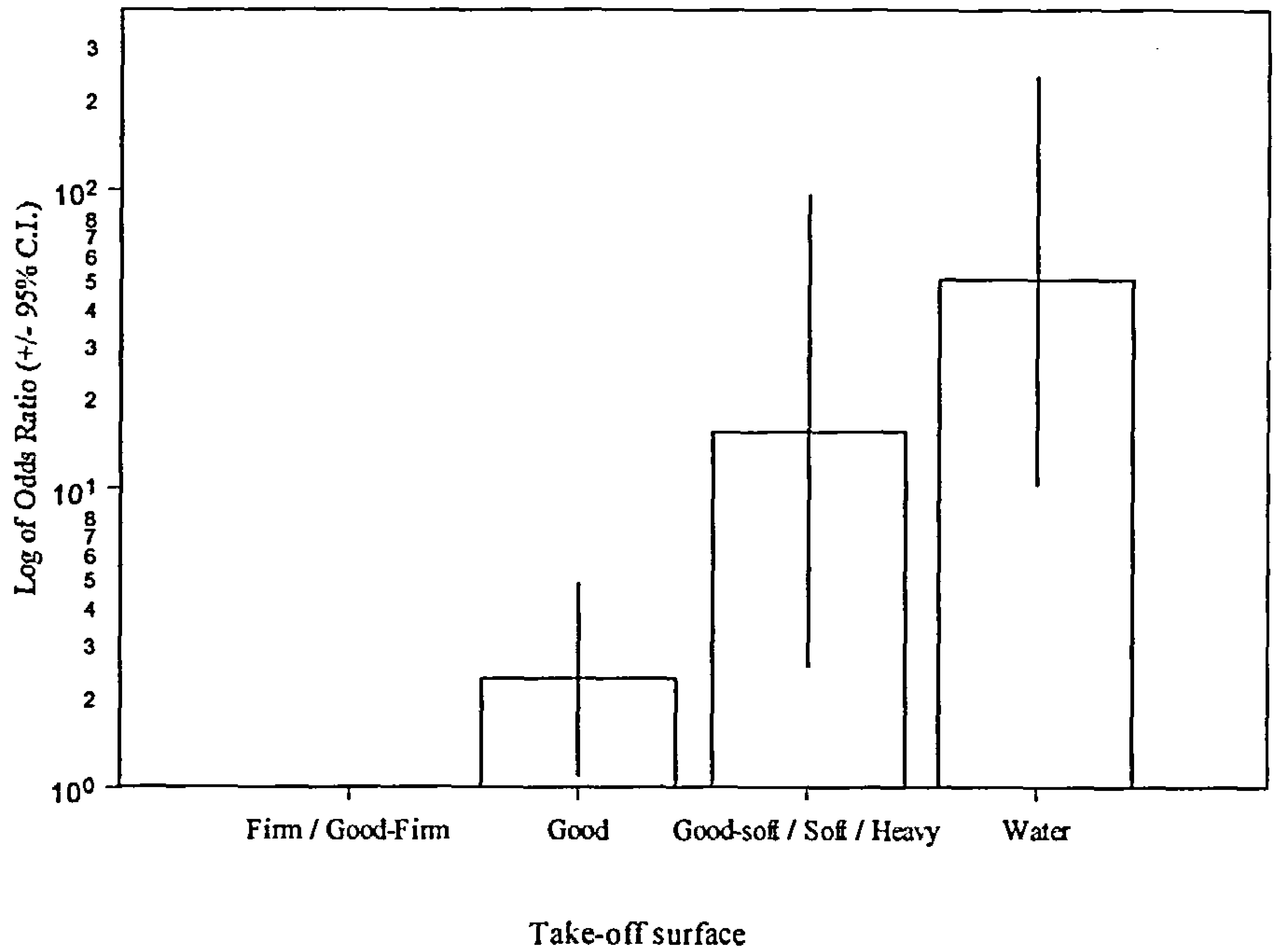
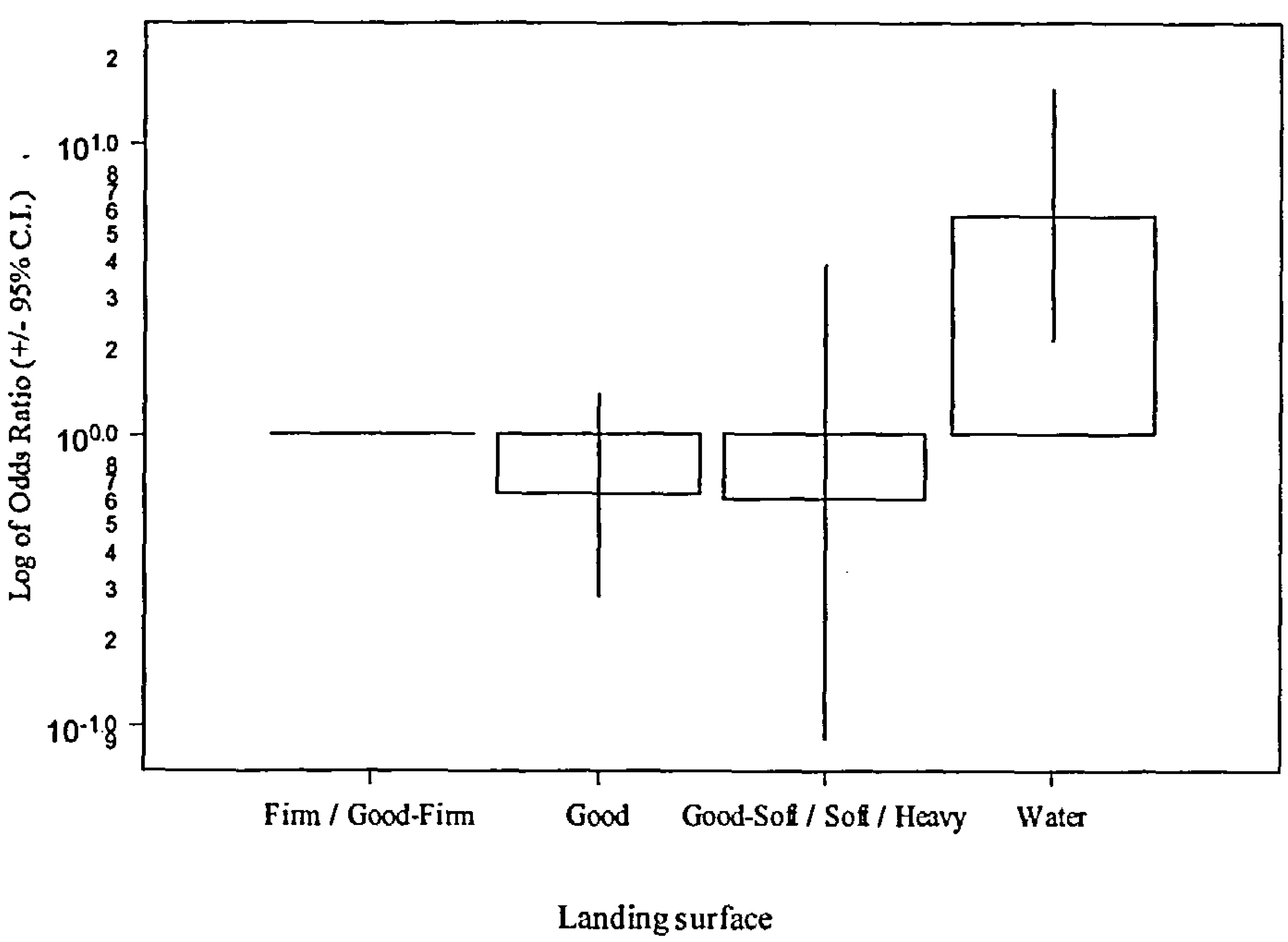


Figure 3. The relationship between landing surface and the risk of a horse fall during the cross-country phase of eventing competitions in Great Britain (2001-2002).



The fit of the model was assessed by examination of the delta betas. Individual cases and controls with delta betas greater than 0.2 and less than –0.2 were removed from the dataset and the model was rerun. The variables of drop landing, angle and spread of the fence, cross-country lessons, approach speed and previous refusals on the course were considered to be stable, as the odds ratios altered by <25% and the significance of the variables remained unchanged. The variables of take-off surface, landing surface and position prior to the cross-country were less stable as the individual removal of 8 cases and 10 controls altered the odds ratio by >25%, although the interpretation of the significance of the variables did not change in relation to the critical P-value of 0.05. Examination of these cases and controls revealed no unusual covariate patterns and the individuals were therefore left in the dataset. The predictive capacity of the model was assessed by calculating the sensitivity and specificity of the model at various cut-off points (Table 3). The specificity of the model was shown to be good, although the sensitivity was less good, particularly at cut-off values of 0.4 and above. Thus, the model was able to predict controls better than cases when the cut-off value was 0.3 or higher.

Table 3. Sensitivity and specificity of the multivariable conditional logistic regression model shown in Table 2 at cut-off points 0.2 to 0.6

Cut-off point	Sensitivity (% of cases predicted)	Specificity (% of controls predicted)
0.2	86.7	74.1
0.3	74.1	84.4
0.4	68.1	88.1
0.5	59.0	93.0
0.6	47.6	96.5

Misclassification

Accuracy of the classification of the response variable was assessed by studying video footage that was available for 42 cases and 122 controls. Classification was 100% accurate for controls and 83% (35/42) accurate for cases. Five of the misclassified cases were horses that had stumbled badly and had fallen onto their knees unseating their riders, but had not fulfilled the case definition that required the horse's shoulders and quarters to touch the ground. The other two cases that had been misclassified were 'rider only' falls, caused by the horse hitting the fence hard; however, neither of these two horses fell onto their knees, shoulders or quarters.

Recall bias

Univariable analysis showed a significant relationship between the number of days since the event and the accuracy of dressage score recall ($P<0.0001$). Dressage scores were less likely to be reported accurately as the number of days increased between the event and questionnaire completion [regression parameter β (SE) = 0.05 (0.01)]. The case-control status of the rider ($P=0.48$) was not associated with the accuracy of the score reported by the rider. There was no evidence of confounding between the variables investigated.

Discussion

This study has identified a number of risk factors for cross-country horse falls. Surface type at the approach of the fence was significantly associated with the risk of a horse fall. Fences jumped out of water were associated with a high risk of a horse fall, compared to fences with a firm or good to firm take-off ($P<0.001$). Fences requiring a take-off out of water were usually sited so that horses would take at least one stride in water before jumping. The increased risk of falling at fences with a take-off in water may have been attributable to miscalculation of the jump height and take-off point by the horse and rider due to the base of the fence being obscured under water, and / or the drag of the water unbalancing the horse. The evidence from this study and an earlier study suggest that water fences should be considered an important area of risk on cross-country courses. Our earlier findings showed an increased risk of injury to horses for falls in water compared to falls on land (OR=2.1, 95% C.I. 1.1, 3.7, P=0.01), Murray et al. (2004a). Whilst jumping into water is considered by some to be an important test of the horse's 'bravery' and obedience, jumping out of water is less of a test for the horse. This was reflected in the higher proportion of refusals recorded at fences jumped into water (10.15 per 1000 jumping efforts) as opposed to fences jumped out of water (0.45 per 1000 jumping efforts), (Murray et al., unpublished data). Fewer horse falls would be anticipated if competitors exited water complexes by cantering up a slope rather than by jumping out of the water.

Good take-off ground (OR=2.3) and good to soft, soft or heavy take-off ground (OR=15.6) were associated with a higher risk of falling when compared to firm and good to firm take-off ground. Human long jump and high jump athletes use a firm take-off surface to aid performance and land on a soft surface to help minimise the risk of injury (Fukuda, 1988). It is possible that equine jumping performance might also be enhanced and the risk of falling reduced, by the provision of good to firm take-off surfaces at cross-country fences.

The width of the fence and the angle of approach were identified as significant risk factors for horse falls. The increased risk of a fall associated with non-angled fences having a base spread of two metres or more, compared with those with a spread of less than two metres, may be due to insufficient impulsion needed to clear the height and spread of the fence. No relationship was observed between the risk of falling and the spread of the fence once the base spread reached two metres or more (P=0.5). During the study period the maximum permitted base spread was 3.0 metres for a fence that required vertical clearance and 4.0 metres for an open ditch (B.E. rules, 2001). These results suggest that reducing the maximum permitted base spread for fences may reduce the risk of a fall.

Angled fences include corner fences and those positioned in such a way that horses were required to jump the fence at an angle. These fences are considered to test the horse's obedience, as penalties may be incurred easily at these fences, as a result of the horse running past the fence. A logical explanation for the increased risk of falling associated with angled fences is that the horse needs to make additional adjustments at take-off, to ensure that both front legs are raised sufficiently in order to clear an angled fence.

The association between fences with drop landings (i.e. the ground level at landing was lower than the ground level at take-off) and an increased risk of a horse fall (OR=3.4) is a logical association that may be explained by a loss of balance by the horse on landing. In contrast with the findings of Singer et al. (2003) who found that fences sited downhill were associated with an increased risk of a horse fall (OR=8.4, 95% C.I., 2.5, 28.8, P=0.001), our results showed no significant association between fences with a downhill approach and the risk of a horse fall in the univariable analysis (OR=0.9, 95% C.I., 0.6, 1.5, P=0.78) or when the variable was added to the multivariable model. The conflicting findings attributed to fences with a downhill approach may be as a result of the different methods of data collection. Singer et al. (2003) collected data retrospectively, which may have led to inaccuracies in the recall of the gradient of the approach to the fence and misclassification of some cases. Singer et al. (2003) found fences with a ditch in front to be associated with an increased risk of a horse fall (OR=5.8, 95% C.I., 1.1, 30.7, P=0.04). Although our study showed no significant association between fences with a ditch in front and the risk of a horse fall when the variable was included in the multivariable model (OR=0.5, 95% C.I. 0.2, 1.2, P=0.10), the confidence intervals from the two studies overlap. The contradictory findings may be partly explained by the different case definitions that were used in the two studies. Singer et al. (2003) included falls that resulted from a refusal. These falls were excluded from our study because the selection of controls did not include attempted jumping efforts that resulted in refusals. Our study excluded six falls that occurred as a result of a refusal, three of which were at fences with a ditch in front. Falls following a refusal may be more likely to occur at fences that have a ditch in front, since the forward momentum of the horse can carry it into the ditch, thus causing a fall. The differing case definitions may therefore explain the different conclusions drawn as to the risk associated with fences with a ditch in front.

The rider's knowledge of their position within the competition at the start of the cross-country phase was associated with the risk of a horse fall. Riders who knew that they were in the lead prior to starting the cross-country course were at a higher risk of falling (OR=4.4) than riders who were unaware of their position. In contrast, riders who knew that they were not in the lead were at a lower risk of falling (OR=0.5) than those that were unaware of their position. It could be hypothesised that horse and rider partnerships that achieved excellent dressage scores (and were therefore in first place) were less proficient at jumping cross-country fences than partnerships that achieved less good dressage scores, thus placing them at an increased risk of a horse fall. Alternatively, this finding may be explained by the fact that riders who knew that they were currently in first position may have been more likely to 'take a risk' during the cross-country phase, in the hope of maintaining their lead in the competition. Conversely, riders who were not in the lead prior to the start of the cross-country may have been riding more cautiously or 'safely' with the priority of completing a round without jumping penalties, irrespective of the time taken.

Riders who had not incurred any refusals on the course, prior to recruitment onto the study, were at an increased risk of a horse fall compared with riders that had already been penalised for a refusal. An explanation for this finding is that some horses and riders would rather attempt to jump a fence and risk a fall than incur a refusal, despite sometimes reaching the fence at a poor take-off point or with inappropriate speed, balance or impulsion. Competitive and determined riders may be reluctant to allow their horses to refuse. If their horses try to refuse a fence, then they may ride strongly, perhaps using their whip and spurs to encourage their horses to jump. An obedient horse may then attempt to jump the fence, and possibly fall, rather than risk punishment for having refused. Conversely, some horses rarely refuse and can be seen to jump at speed with little apparent care for their own safety. The temperament of these horses leads them to attempt to clear a fence and risk an awkward jump or fall, in preference to refusing.

Riders who believed that they had approached the selected fence at an appropriate speed had a lower risk of falling than riders who reported an approach speed that was too slow (OR=5.0) or too fast (OR=6.3). This finding is particularly interesting as inappropriate speed was anecdotally reported to be a contributory factor to some of the fatal falls that occurred during 1999. However, this result should be interpreted with caution as the competitor's retrospective opinion of their speed may be subject to reporting bias. Cases may have been more likely than controls to report an inappropriate speed, in an attempt to find an explanation for their fall. Subjective verification of the speed of a sample of cases and controls needs to be conducted to assess whether bias is present.

Our study found that those riders who received cross-country tuition had an increased risk of falling (OR=1.9) compared with riders that did not receive cross-country tuition. An explanation may be that those riders that took cross-country lessons were doing so because they were aware that they needed tuition to improve their performance on the cross-country course. It is interesting to note that of the riders selected for this study, only 46% (322/694) received cross-country lessons, whilst 94% (651/694) of riders received dressage tuition and 86% (594/694) of riders received show jumping lessons. Further research is recommended to explore the effects of increasing the proportion of riders receiving cross-country tuition in relation to the risk of a horse fall.

In a previous study we found that the risk of falling increased as the number of fences on a cross-country course increased (Singer et al., 2003). As a result of the matching used in the present study, the cases selected from classes with the greatest number of fences (CCI 3* and CCI 4*) were matched to controls competing over the same courses, as these were the only classes held at their respective venues. This could explain the apparent lack of association between number of fences on a course and the risk of falling found here.

There was no difference between cases and controls in the accuracy of reporting dressage scores by telephone interview; however, there was evidence of an effect of the number of days between the event and telephone interview. The most plausible explanation for this is memory decay in the reporting of dressage scores. Although it is possible that as the respondents were forewarned of the telephone interview, they may have kept a copy of their results near the phone for a few days in preparation for the interview. Memory decay was not confounded by case-control status. Our findings highlight the importance of minimising the time period between the event and questionnaire completion in retrospective data collection. However, the time delay experienced in our questionnaire completion was largely due to the non-availability or evasiveness of some of our respondents, rather than insufficient time being allocated for interviewers, and was therefore difficult to improve.

Video analysis indicated some misclassification of cases (7/42) by fence judges. It is expected that the risk factors associated with the stumbles experienced by five of the misclassified case horses would be similar to the risk factors identified for horse falls by this study. The potential effect of the misclassification of cases is currently being investigated, but is not expected to be large.

This study has identified a number of risk factors for horse falls that are associated with the fence and the rider. We are currently in discussion with the sport's officials as to how our findings on course design might be tested through suitable intervention studies.

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APPENDIX: CHAPTER THREE

Table 1. Comparison between final multivariable model presented in Table 2 of Chapter 3 and the model rerun without the variable of approach speed.

	Model without the variable of speed of approach			Original model (Table 2, Chapter 3)		
VARIABLE	Odds ratio	95% confidence intervals	LRT P-value	Odds ratio	95% confidence interfals	LRT P-value
Take-off surface						
Firm / Good-firm	1.00			1.00		
Good	2.09	1.04, 4.17		2.29	1.09, 4.82	
Good-soft / Soft	12.37	2.35, 65.18		15.56	2.54, 95.45	
Water	40.67	9.23, 179.14	<0.001	49.80	10.38, 238.99	<0.001
Landing surface						
Firm / Good-firm	1.00			1.00		
Good	0.69	0.33, 1.43		0.63	0.28, 1.38	
Good-soft / Soft	0.78*	0.14, 4.30		0.60	0.09, 3.83	
Water	4.61	1.83, 11.64	0.001	5.72	2.12, 15.45	<0.001
Landing						
Without a drop	1.00			1.00		
Drop landing	3.23	1.55, 6.74	0.002	3.41	1.60, 7.25	0.001
Angle and spread of fence						
No angle, <2m spread	1.00			1.00		
No angle, ≥2m spread	3.79	2.04, 7.03		3.24	1.71, 6.16	
All angled fences	3.97	1.82, 8.63	<0.001	4.83	2.09, 11.16	<0.001
Position before XC						
Didn't know position	1.00			1.00		
First	3.79	1.28, 11.20		4.39	1.44, 13.43	
Second or lower	0.44	0.23, 0.84	0.002	0.45	0.22, 0.89	0.001
Approach speed						
Appropriate				1.00		
Too slow				5.00	1.90, 13.14	
Too fast				6.30	2.64, 15.02	<0.001
Previous XC refusals on the course incurred by the horse and rider						
Earlier refusals	1.00			1.00		
No refusals	29.77	3.87, 229.04	0.001	23.02	2.98, 178.12	0.003
Rider has XC lessons						
No	1.00			1.00		
Yes	1.95	1.26, 3.03	0.003	1.94	1.21, 3.09	0.006

* Change in coefficient by >25%, when variable of approach speed was removed from the model.

Table 2. A summary of the effect of adding the variables; event level, event type, rider status into the model of risk factors for horse falls presented in Table 2 of Chapter 3.

	Original model (A)	Model A plus event level	Model A plus event type	Model A plus rider status
Variable	Odds Ratio	Odds Ratio	Odds Ratio	Odds Ratio
Take-off surface				
Firm / Good-firm	1.00	1.00	1.00	1.00
Good	2.29*	2.45*	2.28*	2.19*
Good-soft / Soft	15.56*	16.61*	15.52*	15.83*
Water	49.80*	56.41*	49.61*	49.59*
Landing surface				
Firm / Good-firm	1.00	1.00	1.00	1.00
Good	0.63	0.59	0.63	0.63
Good-soft / Soft	0.60	0.49	0.61	0.65
Water	5.72*	5.71*	5.78*	5.64*
Landing				
Without a drop	1.00	1.00	1.00	1.00
Drop landing	3.41*	3.21*	3.43*	3.49*
Angle and spread of fence				
No angle, <2m spread	1.00	1.00	1.00	1.00
No angle, ≥2m spread	3.24*	3.53*	3.24*	3.29*
All angled fences	4.83*	4.60*	4.81*	4.87*
Position before XC				
Didn't know position	1.00	1.00	1.00	1.00
First	4.39*	5.18*	4.38*	4.24*
Second or lower	0.45*	0.42*	0.44*	0.44*
Approach speed				
Appropriate	1.00	1.00	1.00	1.00
Too slow	5.00*	5.18*	5.00*	5.04*
Too fast	6.30*	5.47*	6.31*	6.23*
Previous XC refusals on the course incurred by the horse and rider				
Earlier refusals	1.00	1.00	1.00	1.00
No refusals	23.02*	21.87*	22.51*	22.45*
Rider has XC lessons				
No	1.00	1.00	1.00	1.00
Yes	1.94*	2.17*	1.94	1.96*
Event level				
Intro / Pre-novice		1.00		
Novice		1.90		
Intermediate		2.33		
Advanced		1.00		
Event type				
One-day event			1.00	
Two-/three-day event			1.66	
Rider status				
Professional rider				1.00
Amateur rider				0.73

* P-value < 0.05

Table 3. Population proportional attributable risk values of explanatory variables identified in Table 2 of Chapter 3, for risk factors for cross-country horse falls at eventing competitions in Great Britain (2001-2002).

Explanatory Variable	Population Proportional Attributable Risk (PPAR)
Take-off surface	
Firm/Good-firm	0.00
Good	0.25
Good-soft/soft/heavy	0.06
Water	0.07
Landing surface	
Good-soft/soft/heavy	0.00
Good	0.02
Firm/Good-firm	0.16
Water	0.14
Drop landing	
No	0.00
Yes	0.14
Angle width combined	
(Ref: <2m spread, non-angled)	0.00
≥2m spread, non-angled	0.15
All angled fences	0.09
Position	
(Ref: 2nd or lower)	0.00
First	0.05
Didn't know	0.40
Approach speed	
Appropriate	0.00
Too slow	0.08
Too fast	0.14
XC refusals	
No	0.00
Yes	0.01
Rider has XC lessons	
No	0.00
Yes	0.28

CHAPTER FOUR:

Risk factors for cross-country horse falls at one- and two- / three-day events.

Abstract

Eventing is a popular international equestrian sport which has Olympic status. In 1999 five riders died in eventing competitions in the United Kingdom as a result of horse falls on the cross-country course. In an effort to decrease the risk of human and equine death or injury, a case-control study was carried out to identify variables that increased or decreased the risk of a horse fall on the cross-country phase at event competitions. After initial analysis, the dataset was split according to the categories of one-day events as compared to two- or three-day events to establish whether significant risk factors varied between the different types of eventing competitions. Data were collected for 180 cases (horse falls) and their 540 matched controls (1:3 ratio). There were 121 cases at one-day events and 59 cases at two- or three-day events. Cases were jumping efforts that resulted in a fall of the horse. Controls were matched by competition and day (but not class) and were selected randomly from all jumping efforts that did not result in a horse fall. Data related to course- and fence-level variables, which might be associated with horse falls, were collected on the day of the event. Data related to horse-, rider- and event-level variables were collected by telephone interview and from the British Eventing database.

Conditional logistic regression was used to analyse the data. The variables of no previous refusals on the course, fences with a landing in water and the combined variable of the angle and the spread of the fence were significantly associated with the risk of a horse fall in both datasets. Additional risk factors for one-day event falls were: fences requiring a take-off from water, a drop landing, the rider's knowledge of their position before the cross-country phase and if the rider received cross-country tuition. Three-day event risk factors in the multivariable model included: the camber of the fence and participation in non-equestrian sports by the rider.

This study identified variables that were significantly associated with an increase or a decrease in the risk of a horse fall during the cross-country phase of different types of eventing competitions.

Introduction

Eventing is an equestrian sport appealing to amateur and professional riders, with 8,283 riders and 10,513 horses registered with British Eventing (B.E.) in 2003. A total of six riders died in the United Kingdom (U.K.) as a result of horse and rider falls during the cross-country (XC) phase of eventing competitions during 1999 and 2000. These fatalities raised concerns about the safety of this sport and initiated epidemiological investigations aimed at reducing the risk of injury to horse and rider.

Data suggests that the rate of rider injury at eventing competitions is much greater than for motorcycle or car racing. The rate of eventing injuries to riders has been reported as 0.88% (Paix, 1999) and 1.1% (Whitlock, 1999) compared to 0.24% and 0.14% for motorcycle and car racing competitors, respectively, on U.K. Grand Prix circuits (Chapman and Oni, 1991). Horses are also frequently injured in falls. Previously, we reported that 32% of horses that fell were injured, with 1.5% being euthanased as a result of the injuries sustained (Murray et al., 2004a). Horse falls occurring during the cross-country phase of events present a risk of injury and fatality to horses and riders, therefore it is important to measure this risk to identify the factors that might be modified to decrease the risk.

An eventing competition may be run over one, two or three days and is classified according to the level of difficulty of the cross-country course. There are 5 one-day event levels (in ascending order of difficulty): Intro, Pre-novice, Novice, Intermediate and Advanced. Two-day events are held at Novice and Intermediate levels with the aim of providing competitors with an introductory experience of the four cross-country phases required for a three-day event. Three-day events are also knows as Concours Complet Internationale (CCI) competitions, with the difficulty increasing from 1-star (1*) to 4-star (4*) level. The stages of a one-day event are run in the order of: dressage, show jumping and cross-country. Two-day events have dressage and show jumping on the first day and speed and endurance (incorporating the cross-country phase) on the second day. Three-day events have dressage on the first day, speed and endurance on the second day and show jumping on the final day. The speed and endurance day of two- and three-day events consists of four phases,

phases A, B, C and D. Phase D is equivalent to the cross-country course at one-day events.

The cross-country stage of three-day events covers a distance of 3,900-7,980 metres and includes a maximum of 45 jumping efforts. The cross-country phase of one-day events is shorter with course distances of 1,600-4,000 metres incorporating 18-40 jumping efforts. The cross-country phase requirements vary between the different types of events, particularly with respect to the three phases (A, B and C) that are completed by two- and three-day event competitors before they commence the cross-country course (phase D).

During the cross-country phase of eventing, the criteria on which horses and riders are judged include: time, refusals, rider falls and horse falls. A rider fall is penalised if the rider becomes separated from his/her horse in such a way to necessitate remounting. A horse fall is recorded if the shoulders and quarters of the horse touch either the ground or the obstacle and the ground at the same time (B.E. rules, 2001). A horse fall, which incurs compulsory retirement, usually leads to a fall of the rider, and is therefore also known as a 'horse and rider fall'.

Analysis of retrospective data, using a case-control design, suggested an increased risk of falling associated with fences sited on a downhill slope (OR=8.4, 95% confidence interval (C.I.) 2.5, 28.8, P=0.001) or with a ditch in front (OR=5.8, 95% C.I. 1.1, 30.7, P=0.04) when compared with fences sited on flat ground and without a ditch in front (Singer et al., 2003). The risk of falling also rose as the number of fences on a course increased (OR=1.6, 95% C.I. 1.2, 2.0, P<0.001); however, the risk associated with each additional jumping effort on the course decreased (OR=0.8, 95% C.I. 0.7, 1.0, P=0.01).

Previously we reported risk factors associated with horse falls occurring on the cross-country phase of a combined dataset of one-, two- and three-day eventing competitions (Murray et al., 2004b). Variables related to the fence and the course found to be associated with an increased risk of a horse fall were fences with a take-off from water (OR=49.8, 95% C.I. 10.4, 239.0, P<0.001), a landing in water

(OR=5.7, 95% C.I. 2.1, 15.5, P<0.001), a drop landing (OR=3.4, 95% C.I. 1.6, 7.3, P=0.001), angled fences (OR=4.8, 95% C.I. 2.1, 11.2, P<0.001) and non-angled fences with a spread of two metres or greater (OR=3.2, 95% C.I. 1.7, 6.2, P<0.001). Rider-level variables that were significantly associated with an increased risk of a horse fall were riders who knew they were in first position prior to starting their cross-country round (OR=4.4, 95% C.I. 1.4, 13.4, P=0.001), riders who perceived their speed of approach to the fence to be too slow (OR=5.0, 95% C.I. 1.9, 13.1, P<0.001) or too fast (OR=6.3, 95% C.I. 2.6, 15.0, P<0.001) and riders who received cross-country lessons (OR=1.9, 95% C.I. 1.2, 3.1, P=0.006). Horse and rider partnerships that had not incurred any refusals on the course prior to selection were associated with an increased risk of a horse fall (OR=23.0, 95% C.I. 3.0, 178.1, P=0.003). The results of the combined dataset reported in Chapter 3 provided information regarding the risk factors for horse falls at all types of eventing competitions. The combined dataset analysed in Chapter 3 was divided to allow the separate analysis of one-day event risk factors and two-/three-day event risk factors.

We hypothesise that different risk factors may exist for horse falls that occur at one-day events compared with horse falls occurring at two- and three-day events. The aim of the study was to identify variables that increased or decreased the risk of horse falls during the cross-country phase of one-day events and two- or three-day events. To our knowledge, this is the first study to investigate potential risk factors for the different types of eventing competition.

Materials and Methods

Study Design

A matched prospective case-control design with a ratio of 3 controls per case was used to test associations between course and fence, horse, rider and event related variables and horse falls at one-day events and two-/three-day events. One- and two-day eventing competitions were selected randomly during the 2001 and 2002 British Eventing seasons. Only sixteen three-day event competitions were scheduled for the study period and all were selected for inclusion, to maximise data collection from these competitions. Data were obtained for 180 cases and 540 controls. Controls were matched by venue and day of the cross-country competition. One hundred and twenty-one cases were recorded at one-day events and 59 cases were identified at two- and three-day events. The data were divided into two datasets on the basis of whether competitors starting the cross-country course had previously completed speed and endurance phases A, B and C (two- and three-day events), or not (one-day events).

Case Definition

A case was a jumping effort that resulted in a horse fall on the cross-country phase of an event. A jumping effort was defined as having occurred if the horse had attempted to negotiate a numbered obstacle on the course. A horse fall was defined using the B.E. rule, i.e. the horse's shoulders and quarters touched either the ground or the obstacle and the ground at the same time, as a direct result of an attempted jumping effort. Falls that occurred on the approach to the fence, as a result of the horse attempting to avoid jumping the fence, were not classified as cases. Cases were identified by fence judges positioned at each obstacle to record any penalties incurred by each competitor. Fence judges were briefed at the beginning of the competition on the definition of a horse fall.

Control definition and selection

A control was a jumping effort that did not result in a horse fall. Three controls were selected randomly from all successful jumping efforts that took place on the same day and at the same competition from which their case was selected. Matching was used to control for the potentially confounding effects of month, weather conditions and geographical location.

In order to facilitate the random selection of control jumping efforts every fence on the course was numbered consecutively. In some situations it was not possible to calculate the exact number of jumping efforts taken by a horse and rider combination, because competitors were given the choice between a shorter, technically difficult route, and an easier, but longer alternative with more elements. In situations where the exact number of jumping efforts was unknown, the minimum possible number of the jumping effort was used.

Description of fences

Cross-country courses included between 16 and 42 numbered obstacles requiring a maximum of 18-45 jumping efforts. The majority of obstacles consist of one fence, requiring a single jumping effort; however, some obstacles require multiple jumping efforts as they consist of two or more elements situated in close proximity. These obstacles are known as combination fences. For the purposes of this study, two fences were defined as part of a combination fence if they were positioned so that the average horse would take four or fewer strides between the two fences. (A four-stride distance between fences was equivalent to a mean of 16.8 (SD 1.6) metres in this study.)

Data collection

Data were recorded on the day of the competition for course and fence-level variables (Appendix: Table 1). The ground conditions were categorised subjectively by visual assessment and by digging a heel into the ground to assess the firmness of the ground. Assessments were made by one of two observers (JKM, ERS) who worked together at the beginning of the data collection period to standardise interpretation of the six main categories of 'going' (firm, good-firm, good, good-soft, soft, heavy). Ground was considered to be slippery if the footwear of the observer could slide easily along the surface of the ground. Ground was coded as rutted if it was sufficiently uneven to make walking difficult. Periodically, during the duration of the study, the two observers compared their assessment of ground conditions at events, to maintain consistency and to reduce observer bias. On average, ground conditions were recorded at each fence every 3-4 hours during the day of competition to document any changes that occurred as a result of weather conditions, drainage and soil type. The ground conditions recorded for each case or control were those observed closest to the time of the competitor's cross-country round.

The gradients of the ground on the approach and landing of the selected fences were measured using levelling techniques with a surveyor's staff and level (Nikon Automatic Level AC-2, Nikon, Inc. Instrument Group, Melville, USA). Measurements were recorded from the base of the fence (take-off and landing side), to 20 metres (m), 10m, 5m and 2m on the approach to the fence and to 10m, 5m and 2m on the landing side of the fence. The gradient between two points was calculated as the difference in height (centimetres) between the points divided by the distance (metres) between the points (Figure 1, Appendix). Measurements were not made at 20m from the fence on the landing side, since a horse fall at a distance of more than 10 metres from the fence on the landing side was unlikely to be associated with the fence. For combination fences, the gradient measurements were taken for available distances between elements. Measurements were taken at the right and left of the fence in order that the camber of the fence could be calculated. The jumpable width of the fence was recorded as the distance between the flags that were attached to the left and right limits of all fences, indicating the two points between which the horse must jump.

A letter explaining the study was sent to all cases and controls within 3 days of the event. The letter informed the riders of imminent contact by telephone to complete a questionnaire relating to the event and additional areas such as horse and rider training. The questionnaires were administered by telephone as soon as possible to each rider selected as a case or control. Copies of the questionnaires used for one-day event and two-/three-day event competitors are provided in the Appendix to this chapter. Additional data (dressage and show jumping scores, horse age, horse height) were obtained from the B.E. database and B.E. website (www.britisheventing.com). Data were recorded for rider-, horse- and event-level variables (Appendix: Tables 2, 3, and 4).

Data Analysis

Categorical variables with few observations in one or more categories were recoded where appropriate to create larger categories. In addition, a new variable of 'changing light conditions' was formed from the combination of the variables of 'light to dark' and 'dark to light' conditions.

We had previously shown an interaction between the explanatory variables of fence angle and spread for the complete dataset of all types of event (Chapter 2). A new variable was created that combined the variables of fence angle and spread, which was both biologically plausible and had previously been shown to improve model fit. The new variable was created with three categories (non-angled fence with a spread of <2 metres, non-angled fence with a spread of ≥2 metres and angled fences with any spread). The two separate variables and the combined variable were assessed for inclusion into the multivariable model.

All variables were tested for association with falling using univariable conditional logistic regression models. The statistical packages R (www.r-project.org) and Egret (Cytel Software Corporation, USA) were used for data analysis. Continuous variables were also categorised into quintiles in the univariable analysis. The fit of the categorical variables in the model were compared to the fit of the continuous variables by assessing the change in deviance, (assuming the change in deviance follows a chi-squared distribution with n degrees of freedom, where n is the number of extra parameters fitted). To reduce the effects of collinearity, continuous variables were centred by subtracting the mean of the variable from all recorded observations (Kleinbaum et al., 1988).

The following procedure was conducted for the two datasets (one- and two-/three-day events). Variables with a P-value <0.2 were considered for inclusion in a multivariable submodel, which was built using the technique of backward elimination for each of the four categories of variables (course/fence, horse, rider and event). Variables with one or more empty cells were analysed following the alteration of a randomly selected data point. The selected data point was changed so that no zero cells were present, which allowed univariable analysis that included the variable to be conducted.

A multivariable model for each dataset was then built by backward elimination from variables included in the four submodels. The multivariable models produced for the datasets contained one or more subjective variables that were susceptible to responder bias (speed of approach to the fence, the horse's behaviour prior to the XC, if the fence was ridden according to plan, the quality of the previous jumping effort, the rider's opinion of the level of difficulty of the fence). In order to assess the association of objective variables with the risk of a horse fall in the absence of confounding from variables that were susceptible to responder bias, these subjective variables were removed and the model was rerun to provide a model based solely on objective variables. Variables that had previously been associated with the risk of a horse fall in studies by Singer et al. (2003) and Murray et al. (2004b) were considered for inclusion in the multivariable models. Variables remained in the model if they were shown to improve the fit of the model significantly by assessing the change in deviance, (assuming the change in deviance follows a chi-squared distribution with n degrees of freedom, where n is the number of extra parameters fitted).

The effect of biologically plausible interactions between variables was tested for in the model. The level of the event and the status of the rider (professional or amateur event rider) were evaluated as potential confounders. A change in the regression parameters of >25% was considered to be indicative of confounding. The fit of the model was assessed by examination of the sensitivity and specificity of the model at cut-off points ranging from 0.2 to 0.6. Model stability was assessed by examination of the delta betas. The model was considered to be stable if removal of individual cases or controls altered the odds ratio by <25% and did not affect the significance of individual variables in relation to the critical P-value of 0.05.

Power of the study

The case-control study of all horse falls (one-, two- and three-day events) was designed to have 80% power to detect an odds ratio of 2.0. Dividing the dataset on the basis of event type (one- or two-/three-day event) reduced the power of the analysis for both datasets. Calculations showed that the one-day event horse falls dataset had 80% power to detect odds ratios of 2.2. The two-/three-day event dataset had 80% power to detect odds ratios of 2.9. These calculations were based on a 0.05 probability of a Type-I error (95% confidence) and assumed 10% of controls were exposed to risk factors (Epi-Info 6, CDC, USA).

Population Proportional Attributable Risk

The population attributable risk (PAR) provides a measure of the impact that a variable has on a population, whilst the population proportional attributable risk (PPAR) represents the fraction of cases that would not have occurred if they had not been exposed to the risk factor (Kirkwood, 1988). The PPARs were calculated for each of the explanatory variables included in the final multivariable model by the method outlined by Bruzzi et al. (1985). In order that PPARs could be estimated for all variables, continuous variables were converted to categorical variables. Categorical variables were ordered by ascending odds ratios and the model was rerun to obtain odds ratios used to calculate PPARs for all variables associated with an increased risk of a horse fall.

Results

The overall risk of a horse fall was 0.35 per 1000 jumping efforts (95% C.I. 0.30-0.41) (Table 1). Two- and three-day events were noted to be associated with a higher risk of a horse falling (0.91 falls per 1000 jumping efforts) compared to one-day events (0.27 falls per 1000 jumping efforts).

The results of the univariable analysis are shown in Tables 5-19 of the Appendix to this chapter. Variables that remained in the four submodels were considered for inclusion in the multivariable model for their type of event (one- or two-/three- day event). In all instances where a continuous variable was also analysed as a categorical variable, the continuous variable resulted in a better fit of the model. Multivariable models were built for the risk factors associated with falls of horses during the cross-country phase of one- day events and two-/three-day events (Tables 2 and 3). Within each model, two or more of the variables were subjective and susceptible to reporting bias. Due to the potential for reporting bias and confounding from biased variables, a second model was built for each dataset using objective variables only. The combined variable of angle and width of the fence improved model fit for the two-/three-day dataset and was retained in the final model (Table 5). None of the other variables that had previously been associated with the risk of falls (Singer et al., 2003; Murray et al., 2004b) improved model fit, therefore, these variables were excluded from the final multivariable model. A summary of the effect of adding these variables is provided (Appendix, Tables 20-21). Biologically plausible interactions between variables were tested for with none found to be significant. There was no evidence of confounding by the variables of event level and rider status (Appendix, Tables 22-23). The final multivariable models for risk factors associated with one- and two-/three-day event horse falls are summarised in Tables 4 and 5.

Table 1. A summary of the number of falls per 1000 jumping efforts (j.e.) recorded at different types of eventing competitions in Great Britain during 2001-2002.

Event type	No. of falls	No. of j.e.	No. of falls per 1000 j.e.	95% Confidence Intervals
One-day events	121	444,605	0.27	0.23, 0.33
Two-day events	1	2,847	0.35	0.00, 1.96
Three-day events	58	61,908	0.94	0.71, 1.21
Two- and three-day event total	59	64,755	0.91	0.69, 1.18
Overall total	**180**	**509,360**	**0.35**	**0.30, 0.41**

Table 2. Multivariable conditional logistic regression model for objective and subjective risk factors for cross-country horse falls at one-day eventing competitions in Great Britain (2001-2002).

Variable	Coefficient	Standard Error	Odds Ratio	95% Confidence Interval	LRT P-value
XC refusals prior to the selected fence					
Earlier refusals	Ref.		1.00		
No refusals	3.06	1.15	21.33	2.24, 203.27	0.01
Ride Plan[a]					
Yes	Ref.				
No	2.59	0.55	13.30	4.54, 38.98	<0.001
Fence before[b]					
Not at all well/ not very well	Ref.				
Well	0.06	0.69	1.07	0.28, 4.12	0.93
Very well	1.07	0.65	2.92	0.81, 10.49	0.10
Drop landing					
No	Ref.				
Yes	1.99	0.59	7.31	2.30, 23.25	<0.001
Angle width combined					
Non-angled, <2m	Ref.				
Non-angled, ≥2m	1.81	0.55	6.11	2.07, 18.01	0.001
Angled fences	2.06	0.73	7.81	1.86, 32.85	0.01
Water approach					
No	Ref.				
Yes	4.14	0.94	62.74	9.97, 394.98	<0.001
Water landing					
No	Ref.				
Yes	2.69	0.68	14.76	3.87, 56.27	<0.001
Rider's knowledge of their position prior to XC					
Didn't know	Ref.		1.00		
First place	1.81	0.77	6.09	1.35, 27.52	0.02
Second or lower	-0.65	0.64	0.52	0.15, 1.83	0.31
Normal XC[c]					
No	Ref.		1.00		
Yes	-1.84	0.73	0.16	0.04, 0.67	0.01
Rider has XC lessons					
No	Ref.		1.00		
Yes	0.68	0.33	1.97	1.04, 3.73	0.04

[a] The fence was ridden as planned by the rider.
[b] The rider's opinion of how well the horse jumped the fence prior to the selected fence.
[c] Horse's attitude was normal for the horse prior to the cross-country.

Table 3. Multivariable conditional logistic regression model for objective and subjective risk factors for cross-country horse falls at two-/three-day eventing competitions in Great Britain (2001-2002).

Variable	Coefficient	Standard Error	Odds Ratio	95% Confidence Interval	LRT P-value
XC refusals prior to the selected fence					
Earlier refusals	Ref.		1.00		
No refusals	2.69	1.21	14.79	1.39, 156.98	0.03
Water landing					
No	Ref.		1.00		
Yes	3.61	1.27	36.91	3.09, 440.98	0.004
Camber [a] (continuous variable: linear fit)	-0.28	0.10	0.75	0.62, 0.92	0.006
Route[b]					
Easy / Straightforward	Ref.		1.00		
Fairly difficult /Difficult	1.79	0.78	6.00	1.31, 27.43	0.02
Speed of approach					
Appropriate	Ref.		1.00		
Too slow	2.98	1.03	19.70	2.64, 146.86	0.004
Too fast	2.42	0.89	11.19	1.97, 63.63	0.006
Rider participation in non-equestrian sport					
No	Ref.		1.00		
Yes	2.30	0.66	9.93	2.71, 36.43	<0.001

[a] Unit defined as the difference between the height of the ground at the base of the fence at the right and left flags. Expressed as the difference in centimetres, divided by the distance (metres) between the flags. An increase of one unit was associated with a decreased risk of a horse fall (OR=0.75) and an increase of five units was associated with an odds ratio of 0.24 (i.e. 0.75^5).

[b] Rider's opinion of the route taken at the selected fence.

Table 4. Final multivariable conditional logistic regression model for objective risk factors only for cross-country horse falls at one-day eventing competitions in Great Britain (2001-2002).

Variable	Coefficient	Standard Error	Odds Ratio	95% Confidence Interval	LRT P-value
XC refusals prior to the selected fence					
Earlier refusals	Ref.		1.00		
No refusals	2.33	1.08	10.23	1.22, 85.61	0.03
Drop landing					
No	Ref.				
Yes	1.62	0.50	5.62	2.34, 13.45	0.001
Angle width combined					
Non-angled, <2m	Ref.				
Non-angled, ≥2m	1.73	0.45	5.62	2.34, 13.45	<0.001
Angled fences	1.89	0.60	6.63	2.05, 21.38	0.001
Water approach					
No	Ref.				
Yes	3.22	0.73	25.00	5.92, 105.56	<0.001
Water landing					
No	Ref.				
Yes	1.94	0.56	6.95	2.30, 21.01	<0.001
Rider's knowledge of their position prior to XC					
Didn't know	Ref.		1.00		
First place	1.74	0.66	5.69	1.55, 20.86	0.01
Second or lower	-0.32	0.49	0.73	0.28, 1.91	0.52
Rider has XC lessons					
No	Ref.		1.00		
Yes	0.70	0.29	2.02	1.15, 3.56	0.01

Table 5. Final multivariable conditional logistic regression model for objective risk factors only for cross-country horse falls at two-/three-day eventing competitions in Great Britain (2001-2002).

Variable	Coefficient	Standard Error	Odds Ratio	95% Confidence Interval	LRT P-value
XC refusals prior to the selected fence	Ref.		1.00		
Earlier refusals	2.44	1.11	11.48	1.31, 100.36	0.03
No refusals					
Water landing					
No	Ref.		1.00		
Yes	2.30	0.81	10.02	2.07, 48.60	0.004
Camber[a] (continuous variable: linear fit)	-0.27	0.09	0.77	0.64, 0.91	0.003
Rider participation in non-equestrian sport					
No	Ref.		1.00		
Yes	1.87	0.50	6.52	2.43, 17.50	<0.001
Angle width combined					
Non-angled, <2m	Ref.		1.00		
Non-angled, ≥2m	0.99	0.54	2.69	0.93, 7.75	0.07
Angled fences	1.26	0.61	3.51	1.07, 11.52	0.04

[a] Unit defined as the difference between the height of the ground at the base of the fence at the right and left flags. Expressed as the difference in centimetres, divided by the distance (metres) between the flags. An increase of one unit was associated with a decreased risk of a horse fall (OR=0.77) and an increase of five units was associated with an odds ratio of 0.27 (i.e. 0.77^5).

Model fit

Within the one-day event model, two variables (XC lessons and drop landing) were considered to be stable. All other variables were considered to be unstable as the individual removal of 12 cases and 11 controls with large delta betas either altered the odds ratio by >25% or changed the significance of the variable in relation to the critical P-value of 0.05. Examination of the two-/three-day event model revealed the continuous variable of camber to be stable. All other variables were considered to be unstable as the individual removal of 13 cases and 11 controls either altered the odds ratio by >25% or changed the significance of the variable. Inspection of these cases and controls revealed no unusual conditions and the individuals were therefore retained in their datasets.

Sensitivity and specificity of the models

The predictive capacity of the models was assessed by calculating the sensitivity and specificity of the models at various cut-off points (Table 6 and 7). The specificity of the two models was shown to be good, although the sensitivity was poor at cut-off values of 0.4 and above. The model for one-day events had better capacity for predicting controls than the two-/three-day event model, whereas there was little observed difference in the ability of the two models to predict cases.

Table 6. Sensitivity and specificity of the final multivariable conditional logistic regression model shown in Table 4 for one-day events, at cut-off points 0.2 to 0.6

Cut-off Point	Sensitivity (% of cases Predicted)	Specificity (% of controls Predicted)
0.2	84.3	72.4
0.3	72.2	83.7
0.4	60.2	91.2
0.5	53.7	94.0
0.6	47.2	96.9

Table 7. Sensitivity and specificity of the final multivariable conditional logistic regression model shown in Table 5 for two-/three-day events, at cut-off points 0.2 to 0.6

Cut-off Point	Sensitivity (% of cases Predicted)	Specificity (% of controls Predicted)
0.2	84.2	66.9
0.3	71.9	75.2
0.4	61.4	84.7
0.5	49.1	91.7
0.6	42.1	96.8

Population proportional attributable risk

The population proportional attributable risks (PPAR) were calculated for each of the explanatory variables included in the final multivariable models (Tables 8 and 9). The potentially modifiable variables of non-angled fences with a spread of two metres or more and a landing in water were associated with a high proportion of the horse falls recorded in both datasets (PPAR $\geq$ 0.12). The PPAR was derived from multiple logistic regression and therefore was not additive.

Table 8. Population proportional attributable risk values of explanatory variables for risk factors for cross-country horse falls at one-day eventing competitions in Great Britain (2001-2002).

Explanatory Variable		Population Proportional Attributable Risk (PPAR)
Water approach		
	No	0.00
	Yes	0.09
Water landing		
	No	0.00
	Yes	0.15
Cross-country lessons		
	No	0.00
	Yes	0.29
Drop landing		
	No	0.00
	Yes	0.18
Angle width combined		
	(Ref: <2m spread, non-angled)	0.00
	≥2m spread, non-angled	0.17
	All angled fences	0.08
XC refusals		
	Prior refusals	0.00
	No prior refusals	0.89
Position		
	(Ref: 2nd or lower)	0.00
	First	0.07
	Didn't know	0.22

Table 9. Population proportional attributable risk values of explanatory variables for risk factors for cross-country horse falls at two-/three-day eventing competitions in Great Britain (2001-2002).

Explanatory Variable	Population Proportional Attributable Risk (PPAR)
Water landing	
No	0.00
Yes	0.12
Camber[a]	
(Ref: 4 to 32)	0.00
2 to 3	0.36
0 to 1	0.32
Angle width combined	
(Ref: <2m spread, non-angled)	0.00
≥2m spread, non-angled	0.18
All angled fences	0.09
XC refusals	
Prior refusals	0.00
No prior refusals	0.90
Non-equestrian sport	
No	0.00
Yes	0.58

[a] Difference between the height of the ground at the base of the fence at the right and left flags. Expressed as the difference in centimetres, divided by the distance (metres) between the flags.

Discussion

The analysis of the two datasets identified objective and subjective variables associated with the risk of a horse fall at one-day events and two-/three-day events. We considered some of these subjective variables to be susceptible to reporting bias, as cases may have been more likely than controls to report factors such as inappropriate speed, a 'difficult' fence, or that the horse had not been jumping well, in an attempt to find an explanation for their fall. The associations of the subjective variables with the risk of falling are discussed briefly with respect to the first model created for each dataset (Tables 2 and 3). The second model created for each dataset (Tables 4 and 5) is discussed in more detail, as this model allowed assessment of the association of objective variables with the risk of a horse fall, without the potentially confounding effects of variables subjected to bias. The association between variables remaining in the final models and the risk of a horse fall provides useful information for the design of intervention studies.

Variables susceptible to bias

The model produced for the two-/three-day event dataset (Table 3) provided evidence of an association between the rider's perception of their speed of approach and the risk of a horse fall. Riders who reported an appropriate speed to the selected fence had a lower risk of falling than riders who reported an approach speed that was too slow or too fast. This result should be interpreted with caution since the competitor's retrospective opinion of their speed may be subject to reporting bias. Cases may have been more likely than controls to report an inappropriate speed, in an attempt to find an explanation for their fall. Subjective verification of the speed of a sample of cases and controls needs to be conducted to assess whether bias is present. The variable of approach speed did not remain in the model for one-day event horse falls.

One-day event case riders were more likely than control riders to report their horse's behaviour was "normal" prior to the cross-country phase. Cases in both datasets were more likely than controls to consider the route taken at the selected fence to be fairly difficult or difficult rather than easy or straightforward. Prospective research that involved interviewing riders after they had walked the course and before they started riding the cross-country course would allow assessment of data related to the rider's opinion of the fence and the horse's behaviour prior to the cross-country phase, without the potential for responder bias.

One-day event cases were more likely than controls to report that their horse had jumped the previous fence 'well' or 'very well' compared with 'not very well' or 'not at all well' and that they had not ridden the selected fence as planned. Subjective verification of these variables could be conducted by assessment of video footage by an independent observer.

Final multivariable models

Both datasets

Three variables showed a significant association with horse falls at one-day events and at two- / three-day events. Firstly, horse and rider partnerships that had not incurred any refusals on the cross-country course prior to their inclusion in the study, were at an increased risk of falling compared with partnerships that had already incurred one or more refusals. Although this variable was identified as a risk factor in both datasets, the uncertainty of the level of association was high, as shown by the wide 95% confidence intervals. An explanation for the increased risk associated with no previous refusals is that some horses and riders would rather attempt to jump a fence and risk a fall than incur a refusal. These attempted jumping efforts may be despite reaching the fence at a poor take-off point or with inappropriate speed, balance or impulsion. Competitive and determined riders may be very reluctant to allow their horses to refuse and will use all of their resources (i.e. voice, legs, whip and spurs) to avoid a refusal. An obedient horse may attempt to jump the fence, risking a fall, rather than risking punishment for a refusal. Conversely, some horses rarely refuse and can be seen to jump at speed with little apparent care for their own safety. The temperament of these horses may lead them to attempt to clear a fence and risk an awkward jump or fall, in preference to refusing.

The second variable that was associated with an increased risk of a horse fall at both types of competition was landing in water after jumping an obstacle compared with landing on grass or sand. The exact amount of additional risk associated with these obstacles for one-day events (OR=7.0, 95% C.I. 2.3, 21.0, P<0.001) and for two-/three-day events (OR=10.0, 95% C.I. 2.1, 48.6, P=0.004) was unclear, as indicated by the wide confidence intervals. The increased risk of a horse fall may be due to the drag of the water unbalancing the horse, or shadows and reflections on the surface of the water that made it difficult for the horse to judge the presence or depth of water. The evidence from this and an earlier study suggest that water fences should be considered an important area of risk for horse falls on cross-country courses. Our earlier findings showed an increased risk of injury to horses for falls in water compared to falls on land (OR=2.1, 95% C.I. 1.1, 3.7, P=0.01, Murray et al. 2004a).

The combined variable of the width of the fence and the angle of approach was identified as a significant risk factor for horse falls in both datasets. The results suggested that the degree of increased risk associated with non-angled fences with a spread of two metres or greater was more certain and may be higher for one-day events (OR=5.6, 95% C.I. 2.3, 13.5, P<0.001) than for two-/three-day events (OR=2.7, 95% C.I. 0.9, 7.8, P=0.07). A larger dataset with an associated increase in power may provide stronger evidence of an association between the combined variable of fence width and angle and the risk of a horse fall at two-/three-day events. The increased risk of a fall associated with non-angled fences having a base spread of two metres or more, compared with those with a spread of less than two metres, may be due to insufficient impulsion of the horse, which is needed to clear the height and spread of the fence. During the study period the maximum permitted base spread was 3.0 metres for a fence that required vertical clearance and 4.0 metres for an open ditch (B.E. rules, 2001). The association noted between fences with a wide spread and an increased risk of falling suggest that reducing the maximum permitted base spread for fences may reduce the risk of a horse fall. Angled fences were associated with an increased risk of a horse fall at one-day events (OR=6.6, 95% C.I. 2.1, 21.4, P=0.001) and at two-/three-day events (OR=3.5, 95% C.I. 1.1, 11.5, P=0.04). Non-angled fences with a spread of two metres or greater and angled fences were identified in Chapter 3 as being associated with an increased risk of a horse fall. Suggested reasons for the increased risk associated with these fences include insufficient impulsion to clear the width of fences with large spreads and an inability to raise both front legs sufficiently to clear an angled fence.

One-day events

The final multivariable model for risk factors shown to be associated with the risk of a horse fall at one-day events (Table 4) was very similar to the multivariable model previously produced for the risk factors associated with horse falls at all events (Murray et al., 2004b). In addition to the increased risk of a horse fall at fences with landings in water, there was an increased risk of a horse fall at fences with a take-off from water. Fences requiring the horse to take-off in water were more likely to be associated with a fall than fences that had a take-off on land (OR=25.0, 95% C.I. 5.9, 105.6, P<0.001). This finding supports our earlier work in which an association was noted between a take-off from water and the risk of falling (OR=49.8, 95% C.I. 10.4, 239.0, P<0.001) as compared with a take-off from firm or good to firm ground (Murray et al., 2004b). The increased risk of falling at fences with a take-off in water may have been attributable to miscalculation of the jump height and take-off point by the horse and rider due to the base of the fence being obscured under water, and / or the drag of the water unbalancing the horse.

The rider's knowledge of their position within the competition at the start of the cross-country phase was associated with the risk of a horse fall at one-day events. In particular, riders who knew that they were in the lead prior to starting the cross-country course were at a higher risk of falling than riders who were unaware of their position (OR=5.7, 95% C.I. 1.6, 20.9, P=0.01). It could be hypothesised that horse and rider partnerships that achieved excellent dressage scores (and were therefore in first place) may be less proficient at jumping cross-country fences than partnerships that achieved less good dressage scores, thus placing them at an increased risk of a horse fall. Alternatively, riders who knew that they were currently in first position may have been more likely to 'take risks' during the cross-country phase, in an effort to incur no jumping (and time) penalties and thus maintain their lead in the competition.

In the original dataset, fences with a drop landing were associated with an increased risk of a horse fall (OR=3.4, 95% C.I. 1.6, 7.3, P=0.001) at any type of eventing competition (Murray et al., 2004b). A similar relationship was shown between drop landings and horse falls at one-day events in the analysis reported here (OR=5.6, 95% C.I. 2.3, 13.5, P=0.001). The association between fences with drop landings (i.e. the ground level at landing was lower than the ground level at take-off) and an increased risk of a horse fall is a logical association that may be explained by a loss of balance of the horse on landing. A suggested reason for the lack of an association between the two variables at two-and three-day event competitions (P>0.05) is unclear; however, it may be due partly to the low power (39% power to detect odds ratios of 2.0) of our study of two-/three-day event horse falls. Alternatively, the lack of an association may be attributable to a hypothesised increase in experience of riders and horses at two-/three-day events when compared to partnerships at one-day events. Support for this hypothesis was provided by a comparison of the two datasets. Horses at two-/three-day events had previous experience of a median of 9 cross-country courses at the same level as the selected event, whereas horses at one-day events only had previous experience of a median of 6 cross-country courses at the same level.

The risk of a horse fall at a one-day event was higher for riders who received cross-country tuition compared with riders that did not receive cross-country tuition (OR=2.0, 95% C.I. 1.2, 3.6, P=0.01), supporting our previous finding (Murray et al., 2004b). This is difficult to explain since cross-country lessons should improve riding competence. One explanation may be that those riders that took cross-country lessons were aware that they needed tuition to improve their performance in the cross-country phase. Alternatively, riders who took cross-country lessons might be more competitive and have different personality characteristics when compared to riders who did not take lessons. Evidence from other studies has shown an association between risk-taking behaviour and the risk of injury (Westaby and Lee, 2003) or accident (Sumer, 2003), within their respective contexts of agricultural setting and car safety. The association between rider personality and the risk of a horse fall thus warrants further investigation. The association was not found for two-/three-day event riders, although there was a suggestion of a trend in this direction in the univariable analysis (P=0.13).

Two- and three-day events

The four objective variables from the original model of subjective and objective risk factors (Table 3) remained in the final model for two- and three-day events (Table 5). The addition of the combined variable of angle and width of the fence significantly improved the fit of the model with respect to the deviance so this variable was retained in the final model (Table 5).

The model showed the risk of a horse fall at two- and three-day events to be reduced with every increase of 1 cm per metre in the camber of a fence (OR=0.8, 95% C.I. 0.6, 0.9, P=0.003). For fences in this study, the maximum camber (32 cm per metre) was recorded at a fence with a 45 cm difference in height over a distance of 1.4 metres. A total of 6.9% of fences (15/216) were recorded as having a camber of 10 cm or more per metre. A suggested explanation for the decreased risk of a horse fall with an increase in the camber of the fence was that riders perceived these fences as being difficult and thus rode them with more care. However, it is recognised that the measuring techniques employed for data collection may have detected differences in camber for many fences that were not visible to riders.

An association was found between two- and three-day event riders who participated in non-equestrian sports and the risk of a horse fall. The hypothesis was that riders who participated in non-equestrian sports or fitness activities would be less prone to fatigue, and therefore a horse fall, during the cross-country course. However, the opposite relationship was apparent. Riders who participated in non-equestrian sports or fitness activities had an increased risk of a horse fall when compared with riders who did not participate in other sports or fitness activities (OR=6.5, 95% C.I. 2.4, 17.5, P<0.001). The reason for this association is not clear. There could be a spurious Type I error. Alternatively, these riders may have been more competitive, perhaps leading to a more aggressive riding approach with an increased risk of falling.

The effect of the variable of the rider's knowledge of their position within the competition on the risk of a horse fall was more difficult to assess for two-/three-day events than for one-day events, since all riders competing at two-/three-day events had access to their scores prior to the start of the cross-country phase, unlike the one-day event competitors. A high proportion (95/232) of two-/three-day event riders reported that they either did not know at the time or now could not remember, their position within the competition prior to the cross-country phase. Since the riders would have had easy access to this information at a two- or three-day event, it is considered that most, if not all, of the riders had forgotten their position. Within the two-/three-day event dataset, only three riders (2 controls, 1 case) stated that they had been in the lead before the cross-country phase. A larger study, with more power is needed to investigate the association between a rider's knowledge of their position within the competition and the risk of a horse fall at two- and three-day events.

Proportional population attributable risks provide information that is useful in informing future intervention studies. Factors that may have been associated with a competitive personality, such as taking cross-country lessons and participating in non-equestrian sports had high PPARs, but as it is the nature of a competitive sport for riders to want to achieve good results these variables would be difficult to modify. Fence-related PPARs indicated that reducing the number of fences with a drop landing (PPAR=0.18) at one-day events could be a useful intervention strategy. In addition, both datasets showed high and similar PPARs (0.12-0.18) to be associated with non-angled fences with a spread of two metres or greater and fences requiring the horse to land in water. Reducing the number of these fences could be an effective strategy to reduce the number of horse falls at eventing competitions.

This study has found evidence of an association between the risk of a horse fall at one- and two-/three-day events and variables relating to the rider, the fence and its siting and the performance of the horse and rider on the cross-country course. Further research is needed to assess the validity of the two models, as model diagnostics indicated that both models were unstable for some of the variables and had a low capacity to predict cases at cut-off points of 0.4 and above. In addition, caution must be taken when interpreting the results of non-significant findings in a matched study, such as the study presented here, as matching has the potential to bias the exposure variables towards the null.

The division of the data into two data sets reduced the power of the analyses; however, three variables were associated with the risk of a horse fall at both types of event: fences with a landing in water, previous cross-country refusals by the partnership on the course and the combined variable of the angle and width of the fence. These variables had previously been identified as having an association with the risk of a horse fall at all types of eventing competition (Murray et al., 2004b). The results of this paper provide additional support for the need for future intervention studies to assess the effect on the risk of a horse fall by reducing exposure to fences with a landing in water, non-angled fences with a spread of two metres or greater and angled fences.

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APPENDIX: CHAPTER FOUR

Table 1. Description of course- and fence-level variables recorded during the day of competition for a study of risk factors for cross-country horse falls in eventing competitions in Great Britain (2001-2002).

Course- and fence-level variables	Description
XC level	One-day events: Intro/Pre-novice, Novice, Intermediate, Advanced Two-/three-day events: Novice/CCI 1*, Intermediate/CCI 2*, CCI 3*, CCI 4*
Speed	Official speed required for course (metres per minute)
Distance	Official course distance (metres)
Jumping effort number	Jumping effort number of selected fence
Total jumping efforts	Total number of jumping efforts on the course
Total number of jumps	Total number of obstacles on the course
Element number	Continuous variable of element number of selected fence, (single fences coded as one).
Number of elements	Number of elements at selected fence, (single fences coded as one).
Combination	Two or more fences with $\leq$ 4 strides between each element
Approach	Approach to fence (flat, uphill, downhill, water)
Flat approach	Flat approach to fence (yes/no)
Uphill approach	Uphill approach to fence (yes/no)
Downhill approach	Downhill approach to fence (yes/no)
Water approach	Water approach to fence (yes/no)
Take off going	Ground surface at approach to fence (firm, good to firm, good, good to soft, soft, heavy, water)
Slippery take off	Slippery ground at take off area (yes/no)
Rutted take off	Rutted ground at take off (yes/no)
Landing	Landing of fence (flat, uphill, downhill, water)
Flat landing	Flat landing after fence (yes/no)
Uphill landing	Uphill landing after fence (yes/no)
Downhill landing	Downhill landing after fence (yes/no)
Water landing	Water landing after fence (yes/no)
Landing going	Ground surface at landing of fence (firm, good to firm, good, good to soft, soft, heavy, water)
Slippery landing	Slippery ground at landing area (yes/no)
Rutted landing	Rutted ground at landing (yes/no)
Camber	Fence is positioned on a camber (yes/no)
Fence in open	Fence is sited in the open (yes/no)
Changing light	Fence is jumped from a light to a dark area or *vice versa* (yes/no)
Fence in dark	Fence is sited in a dark area (yes/no)
Shadows	Shadows on fence (yes/no)
Wings	The presence or absence of barriers attached to the left and right of a jump that guide the horse to the fence
Turn before	The approach to the fence involved a turn $\leq$5 strides before fence (yes/no)
Turn after	After jumping the fence a turn is required $\leq$5 strides later (yes/no)
Horse angle	Horses jump fence at an angle. Assessed by watching horses jump the fence and studying hoof prints around the fence.
Fence angle	Fence is positioned at an angle to the line of approach, (e.g. corner fence, angled rails)
Groundline	Use of material (e.g. pole or bark) to help prevent the horse from taking off too close to the fence (yes/no)
Groundline type	Type of groundline (none, true groundline (away from base of fence), filled base of fence, incomplete groundline (eg logs placed in front of fence), incomplete fill of base of fence (eg sharks teeth fence), log, false groundline).

Course- and fence-level variables	Description
True groundline	True groundline, placed infront of base of fence (yes/no)
No groundline	False or no groundline present (yes/no)
Log	Positioned on ground or suspended (e.g. 'hanging' log)
Ground log	Log placed on ground (yes/no)
Hanging log	Log suspended above the ground (yes/no)
Fence type	Upright, ascending slope, ascending spread, square spread, step up, step down, other (e.g. open ditch, slope)
Upright	Upright fence (yes/no)
Ascending slope	Ascending slope, fence <1m spread, (yes/no)
Ascending spread	Ascending spread, fence ≥1m spread (yes/no)
Square spread	Square spread/parallel fence. Fence ≥1m spread. Flat top to fence (yes/no)
Step up	Step up: the landing ground is at the same height as the top of the fence (yes/no)
Step down	Step down: the fence involves no height to be cleared, - but a loss in height from the take off to the landing ground (yes/no)
Ditch	Open, sited in front, under and / or behind fence, trakehner fence (Trakehner fences have a log or rail suspended over a ditch)
Ditch type	Type of ditch (none, ditch in front of fence or in front and under fence, ditch behind fence or behind and under, trakehner, open ditch).
Ditch in front	Ditch in front of fence (yes/no)
Ditch under	Ditch under fence (yes/no)
Ditch behind	Ditch behind fence (yes/no)
Open ditch	Open ditch: no height clearance required, (yes/no)
Trakehner	Log/rail suspended over a ditch (yes/no)
Bounce	Two elements sited so that the horse lands and immediately takes off, without taking a stride in between the elements (yes/no)
Drop landing	Landing is on lower ground than the take-off to the fence (yes/no)
High landing	Landing is on higher ground than the take-off to the fence (yes/no)
Corner	Left or right pointed corner (< or >), (yes/no)
Brush through	Highest point of fence is not rigid, but formed of spruce, hedge etc that the horse can brush through (yes/no)
Narrow	Front face of fence is visibly narrower than the majority of fences found on a cross-country course (yes/no)
Frangible	Fence is constructed with frangible pins (yes/no)
Owlhole	Fence requires the horse to jump underneath a solid structure, i.e. to jump through a 'hole' (yes/no)
Filled front	Front face of fence is solid, i.e. it is not possible to see through the fence (yes/no)
Filled top	Top of a spread fence is solid, i.e. from above the fence, it is not possible to see the ground underneath the fence (yes/no)
Front fill	Material from which the solid front of the fence is constructed (open, wood, brush, other)
Top fill	Material from which the solid top of the fence is constructed (open, wood, brush, other)
Fence height	Measured as the distance from the ground to the highest (lowest for steps down) solid point of the fence that the horse is expected to jump (metres)
Fence spread	Measured at the base of the fence, at the point at which the horse is expected to jump the fence (metres)
Angle width combined	Combined variable of the fence angle and the spread of the fence, (Non-angled, <2m spread, non-angled, ≥2m spread, All angled fences of any spread width)

Course- and fence-level variables	Description
Jumpable width	The shortest distance between the flags attached to the left and right of the fence (metres). Jumpable width was therefore measured in a straight line for all fences, including U-shaped fences.
Strides from	Number of strides from previous jumping effort to the fence (0, 1, 2, 3, 4, 5 or more)
Strides to	Number of strides from the fence to the next jumping effort (0, 1, 2, 3, 4, 5 or more)
Gradient measurements (see Fig. 1 below for diagram)	
Approach: 20m to 10m	Gain or loss in height (cm) over the distance measured from 20m from the fence to 10m from the base of the fence on the approach side. Expressed as the difference in height (cm), divided by the distance covered (10m)
Approach: 10m to 5m	Gain or loss in height (cm) over the distance measured from 10m from the fence to 5m from the base of the fence on the approach side. Expressed as the difference in height (cm), divided by the distance covered (5m)
Approach: 5m to 2m	Gain or loss in height (cm) over the distance measured from 5m from the fence to 2m from the base of the fence on the approach side. Expressed as the difference in height (cm), divided by the distance covered (3m)
Approach: 2m to 0m	Gain or loss in height (cm) over the distance measured from 2m from the fence to 0m from the base of the fence on the approach side. Expressed as the difference in height (cm), divided by the distance covered (2m)
Approach: 5m to 0m	Gain or loss in height (cm) over the distance measured from 5m from the fence to 0m from the base of the fence on the approach side. Expressed as the difference in height (cm), divided by the distance covered (5m)
Approach: 10m to 0m	Gain or loss in height (cm) over the distance measured from 10m from the fence to 0m from the base of the fence on the approach side. Expressed as the difference in height (cm), divided by the distance covered (10m)
Approach: 20m to 0m	Gain or loss in height (cm) over the distance measured from 20m from the fence to 0m from the base of the fence on the approach side. Expressed as the difference in height (cm), divided by the distance covered (20m)
Approach: 10m to 2m	Gain or loss in height (cm) over the distance measured from 10m from the fence to 2m from the base of the fence on the approach side. Expressed as the difference in height (cm), divided by the distance covered (8m)
Approach: 20m to 2m	Gain or loss in height (cm) over the distance measured from 20m from the fence to 2m from the base of the fence on the approach side. Expressed as the difference in height (cm), divided by the distance covered (18m)
Landing gradient	Gain or loss in height (cm) over the distance measured from from the base of the fence on the approach side to the base of the fence on the landing side. Expressed as the difference in height (cm), divided by the spread of the fence (m)
Landing: 0m to 2m	Gain or loss in height (cm) over the distance measured from 0m to 2m from the base of the fence on the landing side. Expressed as the difference in height (cm), divided by the distance covered (2m)
Landing: 2m to 5m	Gain or loss in height (cm) over the distance measured from 2m to 5m from the base of the fence on the landing side. Expressed as the difference in height (cm), divided by the distance covered (3m)

Course- and fence-level variables	Description
Landing: 5m to 10m	Gain or loss in height (cm) over the distance measured from 5m to 10m from the base of the fence on the landing side. Expressed as the difference in height (cm), divided by the distance covered (5m)
Landing: 0m to 5m	Gain or loss in height (cm) over the distance measured from 0m to 5m from the base of the fence on the landing side. Expressed as the difference in height (cm), divided by the distance covered (5m)
Landing: 0m to 10m	Gain or loss in height (cm) over the distance measured from 0m to 10m from the base of the fence on the landing side. Expressed as the difference in height (cm), divided by the distance covered (10m)
Landing: 2m to 10m	Gain or loss in height (cm) over the distance measured from 2m to 10m from the base of the fence on the landing side. Expressed as the difference in height (cm), divided by the distance covered (8m)
Camber	Difference between the height of the ground at the base of the fence at the right and left flags. Expressed as the difference in centimetres, divided by the distance (m) between the flags.

Figure 1: Schematic representation of the location of gradient measurements in metres (m) for a cross-country fence, (not to scale).

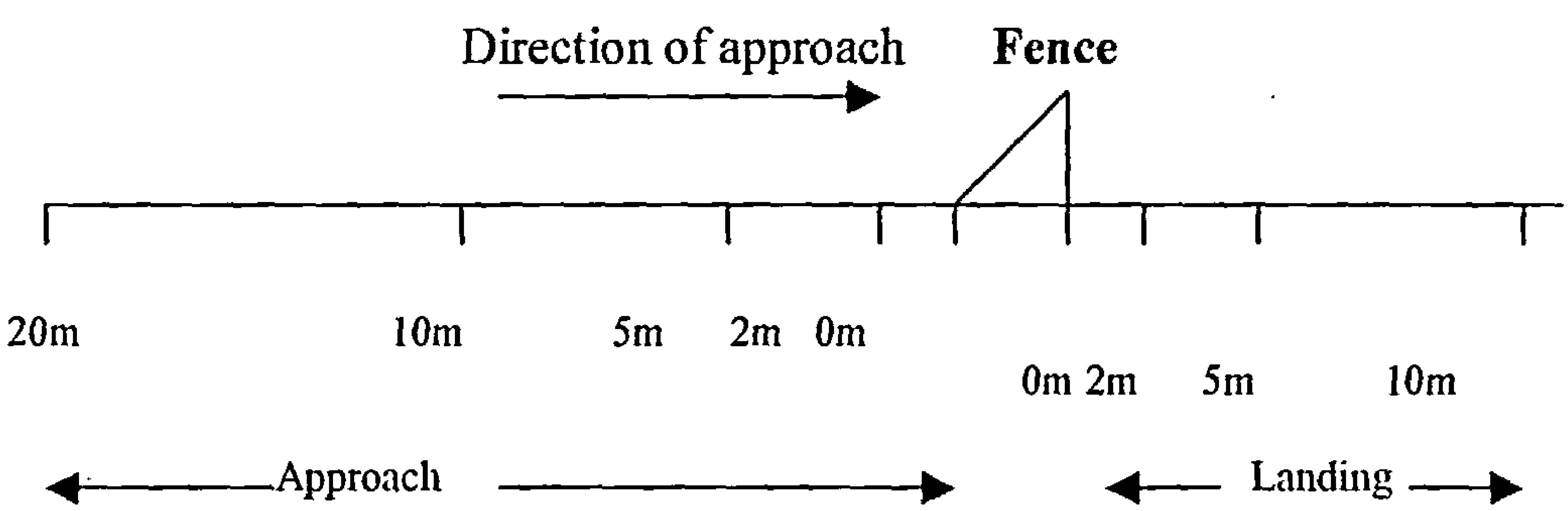

Table 2. Description of rider-level variables recorded during questionnaire interview for a study of risk factors for cross-country horse falls in eventing competitions in Great Britain (2001-2002).

Rider-level variables:	Description
Aware	Rider was aware of the study (yes/no)
Rider status	Amateur / professional event rider
Horse owner	Rider, family member, third party, joint ownership, sponsor
Weeks partnered	Number of weeks rider had been riding this horse for
Years competed	Number of years the rider had been competing this horse in affiliated events
Number of events	Number of affiliated events the horse and rider partnership competed in
Number of placings	Number of affiliated events the horse and rider partnership had been placed in
Any CIC	Rider had competed in $\geq$ 1 CICs with this horse (yes/no)
CIC 1-star	Number of CIC 1-star events in which the partnership had competed
CIC 2-star	Number of CIC 2-star events in which the partnership had competed
CIC 3-star	Number of CIC 3-star events in which the partnership had competed
Any CCI	Rider had competed in $\geq$ 1 CCIs with this horse (yes/no)
CCI 1-star	Number of CCI 1-star events in which the partnership had competed
CCI 2-star	Number of CCI 2-star events in which the partnership had competed
CCI 3-star	Number of CCI 3-star events in which the partnership had competed
CCI 4-star	Number of CCI 4-star events in which the partnership had competed
Time competing	Number of years that the rider has been competing in affiliated events
Years riding	Number of years that the rider has been riding horses
Unaffiliated before	Rider has participated in unaffiliated eventing prior to affiliated eventing (yes/no)
Time unaffiliated	Number of years that the rider competed in unaffiliated eventing before their first affiliated event
Dressage	The rider participates in dressage only competitions (yes/no)
Show jumping	The rider participates in show jumping only competitions (yes/no)
Hunting	The rider participates in hunting (yes/no)
Horse racing	The rider participates in horse racing (yes/no)
Point-to-pointing	The rider participates in point-to-point competitions (yes/no)
Showing	The rider participates in showing competitions (yes/no)
Polo	The rider participates in polo competitions (yes/no)
Team chasing	The rider participates in team chasing competitions (yes/no)
Other	The rider participates in other competitions, e.g. hunter trials, polocrosse, (yes/no)
Last unseated	Time since the rider was last unseated from any horse (0-7 days, 8-21 days, 22-60 days, 4-6 months, 7-12 months, >12 months)
Cause last unseated	Cause of last unseating (Horse bucked/reared, unspecified 'jumping', horse refused a jump, horse hit a jump hard, horse fell whilst jumping, other, e.g. horse shied, slipped)
Rider injured	Rider injured in last fall (yes/no)
Unseated this horse	Rider has previously been unseated by this horse (yes/no)
Cause unseated this horse	Cause of last unseating (Horse bucked/reared, unspecified 'jumping', horse refused a jump, horse hit a jump hard, horse fell whilst jumping, other, e.g. horse shied, slipped)

Rider-level variables:	Description
Rider injured this horse	Rider injured in last fall from this horse (yes/no)
Horses per day	Number of horses ridden in an average day at home
Days ride	Number of days per week on which, on average, the rider can ride
Occupation	Rider occupation (professional event rider, full-time horses, part-time horses, full-time non-horses, part-time non-horses, student, not working)
Time professional	Number of years the rider has been a professional event rider
Teach	Rider teaches riding
Frequency teach	Frequency that rider teaches riding (never, daily, several times a week, once a week, 2-3 times/week, less frequently)
Teach dressage	Rider teaches dressage (yes/no)
Teach show jumping	Rider teaches show jumping (yes/no)
Teach cross-country	Rider teaches cross-country (yes/no)
Teach Pony club	Rider teaches pony club children (yes/no)
Teach other	Rider teaches other equestrian disciplines, e.g. showing (yes/no)
BHS/NVQ qualifications	Highest BHS or NVQ qualification the rider holds (none, stage/level 1 or 2, stage/level 3 or BHSAI or BHSPI, Intermediate-Fellow of the BHS, Overseas or other qualifiations
PC tests	Highest pony club test the rider holds (D or C test, C+ test, B test, H test, A test)
Dressage lessons	Rider receives dressage lessons (yes/no)
Dressage frequency	Frequency of dressage lessons (none, $\geq$ 1/week, fortnightly, one every 3-4 weeks, less often)
Show jumping lessons	Rider receives show jumping lessons (yes/no)
Show jumping frequency	Frequency of show jumping lessons (none, $\geq$ 1/week, fortnightly, one every 3-4 weeks, less often)
Cross-country lessons	Rider receives cross-country lessons (yes/no)
Cross-country frequency	Frequency of cross-country lessons (none, $\geq$ 1/week, fortnightly, one every 3-4 weeks, less often)
Sport	Rider participates in non-equestrian sports or activities (yes/no)
Sport weekly	Frequency of sport is at least weekly (yes/no)
Age	Age of rider (years)
Height	Height of rider (cm)
Weight	Weight of rider (kg)
BMI	Body mass index of rider (weight in kg/ height in metres squared)
Vision	Rider has corrected vision (no, glasses, contact lenses)
Compete glasses	Rider competes with corrected vision (no, glasses, contact lenses)
Medication	Rider takes regular prescription medication (yes/no)

Table 3. Description of horse-level variables recorded during questionnaire interview and from the B.E. database for a study of risk factors for cross-country horse falls in eventing competitions in Great Britain (2001-2002).

Horse-level variables:	Description
Breed	Thoroughbred (Tb), 7/8 Tb, 3/Tb, 5/8 Tb, ½ Tb, Warmblood, Irish, Other
Horse age	Age of horse (years)
Horse height	Height of horse (cm)
Horse gender	Gender of horse (mare, gelding, stallion)
Hunted	Number of times hunted during last 12 months (Never, 1-3 times, 4-8 times, >8 times)
Show jump competitions	Number of times competed in show jumping during last 12 months (Never, 1-3 times, 4-8 times, >8 times)
Dressage competitions	Number of times competed in dressage during last 12 months (Never, 1-3 times, 4-8 times, >8 times)
Raced	Horse has previously raced, (yes/no)
Flat race	Horse has previously raced on the flat (yes/no)
Hurdle	Horse has previously raced over hurdle fences (yes/no)
Schase	Horse has previously raced over steeplechase fences (yes/no)
Point-to-point	Horse has previously raced in point-to-points (yes/no)
Points	Number of eventing points the horse has won
Runs	Number of cross-country starts that the horse has had at this level of event
Higher runs	Number of cross-country starts that the horse has had at a higher level of event than the selected event
Number of events	Number of cross-country starts that the horse has made during the previous two months
Number of weeks	Number of weeks since the horse's last event
Placed last event	Placed at last affiliated event (yes/no)
Last dressage	Dressage score at last event
Last SJ	Show jumping score at last event
Last SJ knockdown	Number of fences knocked down at the horse's last event
Last SJ refused	Refused during the SJ phase at the horse's last event (yes/no)
Last SJ rider fall	Rider fall during the SJ phase of the horse's last event (yes/no)
Last SJ horse fall	Horse fall during the SJ phase of the horse's last event (yes/no)
Last XC penalties	XC jumping penalties at the horse's last event (yes/no)
Last XC refused	Refused during the XC phase at the horse's last event (yes/no)
Last XC rider fall	Rider fall during the XC phase of the horse's last event (yes/no)
Last XC horse fall	Horse fall during the XC phase of the horse's last event (yes/no)
Time off	Horse has had time off during the last 12 months due to injury or illness (yes/no)
Physiotherapy	Horse receives physiotherapy (yes/no)
Osteopathy / Chiropractic	Horse receives osteopathy or chiropractic treatment (yes/no)
Magnotherapy	Horse receives magnotherapy (yes/no)
Homeopathy	Horse receives homeopathy (yes/no)
Back treatment / massage	Horse receives general back treatment or massage (yes/no)
Acupuncture / other	Horse receives acupuncture or other treatment (yes/no)
Vitamin supplements	Horse receives vitamin supplements (yes/no)
Garlic	Horse receives garlic (yes/no)
Electrolytes	Horse receives electrolytes (yes/no)
Herbal supplements	Horse receives herbal supplements (yes/no)
Joint supplements	Horse receives joint supplements (yes/no)
Hoof supplements	Horse receives hoof supplements (yes/no)
Other supplements	Horse receives other supplements (yes/no)
Dressage schooling	Frequency of dressage schooling sessions (Never, 1-2/week, 3-4/week, >4/week)
Show jumping schooling	Frequency of show jumping schooling sessions (Never, 1-2/week, 3-4/week, >4/week)

Horse-level variables:	Description
Cross-country schooling	Frequency of cross-country schooling sessions (Never, >1/month, monthly, start of season, if there's a problem)
Hack	Days/week
Fast work	Frequency of fast work sessions (1/fortnight or less, 1/week or every 5th day, 2/week or every 3rd day, 3-4/week)
Other riders	Other riders exercise the horse (yes/no)
Which riders	Which other riders also exercise the horse (no one, owner, groom, instructor, family, friends / other)
Shoes	Type of shoes (standard, eggbar, four-point shoeing, other)
Previous horse fall	Horse has previously fallen at a cross-country jump (yes/no)
Time previous horse fall	Time since previous horse fall (Has not fallen, <4 months ago, ≥4 months ago)
Previous horse fall injury	Horse was injured in previous horse fall (yes/no)
Previous horse fall, rider injured	Any rider was injured in previous fall of this horse (yes/no)

Table 4. Description of event-level variables recorded during questionnaire interview and from the B.E. database for a study of risk factors for cross-country horse falls in eventing competitions in Great Britain (2001-2002).

Event-level variables:	Description
Saddle padding	Amount of knee roll and padding on saddle (minimal. moderate, heavy)
XC stirrups	Stirrup length used for cross-country riding (short, medium, long)
Holes higher	Number of holes shorter stirrups are used for the XC phase compared with the SJ phase (continuous variable)
Martingale XC schooling	Martingale used for XC schooling (yes/no)
Martingale XC competing	Martingale used for XC competing (yes/no)
Breastplate XC schooling	Type of breastplate(s) used for XC schooling (none, racing, hunting, racing and hunting)
Breastplate XC competing	Type of breastplate(s) used for XC competing (none, racing, hunting, racing and hunting)
Bit XC schooling[a]	Type of bit used for XC schooling (mild, moderate, severe)
Same bit	Was the horse's usual XC bit used at this event? (yes/no)
Bit event[a]	Type of bit used for XC phase of selected event (mild, moderate, severe)
Noseband XC schooling	Type of noseband used for XC schooling (flash/drop, cavesson, grakle, other)
Noseband XC competing	Type of noseband used for XC competing (flash/drop, cavesson, grakle, other)
Same noseband	Was the horse's usual noseband used at this event? (yes/no)
Noseband event	Type of noseband used for XC phase of selected event (flash/drop, cavesson, grakle, other)
Overreach XC schooling	Overreach boots used for XC schooling (yes/no)
Overreach XC competing	Overreach boots used for XC competing (yes/no)
Journey time	Journey time to travel to event (minutes)
Day of travel[b]	Day travelled to event relative to the XC phase (no travel, on the day, day(s) before)
Travelled well	Horse travelled to the event well (yes/no)
Normal travel	Horse's travel behaviour as normal (yes/no)
Stabled away[b]	Horse stabled away from home (yes/no)
Settled	Horse settled in stable overnight (yes/no)
Time before dressage[b]	Number of minutes between arriving at the event and the horse's dressage test
Time before XC[b]	Number of minutes between arriving at the event and the horse's cross-country round
Day before Dr/SJ[b]	Day before phases (no, dressage, dressage and show jumping)
Attitude arrival	Horse's attitude on arrival at the event (very excited, excited, alert, calm)
Normal arrival	Horse's attitude was normal for the horse on arrival at the event (yes/no)
Attitude trot up[c]	Horse's attitude at the first veterinary inspection of the event (very excited, excited, alert, calm)
Normal trot up[c]	Horse's attitude was normal for the horse at the first veterinary inspection of the event (yes/no)
Attitude dressage	Horse's attitude on arrival at the event (very excited, excited, alert, calm)
Normal dressage	Horse's attitude was normal for the horse on arrival at the event (yes/no)
Attitude SJ[b]	Horse's attitude prior to the SJ at the event (very excited, excited, alert, calm)
Normal SJ[b]	Horse's attitude was normal for the horse prior to the SJ (yes/no)

Event-level variables:	Description
Attitude phase A[c]	Horse's attitude prior to phase A (very excited, excited, alert, calm)
Normal A[c]	Horse's attitude was normal for the horse prior to phase A (yes/no)
Attitude phase B[c]	Horse's attitude prior to phase B (very excited, excited, alert, calm)
Normal B[c]	Horse's attitude was normal for the horse prior to phase B (yes/no)
Attitude phase C[c]	Horse's attitude at the beginning of phase C (very excited, excited, alert, calm)
Normal C[c]	Horse's attitude was normal for the horse at the beginning of phase C (yes/no)
Attitude XC	Horse's attitude prior to the XC course (very excited, excited, alert, calm)
Normal XC	Horse's attitude was normal for the horse prior to the XC course (yes/no)
Number of walks	Number of times the rider walked the XC course
Day walked	When the course was walked (day before, on the day, both)
Time walk finished	Time between finishing walking the course and riding the course
Walked alone	Walked XC course alone (yes/no)
Waked trainer	Walked XC course with trainer (yes/no)
Walked owner	Walked XC course with horse's owner (yes/no)
Walked rider	Walked XC course with another event rider (yes/no)
Walked family	Walked XC course with family (yes/no)
Walked friend	Walked XC course with friend (yes/no)
Walked groom	Walked XC course with groom (yes/no)
Front studs	Number of studs in each of the horse's front shoes (none, one, two)
Hind studs	Number of studs in each of the horse's hind shoes (none, one, two)
Grease	Grease used on the horse's legs for the XC phase (yes/no)
Whip	Rider carried a whip on the XC phase (yes/no)
Normal whip	Presence or absence of a whip was normal for the horse (yes/no)
Spurs	Rider wore spurs during the XC phase (yes/no)
Normal spurs	Presence or absence of spurs was normal for the horse (yes/no)
Knew score	Rider knew their score prior to starting the XC course (yes/no)
Dressage score	Horse and rider partnership's dressage score reported by the rider (penalty points)
Web dressage	Dressage score recorded on the internet for the partnership (penalty points)
SJ score[b]	Horse and rider's partnership's SJ score (penalty points)
Web SJ[b]	SJ score recorded on the internet for the partnership (penalty points)
SJ refusals[b]	Number of refusals or run outs awarded to the horse and rider partnership
SJ knockdowns[b]	Number of fences knocked down by the horse and rider partnership
Position	Rider's knowledge of their position in the competition prior to starting the XC course (Didn't know position, first, second to fifth, sixth or lower)
Warm up wanted[b]	Warm up time planned by the rider prior to the start of their XC round (minutes)
Warm up planned[b]	Warm up for the XC phase was as planned (yes/no)
Warm up actual[b]	Warm up time used for the XC phase (minutes)
D box planned[c]	Time in the D box was as planned (yes/no)

Event-level variables:	Description
Route	Rider's opinion of the route taken at the selected fence (easy, straightforward, fairly difficult, difficult)
Route relative	Rider's opinion of the route taken at the selected fence relative to the rest of the course (easier, the same, more difficult)
Ride plan	The fence was ridden as planned by the rider (yes/no)
Which route	Which route at the selected fence was taken by the partnership (only one route, direct route, alternative route)
Striding planned	The number of strides planned between the elements of a selected combination fence were as planned (yes/no)
Ground	Rider's opinion of the ground conditions at the selected fence (firm, good-firm, good, good-soft, soft, heavy, sandy)
Ground affect	The rider believed that the ground conditions affected the way the horse jumped the selected fence (yes/no)
Slippery	The rider believed the ground conditions at the fence to be slippery (yes/no)
Slippery affect	The rider believed that the slippery ground conditions affected the way the horse jumped the selected fence (yes/no)
Light conditions	The rider's opinion of the general light conditions at the fence (good, poor)
Light affect	The rider believed that the light conditions affected the way the horse jumped the selected fence (yes/no)
Lighting of fence	The rider's opinion of the lighting of the selected fence (Light, light to dark, dark to light, in darkness)
Fence light affect	The rider believed that the lighting of the fence affected the way the horse jumped the selected fence (yes/no)
Into sun	The rider believed that the selected fence was jumped directly into the sun (yes/no)
Into sun affect	The rider believed that jumping the selected fence towards the sun affected the way the horse jumped the selected fence (yes/no)
Shadows	The rider believed that the selected fence had shadows on it (yes/no)
Shadows affect	The rider believed shadows on the selected fence affected the way the horse jumped the selected fence (yes/no)
Speed	The rider's opinion of their speed of approach to the selected fence (about right, too slow, too fast)
Speed affect	The rider believed that their speed of approach affected the way the horse jumped the selected fence (yes/no)
Fence before	The rider's opinion of how well the horse jumped the fence prior to the selected fence (very well, well, not very well, not at all well)
Penalties previous	Penalties incurred by the horse and rider partnership at previous fence (yes/no)
How jumping	The rider's opinion of how well the horse was jumping on the XC course prior to the selected fence (good, fine, OK, not very good, frightening)
How going	The rider's opinion of how the horse felt to ride on the XC course prior to the selected fence (uncontrollable, very strong, strong, rideable, 'behind the leg', 'backing off the fences')
Held	The horse and rider partnership were 'held' (or stopped) on the XC course (no, once, twice)
XC refusals	The horse and rider partnership had incurred previous refusals or run outs on the XC course prior to the selected fence (none, one, two, three)

Event-level variables:	Description
XC rider fall	The rider had fallen from the horse on the XC course prior to the selected fence (yes/no)
Important	A clear round or completing the XC course was important to the rider (yes/no)
Why important	Reason for a clear round or completing the XC course being important (not important, qualification, horse for sale, to please the sponsor/owner of the horse, rider satisfaction, horse confidence, first event of the horse and/or rider, first event after a break for the horse and/or rider, prestigious competition, wanted to be placed, selection, other)
Horses at event	Number of horses that the rider was competing at the event
Horses day before	Number of horses that the rider had competed at the event on the previous day
Horses same day	Number of horses that the rider was competing a the event on the same day as their selected horse
XC rounds	Number of XC rounds that the rider had started that day prior to riding the selected horse on the XC course
Time XC round	Number of minutes between the start of the previous XC round and starting the XC round on the selected horse
Helpers	Number of people helping the rider
Social event	Social function attended at the event (yes/no)
Social night before	Social function attended at the event the night before the XC (yes/no)
Sleep well	Rider slept well the night before the XC (yes/no)
Sleep time	Amount of sleep the rider received the night before the XC phase (hours)
Alcohol	Amount of alcohol consumed by the rider the night before the XC (none, low (1-2 units), moderate (3-4 units), heavy (5 or more units))
Medication	Medication taken by the rider on the day of the event prior to the XC phase (yes/no)
Eat	Rider ate on the day of the event prior to the XC phase (yes/no)
Time ate[d]	Minutes between eating and riding the selected horse XC
Drank	Rider drank on the day of the event prior to the XC phase (yes/no)
Time drank[d]	Minutes between drinking and riding the selected horse XC
Hay	Horse received hay between last hard feed and starting the XC course (yes/no)
Hay time[d]	Minutes between the horse having access to hay and starting the XC course
Horse fed[d]	Minutes between the horse's most recent concentrate feed and starting the XC course
Horse water	Minutes between the horse's most recent drink and starting the XC course

[a] **Mild bits**=Snaffles, 3-ring bit with reins on top ring, **Moderate bits**=3-ring bit with reins on middle ring, Pelham, Copper roller, Dr Bristol, Kimblewick, Magennis, **Severe bits**=3-ring bit with reins on bottom ring, Running gag, Waterford, Twisted snaffle, Double bridle, Combination bridle.
[b] Variable only applicable to one-day event data
[c] Variable only applicable to two- and three-day event data
[d] Variable only included for one-day event analysis, as interpretation of the question was ambiguous for two- and three-day event competitors. Some riders referred to the elapsed time before the start of phase A, whilst others referred to the time before the start of phase D.

Table 5. Univariable conditional logistic regression analysis: One-day events, Course and fence-level categorical variables with a P-value <0.2 (in descending order of P-value).

Variable		Number of controls (%)	Number of cases (%)	Odds Ratio	P-value
Flat approach					
	No	194 (53.4)	72 (59.5)	1.00	
	Yes	169 (46.6)	49 (40.5)	0.74	0.196
Filled front					
	Open front	138 (41.8)	38 (34.9)	1.00	
	Filled front	192 (58.2)	71 (65.1)	1.38	0.196
Ditch behind					
	No	352 (97.0)	114 (94.2)	1.00	
	Yes	11 (3.0)	7 (5.8)	1.97	0.17
Turn after					
	No	279 (76.9)	100 (82.6)	1.00	
	Yes	84 (23.1)	21 (17.4)	0.66	0.16
Turn before					
	No	249 (68.6)	92 (76.0)	1.00	
	Yes	114 (31.4)	29 (24.0)	0.69	0.14
Square spread					
	No	319 (87.9)	100 (82.6)	1.00	
	Yes	44 (12.1)	21 (17.4)	1.60	0.13
Wings					
	No wings	176 (48.5)	49 (40.5)	1.00	
	One or more wings	187 (51.5)	72 (59.5)	1.42	0.11
Ascending spread					
	No	258 (71.1)	96 (79.3)	1.00	
	Yes	105 (28.9)	25 (20.7)	0.59	0.05
Fence angle					
	No	349 (96.1)	110 (90.9)	1.00	
	Yes	14 (3.9)	11 (9.1)	2.43	0.03
Fence type					
	Upright	23 (6.3)	4 (3.3)	1.00	
	Ascending slope	132 (36.4)	39 (32.2)	1.72	
	Ascending spread	105 (28.9)	25 (20.7)	1.29	
	Square spread	44 (12.1)	21 (17.4)	2.70	
	Step up	27 (7.4)	20 (16.5)	4.51	
	Step down	19 (5.2)	8 (6.6)	2.64	
	Other (e.g. open ditch)	13 (3.6)	4 (3.3)	1.70	0.03
Downhill landing					
	No	260 (71.6)	100 (82.6)	1.00	
	Yes	103 (28.4)	21 (17.4)	0.53	0.02
Shadows					
	No	322 (88.7)	98 (81.0)	1.00	
	Yes	41 (11.3)	23 (19.0)	2.12	0.02
Combination					
	Single fence	234 (64.5)	62 (51.2)	1.00	
	Combination fence	129 (35.5)	59 (48.8)	1.77	0.01
Approach					
	Flat	169 (46.6)	49 (40.5)	1.00	
	Uphill	109 (30.0)	34 (28.1)	1.09	
	Downhill	80 (22.0)	29 (24.0)	1.37	
	Water	5 (1.4)	9 (7.4)	7.56	0.01
Step up					
	No	336 (92.6)	101 (83.5)	1.00	
	Yes	27 (7.4)	20 (16.5)	2.57	0.003

Variable		Number of controls (%)	Number of cases (%)	Odds Ratio	P-value
Water approach					
	No	358 (98.6)	112 (92.6)	1.00	
	Yes	5 (1.4)	9 (7.4)	6.75	0.002
Landing					
	Flat	166 (45.7)	48 (39.7)	1.00	
	Uphill	76 (20.9)	28 (23.1)	1.17	
	Downhill	103 (28.4)	21 (17.4)	0.69	
	Water	18 (5.0)	24 (19.8)	4.49	<0.001
Element number					
	1	293 (80.7)	71 (58.7)	1.00	
	2	57 (15.7)	32 (26.4)	2.55	
	3	9 (2.5)	14 (11.6)	7.26	
	4 or more	4 (1.1)	4 (3.3)	5.42	<0.001
Number of elements					
	1	293 (80.7)	71 (58.7)	1.00	
	2	57 (15.7)	32 (26.4)	1.06	
	3 or more	13 (3.6)	18 (14.9)	2.99	<0.001
Water landing					
	No	345 (95.0)	97 (80.2)	1.00	
	Yes	18 (5.0)	24 (19.8)	4.78	<0.001
Take off going					
	Firm / Good-Firm	169 (46.6)	49 (40.5)	1.00	
	Good	109 (30.0)	34 (28.1)	1.74	
	Good-Soft / Soft	80 (22.0)	29 (24.0)	4.55	
	Water	5 (1.4)	9 (7.4)	10.37	<0.001
Landing going					
	Firm / Good-Firm	166 (45.7)	48 (39.7)	1.00	
	Good	168 (46.3)	45 (37.2)	0.92	
	Good-Soft / Soft / Heavy	11 (3.0)	4 (3.3)	1.41	
	Water	18 (5.0)	24 (19.8)	4.69	<0.001
Drop landing					
	No	337 (92.8)	96 (79.3)	1.00	
	Yes	26 (7.2)	25 (20.7)	4.69	<0.001
Angle width combined					
	Non-angled, <2m spread	318 (89.3)	84 (71.8)	1.00	
	Non-angled, ≥2m spread	25 (7.0)	22 (18.8)	3.79	
	All angled fences	13 (3.7)	11 (9.4)	3.63	<0.001
Strides from					
	0	11 (3.0)	6 (5.0)	1.00	
	1	27 (7.5)	12 (9.9)	0.25	
	2	23 (6.4)	12 (9.9)	0.29	
	3	4 (1.1)	13 (10.7)	1.37	
	4	7 (1.9)	7 (5.8)	0.32	
	5 or more	290 (80.1)	71 (58.7)	0.15	<0.001

Table 6. Univariable conditional logistic regression analysis: One-day events, Course and fence-level continuous variables with a P-value <0.2 (in descending order of P-value).

Variable	Odds Ratio	P-value
Approach: 5m to 2m (linear fit)	0.97	0.14
Landing: 0m to 5m (linear fit)	0.97	0.12
Fence spread (linear fit)	0.75	0.11
Landing: 0m to 2m (linear fit)	0.97	0.10
Approach: 20m to 10m (quadratic fit)	1.01	0.08
Element number (quadratic fit)	0.76	0.06
Approach: 20m to 0m (linear fit)	0.93	0.06
Approach: 20m to 2m (linear fit)	0.93	0.04
Landing: 5m to 10m (linear fit)	1.05	0.03
Approach: 10m to 0m (linear fit)	0.94	0.02
Approach: 20m to 10m (linear fit)	0.92	0.02
Landing: 0m to 2m (quadratic fit)	1.00	0.02
Approach: 10m to 5m (linear fit)	0.94	0.01
Approach: 10m to 2m (linear fit)	0.93	0.01
Landing gradient (quadratic fit)	1.00	0.01
Element number (linear fit)	2.23	< 0.001
Number of elements (linear fit)	1.55	< 0.001
Fence spread (quadratic fit)	2.46	< 0.001

Table 7. Univariable conditional logistic regression analysis: Three-day events, Course and fence-level categorical variables with a P-value <0.2 (in descending order of P-value).

Variable		Number of controls (%)	Number of cases (%)	Odds Ratio	P-value
Hanging log					
	No	165 (93.2)	58 (98.3)	1.00	
	Yes	12 (6.8)	1 (1.7)	0.24	0.17
Flat Landing					
	No	97 (54.8)	26 (44.1)	1.00	
	Yes	80 (45.2)	33 (55.9)	1.54	0.15
Groundline					
	No	18 (10.2)	10 (16.9)	1.00	
	Yes	159 (89.8)	49 (83.1)	0.51	0.15
Corner					
	No	173 (97.7)	55 (93.2)	1.00	
	Yes	4 (2.3)	4 (6.8)	2.85	0.14
True groundline					
	No	113 (63.8)	31 (52.5)	1.00	
	Yes	64 (36.2)	28 (47.5)	1.65	0.12
Camber					
	No Camber	127 (71.8)	48 (81.4)	1.00	
	Camber	50 (28.2)	11 (18.6)	0.51	0.10
Water approach					
	No	175 (98.9)	56 (94.9)	1.00	
	Yes	2 (1.1)	3 (5.1)	4.50	0.10
Filled front					
	Open front	61 (35.9)	29 (49.2)	1.00	
	Filled front	109 (64.1)	30 (50.8)	0.58	0.08
Flat approach					
	No	97 (54.8)	25 (42.4)	1.00	
	Yes	80 (45.2)	34 (57.6)	1.75	0.08
Take off going					
	Firm / Good-Firm	89 (50.3)	26 (44.1)	1.00	
	Good	83 (46.9)	26 (44.1)	1.65	
	Good-Soft / Soft	3 (1.7)	4 (6.8)	7.28	
	Water	2 (1.1)	3 (5.1)	7.71	0.07
Uphill approach					
	No	117 (66.1)	47 (79.7)	1.00	
	Yes	60 (33.9)	12 (20.3)	0.46	0.04
Landing going					
	Firm / Good-Firm	83 (46.9)	22 (37.3)	1.00	
	Good	87 (49.2)	27 (45.8)	1.49	
	Good - Soft / Soft / Heavy	2 (1.1)	2 (3.4)	4.47	
	Water	5 (2.8)	8 (13.6)	5.76	0.03
Slippery take off					
	No	149 (84.2)	57 (1.0)	1.00	
	Yes	28 (15.8)	2 (3.4)	0.15	0.02
Water Landing					
	No	170 (96.0)	51 (86.4)	1.00	
	Yes	7 (4.0)	8 (13.6)	3.43	0.02
Uphill Landing					
	No	136 (76.8)	57 (96.6)	1.00	
	Yes	41 (23.2)	2 (3.4)	0.12	0.004

Table 8. Univariable conditional logistic regression analysis: Three-day events, Course and fence-level continuous variables with a P-value <0.2 (in descending order of P-value).

Variable	Odds Ratio	P-value
Approach: 20m to 10m (linear fit)	0.95	0.20
Approach: 20m to 0m (linear fit)	0.95	0.20
Total number of jumps (linear fit)	1.17	0.18
Fence spread (quadratic fit)	1.45	0.18
Approach: 2m to 0m (linear fit)	0.96	0.17
Approach: 10m to 5m (linear fit)	0.96	0.15
Approach: 10m to 2m (linear fit)	0.96	0.15
Distance (linear fit)	1.00	0.14
Total jumping efforts (quadratic fit)	0.88	0.14
Landing: 0m to 5m (quadratic fit)	1.00	0.14
Approach: 20m to 2m (linear fit)	0.94	0.11
Landing: 0m to 2m (quadratic fit)	1.00	0.11
Approach: 10m to 0m (linear fit)	0.95	0.10
Landing: 5m to 10m (linear fit)	1.05	0.10
Jumpable width (linear fit)	0.84	0.09
Approach: 5m to 0m (quadratic fit)	0.99	0.09
Approach: 5m to 2m (quadratic fit)	0.99	0.07
Approach: 5m to 2m (linear fit)	0.95	0.04
Approach: 5m to 0m (linear fit)	0.94	0.04
Camber (linear fit)	0.83	0.01

Table 9. Univariable conditional logistic regression analysis: One-day events, Rider-level categorical variables with a P-value <0.2 (in descending order of P-value).

Variable		Number of controls (%)	Number of cases (%)	Odds Ratio	P-value
Compete glasses					
	No	307 (88.5)	107 (93.0)	1.00	
	Yes	40 (11.5)	8 (7.0)	0.59	0.19
Teach Pony club					
	No	149 (74.1)	55 (80.9)	1.00	
	Yes	52 (25.9)	13 (19.1)	0.50	0.13
Time competing					
	0-4 years	98 (28.2)	28 (24.3)	1.00	
	5-8 years	87 (25.1)	27 (23.5)	1.12	
	9-11 years	58 (16.7)	12 (10.4)	0.74	
	12-16 years	53 (15.3)	20 (17.4)	1.37	
	17-42 years	51 (14.7)	28 (24.3)	1.98	0.12
Cross-country frequency					
	None	196 (56.5)	47 (40.9)	1.00	
	1 or more/week	9 (2.6)	5 (4.3)	2.61	
	Fortnightly	11 (3.2)	3 (2.6)	1.31	
	1/3-4 weeks	27 (7.8)	13 (11.3)	2.02	
	Less often	104 (30.0)	47 (40.9)	1.82	0.08
Aware					
	No	158 (49.4)	43 (38.7)	1.00	
	Yes	162 (50.6)	68 (61.3)	1.67	0.03
Height					
	154.94-165.10 cm	94 (27.1)	30 (26.1)	1.00	
	166.00-168.91 cm	53 (15.3)	8 (7.0)	0.44	
	169.00-172.72 cm	84 (24.2)	35 (30.4)	1.31	
	173.00-180.00 cm	61 (17.6)	14 (12.2)	0.73	
	180.34-193.04 cm	55 (15.9)	28 (24.3)	1.55	0.03
Cross-country frequency (combined)					
	None	196 (56.4)	47 (40.9)	1.00	
	Minimum of 1/month	47 (13.5)	21 (18.3)	1.99	
	Less often	104 (30.0)	47 (40.9)	1.83	0.02
Cross-country lessons					
	No	197 (56.8)	47 (40.9)	1.00	
	Yes	150 (43.2)	68 (59.1)	1.89	0.005

Table 10. Univariable conditional logistic regression analysis: One-day events, Rider-level continuous variables with a P-value <0.2 (in descending order of P-value).

Variable	Odds Ratio	P-value
Horses per day (linear fit)	1.06	0.17
Height (linear fit)	1.02	0.13
Age (linear fit)	1.02	0.08
Time competing (linear fit)	1.03	0.05
Years riding (linear fit)	1.03	0.05
Days ride (quadratic fit)	1.17	0.04
Time unaffiliated (linear fit)	1.05	0.03

Table 11. Univariable conditional logistic regression analysis: Three-day events, Rider-level categorical variables with a P-value <0.2 (in descending order of P-value).

Variable		Number of controls (%)	Number of cases (%)	Odds Ratio	P-value
Teach show jumping					
	No	65 (37.4)	16 (27.6)	1.00	
	Yes	109 (62.6)	42 (72.4)	1.58	0.19
Days ride					
	Five days or fewer	11 (63.2)	1 (1.7)	1.00	
	Six or seven days	163 (93.7)	57 (98.3)	4.12	0.19
Dressage lessons					
	No	11 (6.3)	1 (1.7)	1.00	
	Yes	163 (93.7)	57 (98.3)	4.02	0.19
Teach cross-country					
	No	101 (58.0)	27 (46.6)	1.00	
	Yes	73 (42.0)	31 (53.4)	1.56	0.16
Show jumping					
	No	23 (13.2)	13 (22.4)	1.00	
	Yes	151 (86.8)	45 (77.6)	0.58	0.15
Cross-country lessons					
	No	101 (58.0)	27 (46.6)	1.00	
	Yes	73 (42.0)	31 (53.4)	1.60	0.13
Sport weekly					
	No	105 (60.3)	28 (48.3)	1.00	
	Yes	69 (39.7)	30 (51.7)	1.77	0.07
Teach Pony club					
	No	56 (80.0)	19 (61.3)	1.00	
	Yes	14 (20.0)	12 (38.7)	5.67	0.03
Sport					
	No	93 (53.4)	19 (32.8)	1.00	
	Yes	81 (46.6)	39 (67.2)	2.71	0.004

Table 12. Univariable conditional logistic regression analysis: Three-day events, rider-level continuous variables with a P-value <0.2 (in descending order of P-value).

Variable	Odds Ratio	P-value
Weight (linear fit)	0.98	0.19
Days ride (quadratic fit)	1.17	0.18
Weeks partnered (quadratic fit)	1.00	0.17
Number of placings (quadratic fit)	1.00	0.15
BMI (quadratic fit)	1.04	0.12
Height (linear fit)	0.97	0.07

Table 13. Univariable conditional logistic regression: One-day events, Horse-level categorical variables with a P-value <0.2 (in descending order of P-value).

Variable		Number of controls (%)	Number of cases (%)	Odds Ratio	P-value
Other supplements					
	No	185 (54.3)	70 (63.6)	1.00	
	Yes	156 (45.7)	40 (36.4)	0.71	0.14
Other riders					
	No	157 (45.2)	44 (38.3)	1.00	
	Yes	190 (54.8)	71 (61.7)	1.39	0.14
Placed last event					
	No	197 (61.0)	76 (71.7)	1.00	
	Yes	126 (39.0)	30 (28.3)	0.71	0.13
Hoof supplements					
	No	294 (86.2)	89 (80.9)	1.00	
	Yes	47 (13.8)	21 (19.1)	1.60	0.12
Shoes (combined)					
	Standard	321 (92.5)	100 (87.0)	1.00	
	Not standard	26 (7.5)	15 (13.0)	1.79	0.09
Cross-country schooling					
	Never	70 (20.2)	13 (11.3)	1.00	
	>1/month	33 (9.5)	14 (12.2)	2.38	
	Monthly	34 (9.8)	18 (15.7)	2.94	
	Start of season	162 (46.7)	47 (40.9)	1.61	
	If there's a problem	48 (13.8)	23 (20.0)	2.77	0.05
Number of weeks					
	0-1 weeks	77 (23.2)	22 (20.6)	1.00	
	2 weeks	86 (25.9)	42 (39.3)	1.72	
	3 weeks	48 (14.5)	16 (15.0)	1.05	
	4-6weeks	47 (14.2)	13 (12.1)	0.96	
	7-92 weeks	74 (22.3)	14 (13.1)	0.53	0.05
Cross-country schooling (binary)					
	No	70 (20.2)	13 (11.3)	1.00	
	Yes	277 (79.8)	102 (88.7)	2.05	0.03

Table 14. Univariable conditional logistic regression analysis: One-day events, Horse-level continuous variables with a P-value <0.2 (in descending order of P-value).

Variable	Odds Ratio	P-value
Number of events (quadratic fit)	0.94	0.15
Higher runs (quadratic fit)	1.01	0.11
Number of weeks (quadratic fit)	1.00	0.05

Table 15. Univariable conditional logistic regression analysis: Three-day events, Horse-level categorical variables with a P-value <0.2 (in descending order of P-value).

Variable	Number of controls (%)	Number of cases (%)	Odds Ratio	P-value
Osteopathy / Chiropractic				
No	168 (96.0)	54 (93.1)	1.00	
Yes	6 (3.4)	4 (6.9)	2.85	0.14
Flat race				
No	154 (90.6)	55 (98.2)	1.00	
Yes	16 (9.4)	1 (1.8)	0.20	0.12
Previous horse fall				
No	123 (71.9)	46 (83.6)	1.00	
Yes	48 (28.1)	9 (16.4)	0.50	0.09
Dressage competitions				
Never	99 (56.9)	31 (54.4)	1.00	
1-3 times	34 (19.5)	4 (7.0)	0.42	
4-8 times	25 (14.4)	14 (24.6)	1.73	
>8 times	16 (9.2)	8 (14.0)	1.67	0.08
Cross-country schooling (binary)				
No	56 (32.4)	11 (20.0)	1.00	
Yes	117 (67.6)	44 (80.0)	2.12	0.06
Vitamin supplements				
No	76 (44.4)	34 (60.7)	1.00	
Yes	95 (55.6)	22 (39.3)	0.54	0.05

No horse-level two-/three-day event continuous variables had a P-value <0.2.

Table 16. Univariable conditional logistic regression analysis: One-day events, Event-level categorical variables with a P-value <0.2 (in descending order of P-value).

Variable		Number of controls (%)	Number of cases (%)	Odds Ratio	P-value
Horses same day					
	None	12 (3.5)	5 (4.3)	1.00	
	One	195 (56.2)	52 (45.2)	0.49	
	Two	83 (23.9)	34 (29.6)	0.81	
	Three or more	57 (16.4)	24 (20.9)	0.80	0.17
Attitude XC					
	Very excited	32 (9.2)	6 (5.2)	1.00	
	Excited	108 (31.1)	26 (22.6)	1.29	
	Alert	123 (35.4)	50 (43.5)	2.16	
	Calm	84 (24.2)	33 (28.7)	1.97	0.17
Social night before					
	No	326 (93.9)	112 (97.4)	1.00	
	Yes	21 (6.1)	3 (2.6)	0.38	0.16
Time drank					
	1 -10 minutes	74 (24.6)	22 (21.8)	1.00	
	11-25 minutes	54 (17.9)	15 (14.9)	0.93	
	30-40 minutes	80 (26.6)	22 (21.8)	1.02	
	45-540 minutes	86 (28.6)	41 (40.6)	1.90	
	Previous day	7 (2.3)	1 (1.0)	0.62	0.16
Walked family					
	No	256 (74.0)	92 (80.7)	1.00	
	Yes	90 (26.0)	22 (19.3)	0.67	0.15
Which route					
	Only one route	298 (85.9)	92 (80.0)	1.00	
	Direct route	47 (13.5)	20 (17.4)	1.50	
	Alternative route	2 (0.6)	3 (2.6)	5.23	0.12
Walked friend					
	No	286 (82.7)	102 (89.5)	1.00	
	Yes	60 (17.3)	12 (10.5)	0.56	0.10
Horses day before					
	None	306 (88.2)	93 (80.9)	1.00	
	One	19 (5.5)	10 (8.7)	2.14	
	Two or more	22 96.3)	12 (10.4)	2.04	0.10
Front studs					
	None	48 (13.8)	11 (9.6)	1.00	
	One in each shoe	184 (53.0)	53 (46.1)	1.24	
	Two in each shoe	115 (33.1)	51 (44.3)	1.95	0.09
Knew score					
	No	137 (39.6)	34 (29.6)	1.00	
	Yes	209 (60.4)	81 (70.4)	1.51	0.08
Normal XC					
	No	13 (3.8)	9 (7.8)	1.00	
	Yes	327 (96.2)	106 (92.2)	0.45	0.08
Web dressage					
	23-38 penalties	87 (25.1)	33 (28.7)	1.00	
	38.4-42 penalties	53 (15.3)	17 (14.8)	0.70	
	42.18-48 penalties	59 (17.0)	29 (25.2)	1.20	
	48.05-58.61 penalties	71 (20.5)	20 (17.4)	0.68	
	58.8-87.83 penalties	77 (22.2)	16 (13.9)	0.44	0.08
Eat					
	No	79 (22.8)	17 (14.8)	1.00	
	Yes	268 (77.2)	98 (85.2)	1.71	0.07

Variable		Number of controls (%)	Number of cases (%)	Odds Ratio	P-value
Into sun					
	No	343 (98.8)	110 (96.5)	1.00	
	Yes	4 (3.6)	4 (3.5)	4.00	0.07
Sleep time					
	1-5.75 hours	60 (17.6)	9 (7.8)	1.00	
	6-6.92 hours	78 (22.9)	36 (31.3)	3.09	
	7-7.83 hours	99 (29.1)	28 (24.3)	1.86	
	8 -8.75 hours	63 (18.5)	27 (23.4)	2.73	
	9 -11.75 hours	40 (11.8)	15 (13.0)	2.51	0.06
Important					
	No	66 (19.0)	32 (27.8)	1.00	
	Yes	281 (81.0)	83 (72.2)	0.59	0.05
Normal dressage					
	No	41 (12.0)	6 (5.2)	1.00	
	Yes	300 (88.0)	109 (94.8)	2.46	0.05
Social event					
	No	320 (92.2)	112 (97.4)	1.00	
	Yes	27 (7.8)	3 (2.6)	0.20	0.04
Slippery					
	No	330 (95.1)	103 (89.6)	1.00	
	Yes	17 (4.9)	12 (10.4)	2.64	0.03
Position					
	Didn't know	303 (87.3)	95 (82.6)	1.00	
	First	8 (2.3)	9 (7.8)	4.21	
	Second or lower	36 (10.3)	11 (9.6)	0.97	0.02
Speed affect					
	No	205 (59.4)	77 (71.3)	1.00	
	Yes	140 (40.6)	31 (28.7)	0.53	0.01
Fence before (combined)					
	Very well	158 (47.6)	69 (61.6)	1.00	
	Well	148 (44.6)	38 (33.9)	0.53	
	Not very well/not at all well	26 (7.8)	5 (4.5)	0.38	0.01
XC refusals (combined)*					
	No	309 (89.8)	114 (99.1)	1.00	
	Yes	35 (10.2)	1 (0.9)	0.07	0.01
Route					
	Easy	41 (11.8)	6 (5.2)	1.00	
	Straightforward	213 (61.6)	60 (52.2)	1.83	
	Fairly difficult	82 (23.7)	36 (31.30	3.17	
	Difficult	10 (2.9)	13 (11.3)	9.86	<0.001
Route relative					
	Easier	123 (35.5)	18 (15.7)	1.00	
	The same	141 (40.8)	60 (52.2)	3.20	
	More difficult	82 (23.7)	37 (32.2)	3.54	<0.001
Ride plan					
	No	24 (6.9)	26 (23.2)	1.00	
	Yes	322 (93.1)	86 (76.8)	0.29	<0.001
Speed					
	About right	314 (90.8)	86 (76.1)	1.00	
	Too slow	17 (4.9)	10 (8.8)	2.05	
	Too fast	15 (4.3)	17 (15.0)	4.62	<0.001

*Case 19 was selected randomly and recoded as having had a refusal.

Table 17. Univariable conditional logistic regression analysis: One-day events, Event-level continuous variables with a P-value <0.2 (in descending order of P-value).

Variable	Odds Ratio	P-value
Drank (linear fit)	1.00	0.19
Warm up actual (quadratic fit)	1.00	0.17
Sleep (linear fit)	1.11	0.15
Warm up wanted (quadratic time)	1.00	0.13
Sleep (quadratic fit)	0.93	0.09
Time walked (linear fit)	1.00	0.09
Web dressage (linear fit)	0.96	0.03

Table 18. Univariable conditional logistic regression analysis: Three-day events, Event-level categorical variables with a P-value <0.2 (in descending order of P-value).

Variable		Number of controls (%)	Number of cases (%)	Odds Ratio	P-value
Normal travel					
	No	5 (2.9)	4 (6.9)	1.00	
	Yes	169 (97.1)	54 (93.1)	0.42	0.19
Breastplate XC schooling					
	No	11 (10.3)	2 (4.7)	1.00	
	Racing	46 (43.0)	15 (34.9)	1.52	
	Hunting	47 (43.9)	24 (55.8)	3.77	
	Racing and Hunting	3 (2.8)	2 (4.7)	2.78	0.18
Normal A					
	No	2 (1.2)	3 (5.2)	1.00	
	Yes	163 (98.8)	55 (94.8)	0.27	0.16
Whip					
	No	3 (1.7)	3 (5.2)	1.00	
	Yes	171 (98.3)	55 (94.8)	0.27	0.16
Alcohol					
	None	65 (37.4)	32 (55.2)	1.00	
	Low	65 (37.4)	17 (29.3)	0.54	
	Moderate	40 (23.0)	8 (13.8)	0.41	
	Heavy	4 (2.3)	1 (1.7)	0.46	0.14
Important					
	No	8 (4.6)	6 (10.3)	1.00	
	Yes	166 (95.4)	52 (89.7)	0.40	0.12
Overreach XC schooling					
	No	18 (16.8)	13 (30.2)	1.00	
	Yes	89 (83.2)	30 (69.8)	0.40	0.09
Walked trainer					
	No	127 (73.4)	49 (84.5)	1.00	
	Yes	46 (26.6)	9 (15.5)	0.48	0.09
Web dressage					
	38.4-52.4 penalties	40 (23.1)	7 (12.1)	1.00	
	52.6-58.0 penalties	37 (21.4)	9 (15.5)	1.61	
	58.01-63.0 penalties	33 (19.1)	13 (22.4)	2.65	
	63.2-68.6 penalties	29 (16.8)	17 (29.3)	4.49	
	68.8-87.83 penalties	34 (19.7)	12 (20.7)	2.57	0.09
Saddle Padding					
	Minimal	91 (52.3)	22 (37.9)	1.00	
	Moderate	67 (38.5)	32 (55.2)	2.04	
	Heavy	16 (9.2)	4 (6.9)	1.09	0.08
Eat					
	No	49 (28.2)	9 (15.5)	1.00	
	Yes	125 (71.8)	49 (84.5)	2.04	0.07
Route relative					
	Easier	54 (31.2)	9 (15.5)	1.00	
	The same	75 (43.4)	30 (51.7)	2.31	
	More difficult	44 (25.4)	19 (32.8)	2.67	0.07
Martingale XC competing					
	No	42 (39.6)	9 (21.4)	1.00	
	Yes	64 (60.4)	33 (78.6)	2.18	0.06
Overreach XC competing					
	No	24 (13.9)	14 (24.1)	1.00	
	Yes	149 (86.1)	44 (75.9)	0.48	0.06

Variable	Number of controls (%)	Number of cases (%)	Odds Ratio	P-value
Alcohol (combined)				
None	65 (37.4)	32 (55.2)	1.00	
Low	65 (37.4)	17 (29.3)	0.54	
Moderate/heavy	44 (25.3)	9 (15.5)	0.41	0.06
Sleep time				
3-7 hours	36 (20.8)	10 (17.2)	1.00	
7.25-7.75 hours	37 (21.4)	5 (8.6)	0.56	
8 hours	40 (23.1)	11 (19.0)	1.27	
8.25-9 hours	35 (20.2)	17 (29.3)	2.05	
9.25-12 hours	25 (14.5)	15 (25.9)	2.81	0.05
Normal C				
No	8 (4.6)	8 (13.8)	1.00	
Yes	165 (95.4)	50 (86.2)	0.31	0.03
Position				
Didn't know / can't remember	63 (36.2)	32 (55.2)	1.00	
First	2 (1.1)	1 (1.7)	1.19	
2nd-10th	25 (14.4)	3 (5.2)	0.19	
11th or lower	84 (48.3)	22 (37.9)	0.39	0.03
Social night before				
No	140 (80.5)	55 (94.8)	1.00	
Yes	34 (19.5)	3 (5.2)	0.22	0.02
Helpers				
None	2 (1.1)	1 (1.7)	1.00	
One	46 (26.4)	7 (12.1)	0.38	
Two	52 (29.9)	11 (19.0)	0.48	
Three or more	74 (42.5)	39 (67.2)	1.33	0.02
XC refusals*				
No	147 (86.0)	57 (98.3)	1.00	
Yes	24 (14.0)	1 (1.7)	0.09	0.02
Martingale XC schooling				
No	42 (39.6)	9 (21.4)	1.00	
Yes	64 (60.4)	33 (78.6)	3.22	0.01
Route				
Easy	14 (8.1)	3 (5.2)	1.00	
Straightforward	81 (46.8)	20 (34.5)	1.10	
Fairly difficult	64 (37.0)	20 (34.5)	1.60	
Difficult	14 (8.1)	15 (25.9)	5.90	0.008
Ride plan				
No	15 (8.6)	17 (29.8)	1.00	
Yes	159 (91.4)	40 (70.2)	0.20	<0.001
Speed				
About right	158 (91.3)	39 (68.4)	1.00	
Too slow	6 (3.5)	7 (12.3)	5.19	
Too fast	9 (5.2)	11 (19.3)	7.26	<0.001

* Case 177 was selected randomly and recoded as having had a refusal.

Table 19. Univariable conditional logistic regression analysis: Three-day events, Event-level continuous variables with a P-value <0.2 (in descending order of P-value).

Variable	Odds Ratio	P-value
Sleep (quadratic fit)	1.10	0.06
Sleep (linear fit)	1.37	0.02
Web dressage (linear fit)	1.05	0.01

Table 20. Summary of the effect of adding variables into the model for one-day events shown in Table 4 of Chapter 4 as a result of *a priori* evidence.

Variable added	P-value	Odds ratio (95% C.I.)	Deviance	Degrees of freedom
Original Model (Table 4)			186.37	9
Jumping effort number (linear fit)	0.41	1.02 (0.98, 1.05)	185.69	10
Total number of jumps on course (linear fit)	0.81	1.03 (0.82, 1.30)	186.31	10
Total number of jumping efforts on course (linear fit)	0.46	1.05 (0.92, 1.21)	194.10	8
Downhill take off (binary)	0.45	0.74 (0.34, 1.60)	185.79	10
Ditch in front (binary)	0.32	0.58 (0.20, 1.70)	187.52	10
Occupation of rider				
Professional event rider / Full-time horses	Ref.	1.00		
Full-time other	0.10	1.90 (0.88, 4.10)		
Student, Part-time other, not working	0.69	0.84 (0.36, 1.94)	183.88	9

Table 21. Summary of the effect of adding variables into the model for two-/three-day events shown in Table 5 of Chapter 4 as a result of *a priori* evidence.

Variable added	P-value	Odds ratio (95% C.I.)	Deviance	Degrees of freedom
Original Model (Table 5)			95.50	6
Jumping effort number (linear fit)	0.50	1.01 (0.97, 1.06)	96.05	7
Total number of jumps on course (linear fit)	0.62	1.08 (0.79, 1.49)	96.26	7
Total number of jumping efforts on course (linear fit)	0.81	0.97 (0.74, 1.27)	96.44	7
Downhill take off (binary)	0.74	1.18 (0.45, 3.08)	96.39	7
Ditch in front (binary)	0.32	0.49 (0.12, 2.03)	95.46	7
Rider's knowledge of their position prior to XC				
Didn't know	Ref.	1.00		
First place	0.57	2.07 (0.17, 25.59)		
Second or lower	0.04	0.38 (0.14, 0.94)	91.51	8
Occupation of rider				
Professional event rider / Full-time horses	Ref.	1.00		
Full-time other	0.34	0.49 (0.12, 2.08)		
Student, Part-time other, not working	0.67	0.79 (0.27, 2.34)	95.51	8
Rider has XC lessons				
No	Ref.	1.00		
Yes	0.15	1.84 (0.81, 4.17)	94.34	7
Drop landing				
No	Ref.	1.00		
Yes	0.38	0.55 (0.14, 2.10)	95.71	7
Take-off surface				
Firm / good-firm	Ref.	1.00		
Good	0.18	2.65 (0.64, 10.86)		
Good-soft / Soft	0.10	10.95 (0.65,184.92)		
Water	0.11	21.22 (0.53,851.13)	91.10	9

Table 22. A summary of the effect of adding the variables; event level and rider status into the model of risk factors for horse falls at one-day events presented in Table 4 of Chapter 4.

	Original model (A)	Model A plus event level	Model A plus rider status
Variable	**Odds Ratio**	**Odds Ratio**	**Odds Ratio**
Take-off surface			
Land	1.00	1.00	1.00
Water	25.00*	26.70*	26.06*
Landing surface			
Land	1.00	1.00	1.00
Water	6.95*	7.08*	7.06*
Landing			
Without a drop	1.00	1.00	1.00
Drop landing	5.04*	5.21*	5.27*
Angle and spread of fence			
No angle, <2m spread	1.00	1.00	1.00
No angle, ≥2m spread	5.62*	5.89*	5.89*
All angled fences	6.63*	5.73*	7.24*
Position before XC			
Didn't know position	1.00	1.00	1.00
First	5.69*	6.20*	5.70*
Second or lower	0.73	0.72	0.71
Previous XC refusals on the course incurred by the horse and rider			
Earlier refusals	1.00	1.00	1.00
No refusals	10.23*	10.43*	10.40*
Rider has XC lessons			
No	1.00	1.00	1.00
Yes	2.02*	2.31*	2.05*
Event level			
Intro/Pre-novice		1.00	
Novice		1.28	
Intermediate		2.96	
Advanced		1.20	
Rider status			
Professional rider			1.00
Amateur rider			0.68

* P-value <0.05

Table 23. A summary of the effect of adding the variables; event level and rider status into the model of risk factors for horse falls at two-/three-day events presented in Table 5 of Chapter 4.

	Original model (A)	Model A plus event level	Model A plus rider status
Variable	**Odds Ratio**	**Odds Ratio**	**Odds Ratio**
Landing surface			
Land	1.00	1.00	1.00
Water	10.02*	10.80*	10.02*
Angle and spread of fence			
No angle, <2m spread	1.00	1.00	1.00
No angle, ≥2m spread	2.69	2.67	2.69
All angled fences	3.51*	3.46*	3.51*
Previous XC refusals on the course incurred by the horse and rider			
Earlier refusals	1.00	1.00	1.00
No refusals	11.48*	12.71*	11.48*
Camber	0.77*	0.76*	0.77*
Rider participated in non-equestrian sports			
No	1.00	1.00	1.00
Yes	6.52*	6.87*	6.52*
Event Level			
Intro/Pre-novice/Novice		1.00	
Intermediate/Advanced		0.67	
Rider status			
Professional rider			1.00
Amateur rider			1.00

* P-value <0.05

The variable of event level was collapsed into two categories to enable the model to converge.

Questionnaire: One-day events

THE UNIVERSITY
of LIVERPOOL

1 DAY EVENT : QUESTIONNAIRE

Case / Control

Case Number:			Event:		Class:	
Date of Event:		Day:	Horse:			
Horse Number:			Rider:			
Date of questionnaire:			Tel. No:			

Hello, my name is .... I am involved with the Study of Risk Factors associated with Falls of Horses in Eventing being carried out by the University of Liverpool. We recently sent you a letter outlining the study and explaining why you have been selected to participate in the study. Did you receive the letter? **NO/ YES**

NO: The University of Liverpool has been funded by **the Home of Rest for Horses** to conduct a study to assess the risk factors associated with falls of horses in the sport of Eventing. This study is being conducted with the co-operation of British Eventing and the FEI. The aim of the study is to identify risk factors associated with falls of horses and to provide an estimate of their relative importance. The study will examine factors associated with the level of the event, the obstacle, the horse and the competitor. The study design, a case:control study, requires collection of identical information specific to the case (falling horse) and a number of randomly selected controls (no horse fall). The difference between the case and control populations can then be analysed. This information will then allow logical changes to be made within the sport so as to decrease the incidence of injuries to horses and riders.

ALL: Does this explanation clarify the aims of our study?

The Event I am enquiring about is:

____________________Horse Trials, at which you rode ________________________.

You were selected to participate in the study: because your horse fell / as a random control, at this event.

Prior to the event, were you aware of this study? **NO / YES / NOT SURE**

The information I am particularly interested in pertains to the preparation of horse and rider for the event, as well as some specific questions about you and your horse. Just to reassure you, the information that is provided is for the use of the study only and will be kept completely confidential.

Would it be convenient to ask you some questions over the telephone? It should take about 15-20 minutes.
If now is not a convenient time, when might be more convenient for you?
Date: *Time:*

Is there a different number at which you would rather I call you?

SECTION A:

I'd first like to ask you a few questions about the horse ________________.

What breed is the horse? ____

1. Who owns the horse?
   Rider
   Member of family, ***state who*****:**
   Owner
   Rider jointly owns with 'owner' / sponsor
   Sponsor

2. How long have you been partnered with this horse?

   _____ **years** **or** _____ **months** **or** _____ **weeks**

3. Excluding this year, how many years have you competed this horse?

   _________ **(1st season =0, 0.5 season=1)**

3. Prior to _____HT how many Horse Trials had you **completed** with this horse in total?

5. Prior to ____HT, in total how many Horse Trials had you **been placed in** with this horse? _______

6. Prior to ____, had you competed at any CIC's with this horse? **NO / YES**

If YES: How many CIC's have you competed at with this horse at each level? How many did you complete? How many were you placed in?

·	Competed	Completed	Placed
CIC*			
CIC**			
CIC***			

7. Have you competed at any 3 day events with this horse? **NO / YES**

If YES: How many 3 day events have you completed with this horse at each level? How many were you placed in?

	Competed	Completed	Placed
CCN*			
CCN**			
CCI*			
*CCI***			
CCI***			
CCI****			

8. How many H.T had this horse completed **prior to the start of your partnership?** _____

(If multiple, i.e. more than 50, please state number of seasons of horse trials) _____

9. How many 3DE had this horse completed **prior to the start of your partnership?** ____

(If multiple, i.e. more than 50, please state number of seasons of horse trials) ______

10. How often has this horse **HUNTED,,...,** within the last 12 months? *Tick box:*

	DK / recently acquired horse	**Never**	**1-3 times**	**4-8 times**	**9+ times**
Hunted					
Competed SJ					
Competed Dressage					

11. Has this horse raced? **NO / YES**

12. *If YES*: Was this:
Flat racing? **NO / YES**
Hurdling? **NO / YES**
Steeplechasing? **NO / YES**
Point-to-Pointing? **NO / YES**

13. How many points did he/she have prior to this Event at.....................? _______ points

14. Prior to ____HT, how many runs XC has this horse had at _____ (*eg Intermediate*) level? __________*(level of event at which competitor was selected)*
How many runs XC, if any, has this horse had at a higher level? __________*(than the level of event at which competitor was selected)*

15. Has the horse completed on each occasion? **NO / YES**
16.. *If NO*, What were the reasons?

	No. of times		**No.of times**
WD/Elim poor SJ		**Elim/retired on XC (refusals)**	
WD lameness		**Elim/retired on XC (rider falls)**	
Elim error of course (XC or SJ)		**Elim XC (horse fall)**	
		Other	

17. Prior to ________Horse Trials, in how many Events had the horse started the XC phase, during the last 2 months? _________

At what level?

Level: __________ No. of events: ___________
Level: __________ No. of events: ___________

18. When did the horse last event, prior to _________ Horse Trials? (*Event at which competitor was selected)*

Name/
Date:............................... ....months ago ......weeks ago

19. Was the horse placed at his/her last event? **NO / YES / DK / n/a: first event**
If YES: Where was the horse placed? Place : ....

ASK ALL: How many dressage penalties did you have? _______
What was your SJ score? ______
If SJ penalties: what were the penalties for?
(State number of refusals, etc. rather than penalties.
_____ **fences down** ______**refusals/run outs**
______ **rider fall** ______ **horse fall**
______**time penalties**

20. Did the horse have any XC Jumping or Time penalties? NO / YES / DK
What were the penalties for?

	Refusal	Run out	Horse fall	Rider fall	Time
No. of:					

21. ***If the horse did not complete*:**
What was the reason for not completing? (Tick one that applies)

WD poor Dr mark		**Elim/retired on XC (refusals)**	
WD/Elim poor SJ		**Elim/retired on XC (rider falls)**	
WD lameness		**Elim XC (horse fall)**	
WD XC ground conditions		**Elim error of course (XC or SJ)**	
WD XC too tough		**Other**	

22. Has this horse had any time off within the last 6 months, due to illness or injury? **NO/YES**

If Yes:
How long ago? _____________

How long was the horse off for? __________

For what reason did the horse have time off?____

23. Has this horse received any alternative treatments such as homeopathy, osteopathy, physiotherapy, magnotherapy or acupuncture? **NO / YES**

What form of treatment did the horse have?________________

For what injury?________________

How long before this competition did this treatment stop?_________________

How long has this treatment been in progress?________________

24. Does the horse receive any of the following nutritional supplements?

	Tick all that apply		Tick all that apply
Vitamins		**Jt. Supplement** (Flex Free, Cortaflex)	
Garlic		**Hoof supplement** (Farriers formaula)	
Electrolytes		**Other:**	
Herbal		**None**	

<u>I'm now going to ask you about your training schedule for this horse</u>

25.How often is the horse **schooled on the flat, ...?**

	Schooled on the Flat	Schooled over SJ	XC Schooled	Hacked	Fitness work (Canter/Gallop)
Days / week					
Days / month					
Start of season					
If problem					
Other: state					

26. Does anyone other than you ride this horse on a regular basis, by that I mean at least once a fortnight? **NO / YES**

Who else rides the horse? **Owner Groom Instructor Friend Family Other**

<u>I'm now going to ask you about your tack</u>

27. Would you describe the amount of padding/knee roll on your XC saddle as:

minimal **moderate** or **heavy?**

28a. Would you describe the length of your stirrup leathers for the XC phase as:

short **medium** or **long?**

28b.How many holes higher are your stirrup leathers for the XC phase, compared to the length that you ride for Show Jumping? _______

29. Does this horse wear a martingale for XC schooling? NO / YES / n/a don't school

30. Does this horse wear a martingale for competing XC? NO / YES

31. What type of breast plate, if any, does the horse wear for XC schooling?

None Racing Hunting Both / n/a don't school

32. What type of breast plate, if any, does the horse wear for competing XC?

None Racing Hunting Both

33a.What type of bit does this horse have in for XC schooling? _______________
33b. *If applicable, eg 3 ring bit:* Which ring are the reins attached to?
(top/middle/bottom)__________

34. What type of bit does this horse usually have in when competing XC? ______________
34b. *If applicable, eg 3 ring bit:* Which ring are the reins attached to?
(top/middle/bottom)__________
35. Was this the bit used at _____________ horse trials? **NO / YES**
If applicable, eg 3 ring bit: Which ring were the reins attached to?
(top/middle/bottom)__________
If No: What bit was used?________________

Why did you change bits?
Forgot 'normal' bit
Previous bit too strong
Previous bit too mild / needed more control
Horse didn't like bit
Experimenting to find 'better' bit
Other : ___________________

36. What type of noseband does this horse wear for XC schooling? ________________

37.What type of noseband does this horse usually wear when competing XC? ______________

38.Was this the noseband used at _____________ horse trials? **NO / YES**

If No: What noseband was used?________________

Why did you change nosebands?
Forgot 'normal' noseband
Needed more control
Horse getting tongue over bit
Horse opening mouth
Wanted 'milder' noseband
Other : ___________________

39. What type of protective leg boots/bandages do you use for **XC Schooling,.... and what about for Competing?**

	Infront / Behind	
XC Schooling	_______________ / __________________	
Competing	_______________ / __________________	
	Schooling	**Competing**
Overreach	**NO / YES**	**NO / YES**

40. What type of shoes does the horse wear? **Standard Egg bar 4-Pt Other**

<u>**Next I would like to ask some questions about your experience as a rider.**</u>

41. How long have you been competing in B.E. Horse Trials? ______ **years or** ____ **months**
(To include Ponies & Juniors)
Did you compete in Unaffiliated Horse Trials prior to this? **NO / YES**
If Yes: How many years were you competing in unaffiliated Horse Trials before you started competing in B.E. Horse Trials? ____ **years or** ___ **months**

42. How long have you been riding horses in general? _____ **years or** ____ **months**

43. Besides eventing, in which other equestrian sports do you participate on a regular basis, by that I mean at least 4 times a year?

S.J.	**Dressage**	**Hunting**	**Team chasing**
Pt-Pt	**Racing**	**Showing**	**Driving**
Polo	**Endurance**		

44. How long ago were you last unseated by a horse? _______________

What caused the fall?______________________________________

Were you injured? **NO / YES** What was the injury?____________________

45. Have you ever been unseated from this horse? **NO / YES**

What caused the fall?______________________________________

Were you injured? **NO / YES** What was the injury?____________________

46. Has this horse ever had a fall out competeing? **NO / YES / DK**
If Yes:
How long ago? ___________

What type of fence? ____________

Any injuries to the horse? **NO / YES** *If Yes,* What were they?

____

____

Were you riding the horse? **NO / YES**
Any injuries to you / the rider? **NO / YES** *If Yes,* What were they?

____

____

47. How many different horses do you ride in an average day at home? _________

48. How many different horses do you ride on average at an event? _________

49. Do you consider your riding to be a profession or a hobby? **Profession Hobby**

50. *If hobby,* What is your occupation? ____________________ .

51. *If hobby,* On average, how many days per week are you able to ride? ________________

52. *If Profession:* For how long have you been a professional horseman/woman? __________

53. Do you teach riding to others? **NO / YES**

54. *If YES:* How frequently? **Daily** **Several times a week**
Once a week **2-3 times a month** **Less frequently**

55. *If YES*: Which discipline(s) do you teach the majority of the time?
Dressage **S.J.** **X-C** **Mixture** **P.C.** **Other:**

56. Do you have any BHS or NVQ qualifications? **NO / YES.** *If YES:* Which ones? _____

57. Do you have any Pony Club qualifications? **NO / YES.** *If YES:* Which ones? _____

58. Do you have **Dressage lessons** on your own horses/horses that you ride? **NO / YES**

If Yes: **How frequently?**

What about **XC instruction...?** **NO / YES**
And SJ instruction? **NO / YES**

	Dressage	XC	SJ
Frequency of instruction (on average)	Weekly Fortnightly Monthly Less often Only when problem	Weekly Fortnightly Monthly Less often Start of season Only when problem	Weekly Fortnightly Monthly Less often Only when problem

59. Do you participate in other fitness sports or activities? **NO / YES**

What are they? How often do you take part in these sports or activities?

Sport	Frequency played
	Daily / 2-3 times wk / weekly / fortnightly / monthly / less often
	Daily / 2-3 times wk / weekly / fortnightly / monthly / less often
	Daily / 2-3 times wk / weekly / fortnightly / monthly / less often

Now a few general questions about yourself:

60. What is your age? __________

61. How much do you weigh? **Stones** _________ **or Kgs** __________

62. How tall are you? **Feet**__________ **or cm** ____________

63. Do you wear glasses or contact lenses? **NO / YES**
If Yes :
Which do you wear? **G** **CL** **Both**
Which do you wear when competing? **Glasses** **Contacts** **Neither**

64. Do you regularly take any prescription medication? **NO / YES**
If Yes:
What do you take? ___________________

SECTION B:

Next I would like to ask some specific questions about ____________________Horse Trials.

1a. How long was the journey from home? ________days ___________hrs __________mins

1b. Did you travel to the event on the day that you were competing, or the previous day?

On the Day / Day before / >1 day before

2. Did this horse travel well? **NO / YES**
3. Is this normal? **NO / YES**
4. *If applicable:* Did you stable away from home? **NO / YES**
5. *If applicable:* Did the horse appear settled overnight? **NO / YES**
6. *If travelled on XC day:* What time did you arrive at the event ?______________
7. How long before your dressage time did you arrive at the event? ____________
8. What time did you go XC on this horse? _________________

9. Using the terms, very excited, excited, alert or calm, how would you describe this horse's attitude **on arrival, ...,** is this normal?

	On arrival	**At the dressage**	**Prior to SJ**	**Prior to XC**	**After XC**
V excited					
Excited					
Alert					
Calm					
Normal (N/Y)					

8. How many times did you walk the cross country course? ___________

When in relation to your ride: **Day before only**
On the day only
Day(s) before and on the day

How long before your XC ride did you (last) finish walking the course? _______

9. Did you walk the course alone? **NO / YES / >1 walk: alone & with company**

If applicable; with whom did you walk? _________________________

Thinking now specifically about the cross country phase.

10a. If any, what type of studs were in the shoes?

10b. How many studs were in each shoe in front, ... and in each shoe behind?
If one stud in shoe: In which location was that?

Front shoes		Hind shoes	
Outside	Inside	Outside	Inside
Rd / sm / med /lge /dk	Rd /sm /med /lge /dk	Rd /sm /med /lge /dk	Rd /sm /med /lge /dk
Rd / pts / Sq / dk	Rd / pts / Sq / dk	Rd / pts / Sq / dk	Rd / pts / Sq / dk

11. Did you grease the legs before the X-C phase? **NO / YES**

12. Were you carrying a whip? **NO / YES / DROPPED WHIP AT FENCE NO: ____**

13. **Is this usual when riding this horse XC?** NO / YES

14. Were you wearing spurs? **NO / YES**

15. **Is this usual when riding this horse XC?** NO / YES

16. Did you know your current score or position, before starting on the XC? **NO / YES**
ASK ALL: What was your dressage score? What was your SJ score
DR = ________ penalties SJ = ______penalties

What were the SJ penalties for? _________time penalties _________(no. of)fences down

_________(no. of) refusals _________ rider fall _______horse fall

What was your position? _____ **place / or: top third / middle / bottom third**

Position after **DR / SJ**

17. How long did you allow to warm up for the XC : _________ mins

18. Was your XC warm up as planned? **NO / YES**
If NO: Why not?
Held at start XC running late XC running early
Competitor running late Competitor running early
Other:

If held at start: **How long were you held at the start for? ____________ mins** ***(extra time held for)***

If XC or competitor running late or early:
How long did you warm up for? _____________ mins

Now I would like to ask you about fence number _______, the ___________________ which has been randomly selected/at which your horse fell.

19. What did you think of this fence / the **direct route** when you walked the course?
Direct route or ONLY route:
Easy Straightforward Fairly Difficult Difficult

What did you think of the **alternative route** when you walked the course?
Alternative route:
Easy Straightforward Fairly Difficult Difficult

20. How would you rate this jump / the **direct route** relative to the other fences on the course?
Direct route or ONLY route:
Easier the same More difficult

How would you rate the **alternative route** relative to the other fences on the course?
Alternative route:
Easier the same More difficult

21. Did you ride the fence as you had planned when walking the course?
NO / YES
If no, **What prompted you to change your plan?**

22. *If a combination*: Which route did you jump?

Direct   Alternative   N/A : one route only

Why did you jump this route?

	Tick
Confident of horse's ability/Not difficult fence	
To save time	
To educate horse	
To test horses ability/ about to upgrade	
Refusal/trouble at one element	
Refusal/trouble at previous fence	
Uncertain of horse's ability to go well through the straight route	
Tired horse	
Other:	

23. *If a combination:* When you walked the course, how many strides, if any, did you plan to take in between the elements?
And, how many strides did your horse take?

Elements	Planned no. of strides	Actual no. of strides
a-b		
b-c		
c-d		
d-e		

24. How would you describe the ground conditions at this fence?

	Tick any that apply	Did this affect the way you jumped the fence? *If Yes:* How?	
Firm / Hard		N / Y	
Good – Firm		N / Y	
Good		N / Y	
Good- Soft		N / Y	
Soft		N / Y	
Heavy		N / Y	
Slippery		N / Y	
Sandy		N / Y	
Deep water		N / Y	
Hole		N / Y	
Other		N / Y	

25.How would you describe the light conditions at the fence?

	Tick all that apply	Did this affect the way you jumped the fence? *If Yes:* How?	
Good		N / Y	
Poor light		N / Y	
Open, L-L		N / Y	
L–D		N / Y	
D-L		N / Y	
D-D		N / Y	
Jumping into sun		N / Y	
Shadows		N / Y	

26.How would you describe your speed of approach?

	Tick one	Did this affect the way the horse jumped the fence? *If Yes;* How?	
About right		N / Y	
Too slow		N / Y	
Too fast		N / Y	

27. Did a horse or rider error occur when you were riding this fence?

	Tick	What was the error?	Did this affect the way the horse jumped the fence? How?
No error			
Horse error			
Rider error			

28. Now thinking specifically about the fence BEFORE the one we have been talking about. Did your horse jump this fence , the ____________:

Very Well **Well** **Not very well** **or** **Not at all well**

Circle the following if applicable, - check with rider if response was 'not very/not at all well': Did you incur any penalties at this fence? **NO / YES.** *If yes:* ***What for?***

Refusal
Rider fall

29. Which of the following phrases best describes your XC round up until the __________fence that we have been talking about, in terms of how the horse was jumping?

	Tick one
Good, the horse was jumping really well	
Fine, - the odd fence could have been better	
OK – we had had a few mistakes though	
Not very good, the horse was not jumping well at all	
Frightening! We'd already had a near miss.	

30. Which of the following phrases best describes, overall, the horse's way of going during the XC phase, **up until the** __________**fence** that we have been talking about? Was he/she:

	Tick
Uncontrollable	
Very strong	
Strong, but in control	
Rideable	
Behind the leg	
Backing off the fences	
Not listening to the rider	

31. Were you held on the course? **NO / YES**
Before which fence were you held? _________

For how long were you held? ___________

32. How many time penalties did you acquire if any?
_______ **or** **None**

33. Did your horse have any jumping penalties on the course? **NO / YES**

Fence	Refusal	Run out	Horse Fall	Rider Fall

34. *Cases only*:
Please could you sum up what you felt were the main causes of the fall?

35. Was completing or a clear round XC particularly important at this event? **NO / YES**

If Yes: Why?

Qualification

Horse for sale

Sponsor / owner present at event

Wanted a clear for rider's satisfaction/ confidence

Other ____________________

Thinking now about the event as a whole:

36. How many horses did you compete on at this event?____________

Day 1 of the event (________): _______horses

Day 2 of the event (________): _______horses

Selected for Day:	

If only1 horse in total: **go to Q43**

If >1 horse, but only one on day in question: go to Q41

37. What was the time interval between your Cross-country rounds on the day that you were riding ___________? __________

38. How many XC rounds had you jumped this day, prior to riding this horse? _____

If None, go to Q43

39. How long did you have between your previous XC round and the round on the horse we have been talking about here? ____________

40. *If more than 2 horses being competed that day:*

Had you Show jumped another horse since the previous XC round? **NO / YES**

If YES: How long was this before your XC ride on ________? _______mins

Had you ridden a dressage test on another horse since the previous XC round? **NO /YES**

If YES: How long was this before your XC ride on ________? _______mins

41. Did you have any XC jumping penalties on the other horse(s) that you rode **BEFORE** the horse we have been talking about here? ___/___/___

42. Did you have any XC time penalties on the other horse(s) that you rode **BEFORE** the horse we have been talking about here? ___/___/___

43. How many people were helping you at the Event? _______

44. Did you attend any social functions at the event? **NO / YES**

If Yes: When in relation to your XC ride:

Night before **Previous to this**

45. What time did you get to sleep the night before the competition? _________

What time did you get up? ___________

Did you sleep well? **NO / YES**

46. How would you rate your alcohol consumption the night before the event?

None

Low – 1 glass wine, 1 pint beer

Moderate – 2-3 glasses wine, 1-3 pints beer

Heavy

47. Did you take any medication on the day of the event, prior to the XC? **NO / YES**
Circle any that respondent says. __DO NOT__ read list out.
Aspirin Ibuprofen Paracetamol Insulin Vallium Other

48. Did you eat on the day of the event, before you rode? **NO / YES**

49. Which meals did you eat? Did you eat anything else?
Breakfast Lunch Dinner Sandwiches/Snacks

Other?
How long before you rode __________XC, had you eaten? ________

50. Did you drink any fluids before riding? **NO / YES**
Amount of time between drinking fluids and riding this horse XC. __________

51. How long before your XC round was the horse last given a hard feed? ____________

52. Since the last hard feed, had the horse had any hay or haylage? **NO / YES**
If Yes:
53. How long before your XC round was the hay/haylage removed? ____________

54. How long before your XC round had the horse last had access to water? __________
55. Did the horse drink on this occasion? **NO / YES/ DK**
If NO:
56. What was the time interval between the horse's last drink and starting the XC course?
____

57. Did your horse finish the Event sound? NO / YES
58. Is your horse sound now, ______ days after the event? NO / YES
If not, Do you know the cause of the lameness?
What is the estimated time that the horse will be off work for?

____

____

Thank you very much for your time and help in completing this questionnaire.

Do you have any comments you would like to make?

Questionnaire: Three-day events

THE UNIVERSITY
of LIVERPOOL

3 DAY EVENT : QUESTIONNAIRE

Case / Control

Case Number:			Event:		Class:	
Date of Event:		Day:	Horse:			
Horse Number:			Rider:			
Date of questionnaire:			Tel. No:			

CONTACT MESSAGES:

Hello, my name is .... I am involved with the Study of Risk Factors associated with Falls of Horses in Eventing being carried out by the University of Liverpool. We recently sent you a letter outlining the study and explaining why you have been selected to participate in the study. Did you receive the letter? NO/ YES

NO: The University of Liverpool has been funded by **the Home of Rest for Horses** to conduct a study to assess the risk factors associated with falls of horses in the sport of Eventing. This study is being conducted with the co-operation of British Eventing and the FEI. The aim of the study is to identify risk factors associated with falls of horses and to provide an estimate of their relative importance. The study will examine factors associated with the level of the event, the obstacle, the horse and the competitor. The study design, a case:control study, requires collection of identical information specific to the case (falling horse) and a number of randomly selected controls (no horse fall). The difference between the case and control populations can then be analysed. This information will then allow logical changes to be made within the sport so as to decrease the incidence of injuries to horses and riders.

ALL: Does this explanation clarify the aims of our study?

The Event I am enquiring about is:

____________________Horse Trials, at which you rode ________________________.

You were selected to participate in the study: because your horse fell / as a random control, at this event.

Prior to the event, were you aware of this study? NO / YES / NOT SURE

The information I am particularly interested in pertains to the preparation of horse and rider for the event, as well as some specific questions about you and your horse. Just to reassure you, the information that is provided is for the use of the study only and will be kept completely confidential.

Would it be convenient to ask you some questions over the telephone? It should take about 15-20 minutes.

If now is not a convenient time, when might be more convenient for you?

Date: *Time:*

Is there a different number at which you would rather I call you?

SECTION A:

I'd first like to ask you a few questions about the horse ________________.

What breed is the horse? ____

1. Who owns the horse?
   Rider
   Member of family, ***state who*:**
   Owner
   Rider jointly owns with 'owner' / sponsor
   Sponsor

4. How long have you been partnered with this horse?

   _____ **years** **or** _____ **months** **or** _____ **weeks**

3. Excluding this year, how many years have you competed this horse?

   _________ **(1st season =0, 0.5 season=1)**

4. Prior to _____HT how many Horse Trials had you **completed** with this horse.?

____

5. Prior to ____HT how many Horse Trials had you **been placed in** with this horse?

____

8. Prior to ____, had you competed at any CIC's with this horse? **NO / YES**

If YES: How many CIC's have you competed at with this horse at each level? How many did you complete? How many were you placed in?

	Competed	Completed	Placed
CIC*			
CIC**			
CIC***			

9. Prior to ___, had you competed at any 3 day events with this horse? **NO / YES**

If YES: How many 3 day events have you completed with this horse at each level? How many were you placed in?

	Competed	Completed	Placed
CCN*			
CCN**			
CCI*			
CCI**			
CCI***			
CCI****			

8. How many H.T had this horse completed **prior to the start of your partnership?** _____

(If multiple, i.e. more than 50, please state number of seasons of horse trials) _____

9. How many 3DE had this horse completed **prior to the start of your partnership?** ____

(If multiple, i.e. more than 50, please state number of seasons of horse trials) ______

10. How often has this horse **HUNTED,,....,** within the last 12 months? *Tick box:*

	DK / recently acquired horse	Never	1-3 times	4-8 times	9+ times
Hunted					
Competed SJ					
Competed Dressage					

11. Has this horse raced? **NO / YES**

12. *If YES*: Was this:
Flat racing? **NO / YES**
Hurdling? **NO / YES**
Steeplechasing? **NO / YES**
Point-to-Pointing? **NO / YES**

13. How many points did he/she have prior to this Event at.....................? ________ **points**

17. Prior to ____HT, how many runs XC has this horse had at _____ (*eg Intermediate*) level?
__________*(level of event at which competitor was selected)*
How many runs XC, if any, has this horse had at a higher level?:
___________________*(than the level of the event at which competitor was selected)*

15. Has the horse completed on each occasion? **NO / YES**

16. If NO, What were the reasons?

	No. of times		**No.of times**
WD/Elim poor SJ		Elim/retired on XC (refusals)	
WD lameness		Elim/retired on XC (rider falls)	
Elim error of course (XC or SJ)		Elim XC (horse fall)	
		Other	

17. Prior to _________Horse Trials, in how many Events had the horse started the XC phase, during the last 2 months? __________

At what level?

Level: __________ No. of events: ____________
Level: __________ No. of events: ____________

18. When did the horse last event, prior to __________ Horse Trials? (*Event at which competitor was selected)*
Name/
Date:................................ ....months ago ......weeks ago

19. Was the horse placed at his/her last event? **NO / YES / n/a: first event**

If YES: Where was the horse placed? Place : ....
ASK ALL: How many dressage penalties did you have? ________
What was your SJ score? _______
If SJ penalties: what were the penalties for?
(State number of refusals, etc. rather than penalties.
_____ **fences down** _______**refusals/run outs**
_____ **rider fall** _______ **horse fall**
______**time penalties**

20. Did the horse have any XC Jumping or Time penalties? NO / YES
What were the penalties for?

	Refusal	Run out	Horse fall	Rider fall	Time
No. of:					

21. ***If the horse did not complete*:**
What was the reason for not completing? (Tick one that applies)

WD poor Dr mark		Elim/retired on XC (refusals)	
WD/Elim poor SJ		Elim/retired on XC (rider falls)	
WD lameness		Elim XC (horse fall)	
WD XC ground conditions		Elim error of course (XC or SJ)	
WD XC too tough		Other	

22. Has this horse had any time off within the last 6 months, due to illness or injury?NO/YES
If Yes:
How long ago? _______________

How long was the horse off for? ___________

For what reason did the horse have time off?____

23. Has this horse received any alternative treatments such as homeopathy, osteopathy, physiotherapy, magnotherapy or acupuncture? **NO / YES**

What form of treatment did the horse have?________________

For what injury?________________

How long before this competition did this treatment stop?__________________

How long has this treatment been in progress?________________

24. Does the horse receive any of the following nutritional supplements?

	Tick all that apply		Tick all that apply
Vitamins		**Jt. Supplement** (Flex Free, Cortaflex)	
Garlic		**Hoof supplement** (Farriers formaula)	
Electrolytes		**Other:**	
Herbal		**None**	

<u>I'm now going to ask you about your training schedule for this horse</u>

25.How often is the horse **schooled on the flat, ...?**

	Schooled on the Flat	Schooled over SJ	XC Schooled	Hacked	Fitness work (Canter/Gallop)
Days / week					
Days / month					
Start of season					
If problem					
Other: state					

26. Does anyone other than you ride this horse on a regular basis, by that I mean at least once a fortnight? **NO / YES**

Who else rides the horse? **Owner Groom Instructor Friend Family Other**

<u>I'm now going to ask you about your tack</u>

27. Would you describe the amount of padding/knee roll on your XC saddle as:

minimal **moderate** or **heavy?**

28a. Would you describe the length of your stirrup leathers for the XC phase as:

short **medium** or **long?**

28b.How many holes higher are your stirrup leathers for the XC phase, compared to the length that you ride for Show Jumping? ________

29. Does this horse wear a martingale for XC schooling? NO / YES / n/a don't school

30. Does this horse wear a martingale for competing XC? NO / YES / n/a don't school

31. What type of breast plate, if any, does the horse wear for XC schooling?

None Racing Hunting Both n/a don't school

32. What type of breast plate, if any, does the horse wear for competing XC?

None Racing Hunting Both

33a.What type of bit does this horse have in for XC schooling? _______________
33b. *If applicable, eg 3 ring bit:* Which ring are the reins attached to?
(top/middle/bottom)__________

34. What type of bit does this horse usually have in when competing XC? ______________
34b. *If applicable, eg 3 ring bit:* Which ring are the reins attached to?
(top/middle/bottom)__________
37. Was this the bit used at ____________ horse trials? **NO / YES**
If applicable, eg 3 ring bit: Which ring were the reins attached to?
(top/middle/bottom)__________
If No: What bit was used?_______________

Why did you change bits?
Forgot 'normal' bit
Previous bit too strong
Previous bit too mild / needed more control
Horse didn't like bit
Experimenting to find 'better' bit
Other : ___________________
36. What type of noseband does this horse wear for XC schooling? _______________

37.What type of noseband does this horse usually wear when competing XC? ______________

38.Was this the noseband used at ____________ horse trials? **NO / YES**

If No: What noseband was used?_______________

Why did you change nosebands?
Forgot 'normal' noseband
Needed more control
Horse getting tongue over bit
Horse opening mouth
Wanted 'milder' noseband
Other : ___________________

39. What type of protective leg boots/bandages do you use for **XC Schooling,.... and what about for Competing?**

	Infront / Behind	
XC Schooling	______________ / _________________	
Competing	______________ / _________________	
	Schooling	**Competing**
Overreach	**NO / YES**	**NO / YES**

40. What type of shoes does the horse wear? **Standard Egg bar 4-Pt Other**

<u>**Next I would like to ask some questions about your experience as a rider.**</u>

41. How long have you been competing in B.E. Horse Trials? _____ **years or** ___ **months**
(To include Ponies & Juniors)

Did you compete in Unaffiliated Horse Trials prior to this? **NO / YES**

If Yes: How many years were you competing in unaffiliated Horse Trials before you started competing in B.E. Horse Trials? ____ **years or** ___ **months**

42. How long have you been riding horses in general? ______ **years or** _____ **months**

43. Besides eventing, in which other equestrian sports do you participate on a regular basis, by that I mean at least 4 times a year?

S.J.	**Dressage**	**Hunting**	**Team chasing**
Pt-Pt	**Racing**	**Showing**	**Driving**
Polo	**Endurance**		

44. How long ago were you last unseated by a horse? _______________

What caused the fall?______________________________________

Were you injured? **NO / YES** What was the injury?____________________

45. Have you ever been unseated from this horse? **NO / YES**

What caused the fall?______________________________________

Were you injured? **NO / YES** What was the injury?____________________

65. Has this horse ever had a fall out competing? **NO / YES / DK**
If Yes:
How long ago? ___________

What type of fence? ____________

Any injuries to the horse? **NO / YES** *If Yes*, What were they?

____

____

Were you riding the horse? **NO / YES**
Any injuries to you / the rider? **NO / YES** *If Yes*, What were they?

____

____

66. How many different horses do you ride in an average day at home? ________

67. How many different horses do you ride on average at an event? ________

68. Do you consider your riding to be a profession or a hobby? **Profession Hobby**

69. *If hobby*, What is your occupation? ____________________ .

70. *If hobby,* On average, how many days per week are you able to ride? ________________

71. *If Profession:* For how long have you been a professional horseman/woman? __________

72. Do you teach riding to others? **NO / YES**

73. *If YES:* How frequently? **Daily** **Several times a week**
Once a week **2-3 times a month** **Less frequently**

74. *If YES*: Which discipline(s) do you teach the majority of the time?
Dressage **S.J.** **X-C** **Mixture** **P.C.** **Other:**

75. Do you have any BHS or NVQ qualifications? **NO / YES.** *If YES:* Which ones? ______

76. Do you have any Pony Club qualifications? **NO / YES.** *If YES:* Which ones? ______

77. Do you have **Dressage lessons** on your own horses/horses that you ride? **NO / YES**

If Yes: **How frequently?**

What about **XC instruction...? NO / YES**
And SJ instruction? NO / YES

	Dressage	XC	SJ
Frequency of instruction (on average)	Weekly Fortnightly Monthly Less often Only when problem	Weekly Fortnightly Monthly Less often Start of season Only when problem	Weekly Fortnightly Monthly Less often Only when problem

78. Do you participate in other fitness sports or activities? **NO / YES**

What are they? How often do you take part in these sports or activities?

Sport	Frequency played
	Daily / 2-3 times wk / weekly / fortnightly / monthly / less often
	Daily / 2-3 times wk / weekly / fortnightly / monthly / less often
	Daily / 2-3 times wk / weekly / fortnightly / monthly / less often

Now a few general questions about yourself:

79. What is your age? __________

80. How much do you weigh? **Stones** _________ **or Kgs** __________

81. How tall are you? **Feet**__________ **or cm** ____________

82. Do you wear glasses or contact lenses? **NO / YES**
If Yes :
Which do you wear? **G CL Both**
Which do you wear when competing? **Glasses** **Contacts** **Neither**

83. Do you regularly take any prescription medication? **NO / YES**
If Yes:
What do you take? ___________________

SECTION B:
Next I would like to ask some specific questions about ____________________3DE.

1a. How long was the journey from home? ________days __________hrs __________mins
1b.Which day did you travel to the Event?

____

10. Did this horse travel well? **NO / YES**
11. Is this normal? **NO / YES**
12. *If applicable:* Did you stable away from home? **NO / YES**
13. *If applicable:* Did the horse appear settled overnight? **NO / YES**
14. What time did you start phase D?__________

15. Using the terms, very excited, excited, alert or calm, how would you describe this horse's attitude **on arrival, ...,** is this normal?

	On arrival	At the 1st trot up	At the dressage	Prior to Phase A	Prior to Phase B	Prior to Phase C	Prior to Phase D	After Phase D
V excited								
Excited								
Alert								
Calm								
Normal (Y/N)								

8. How many times did you walk the cross country course? ____________

When in relation to your ride: **Day before only**
On the day only
Day(s) before and on the day

How long before your XC ride did you (last) finish walking the course? _______

9. Did you walk the course alone? **NO / YES / >1 walk: alone & with company**

If applicable; with whom did you walk? __________________________

Thinking now specifically about the cross country phase.

10a. If any, what type of studs were in the shoes?
10b. How many studs were in each shoe in front, ... and in each shoe behind?
If one stud in shoe: In which location was that?

Front shoes		Hind shoes	
Outside	Inside	Outside	Inside
Rd / sm / med /lge /dk	Rd /sm /med /lge /dk	Rd /sm /med /lge /dk	Rd /sm /med /lge /dk
Rd / pts / Sq / dk	Rd / pts / Sq / dk	Rd / pts / Sq / dk	Rd / pts / Sq / dk

11. Did you grease the legs before the X-C phase? **NO / YES**

12. Were you carrying a whip? **NO / YES / DROPPED WHIP AT FENCE NO: ___**

16. **Is this usual when riding this horse XC?** NO / YES

17. Were you wearing spurs? **NO / YES**

18. **Is this usual when riding this horse XC?** NO / YES

16. Did you know your current score or position, before starting on the XC? **NO / YES**
ASK ALL: What was your dressage score?
DR = _______ penalties

What was your position? _____ **place / or top ____ /or middle / or bottom _____**

18. Was your time in the D box as planned? **NO / YES**
If NO: Why not?
Held at start **XC running late** **XC running early**
Competitor running late **Competitor running early**
Other:

If held at start: **How long were you held at the start of the XC for? __________ mins**
(extra time held for)

If XC or competitor running late or early:
How long did you warm up for? ___________ mins

Now I would like to ask you about fence number ______, the _________________ which has been randomly selected/at which your horse fell.

19. What did you think of this fence / the **direct route** when you walked the course?
Direct route or ONLY route:

Easy **Straightforward** **Fairly Difficult** **Difficult**

What did you think of the **alternative route** when you walked the course?
Alternative route:

Easy **Straightforward** **Fairly Difficult** **Difficult**

20. How would you rate this jump / the **direct route** relative to the other fences on the course?
Direct route or ONLY route:

Easier **the same** **More difficult**

How would you rate the **alternative route** relative to the other fences on the course?
Alternative route:

Easier **the same** **More difficult**

21. Did you ride the fence as you had planned when walking the course?
NO / YES
***If no,* What prompted you to change your plan?**

22. *If a combination*: Which route did you jump?

Direct **Alternative** **N/A : one route only**

Why did you jump this route?

	Tick
Confident of horse's ability/Not difficult fence	
To save time	
To educate horse	
To test horses ability/ about to upgrade	
Refusal/trouble at one element	
Refusal/trouble at previous fence	
Uncertain of horse's ability to go well through the straight route	
Tired horse	
Other:	

23. *If a combination:* When you walked the course, how many strides, if any, did you plan to take in between the elements?

And, how many strides did your horse take?

Elements	Planned no. of strides	Actual no. of strides
a-b		
b-c		
c-d		
d-e		

24. How would you describe the ground conditions at this fence?

	Tick any that apply	Did this affect the way you jumped the fence? *If Yes:* How?	
Firm / Hard		N / Y	
Good – Firm		N / Y	
Good		N / Y	
Good- Soft		N / Y	
Soft		N / Y	
Heavy		N / Y	
Slippery		N / Y	
Sandy		N / Y	
Deep water		N / Y	
Hole		N / Y	
Other		N / Y	

25.How would you describe the light conditions at the fence?

	Tick all that apply	Did this affect the way you jumped the fence? *If Yes:* How?	
Good		N / Y	
Poor light		N / Y	
Open, L-L		N / Y	
L-D		N / Y	
D-L		N / Y	
D-D		N / Y	
Jumping into sun		N / Y	
Shadows		N / Y	

26.How would you describe your speed of approach?

	Tick one	Did this affect the way the horse jumped the fence? *If Yes;* How?	
About right		N / Y	
Too slow		N / Y	
Too fast		N / Y	

31. Did a horse or rider error occur when you were riding this fence?

	Tick	What was the error?	Did this affect the way the horse jumped the fence? How?
No error			
Horse error			
Rider error			

32. Now thinking specifically about the fence BEFORE the one we have been talking about. Did your horse jump this fence , the ____________:

Very Well **Well** **Not very well** **or** **Not at all well**

Circle the following if applicable, - check with rider if response was 'not very/not at all well': Did you incur any penalties at this fence? **NO / YES.** *If yes:* ***What for?***

Refusal
Rider fall

33. Which of the following phrases best describes your XC round up until the __________fence that we have been talking about, in terms of how the horse was jumping?

	Tick one
Good, the horse was jumping really well	
Fine, - the odd fence could have been better	
OK – we had had a few mistakes though	
Not very good, the horse was not jumping well at all	
Frightening! We'd already had a near miss.	

34. Which of the following phrases best describes, overall, the horse's way of going during the XC phase, **up until the** __________**fence** that we have been talking about? Was he/she:

	Tick
Uncontrollable	
Very strong	
Strong, but in control	
Rideable	
Behind the leg	
Backing off the fences	
Not listening to the rider	

31. Were you held on the course? **NO / YES**
Before which fence were you held? __________

For how long were you held? ___________

32. How many time penalties did you acquire on each phase, if any?
A _______ B ________ C _________ D _______ None

33. Did your horse have any jumping penalties on the course? **NO / YES**

Fence	Refusal	Run out	Horse Fall	Rider Fall

34. *Cases only*:

Please could you sum up what you felt were the main causes of the fall?

35. Was completing or a clear round XC particularly important at this event? **NO / YES**

If Yes: Why?

Qualification

Horse for sale

Sponsor / owner present at event

Wanted a clear for rider's satisfaction/ confidence

Other ____________________________

38. Did your horse show jump on the third day? **NO / YES**

If NO: What was the reason for not show jumping?

Retired XC	
Eliminated XC	
Unsound after XC	
Poor score XC	
Rider injury	
Other: state	

What was your SJ score? ______

If SJ penalties: what were the penalties for?

(State number of refusals, etc. rather than penalties)

_____ **fences down** ______**refusals/run outs**

_____ **rider fall** ______ **horse fall** ________ **time penalties**

Thinking now about the event as a whole:

39. How many horses did you compete on at this event?______________

Day 1 of the event (_________): _______horses

Day 2 of the event (_________): _______horses

Selected for Day:	

***If only1 horse in total:* go to Q43**

If >1 horse, but only one on day in question: go to Q41

37. What was the time interval between your Cross-country rounds on the day that you were riding ____________? ___________

38. How many XC rounds had you jumped this day, prior to riding this horse? _____

If None, go to Q43

39. How long did you have between your previous XC round and the round on the horse we have been talking about here? _______________ *(end phase D to start of next phase A)*

41. Did you have any XC jumping penalties on the other horse(s) that you rode **BEFORE** the horse we have been talking about here? ___/___/___

42. Did you have any XC time penalties on the other horse(s) that you rode **BEFORE** the horse we have been talking about here? ___/___/___

43. How many people were helping you at the Event? _______

44. Did you attend any social functions at the event? **NO / YES**
If Yes: which night(s):
Wednesday Thursday Friday Saturday

45. What time did you get to sleep the night before the competition? __________
What time did you get up? _____________

Did you sleep well? **NO / YES**

46. How would you rate your alcohol consumption the night before the event?
None
Low – 1 glass wine, 1 pint beer
Moderate – 2-3 glasses wine, 1-3 pints beer
Heavy

47. Did you take any medication on the day of the event, prior to the XC? NO / YES
Circle any that respondent says. DO NOT read list out.
Aspirin Ibuprofen Paracetamol Insulin Vallium Other

48. Did you eat on the day of the event, before you rode? **NO / YES**

49. Which meals did you eat? Did you eat anything else?
Breakfast Lunch Dinner Sandwiches/Snacks

Other?
How long before you rode __________XC, had you eaten? _______

50. Did you drink any fluids before riding? NO / YES
Amount of time between drinking fluids and riding this horse XC. _________

59. How long before your XC round was the horse last given a hard feed? ___________

60. Since the last hard feed, had the horse had any hay or haylage? NO / YES
If Yes:
61. How long before your XC round was the hay/haylage removed? ___________

62. How long before your XC round had the horse last had access to water? _________
63. Did the horse drink on this occasion? NO / YES/ DK
If NO:
64. What was the time interval between the horse's last drink and starting the XC course?
____

51. Did your horse finish the Event sound? NO / YES
52. Is your horse sound now, ______ days after the event? NO / YES
If not, Do you know the cause of the lameness?
What is the estimated time that the horse will be off work for?

____

____

Thank you very much for your time and help in completing this questionnaire.

Do you have any comments you would like to make?

CHAPTER FIVE:

Risk factors for rotational and non-rotational cross-country horse falls in eventing competitions.

Abstract

Eventing is a popular international, Olympic equestrian sport. In 1999 five riders died in the United Kingdom as a result of horse falls on the cross-country phase of eventing competitions. In a previous study we identified the risk factors for all types of horse fall on the cross-country course. Here we focus on two different types of fall, rotational (where the horse somersaults) and non-rotational horse falls, because most of the rider fatalities were anecdotally associated with rotational falls. In a case-control study we collected data for 33 rotational falls, 147 non-rotational falls and 540 matched controls (1:3 ratio). Cases were jumping efforts that resulted in a fall of the horse. Controls were selected randomly from all jumping efforts that did not result in a horse fall and were matched by competition and day (but not class). Data related to course- and fence-level variables, which might be associated with horse falls, were collected on the day of the event. Data related to horse-, rider- and event-level variables were collected by telephone interview and from the British Eventing database.

Conditional logistic regression was used to analyse the data. Three categorical variables were significantly associated with the risk of a rotational horse fall. Horses ridden by professional event riders and riders in full-time employment were associated with an increased risk of a rotational horse fall compared with horses ridden by riders who were: students, in part-time employment or not working. Angled fences, non-angled fences with a spread of two metres or greater and fences with a downhill gradient on landing were associated with an increased risk of a rotational fall when compared with non-angled fences with a spread of less than two metres and fences with a flat or uphill gradient on the landing side, respectively. Six variables were identified as being significantly associated with the risk of a non-rotational horse fall. Fence and course-level variables that were associated with an increased risk of a non-rotational fall were: fences with a flat or uphill take-off, fences that required the horse to take-off or land in water and an increased total number of jumping efforts on the course. Horses that received cross-country schooling were more likely to have a non-rotational fall than horses that did not receive cross-country schooling. Riders who were either unaware of their position in the competition prior to the cross-country phase or knew that they were in the lead

prior to the cross-country phase were more likely to have a non-rotational horse fall than those who knew that they were in second or lower position.

This study identified variables that were significantly associated with the risk of rotational and non-rotational horse falls during the cross-country phase of eventing competitions.

Introduction

Eventing is an equestrian sport that appeals to amateur and professional riders across the world, with 8,283 riders and 10,513 horses registered with British Eventing (B.E.) in 2003. A total of six riders died in the United Kingdom (U.K.) as a result of horse and rider falls during the cross-country (XC) phase of eventing competitions during 1999 and 2000. These fatalities raised concerns about the safety of this sport and initiated an epidemiological investigation aimed at reducing the risk of injury to horse and rider.

Data suggests that the rate of rider injury at eventing competitions is much greater than the rate of injury for competitors participating in motorcycle or car racing. The rate of human eventing injuries has been reported as 0.88% (Paix, 1999) and 1.1% (Whitlock, 1999) compared with 0.24% and 0.14% for motorcycle and car racing respectively at U.K. Grand Prix circuits (Chapman and Oni, 1991). Anecdotally, rider fatalities have been linked to rotational falls of the horse, caused by the horse somersaulting over the cross-country fence and landing on the rider. Whitlock (1999) reported a rider fatality rate of 0.12 fatalities per 1000 cross-country rides, whilst Paix (1999) reported a rider fatality rate of 0.24 fatalities per 1000 competitors. The three fatalities recorded by Paix (1999) and Whitlock (1999) were noted to be as a result of the horse falling and landing on the rider.

Horses are also frequently injured in falls. We recently reported that 32% of horses that fell were injured, with 1.5% of fallers euthanased as a result of their injuries (Murray et al., 2004a). Horse falls occurring during the cross-country phase of events thus present a risk of injury and fatality to horses and riders.

An eventing competition may be run over one, two or three days and is classified according to the level of difficulty of the cross-country course. There are 5 levels of one-day event (in ascending order of difficulty): Intro, Pre-novice, Novice, Intermediate and Advanced. Two-day events have two levels, Novice and Intermediate. Three-day events, also known as Concours Complet Internationale (CCI) competitions, have four levels, with the difficulty increasing from 1-star (1*) to 4-star (4*). Each event has three different stages. In a one-day event these are run in the following order: dressage, show jumping and cross-country. Two-day events have dressage and show jumping on the first day and cross-country on the second day (as part of the speed and endurance stage). Three-day events have dressage on the first day, cross-country (speed and endurance) on the second day and show jumping on the final day. The speed and endurance day of two- and three-day events consists of four phases, A, B, C and D. Phase D is the cross-country phase.

The cross-country stage (phase D) of three-day events covers a distance of 3,900–7,980 metres and includes a maximum of 30-45 jumping efforts. The cross-country phase of one-day events is shorter with course distances of 1,600-4,000 metres incorporating 18-40 jumping efforts. (A summary of the cross-country requirements for the different types and levels of event is provided in the Appendix to Chapter 1).

During the cross-country phase of eventing, the criteria on which horses and riders are judged include: time, refusals, rider falls and horse falls. A rider fall incurs a penalty if the rider becomes separated from his/her horse in such a way to necessitate remounting. A horse fall is recorded if the shoulders and quarters of the horse touch either the ground or the obstacle and the ground at the same time (B.E. r ``ules, 2001). A horse fall, which incurs compulsory retirement, usually leads to a fall of the rider, and is therefore also known as a 'horse and rider fall'.

Horse falls occurring during the cross-country phase of events present a risk of injury and fatality to horses and riders. It is important to measure this risk and to identify the factors that might be manipulated to decrease the risk. Epidemiological studies have investigated risk factors associated with an increased or decreased risk of a horse fall occurring during the cross-country phase of all types of eventing competitions (Murray et al., 2004b) and at different types of eventing competition (Chapter 4: one-day events and two-/three-day events).

Analysis of retrospective data, using a case-control design, suggested an increased risk of falling associated with fences sited on a downhill slope (OR=8.4, 95% confidence interval (C.I.) 2.5, 28.8, P=0.001) or with a ditch in front (OR=5.8, 95% C.I. 1.1, 30.7, P=0.04) when compared with fences sited on flat ground and without a ditch in front (Singer et al., 2003). The risk of falling also rose as the number of fences on a course increased (OR=1.6, 95% C.I. 1.2, 2.0, P<0.001); however, the risk associated with each additional jumping effort on the course decreased (OR=0.8, 95% C.I. 0.7, 1.0, P=0.01).

Previously we reported risk factors associated with horse falls occurring on the cross-country phase of a combined dataset of one-, two- and three-day eventing competitions (Murray et al., 2004b). Variables related to the fence and the course found to be associated with an increased risk of a horse fall were fences with a take-off from water (OR=49.8, 95% C.I. 10.4, 239.0, P<0.001), a landing in water (OR=5.7, 95% C.I. 2.1, 15.5, P<0.001), a drop landing (OR=3.4, 95% C.I. 1.6, 7.3, P=0.001), angled fences (OR=4.8, 95% C.I. 2.1, 11.2, P<0.001) and non-angled fences with a spread of two metres or greater (OR=3.2, 95% C.I. 1.7, 6.2, P<0.001). Rider-level variables that were significantly associated with an increased risk of a horse fall were riders who knew they were in first position prior to starting their cross-country round (OR=4.4, 95% C.I. 1.4, 13.4, P=0.001), riders who perceived their speed of approach to the fence to be too slow (OR=5.0, 95% C.I. 1.9, 13.1, P<0.001) or too fast (OR=6.3, 95% C.I. 2.6, 15.0, P<0.001) and riders who received cross-country lessons (OR=1.9, 95% C.I. 1.2, 3.1, P=0.006). Horse and rider partnerships that had not incurred any refusals on the course prior to selection were associated with an increased risk of a horse fall (OR=23.0, 95% C.I. 3.0, 178.1, P=0.003).

The dataset was sub-divided to allow identification of risk factors for horse falls at one-day and two-/three-day events, presented in Chapter 4. Risk factors identified for one-day events were similar to those identified for the complete dataset outlined above. Absence of previous refusals on the course, fences requiring a landing into water and angled fences were significantly associated with an increased risk of a horse fall at one-day events and at two-/three-day events. Rider participation in non-equestrian sports was associated with an increased risk of a horse fall at two-/three-day events, whilst an increase in the gradient of the camber of the fence was associated with a decreased risk of a horse fall.

Anecdotally rotational falls, (also known as somersault falls), have been associated with many of the recent rider fatalities. We hypothesise that different risk factors might exist for rotational horse falls and non-rotational horse falls. In this paper we report the results of a study conducted to investigate whether different risk factors exist for rotational and non-rotational horse falls. In particular, this analysis aims to identify variables that increase or decrease the risk of rotational horse falls during the cross-country phase of events. Information obtained from this study can be used to inform future intervention studies with the aim of reducing the risk of rotational horse falls and the associated risk of serious rider injury. To our knowledge, this is the first study to investigate potential risk factors for the different types of horse falls.

Materials and Methods

Study Design

A matched prospective case-control design was used to test associations between course/fence, horse, rider and event related variables and horse falls. Three controls were selected per case recruited onto the study. One- and two-day eventing competitions were selected randomly during the 2001 and 2002 British Eventing seasons. Only sixteen three-day event competitions were scheduled for the study period and all were selected for inclusion, to maximise data collection from these competitions. Data were obtained for 180 cases and 540 controls. Controls were matched by venue and by day of cross-country competition. The data were divided into two datasets on the basis of whether the fence judge had recorded a rotational or non-rotational fall of the horse. Fence judges recorded 33 rotational horse falls and 147 non-rotational horse falls.

Case Definition

A case was a jumping effort that resulted in a horse fall on the cross-country phase of an event. A jumping effort was defined as having occurred if the horse attempted to negotiate a numbered obstacle on the cross-country course. A horse fall was defined using the B.E. rule, i.e. the horse's shoulders and quarters touched either the ground or the obstacle and the ground at the same time, as a direct result of an attempted jumping effort. Falls that occurred on the approach to the fence, as a result of the horse attempting to avoid jumping the fence, were not classified as cases. Cases were identified by fence judges positioned at each obstacle to record any penalties incurred by each competitor. Fence judges were briefed at the beginning of the competition on the definition of a horse fall.

Rotational and non-rotational fall definitions

Falls were classified as rotational falls according to the report given by the fence judge. Rotational falls are defined as those in which the horse somersaulted before landing. Non-rotational falls included all other falls of the horse.

Misclassification of rotational and non-rotational horse falls

Misclassification of the fence judges' reporting of rotational and non-rotational falls was assessed by video analysis. Video footage was available for a total of 36 cases from three sources (Television in Europe Ltd.[1], Total Recall Videos[2] and Lucid Dreams Media[3]). The author was 'blind' to the type of fall recorded by the fence judges and independently classified the falls as rotational or non-rotational falls from the video footage.

Control definition and selection

A control was a jumping effort that did not result in a horse fall. Three controls were selected randomly from all successful jumping efforts that took place on the same day and at the same competition from which their case was selected. Matching was used to control for the potentially confounding effects of month, weather conditions and geographical location.

In order to facilitate the random selection of control jumping efforts every fence on the course was numbered consecutively. In some situations it was not possible to calculate the exact number of jumping efforts taken by a horse and rider combination, because competitors were given the choice between a shorter, technically difficult route, and an easier, but longer alternative with more elements. In situations where the exact number of jumping efforts was unknown, the minimum possible number of the jumping effort was used.

Description of fences

Cross-country courses included between 16 and 42 numbered obstacles requiring a maximum of 18-45 jumping efforts. The majority of obstacles consist of one fence, requiring a single jumping effort; however, some obstacles require multiple jumping efforts as they consist of two or more elements situated in close proximity. These obstacles are known as combination fences. For the purposes of this study, two

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[1] Television in Europe Ltd., London.
[2] Total Recall Videos, Northants.
[3] Lucid Dreams Media, Northern Ireland.

fences were defined as part of a combination fence if they were positioned so that the average horse would take four or fewer strides between the two fences. (A four-stride distance between fences was equivalent to a mean of 16.8 (SD 1.6) metres in this study.)

Data collection

Data were recorded on the day of the competition for course and fence-level variables described in Table 1 of the Appendix to Chapter 4. The ground conditions were categorised subjectively by visual assessment and by digging a heel into the ground to assess the firmness of the ground. Assessments were made by one of two observers (JKM, ERS) who worked together at the beginning of the data collection period to standardise interpretation of the six main categories of 'going' (firm, good-firm, good, good-soft, soft, heavy). Ground was considered to be slippery if the footwear of the observer could slide easily along the surface of the ground. Periodically, during the duration of the study, the two observers compared their assessment of ground conditions at events, to maintain consistency and to reduce observer bias. On average, ground conditions were recorded at each fence every 3-4 hours during the day of competition to document any changes that occurred as a result of weather conditions, drainage and soil type. The ground conditions recorded for each case or control were those observed closest to the time of the competitor's cross-country round.

The gradients of the ground on the approach and landing of the selected fences were measured using levelling techniques with a surveyor's staff and level (Nikon Automatic Level AC-2, Nikon, Inc. Instrument Group, Melville, USA). Measurements were recorded from the base of the fence (take-off and landing side), to 20 metres (m), 10m, 5m and 2m on the approach to the fence and to 10m, 5m and 2m on the landing side of the fence (Appendix to Chapter 4, Figure 1). The gradient between two points was calculated as the difference in height (centimetres) between the points divided by the distance (metres) between the points. Measurements were not made at 20 metres from the fence on the landing side, since a horse fall at a distance of more than 10 metres from the fence on the landing side would be unlikely to be associated with the fence. For combination fences, the gradient measurements were taken for available distances between elements. Measurements were taken at the right and left of the fence in order that the camber of the fence could be calculated. The jumpable width of the fence was recorded as the distance between the flags that were attached to the left and right limits of all fences, indicating the two points between which the horse must jump.

A letter explaining the study was sent to the riders of all case and control horses within 3 days of the event. The letter informed the riders of imminent contact by telephone to complete a questionnaire relating to the event and additional areas such as horse and rider training. The questionnaires were administered by telephone as soon as possible after the event. Copies of the questionnaires used are provided in the Appendix of Chapter 4. Additional data (dressage and show jumping scores, horse age, horse height) was obtained from the B.E. database and B.E. website (www.britsheventing.com). Data were recorded for rider-, horse- and event-level variables (Appendix to Chapter 4: Tables 2, 3, and 4). Data were entered onto a database (Microsoft Access 97, Microsoft Corporation) and double-checked to maximise accuracy.

Data obtained for the variable of rider status (professional or amateur event rider) were based on whether the riders reported their riding to be a profession or a hobby.

Data Analysis

Categorical variables with few observations in one or more categories were recoded to create fewer categories with more observations. In addition, a new variable of 'changing light conditions' was formed from the combination of the variables of 'light to dark' and 'dark to light' conditions.

We had previously shown an interaction between the explanatory variables of fence angle and spread for the complete dataset of all types of event (Chapter 2). A new variable was created that combined the variables of fence angle and spread, which was both biologically plausible and had previously been shown to improve model fit. The new variable was created with three categories (non-angled fence with a spread of <2 metres, non-angled fence with a spread of ≥2 metres and angled fences of any spread). The two separate variables and the combined variable were assessed for inclusion into the multivariable model.

Variables with one or more empty cells were analysed following the alteration of a randomly selected data point. The selected data point was changed so that no zero cells were present, which allowed univariable analysis that included the variable to be conducted.

All variables were tested for association with falling using univariable conditional logistic regression models. The statistical packages R (www.r-project.org) and Egret (Cytel Software Corporation, USA) were used for data analysis. Continuous variables were also categorised into quintiles in the univariable analysis. The fit of the categorical variables in the model were compared to the fit of the continuous variables by assessing the change in deviance, (assuming the change in deviance follows a chi-squared distribution with n degrees of freedom, where n is the number of extra parameters fitted). To reduce the effects of collinearity, continuous variables were centred by subtracting the mean of the variable from all recorded observations (Kleinbaum et al., 1988).

The following procedure was conducted for the two datasets (rotational and non-rotational falls). Variables with a P-value <0.2 were considered for inclusion in a multivariable submodel, which was built using the technique of backward elimination for each of the four categories of variables (course/fence, horse, rider and event).

A multivariable model for each dataset was then built by backward elimination from variables included in the four submodels. The first multivariable model (Appendix, Table 17) produced for the non-rotational falls dataset contained four subjective variables that were susceptible to responder bias (speed of approach to the fence, normal behaviour for the horse prior to the XC phase, fence ridden according to plan, rider's opinion of the fence relative to the rest of the course). In order to assess the association of objective variables with the risk of a non-rotational horse fall in the absence of potential confounding from variables that were susceptible to responder bias, these subjective variables were removed and the model was rerun to provide a model based solely on objective variables. The multivariable model built for the rotational horse fall dataset did not include variables that were susceptible to responder bias and thus was left unchanged. Variables previously associated with the risk of a horse fall in our analysis of the complete dataset (Murray et al., 2004b) and analysis of one- and two-/three-day events (Chapter 4) were considered for inclusion in the multivariable models, together with the variables identified by Singer et al. (2003). Variables remained in the model if they were shown to significantly improve the fit of the model by assessing the change in deviance, (assuming the change in deviance follows a chi-squared distribution with n degrees of freedom, where n is the number of extra parameters fitted).

The effects of interactions between variables, that we considered were biologically plausible, were tested for in the model. The level of the event (Intro/Pre-novice, Novice, Intermediate or Advanced), event type (one- or two-/three-day event) and rider status (professional or amateur event rider) were evaluated as potential confounders. A change in the regression parameters of >25% was considered to be indicative of confounding. The fit of the model was assessed by examination of the sensitivity and specificity of the model at cut-off points ranging from 0.2 to 0.6. Model stability was assessed by examination of the delta betas. The model was considered to be stable if removal of individual cases or controls altered the odds ratio by <25% and did not affect the significance of individual variables in relation to the critical P-value of 0.05.

Power of the study

The case-control study including all horse falls (rotational and non-rotational) was designed to have 80% power to detect an odds ratio of 2.0. Dividing the dataset on the basis of the type of horse fall (rotational or non-rotational) reduced the power of the analysis for both datasets. Calculations showed that the rotational horse falls dataset had 80% power to detect odds ratios of 3.9 and only 24% power to detect odds ratios of 2.0. The non-rotational dataset had 80% power to detect odds ratios of 2.07. These calculations were based on a 0.05 probability of a Type-I error (95% confidence) and assumed 10% of controls were exposed to risk factors (Epi-info 6, CDC, USA).

Population proportional attributable risk

The population attributable risk (PAR) provides a measure of the impact that a variable has on a population, whilst the population proportional attributable risk (PPAR) represents the fraction of cases that would not have occurred if they had not been exposed to the risk factor (Kirkwood, 1988). The PPARs were calculated for each of the explanatory variables included in the final multivariable model by the method outlined by Bruzzi et al. (1985). In order that PPARs could be estimated for all variables associated with an increased risk of a horse fall, continuous variables were converted to categorical variables and all categorical variables were ordered by ascending odds ratios. The model was rerun to obtain odds ratios used to calculate PPARs for all variables.

Results

Fence judges recorded 33 rotational falls, which represented 18.3% (33/180) of all horse falls included in our study.

Misclassification of rotational and non-rotational falls

Accuracy of the fence judges classification of 8 rotational and 28 non-rotational falls was assessed by studying video footage that was available for 36 horse falls, representing 20% of falls included in the case-control study. Classification of fall type by fence judges was 62.5% (95% C.I. 24.5, 91.5) accurate for rotational falls and 96% (95% C.I. 81.7, 99.9) accurate for non-rotational falls.

A summary of the variables considered for inclusion in a multivariable submodel following univariable analysis is provided in Tables 1-16 of the Appendix to this chapter. Multivariable models were built for the risk factors associated with rotational and non-rotational falls of horses during the cross-country phase of eventing competitions. The variable of rider occupation, which had previously been associated with the risk of any type of horse fall (Singer et al., 2003), improved the model fit for rotational horse falls and was thus included in the final multivariable model (Table 1). The variable of the total number of jumping efforts on the course, identified by Singer et al. (2003) as a risk factor for horse falls, improved model fit for the non-rotational horse falls model, and was retained in the final model (Table 2). Biologically plausible interactions between variables were tested for. Interaction was found in the non-rotational falls model for the variables of take-off and landing in water (OR=0.01, 95% C.I. 0.00, 0.43, P=0.01). There was no evidence of confounding by the variables of event level, event type and rider status (Appendix, Tables 18-19).

Table 1. Multivariable conditional logistic regression model for risk factors for cross-country horse falls classified as rotational falls in eventing competitions in Great Britain (2001-2002).

Variable	Coefficient	Standard error	Odds ratio	95% confidence intervals	LRT P-value
Gradient:					
0m to 10m Landing[a] (continuous variable: linear fit)	-0.45	0.16	0.64	0.47, 0.88	0.005
Occupation					
Professional event rider / FT horses[b]	Ref.		1.00		
FT other[c]	2.91	1.14	18.32	1.96, 171.13	0.01
PT other[d] / student / not working	-0.89	0.94	0.41	0.06, 2.60	0.34
Angle width of fence combined					
Non-angled, <2m	Ref.		1.00		
Non-angled, ≥2m	2.71	1.08	15.13	1.80, 126.83	0.01
Angled fences	3.01	1.26	20.22	1.70, 239.85	0.02

[a] Unit defined as a gain or loss in height of the ground (cm) over the distance measured from 0m to 10m from the base of the fence on the landing side. Expressed as the difference in height (cm), divided by the distance covered (10m). A decrease of one unit was associated with a reduced risk of a fall (OR=0.64).

[b] FT horses: Riders whose full-time employment included riding (e.g. riding instructors, grooms).

[c] FT other: Riders who were in full-time non-equestrian employment.

[d] PT other: Riders who were in part-time non-equestrian employment.

Table 2. Multivariable conditional logistic regression model for objective risk factors for cross-country horse falls that were classified as non-rotational falls in eventing competitions in Great Britain (2001-2002).

Variable		Coefficient	Standard error	Odds ratio	95% confidence intervals	LRT P-value
Downhill take-off						
	No	Ref.		1.00		
	Yes	-0.76	0.34	0.47	0.24, 0.91	0.03
Take-off water						
	No	Ref.		1.00		
	Yes	3.05	0.82	21.20	4.24, 106.03	<0.001
Landing water						
	No	Ref.		1.00		
	Yes	2.52	0.46	12.47	5.08, 30.60	<0.001
XC Schooling (horse)		Ref.		1.00		
	No	1.01	0.33	2.73	1.43, 5.24	0.003
Total jumping efforts		0.16	0.07	1.17	1.02, 1.34	0.02
Position						
	Second or lower	Ref.		1.00		
	Don't know	0.83	0.37	2.29	1.12, 4.68	0.02
	First	1.51	0.74	4.52	1.06, 19.27	0.04
Take-off water / Landing water interaction		-4.22	1.72	0.01	0.00, 0.43	0.01

Model fit

Within the rotational horse falls model, the variable of gradient on landing (0m to 10m) was considered to be stable. All other variables were considered to be unstable as the individual removal of 9 cases and 8 controls with large delta betas either altered the odds ratio by >25% or changed the significance of the variable in relation to the critical P-value of 0.05. Examination of the non-rotational horse falls model revealed two variables to be stable (XC schooling and total number of jumping efforts). All other variables were considered to be unstable as the individual removal of 9 cases and 4 controls either altered the odds ratio by >25% or changed the significance of the variable. Inspection of these cases and controls revealed no unusual covariate patterns and the individuals were therefore retained in their datasets.

Sensitivity and specificity of the models

The predictive capacity of the models was assessed by calculating the sensitivity and specificity of the models at various cut-off points (Table 3 and 4). The sensitivity of the model for rotational falls was greater than the sensitivity of the model for non-rotational falls. The specificity of both models was higher than the sensitivity. The sensitivity of the model for rotational falls was good (>85%) at cut-off points of 0.3 and above, whereas the sensitivity of the model for non-rotational falls was >61% at values of 0.3 and above.

Table 3. Sensitivity and specificity of the final multivariable conditional logistic regression model shown in Table 1 for rotational falls of horses in eventing competitions in Great Britain (2001-2002), at cut-off points 0.2 to 0.6

Cut-off Point	Sensitivity (% of cases Predicted)	Specificity (% of controls Predicted)
0.2	92.9	81.7
0.3	85.7	85.9
0.4	85.7	87.3
0.5	67.9	93.0
0.6	64.3	95.7

Table 4. Sensitivity and specificity of the final multivariable conditional logistic regression model shown in Table 2 for non-rotational falls of horses at eventing competitions in Great Britain (2001-2002), at cut-off points 0.2 to 0.6

Cut-off Point	Sensitivity (% of cases Predicted)	Specificity (% of controls Predicted)
0.2	83.6	60.0
0.3	61.4	82.3
0.4	47.9	91.3
0.5	35.7	94.9
0.6	25.0	97.6

Population proportional attributable risk

The population proportional attributable risks (PPAR) were calculated (Tables 5 and 6) for each of the explanatory variables included in the final multivariable models. The PPARs were derived from multiple logistic regression and therefore were not additive.

Table 5. Population proportional attributable risk values of explanatory variables for risk factors for rotational cross-country horse falls at eventing competitions in Great Britain (2001-2002).

Explanatory Variable	Population Proportional Attributable Risk (PPAR)
Occupation	
Part-time other, student, non-working	0.00
Full-time other	0.32
Professional event rider, Full-time horses	0.39
Angle width combined	
<2m spread, non-angled	0.00
≥2m spread, non-angled	0.38
All angled fences	0.19
*Landing gradient: 0m to 10m**	
+2.30 to +16.30	0.00
-0.75 to +2.00	0.19
-10.55 to −1.00	0.14

*Gain or loss in height (cm) over the distance measured from 0m to 10m from the base of the fence on the landing side. Expressed as the difference in height (cm), divided by the distance covered (10m)

Table 6. Population proportional attributable risk values of explanatory variables for risk factors for non-rotational cross-country horse falls at eventing competitions in Great Britain (2001-2002).

Explanatory Variable		Population Proportional Attributable Risk (PPAR)
Downhill take-off		
	Yes	0.00
	No	0.45
Water approach		
	No	0.00
	Yes	0.08
Water landing		
	No	0.00
	Yes	0.18
Horse XC schooling		
	No	0.00
	Yes	0.56
Position		
	2nd or lower	0.00
	Don't know	0.43
	First	0.03
Total jumping efforts		
	16 to 27	0.00
	28 to 31	0.17
	32 to 45	0.31

Discussion

Video evidence of a sample of horse falls indicated a misclassification rate by fence judges of 37.5% for rotational falls and 4% for non-rotational falls. The high rate of misclassification of rotational falls needs to be addressed if risk factors are to be reliably associated with these falls. Fence judges are unpaid volunteers who may be on duty for up to 9 hours, with no scheduled rest periods. Factors such as fatigue and lack of concentration may have contributed to fence judges failing to witness or recall details of some falls accurately, leading to the observed misclassification. Therefore, the results of this chapter must thus be treated with some caution. Further research of the risk factors associated with rotational falls should be based on data with a lower misclassification rate. A lower misclassification rate might be achieved by further training of fence judges or by shortening judging periods. Alternatively, video footage could be obtained for a larger sample of falls, allowing the classification of rotational falls to be based on video footage, rather than the description provided by fence judges.

Rotational horse falls

The combined variable of the angle and spread of the fence showed a significant association with the risk of a rotational fall. This variable has been associated with the risk of a horse fall in the combined dataset (Murray et al., 2004b) and for one-day events and two-/three-day events (Chapter 4). Angled fences (OR=20.2, 95% C.I. 1.7, 239.9, P=0.02) and non-angled fences with a spread of two metres or greater (OR=15.1, 95% C.I. 1.8, 126.8, P=0.01) increased the risk of a rotational fall when compared to non-angled fences with a spread of less than two metres. The reason for the increased risk of a rotational fall at these two fence types is unclear; however, research conducted by the Transport Research Laboratory (TRL) has shown that rotational falls are often associated with the horse hitting the fence between the knees and shoulders (Walcott, 2003). The risk of a horse hitting the fence between the knees and shoulders may thus be increased at wide or angled fences, either as a result of the horse miscalculating the height needed to clear the fence or as a result of the spread or angle of the fence. No relationship was found between the construction of the fence (solid or open top) and the risk of a rotational horse fall (P>0.05). The high

PPAR (0.38) associated with wide, non-angled fences suggests that these fences should be the focus of future intervention studies, in order to decrease the risk of rotational falls and the associated risk of injury to horse and rider.

Ground that sloped downhill during the first 10 metres on the landing side of the fence was associated with an increased risk of a rotational horse fall for data analysed in this chapter. The reason for the association between landing gradient and the risk of a rotational horse fall is not clear as rotational falls, by definition, will have occurred before the horse lands from the jump. The gradient on the take-off and landing side will affect the optimum speed of approach to the fence required by the horse and rider. More precision and control are needed to jump downhill fences (Gordon Watson, 1991). Fences often have different slopes on their approach and landing (flat, uphill or downhill), as course designers utilise the natural features of the land to build fences, requiring different approaches from the horse and rider. We suggest that some riders may have been 'worrying' about the landing, particularly if the landing sloped downhill steeply, therefore rider error may have contributed to the increased risk of a rotational horse fall at these fences.

The third variable to be associated with the risk of a rotational horse falls was the rider's occupation. Riders in full-time employment that did not involve riding horses were at a significantly higher risk of a rotational fall (OR= 18.3, 95% C.I. 2.0, 171.1, P=0.01) as compared to professional event riders and riders in full-time employment with horses. The wide confidence interval and the lack of stability of this variable suggest that the apparent association between the occupation of the rider and the risk of a rotational fall needs further investigation. Despite the above concerns, our result was in agreement with previous work by Singer et al. (2003), who reported riders in full-time non-equine employment to be associated with a higher risk of a horse fall (OR=19.4, 95% C.I. 2.0, 187.4, P=0.01) when compared with full-time event riders. An explanation for the increased risk associated with riders in full-time (non-equine) employment may be that less time was available to prepare themselves and their horse(s) for competition, when compared with riders whose employment enables them to exercise their horse(s) within their working day.

In contrast to the findings of Singer et al. (2003), we found no evidence for students to be at an increased risk of a fall when categorised by themselves, or when categorised with riders in part-time employment and non-working riders. Singer et al. (2003) had previously reported students to be at an increased risk of a fall when compared to professional event riders (OR=19.8, 95% C.I. 2.0, 194.6, P=0.01). The reason for the different findings is unclear; however, students were also not associated with an increased risk of a fall in analysis of the complete dataset or in the analysis of one- and two-/three-day events.

Fences with a take-off or landing in water have been identified as increasing the risk for all horse falls (Murray et al. 2004b), horse falls at one-day events (Chapter 4) and non-rotational falls investigated within this chapter. Fences with a landing in water have also been associated with an increased risk of a horse fall at three-day events (Chapter 4). In contrast with our previous findings, no association was found between fences with a take-off or landing in water and the risk of a rotational horse fall. The reason for this lack of an association between fences requiring a take-off or landing in water and the risk of a rotational horse fall is unclear. One potential explanation is the low power of the study to detect small odds ratios (24% power to detect odds ratios of 2.0). A second explanation may be the low number of obstacles at water recorded within the rotational falls dataset (6 fences and 2 steps were jumped into water and 3 steps were jumped out of water). In addition, steps down are unlikely to be associated with an increased risk of a rotational fall as it would be biomechanically implausible for a horse to strike the step between its knee and shoulder.

Results from the study reported here provide evidence of a relationship between rider occupation and the risk of a rotational horse fall; however, no relationship was found between variables previously hypothesised to be associated with the risk of a rotational horse fall, such as rider experience or status (professional / amateur). Caution must be taken when interpreting the results of non-significant findings in a matched study, such as the study presented here as matching has the potential to bias the exposure variables towards the null. Further research is therefore recommended to investigate the relationship between variables such as rider experience and rider status and the risk of a horse fall.

Non-rotational falls

Variables identified as being significantly associated with the risk of a non-rotational horse fall were similar to those previously identified as being associated with the risk of all types of horse fall (Murray et al., 2004b). The similarity between the models built for non-rotational falls (Table 2) and the complete dataset (Murray et al., 2004b) was as expected since 82% of the cases in the complete dataset were classified by fence judges as non-rotational falls. Risk factors identified for non-rotational horse falls included fences requiring the horse to take-off from water (OR=21.2, 95% C.I. 4.2, 106.0, $P<0.001$) or to land in water (OR=12.5, 95% C.I. 5.1, 30.6, $P<0.001$). The increased risk of a non-rotational fall at fences jumped into or out of water may be due to the drag of the water unbalancing the horse, or shadows and reflections on the surface of the water that made it difficult for the horse to judge the presence or depth of water.

Interaction existed between the variables of take-off and landing in water (OR=0.01, 95% C.I. 0.00, 0.43, P=0.01) and had the effect of reducing the risk of a horse fall when both variables were present. The suggested reason for the protective effect of this interaction is the increased care taken by riders at these fences. Further research is needed to confirm the identified interaction, as only one case and one control within the non-rotational horse fall dataset were recruited at fences fulfilling this criterion.

Rider knowledge of their position in the competition prior to starting the cross-country course was shown to be a significant risk factor for a non-rotational horse fall. Riders who knew that they were in first place were more likely to fall (OR=4.5, 95% C.I. 1.1, 19.3, P=0.04) when compared with riders who knew that they were in second place or lower within the competition. It could be hypothesised that horse and rider partnerships that achieved excellent dressage scores (and were therefore in first place) were less proficient at jumping cross-country fences than partnerships that achieved poor dressage scores, thus placing them at an increased risk of a horse fall. Alternatively, this finding may be explained by the fact that riders who knew they were in first position prior to starting the cross-country course may have been more likely to 'take a risk' during this phase, in the hope of maintaining their lead in the competition. Conversely, riders who were not in the lead prior to the start of the cross-country may have been riding more cautiously or 'safely' with the priority of completing a round without jumping penalties.

There was a decreased risk of a non-rotational fall at fences with a downhill approach, compared to fences that had a flat or uphill approach (OR=0.5, 95% C.I. 0.2, 0.9, P=0.03). This finding is in contrast to a previous study (Singer et al., 2003), in which an increased risk was associated with fences sited downhill (OR=8.4, 95% C.I. 2.5, 28.8, P=0.001) when compared to the reference category of fences sited on flat ground. The conflicting findings attributed to fences with a downhill approach may result from the different methods of data collection. Singer et al. (2003) collected data retrospectively, which may have led to inaccuracies in the recall of the gradient of the approach to the fence. In contrast, for the study reported here, one of the authors (JKM or ERS) made a visual assessment of the slope of the ground before the competition began, ensuring that observations were free from observer bias related to case-control status of the fence.

Horses that were schooled over cross-country fences as part of their training programme were at a higher risk of a non-rotational fall when compared to horses that were reported as not receiving cross-country practice (OR=2.7, 95% C.I. 1.4, 5.2, P=0.003). We anticipate that this variable reflects the training practice received by the partnership as a pair over cross-country fences. Whilst exceptions exist, practice of the partnership is generally viewed as an aid to improving competition performance. The explanations for our finding are unclear; however, they may be similar to those previously suggested for the increased risk of all types of horse fall (rotational or non-rotational) associated with riders who receive cross-country tuition (Murray et al., 2004b). It is possible that horses with proven cross-country ability were less likely to be schooled over cross-country fences than inexperienced horses or horses with poor performances in the cross-country phase. Examination of the data provides some support for our hypothesis. Data that were not normally distributed revealed horses that were schooled over cross-country fences to have a lower median number of points (21) than horses that were not schooled over cross-country fences (38). (The number of points a horse has is an indication of the horse's previous eventing success, as points are awarded to horses placed 1st to 8th in eventing competitions and to all other horses achieving cross-country and show jumping rounds without jumping penalties). Further research is needed to clarify why horses that are taken cross-country schooling are at a higher risk of a non-rotational fall, as univariable analysis found no evidence for a significant relationship between the horse's number of points and the risk of a non-rotational fall in our study (P=0.58).

An increase in the total number of jumping efforts on the cross-country course was associated with an increased risk of a non-rotational horse fall in our study. An increase of one jumping effort resulted in an odds ratio of 1.2 (95% C.I. 1.0, 1.3, P=0.02). Our finding contradicted the results of Singer et al. (2003), who reported the risk of a horse fall to decrease with every additional jumping effort (OR=0.8, 95% C.I. 0.7, 1.0, P=0.01) and to increase with every additional jump on the course (OR=1.6, 95% C.I. 1.2, 2.0, P<0.001), perhaps indicating the extra care taken by riders whilst negotiating combination fences. We forced the variable of total number of jumps into the model to observe the effect on the risk associated with the total number of jumping efforts. The odds ratio for the variable of total number of jumping efforts and the risk of a horse fall remained similar but became non-significant (OR=1.2, 95% C.I. 0.9, 1.6, P=0.31) whilst the total number of jumps on a course remained non-significant (OR=1.0, 95% C.I. 0.7, 1.5, P=0.95) and the model fit was not improved significantly. No significant interaction (P=0.95) was found between the variables of total number of jumping efforts and total number of jumps on a course.

The different findings of the previously cited retrospective study and the current prospective study may be attributed to the different case-control study designs. The retrospective study by Singer et al. (2003) used unmatched controls, whereas the controls selected for our study were matched by event and day of competition. As a result of the matching used in our study, the cases selected from courses with a high number of jumping efforts and jumps were usually matched to controls competing over the same courses, as these were the often the only classes held at their respective venues. The methods used to select controls could thus explain the different association reported between the total number of jumping efforts and the total number of jumps on a course and the risk of falling reported in the two studies.

In conclusion, this study has identified different risk factors for rotational horse falls and non-rotational horse falls. In particular, whilst strong evidence was found of an association between fences with a take-off or landing in water and the risk of a non-rotational horse fall, no evidence was found of an association between these fences and the risk of a rotational horse fall. Non-angled fences with a spread of two metres or greater and angled fences were associated with an increased risk of a rotational fall in this study. The high PPAR (0.38) associated with wide, non-angled fences and the risk of a rotational fall suggest that reducing the number of these fences would be a useful intervention strategy to decrease the number of rotational falls. The results of this study highlight the importance of distinguishing between the two main types of horse fall for the identification of risk factors.

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APPENDIX: CHAPTER FIVE

Table 1. Univariable conditional logistic regression analysis: Rotational horse falls, Course and fence-level categorical variables with a P-value <0.2 (in descending order of P-value).

Variable		Number of controls (%)	Number of cases (%)	Odds Ratio	P-value
Drop landing					
	No	87 (93.5)	27 (87.1)	1.00	
	Yes	6 (6.5)	4 (12.9)	3.26	0.197
Flat landing					
	No	44 (47.3)	19 (61.3)	1.00	
	Yes	49 (52.7)	12 (38.7)	0.59	0.19
No groundline					
	Some groundline	82 (88.2)	24 (77.4)	1.00	
	False or no groundline	11 (11.8)	7 (22.6)	2.04	0.17
Camber					
	No Camber	76 (81.7)	22 (71.0)	1.00	
	Camber	17 (18.3)	9 (29.0)	2.20	0.16
Filled front					
	Open front	41 (44.1)	19 (61.3)	1.00	
	Filled front	45 (48.4)	12 (38.7)	0.54	0.16
Trakehner					
	No	90 (96.8)	28 (90.3)	1.00	
	Yes	3 (3.2)	3 (9.7)	3.71	0.16
Fence in open					
	No	16 (17.2)	2 (6.5)	1.00	
	Yes	77 (82.8)	29 (93.5)	3.30	0.14
Groundline					
	No	10 (10.8)	7 (22.6)	1.00	
	Yes	83 (89.2)	24 (77.4)	0.46	0.12
Ditch in front					
	No	87 (93.5)	26 (83.9)	1.00	
	Yes	6 (6.5)	5 (16.1)	3.00	0.11
Jumping effort number					
	1 to 6	17 (18.3)	6 (19.4)	1.00	
	7 to 12	13 (14.0)	11 (35.5)	2.66	
	13 to 16	22 (23.7)	4 (12.9)	0.40	
	17 to 22	23 (23.7)	4 (12.9)	0.40	
	23 to 33	18 (19.4)	6 (19.4)	0.69	0.09
Uphill approach					
	No	59 (63.4)	25 (80.6)	1.00	
	Yes	34 (36.6)	6 (19.4)	0.43	0.09
Downhill landing					
	No	72 (77.4)	19 (61.3)	1.00	
	Yes	21 (22.6)	12 (38.7)	2.39	0.07
Fence angle					
	No	85 (91.4)	24 (77.4)	1.00	
	Yes	8 (8.6)	7 (22.6)	3.84	0.04
Approach					
	Flat	39 (41.9)	10 (32.3)	1.00	
	Uphill	34 (36.6)	6 (19.4)	0.72	
	Downhill	17 (18.3)	15 (48.4)	1.46	
	Water	3 (3.2)	0 (0.0)	0.10	0.02
Fence spread					
	0.00 to 0.58 metres	19 (20.4)	5 (16.1)	1.00	
	0.60 to 1.00 metres	21 (22.6)	4 (12.9)	0.39	
	1.05 to 1.40 metres	20 (21.5)	7 (22.6)	0.79	
	1.44 to 1.85 metres	20 (21.5)	2 (6.5)	0.04	
	1.90 to 2.70 metres	13 (14.0)	13 (41.9)	1.20	0.02

Variable	Number of controls (%)	Number of cases (%)	Odds Ratio	P-value
Wings				
No wings	32 (34.4)	19 (61.3)	1.00	
One or more wings	61 9(65.6)	12 (38.7)	0.29	0.01
Downhill approach				
No	76 (81.7)	16 (51.6)	1.00	
Yes	17 (18.3)	15 (48.4)	4.74	0.002
Angle width combined				
Non-angled, <2m spread	77 (82.8)	13 (41.9)	1.00	
Non-angled, ≥2m spread	8 (8.6)	11 (35.5)	8.00	
All angled fences	8 (8.6)	7 (22.6)	5.17	<0.001

Table 2. Univariable conditional logistic regression analysis: Rotational horse falls, Course and fence-level continuous variables with a P-value <0.2 (in descending order of P-value).

Variable	Odds Ratio	P-value
Total jumping efforts (linear fit)	0.88	0.19
Landing gradient (quadratic fit)	1.00	0.14
Element number (quadratic fit)	4.58	0.09
Number of elements (quadratic fit)	1.71	0.08
Landing: 0m to 10m (quadratic fit)	1.02	0.03
Camber (quadratic fit)	0.93	0.02
Approach: 5m to 0m (linear fit)	0.88	0.01
Landing: 0m to 5m (quadratic fit)	1.01	0.01
Approach: 20m to 0m (linear fit)	0.81	0.01
Approach: 10m to 0m (linear fit)	0.79	0.005

Table 3. Univariable conditional logistic regression analysis: non-rotational falls, Course and fence-level categorical variables with a P-value <0.2 (in descending order of P-value).

Variable		Number of controls (%)	Number of cases (%)	Odds Ratio	P-value
Fence angle					
	No	424 (94.9)	137 (91.9)	1.00	
	Yes	23 (5.1)	12 (8.1)	1.60	0.1997
Ditch in front					
	No	405 (90.6)	140 (94.0)	1.00	
	Yes	42 (9.4)	9 (6.0)	0.60	0.19
Fence height					
	-1.80 to 0.88 metres	62 (15.9)	31 (23.7)	1.00	
	0.90 to 1.02 metres	88 (22.6)	30 (22.9)	0.70	
	1.03 to 1.10 metres	100 (25.6)	24 (18.3)	0.40	
	1.11 to 1.18 metres	67 (17.2)	24 (18.3)	0.65	
	1.19 to 1.60 metres	73 (18.7)	22 (16.8)	0.50	0.19
Hanging log					
	No	422 (94.4)	145 (97.3)	1.00	
	Hanging log	25 (5.6)	4 (2.7)	0.47	0.16
XC Level					
	Intro / Pre-novice	69 (15.4)	18 (12.1)	1.00	
	Novice	145 (32.4)	49 (32.9)	2.47	
	Intermediate	117 (26.2)	42 (28.2)	4.40	
	Advanced	116 (26.0)	40 (26.8)	7.33	0.15
Downhill approach					
	No	350 (78.3)	125 (83.9)	1.00	
	Yes	97 (21.7)	24 (16.1)	0.68	0.13
Uphill landing					
	No	346 (77.4)	124 (83.2)	1.00	
	Yes	101 (22.6)	25 (16.8)	0.42	0.13
Turn before					
	No	286 (64.0)	106 (71.1)	1.00	
	Yes	161 (36.0)	43 (28.9)	0.71	0.10
Slippery take off					
	No	400 (89.5)	139 (93.3)	1.00	
	Yes	47 (10.5)	10 (6.7)	0.47	0.09
Ditch					
	No	388 (86.8)	137 (91.9)	1.00	
	Yes	59 (13.2)	12 (8.1)	0.56	0.09
Turn after					
	No	345 (77.2)	125 (83.9)	1.00	
	Yes	102 (22.8)	24 (16.1)	0.63	0.07
Strides from					
	0	21 (4.7)	10 (6.7)	1.00	
	1	32 (7.2)	15 (10.1)	1.07	
	2	27 (6.1)	15 (10.1)	1.25	
	3	4 (0.9)	12 (8.1)	6.18	
	4	12 (2.7)	10 (6.7)	1.72	
	5 or more	350 (78.5)	87 (58.4)	0.56	0.07
Fence type					
	Upright	27 (6.0)	9 (6.0)	1.00	
	Ascending slope	150 (33.6)	45 (30.2)	0.91	
	Ascending spread	145 (32.4)	35 (23.5)	0.72	
	Square spread	61 (13.6)	25 (16.8)	1.22	
	Step up	31 (6.9)	23 (15.4)	2.26	
	Step down	20 (4.5)	8 (5.4)	1.28	
	Other (e.g. open ditch)	13 (2.9)	4 (2.7)	0.94	0.05

Variable		Number of controls (%)	Number of cases (%)	Odds Ratio	P-value
Ascending spread					
	No	302 (67.6)	114 (76.5)	1.00	
	Yes	145 (32.4)	35 (23.5)	0.62	0.03
Angle width combined					
	Non-angled, <2m spread	380 (86.2)	115 (77.2)	1.00	
	Non-angled, ≥2m spread	38 (8.6)	22 (14.8)	2.03	
	All angled fences	23 (5.2)	12 (8.1)	1.70	0.03
Combination					
	Single fence	264 (59.1)	70 (47.0)	1.00	
	Combination fence	183 (40.9)	79 (53.0)	1.66	0.01
Camber					
	No Camber	339 (75.9)	127 (85.2)	1.00	
	Camber	108 (24.2)	22 (14.8)	0.50	0.01
Shadows					
	No	385 (86.1)	116 (77.9)	1.00	
	Yes	62 (13.9)	33 (22.1)	2.00	0.01
Wings					
	No wings	228 (51.0)	55 (36.9)	1.00	
	One or more wings	219 (49.0)	94 (63.1)	1.80	0.003
Downhill landing					
	No	317 (70.9)	124 (83.2)	1.00	
	Yes	130 (29.1)	25 (16.8)	0.46	0.002
Step up					
	No	416 (93.1)	126 (84.6)	1.00	
	Yes	31 96.9)	23 (15.4)	2.50	0.002
Water approach					
	No	443 (99.1)	136 (91.3)	1.00	
	Yes	4 (0.9)	13 (8.7)	9.75	<0.001
Take off going					
	Firm / Good-Firm	230 (51.5)	62 (41.6)	1.00	
	Good	202 (45.2)	65 (43.6)	1.61	
	Good-Soft / Soft	11 (2.5)	9 (6.0)	6.63	
	Water	4 (0.9)	13 (8.7)	13.95	<0.001
Water landing					
	No	428 (95.7)	119 (79.9)	1.00	
	Yes	19 (4.3)	30 (20.1)	5.82	<0.001
Landing going					
	Firm / Good-Firm	214 (47.9)	59 (39.6)	1.00	
	Good	206 (46.1)	54 (36.2)	0.93	
	Good-Soft / Soft / Heavy	10 (2.2)	6 (4.0)	2.85	
	Water	17 (3.8)	30 (20.1)	6.97	<0.001
Drop landing					
	No	406 (91.0)	120 (80.5)	1.00	
	Yes	40 (9.0)	29 (19.5)	2.80	<0.001
Landing					
	Flat	197 (44.1)	69 (46.3)	1.00	
	Uphill	101 (22.6)	25 (16.8)	0.65	
	Downhill	130 (29.1)	25 (16.8)	0.50	
	Water	19 (4.3)	30 (20.1)	4.59	<0.001
Fence spread					
	0.00 to 0.48 metres	77 (17.5)	44 (29.5)	1.00	
	0.50 to 0.97 metres	84 (19.0)	29 (19.5)	0.59	
	1.00 to 1.40 metres	108 (24.5)	36 (24.2)	0.55	
	1.43 to 1.84 metres	97 (22.0)	11 (7.4)	0.18	
	1.85 to 3.10 metres	75 (17.0)	29 (19.5)	0.63	<0.001

Table 4. Univariable conditional logistic regression analysis: Non-rotational horse falls, Course and fence-level continuous variables with a P-value <0.2 (in descending order of P-value).

Variable	Odds Ratio	P-Value
Approach: 5m to 0m (linear fit)	0.98	0.19
Approach: 20m to 0m (linear fit)	0.96	0.10
Landing: 0m to 10m (linear fit)	1.04	0.10
Speed (linear fit)	1.01	0.06
Approach: 10m to 0m (linear fit)	0.96	0.04
Jumping effort number (linear fit)	1.02	0.03
Total jumping efforts (linear fit)	1.13	0.02
Element number (linear fit)	1.77	< 0.001
Number of elements (linear fit)	1.44	< 0.001
Landing gradient (quadratic fit)	1.00	< 0.001

Table 5. Univariable conditional logistic regression analysis: Rotational falls, Rider-level categorical variables with a P-value <0.2 (in descending order of P-value).

Variable	Number of controls (%)	Number of cases (%)	Odds Ratio	P-value
Cross-country lessons				
No	50 (54.9)	13 (41.9)	1.00	
Yes	41 (45.1)	18 (58.1)	1.84	0.18
Show jumping				
No	7 (7.7)	5 (16.1)	1.00	
Yes	84 (92.3)	26 (83.9)	0.44	0.18
Rider Status				
Professional event rider	54 (59.3)	13 (41.9)	1.00	
Amateur event rider	37 (40.7)	18 (58.1)	2.20	0.08
Unaffiliated before				
No	13 (14.3)	9 (29.0)	1.00	
Yes	78 (85.7)	22 (71.0)	0.37	0.06
Height				
154.94-165.10 cm	23 (25.3)	3 (9.7)	1.00	
167.64-169.00 cm	16 (17.6)	5 (16.1)	2.66	
170.18-172.00 cm	15 (16.5)	8 (25.8)	4.34	
172.72-177.80 cm	27 (29.7)	5 (16.1)	1.62	
178.50-193.04 cm	10 (11.0)	10 (32.3)	8.17	0.04

Table 6. Univariable conditional logistic regression analysis: Rotational falls, Rider-level continuous variables with a P-value <0.2 (in descending order of P-value).

Variable	Odds Ratio	P-value
Days ride (quadratic fit)	1.32	0.18
Age (linear fit)	1.03	0.18
Time unaffiliated (quadratic fit)	1.02	0.05
Time professional (linear fit)	1.01	0.05
Weight (linear fit)	1.06	0.04
Height (linear fit)	1.08	0.02

Table 7. Univariable conditional logistic regression analysis: Non-rotational falls, Rider-level categorical variables with a P-value <0.2 (in descending order of P-value).

Variable		Number of controls (%)	Number of cases (%)	Odds Ratio	P-value
Point-to-pointing					
	No	416 (97.2)	134 (94.4)	1.00	
	Yes	12 (2.8)	8 (5.6)	2.09	0.14
Show jumping lessons					
	No	64 (15.0)	14 (9.9)	1.00	
	Yes	364 (85.0)	128 (90.1)	1.62	0.13
Rider injured this horse					
	No	382 (89.3)	133 (94.3)	1.00	
	Yes	46 (10.7)	8 (5.7)	0.51	0.09
Days ride					
	Five days or fewer	45 (10.5)	8 (5.6)	1.00	
	Six or seven days	382 (89.5)	134 (94.4)	2.00	0.08
Sport					
	No	228 (53.3)	62 (43.7)	1.00	
	Yes	200 (46.7)	80 (56.3)	1.47	0.05
Cross-country lessons					
	No	247 (57.7)	61 (43.0)	1.00	
	Yes	181 (42.3)	81 (57.0)	1.79	0.004
Cross-country frequency					
	None	247 (57.8)	61 (43.0)	1.00	
	Minimum of 1/month	44 (10.3)	29 (20.4)	2.73	
	Less often	136 (31.9)	52 (36.6)	1.49	0.002

Table 8. Univariable conditional logistic regression analysis: Non-rotational falls, Rider-level continuous variables with a P-value <0.2 (in descending order of P-value).

Variable	Odds Ratio	P-value
Horses per day (linear fit)	1.06	0.18
Days ride (linear fit)	1.17	0.18
Number of placings (linear fit)	0.99	0.16
Years riding (quadratic fit)	1.00	0.15
Weeks partnered (quadratic fit)	1.00	0.12
Years riding (linear fit)	1.02	0.07
Days ride (quadratic fit)	1.12	0.07
Time competing (linear fit)	1.03	0.06
Time unaffiliated (linear fit)	1.05	0.02

Table 9. Univariable conditional logistic regression analysis: Rotational falls, Horse-level categorical variables with a P-value <0.2 (in descending order of P-value).

Variable	Number of controls (%)	Number of cases (%)	Odds Ratio	P-value
Other riders				
No	48 (52.7)	12 (38.7)	1.00	
Yes	43 (47.3)	19 (61.3)	2.08	0.12
Dressage schooling				
1-2/week or less often	30 (33.0)	17 (54.8)	1.00	
3-4/week	51 (56.0)	12 (38.7)	0.34	
>4/week	10 (11.0)	2 (6.5)	0.31	0.07
Garlic				
No	58 (63.7)	28 (90.3)	1.00	
Yes	33 (36.3)	3 (9.7)	0.18	0.008

Table 10. Univariable conditional logistic regression analysis: Rotational falls, Horse-level continuous variables with a P-value <0.2 (in descending order of P-value).

Variable	Odds Ratio	P-value
Runs (quadratic fit)	1.00	0.17
Last SJ (linear fit)	1.07	0.08
Number of events (quadratic fit)	0.78	0.06

Table 11. Univariable conditional logistic regression analysis: Non-rotational falls, Horse-level categorical variables with a P-value <0.2 (in descending order of P-value).

Variable		Number of controls (%)	Number of cases (%)	Odds Ratio	P-value
Placed last event					
	No	232 (57.4)	86 (64.7)	1.00	
	Yes	172 (42.6)	47 (35.3)	0.76	0.19
Flat race					
	No	394 (93.8)	136 (97.1)	1.00	
	Yes	26 (6.2)	4 (2.9)	0.47	0.18
Acupuncture / other					
	No	414 (96.7)	133 (93.7)	1.00	
	Yes	14 (3.3)	9 (6.3)	1.83	0.16
Number of weeks					
	0-1 weeks	86 (20.7)	25 (18.2)	1.00	
	2 weeks	110 (26.5)	48 (35.0)	1.54	
	3 weeks	65 (15.7)	24 (17.5)	1.21	
	4-5weeks	66 (31.6)	22 (16.1)	1.26	
	6-88 weeks	88 (21.2)	18 (13.1)	0.66	0.14
Hurdle					
	No	416 (99.0)	136 (97.1)	1.00	
	Yes	4 (1.0)	4 (2.9)	2.85	0.14
Breed					
	Tb	126 (29.4)	58 (40.8)	1.00	
	7/8 Tb	61 (14.3)	19 (13.4)	0.64	
	3/4 & 5/8 Tb	151 (35.3)	41 (28.9)	0.56	
	1/2 Tb	15 (3.5)	4 (2.8)	0.57	
	Warmblood	36 (8.4)	12 (8.5)	0.66	
	Irish	39 (9.1)	8 (5.6)	0.42	0.14
Other supplements					
	No	228 (54.3)	85 (63.0)	1.00	
	Yes	192 (45.7)	50 (37.0)	0.70	0.09
Shoes					
	Standard	396 (92.5)	123 (87.2)	1.00	
	Not standard	32 (7.5)	18 (12.8)	1.83	0.06
Cross-country schooling					
	Never	105 (24.6)	17 (12.1)	1.00	
	>1/month	30 (7.0)	17 (12.1)	3.95	
	Monthly	30 (7.0)	17 (12.1)	4.06	
	Start of season	207 (48.5)	68 (48.6)	2.19	
	If there's a problem	55 (12.9)	21 (15.0)	2.80	0.005
Cross-country schooling (binary)					
	No	105 (24.6)	17 (12.1)	1.00	
	Yes	322 (75.4)	123 (87.9)	2.60	0.001

Table 12. Univariable conditional logistic regression analysis: Non-rotational falls, Horse-level continuous variables with a P-value <0.2 (in descending order of P-value).

Variable	Odds Ratio	P-value
Higher runs (linear fit)	0.93	0.15
Horse age (quadratic fit)	0.98	0.13
Number of weeks (quadratic fit)	1.00	0.07

Table 13. Univariable conditional logistic regression analysis: Rotational falls, Event-level categorical variables with a P-value <0.2 (in descending order of P-value).

Variable		Number of controls (%)	Number of cases (%)	Odds Ratio	P-value
Front studs (combined)					
	No	15 (16.5)	2 (6.5)	1.00	
	Yes	76 (83.5)	29 (93.5)	2.73	0.196
Day before Dr/SJ					
	No	57 (83.8)	17 (73.9)	1.00	
	Dressage only	11 (16.2)	6 (26.1)	2.91	0.17
Walked alone (combined)					
	No/both	64 (71.1)	26 (83.9)	1.00	
	Yes	26 (28.9)	5 (16.1)	0.42	0.14
SJ refusals					
	No	62 (98.4)	19 (90.5)	1.00	
	Yes	1 (1.6)	2 (9.5)	6.00	0.14
Into sun					
	No	90 (98.9)	29 (93.5)	1.00	
	Yes	1 (1.1)	2 (6.5)	6.00	0.14
Hind studs					
	None	6 (6.6)	2 (6.5)	1.00	
	One in each shoe	40 (44.0)	20 (64.5)	1.44	
	Two in each shoe	45 (49.5)	9 (29.0)	0.56	0.13
Route					
	Easy / straightforward	66 (73.3)	17 (54.8)	1.00	
	Fairly difficult	20 (22.2)	11 (35.5)	2.41	
	Difficult	4 (4.4)	3 (9.7)	3.42	0.13
Walked owner					
	No	87 (95.6)	27 (87.1)	1.00	
	Yes	4 (4.4)	4 (12.9)	3.48	0.11
Breastplate XC competing (combined)					
	No	5 (5.5)	5 (16.1)	1.00	
	Yes	86 (94.5)	26 (83.9)	0.28	0.09
Ground affect					
	No	71 (83.5)	28 (96.6)	1.00	
	Yes	14 (16.5)	1 (3.4)	0.16	0.08
Number of helpers*					
	None	3 (3.3)	1 (3.2)	1.00	
	One	39 (42.9)	5 (16.1)	0.24	
	Two	25 (27.5)	13 (41.9)	1.44	
	Three or more	24 (26.4)	12 (38.7)	1.32	0.07
Speed affect					
	No	52 (57.1)	22 (73.3)	1.00	
	Yes	39 (42.9)	8 (26.7)	0.39	0.06
XC refusals (combined)					
	No	81 (89.0)	31 (100.0)		
	Yes	10 (11.0)	0 (0.0)		0.06
XC stirrups (combined)					
	Short	61 (67.0)	15 (48.4)	1.00	
	Medium/long	30 (33.0)	16 (51.6)	2.27	0.06
Walked groom					
	No	88 (96.7)	27 (87.1)	1.00	
	Yes	3 (3.3)	4 (12.9)	5.16	0.06
Knew score					
	No	32 (35.2)	5 (16.1)	1.00	
	Yes	59 (64.8)	26 (83.9)	4.08	0.04
Ride plan					
	No	10 (11.0)	10 (34.5)	1.00	
	Yes	81 (89.0)	19 (65.5)	0.28	0.01

* Case number 40 selected randomly and changed from 'three or more' to 'none'.

Table 14. Univariable conditional logistic regression analysis: Rotational falls, Event-level continuous variables with a P-value <0.2 (in descending order of P-value).

Variable	Odds Ratio	P-value
Time walked (quadratic fit)	1.00	0.19
Horse water (linear fit)	1.00	0.13
Web SJ (linear fit)	1.05	0.10
Eat (quadratic fit)	1.00	0.08
Web dressage (quadratic fit)	1.00	0.07

Table 15. Univariable conditional logistic regression analysis: Non-rotational falls, Event-level categorical variables with a P-value <0.2 (in descending order of P-value).

Variable		Number of controls (%)	Number of cases (%)	Odds Ratio	P-value
Alcohol					
	None	215 (50.2)	82 (58.2)	1.00	
	Low	123 (28.7)	36 (25.5)	0.73	
	Moderate / heavy	90 (21.0)	23 (16.3)	0.64	0.197
Walked trainer					
	No	370 (86.9)	128 (90.8)	1.00	
	Yes	56 (13.1)	13 (9.2)	0.64	0.19
Light conditions					
	Good	409 (95.8)	130 (92.9)	1.00	
	Poor	18 (4.2)	10 (7.1)	1.80	0.18
Shadows					
	No	412 (96.3)	133 (93.7)	1.00	
	Yes	16 (3.7)	9 (6.3)	1.81	0.18
Held					
	No	415 (97.2)	141 (99.3)	1.00	
	Once	12 (2.8)	1 (0.7)	0.24	0.17
Alcohol					
	None	215 (50.2)	82 (58.2)	1.00	
	Low	123 (28.7)	36 (25.5)	0.71	
	Moderate	75 (17.5)	22 (15.6)	0.75	
	Heavy	15 (3.5)	1 (0.7)	0.15	0.17
Attitude XC					
	Very excited	41 (9.6)	10 (7.0)	1.00	
	Excited	133 (31.1)	32 (22.5)	1.04	
	Alert	143 (33.4)	54 (38.0)	1.61	
	Calm	111 (25.9)	46 (32.4)	1.74	0.16

Variable		Number of controls (%)	Number of cases (%)	Odds Ratio	P-value
Walked family					
	No	330 (77.5)	117 (83.0)	1.00	
	Yes	96 (22.50	24 (17.0)	0.68	0.13
Horses day before					
	None	392 (91.6)	122 (86.5)	1.00	
	One	15 (3.5)	9 (6.4)	2.66	
	Two or more	21 (4.9)	10 (7.1)	1.74	0.13
Into sun					
	No	426 (99.5)	138 (97.9)	1.00	
	Yes	2 (0.5)	3 (2.1)	4.50	0.10
Hind studs					
	None	10 (2.3)	3 (2.1)	1.00	
	One in each shoe	224 (52.5)	61 (43.0)	0.94	
	Two in each shoe	193 (45.2)	78 (54.9)	1.51	0.09
Social event					
	No	277 (64.7)	99 (69.7)	1.00	
	Yes	151 (35.3)	43 (30.3)	0.50	0.06
Normal XC					
	No	16 (3.8)	12 (8.5)	1.00	
	Yes	402 (96.2)	130 (91.5)	0.43	0.04
Position					
	Didn't know	301 (70.3)	109 (76.8)	1.00	
	First	8 (1.9)	5 (3.5)	2.03	
	2nd-5th	25 (5.8)	8 (9.2)	0.73	
	6th or lower	94 (22.0)	20 (14.1)	0.40	0.04
Sleep time					
	1-5.75 hours	52 (12.4)	9 (6.3)	1.00	
	6-6.75 hours	75 (17.9)	34 (23.9)	2.73	
	7-7.83 hours	125 (29.8)	30 (21.1)	1.48	
	8 -8.25 hours	67 (16.0)	25 (17.6)	2.37	
	8.5-12 hours	101 (24.0)	44 (31.0)	2.83	0.03
Slippery					
	No	411 (96.0)	131 (92.3)	1.00	
	Yes	17 (4.0)	11 (7.7)	2.63	0.03
Time ate					
	2-60 minutes	81 (19.4)	26 (17.4)	1.00	
	75-120 minutes	72 (17.3)	34 (22.8)	1.53	
	140-210 minutes	67 (16.1)	25 (16.8)	1.18	
	230-660 minutes	88 (21.1)	35 (23.5)	1.23	
	Previous day	109 (26.1)	19 (12.8)	0.53	0.02
Important					
	No	59 (13.8)	31 (21.8)	1.00	
	Yes	369 (86.2)	111 (78.2)	0.54	0.02
Normal C					
	No	7 (4.7)	8 (16.0)	1.00	
	Yes	143 (95.3)	42 (84.0)	0.27	0.02

Variable		Number of controls (%)	Number of cases (%)	Odds Ratio	P-value
Social night before					
	No	383 (89.5)	136 (95.8)	1.00	
	Yes	45 (10.5)	6 (4.2)	0.31	0.01
Front studs					
	None	37 (8.6)	9 (6.3)	1.00	
	One in each shoe	215 (50.2)	55 (38.7)	1.10	
	Two in each shoe	176 (41.1)	78 (54.9)	2.05	0.01
Eat					
	No	110 (25.7)	19 (13.4)	1.00	
	Yes	318 (74.3)	123 (86.6)	2.27	0.003
XC refusals (combined)*					
	No	374 (88.6)	141 (99.3)	1.00	
	Yes	48 (11.4)	1 (0.7)	0.05	0.003
Route					
	Easy	45 (10.5)	9 (6.3)	1.00	
	Straightforward	240 (56.2)	65 (45.8)	1.21	
	Fairly difficult	123 (28.8)	45 (31.7)	1.89	
	Difficult	19 (4.4)	23 (16.2)	6.34	<0.001
Route relative					
	Easier	156 (36.5)	23 (16.2)	1.00	
	The same	169 (39.6)	73 (51.4)	2.93	
	More difficult	102 (23.9)	46 (32.4)	3.24	<0.001
Ride plan					
	No	29 (6.8)	33 (23.6)	1.00	
	Yes	398 (93.2)	107 (76.4)	0.25	<0.001
Speed					
	About right	388 (91.1)	102 (72.9)	1.00	
	Too slow	19 (4.5)	14 (10.0)	2.65	
	Too fast	19 (4.5)	24 (17.1)	6.40	<0.001

* Case number 125 selected randomly and changed from 'No' to 'Yes' for XC refusals.

Table 16. Univariable conditional logistic regression analysis: Non-rotational falls, Event-level continuous variables with a P-value <0.2 (in descending order of P-value).

Variable	Odds Ratio	P-value
Warm up wanted (quadratic time)	1.00	0.09
Time walked (linear fit)	1.00	0.04
Web dressage (quadratic fit)	1.00	0.04
Sleep (linear fit)	1.17	0.03

Table 17. Multivariable model of subjective and objective risk factors associated with non-rotational falls of horses in the cross-country phase of eventing competitions in Great Britain (2001-2002).

Variable		Coefficient	Standard Error	P-value	Odds ratio (95% C.I.)
Downhill landing slope					
	No	Ref.			Ref.
	Yes	-1.04	0.39	0.008	0.36 (0.16, 0.77)
Take off surface					
	Land	Ref.			Ref.
	Water	2.72	0.81	<0.001	15.12 (3.08, 74.34)
Landing surface					
	Land	Ref.			Ref.
	Water	2.88	0.51	<0.001	17.73 (6.50, 48.34)
Horse's behaviour prior to the XC					
	Normal	Ref.			Ref.
	Not normal	-1.82	0.62	0.003	0.16 (0.05, 0.54)
Time between finishing walking the XC course and starting the course					
	≤ 120 mins	Ref.			Ref.
	>120 mins (same day)	0.85	0.36		2.34 (1.16, 4.71)
	Day before	0.15	0.36	0.03	1.17 (0.58, 2.36)
Rider's opinion of the fence compared to the rest of the course					
	Easier	Ref.			Ref.
	The same	1.08	0.36		2.94 (1.45, 5.97)
	More difficult	0.98	0.40	0.009	2.66 (1.22, 5.84)
Fence was ridden as planned					
	No	Ref.			Ref.
	Yes	-1.66	0.42	<0.001	0.19 (0.08, 0.43)
Horse is schooled XC					
	No	Ref.			Ref.
	Yes	1.01	0.39	0.01	2.75 (1.27, 5.92)
Total no. of jumping efforts on the course (continuous)		0.20	0.08	0.02	1.22 (1.04, 1.43)
Rider's knowledge of their position before starting the XC course					
	Didn't know	Ref.			Ref.
	First	0.89	0.78		2.43 (0.52, 11.30)
	Second or lower	-0.98	0.40	0.02	0.37 (0.17, 0.82)
Rider's opinion of their speed of approach					
	Appropriate	Ref.			Ref.
	Too slow	0.64	0.53		1.89 (0.66, 5.39)
	Too fast	1.47	0.53	0.02	4.35 (1.53, 12.36)

Table 18. A summary of the effect of adding the variable of event level into the model of risk factors for rotational horse falls during the cross-country phase of eventing competitions presented in Table 1 of Chapter 5.

	Original model (A)	Model A plus event level
Variable	Odds Ratio	Odds Ratio
Gradient: 0 to 10m landing	0.64*	0.62*
Occupation		
Professional event rider / FT horses	1.00	1.00
FT other	18.32*	16.39*
PT other / student / non-working	0.41	0.36
Angle and spread of fence		
No angle, <2m spread	1.00	1.00
No angle, ≥2m spread	15.13*	23.65*
All angled fences	20.22*	42.67*
Event Level		
Intro/Pre-novice/Novice		1.00
Intermediate/Advanced		0.28

* P-value <0.05

The variables of event type and rider status did not converge when added to model A.

Table 19. A summary of the effect of adding the variables; event level and rider status into the model of risk factors for non-rotational horse falls during the cross-country phase of eventing competitions presented in Table 2 of Chapter 5.

	Original model (A)	Model A plus event level	Model A plus event type	Model A plus rider status
Variable	Odds Ratio	Odds Ratio	Odds Ratio	Odds Ratio
Down take-off				
No	1.00	1.00	1.00	1.00
Yes	0.47*	0.47*	0.47*	0.47*
Take-off water				
No	1.00	1.00	1.00	1.00
Yes	21.20*	22.65*	21.20*	21.21*
Landing water				
No	1.00	1.00	1.00	1.00
Yes	12.47*	12.89*	12.48*	12.52*
XC Schooling (horse)				
No	1.00	1.00	1.00	1.00
Yes	2.73*	2.74*	2.73*	2.73*
Total jumping efforts (continuous variable)	1.17*	1.22	1.17*	1.17*
Position				
Second or lower	1.00	1.00	1.00	1.00
Didn't know	1.97	1.99	1.97	1.97
First	0.44*	0.43*	0.44*	0.43*
Take-off water and landing water interaction	0.01*	0.01*	0.01*	0.02*
Event level				
Intro / Pre-novice		1.00		
Novice		0.51		
Intermediate		0.42		
Advanced		0.58		
Event type				
One-day event			1.00	
Two-/three-day event			0.96	
Rider status				
Professional				1.00
Amateur				1.08

* P-value <0.05

CHAPTER SIX:

Video analysis as a method of verifying data obtained by questionnaire in a case-control study of eventing horse falls.

Abstract

Misclassification of the response variable and/or explanatory variables has the potential to bias the results of a study. The use of a 'gold standard' is recommended to quantify any misclassification within a study.

The two objectives of this study were to quantify misclassification of a sample of cases and controls recruited onto a study of cross-country horse falls, and to compare data collected by telephone interview with video evidence. Cases were defined as horses that had fallen whilst attempting to negotiate an obstacle on the cross-country course. Controls were selected randomly from successful jumping efforts and matched by competition venue and by day of cross-country competition. No misclassification of controls (0/122) was observed, whereas 17% (7/42) of cases were classified incorrectly. Of the misclassified horses, five had fallen onto their knees unseating their rider, whilst the other two horses had not fallen, but had unseated their riders. Data obtained by studying video footage of 47 cases and 159 controls were compared with data obtained by questionnaire. Kappa values ≥ 0.75 defined excellent agreement, 0.40-0.74 defined fair to good agreement and <0.40 defined poor agreement between the two datasets. Data relating to the equipment used (spurs, type of bit and type of noseband) was reported with varying levels of agreement by cases (kappa=0.34-0.87) and controls (kappa=0.52-0.87) when compared with data obtained from video footage. The level of agreement between data for subjective variables (evaluation of the speed of approach to a fence and quality of previous jumping effort) provided by the observer and by the riders was poor to fair (kappa=0.10-0.52).

The results of this study indicated agreement that varied from poor to excellent between data obtained by questionnaire interview and data obtained from video footage for objective variables. Data obtained for subjective variables showed poor to fair agreement with data obtained by video footage, highlighting the difficulty in validating subjective data. No consistent difference was observed in the level of agreement attributable to the case-control status of the rider.

Introduction

Eventing is an equestrian sport that appeals to amateur and professional riders, with 8,283 riders registered with British Eventing in 2003. Eventing consists of three stages: dressage, cross-country and show jumping. Events may be run over one, two or three days and are classified according to the level of difficulty of the cross-country course. There are 5 one-day event levels (in ascending order of difficulty): Intro, Pre-novice, Novice, Intermediate and Advanced. Three-day events are also knows as Concours Complet Internationale (CCI) competitions, with the difficulty increasing from 1-star (1*) to 4-star (4*) level.

Falls of horses during the cross-country phase of eventing competitions have been associated with fatalities of the horse (Murray et al., 2004a) and rider (Whitlock, 1999). Recent epidemiological research has identified risk factors associated with an increased or decreased risk of a horse fall on the cross-country phase of eventing competitions in retrospective (Singer et al., 2003) and prospective (Murray et al., 2004b) case-control studies. The validity of the results of case-control studies depends on a number of factors. These factors include the correct classification of the response variable and the reliability of the data related to the explanatory variables. This paper assesses the reliability of the classification of the response variable and the reliability of a small proportion of the data obtained by telephone interview for a case-control study of horse falls in eventing competitions.

Misclassification of the response variable has the potential to bias the results of a study. Non-differential misclassification (i.e. independent of exposure status) may lead to risk factors being biased towards the null (Suadicani et al., 1997; Brenner and Gefeller, 1993) as demonstrated by Platz et al. (2004). Suadicani et al. (1997) reported potential differential misclassification (i.e. dependent on exposure status) of smokers as non-smokers, possibly leading to incorrect estimations of the effects of passive smoking on health. Methods have been suggested for correcting the effects of differential and non-differential misclassification (Magder and Hughes, 1997; Brenner and Gefeller, 1993).

Misclassification of an exposure variable is also a potential source of bias in a study. The effects of non-differential bias can reduce the apparent effect of the exposure

(Clayton and Hills, 1993). Conversely, differential misclassification of rare exposures may lead to an overestimation of their effects (Daniels et al., 2001). Non-differential and differential misclassification of exposures has been shown to bias multiplicative and additive interaction effects towards the null, whilst non-differential misclassification biased additive interaction effects away from the null in other situations (Garcia-Closas et al., 1999). Marshall (1999) reviewed 16 studies and concluded that despite misclassification of exposures (that could not be assumed to be non-differential), estimates of relative risk were not greatly affected, providing little evidence for misclassification bias.

Accuracy of data collected by questionnaire is dependent, to some extent, on the respondent's memory and willingness to provide accurate information. Verification of data obtained by questionnaire interview is important to ascertain the reliability of results obtained in a study. Data obtained during a single telephone interview has been shown to be reproducible and valid in the assessment of exposure to risk factors of non-traumatic events, i.e. work tasks (Kallio et al., 2000) and pet nutrition (Sallander et al., 2001). Traumatic events have been associated with increased (Southwick et al., 1997) and decreased (Lombardi et al., 2002) recall reliability when compared to the recall of non-traumatic events. Unexpected events with emotional and consequential associations can lead to 'flashbulb memories', which are characterised as being very vivid and long-lasting (Talarico and Rubin, 2003). A fall of a horse and rider may constitute a traumatic event for some riders, particularly if the fall was associated with serious injury to the horse or rider, and may cause these riders to have a 'flashbulb memory' of the fall. Evidence suggests that 'flashbulb memories' are perceived to be more accurate than everyday memories, but are in reality no more accurate (Talarico and Rubin, 2003). Alternatively, some riders may suffer concussion as a result of a fall (although no published incident rates are available), with associated memory loss that varies in length according to the severity of the injury (McCrea et al., 2002).

Case-control studies are subject to biases arising from differential reporting from cases and controls (Schlesselman, 1982). Motivation to recall exposure variables may lead to differential reporting and can result in Type-I (Lindefors-Harris et al., 1991) or Type-II errors (Rockenbauer et al., 2001; Cockburn et al., 2001; Weinstock et al., 1991). Type-I errors can occur if cases are more likely than controls to fail to report risk factors - particularly, risk factors with negative associations. Type-II errors can occur if cases are more likely than controls to recall and report risk factors, in an attempt to explain the outcome.

Previously, we found no evidence for case-control bias when the reporting of dressage and cross-country scores were analysed as a function of respondent category, based on data collected for a case-control study of horse falls (Murray et al., 2004c, *in press*). Despite our previous finding of no case-control bias, it is possible that differential recall might exist for variables relating more directly to the horse fall, such as the horse and rider partnership's speed of approach to the fence. Cases may demonstrate better or worse recall accuracy when compared to controls, particularly if cases were traumatised or concussed as a result of their fall.

Video footage has been used to investigate potential risk factors associated with fatal distal limb fractures of Thoroughbred racehorses (Parkin et al., 2003) and falls of racehorses in hurdle and steeplechase races (Pinchbeck et al., 2004c, *in press*). In the study presented in this paper, controls were selected randomly from all successful jumping efforts during the day on which the case horse fell. A wide diversity of fence types are found on a cross-country course. Therefore, the randomly selected fences for controls were often different in type to the case fence. Different fence types and / or different siting of fences can require different approaches in terms of pace and riding style (Gordon Watson, 1991). In addition, fences were often filmed from varying angles and distances. Consequently, we considered that an analysis of potential risk factors for horse falls that had previously been employed by Parkin et al. (2003) and Pinchbeck et al. (2004c, *in press*) was not appropriate for the video footage available for the study presented here.

The aim of this paper was to determine the misclassification rate of horse falls (response variable) and to assess the reliability of data collected by questionnaire interview (explanatory variables) in a case-control study of eventing horse falls.

Materials and Methods

The data used for this study were collected as part of a case-control study of risk factors for horse falls, which included variables at the levels of the course and fence, horse, rider and event. One-day event competitions were selected randomly from the 2001 and 2002 British Eventing (B.E.) seasons. All three-day event competitions were also selected, as only sixteen were scheduled in Great Britain (G.B.) for the study period. From a total of 120 days of cross-country competition, data were collected for 180 cases and 540 controls, matched by day of event.

Case definition

A case was defined as a jumping effort that resulted in a horse fall on the cross-country phase of an event. A jumping effort was defined as having occurred if the horse attempted to negotiate an obstacle on the cross-country course. A horse fall was defined by B.E. rules (2001) as: the horse's shoulders and quarters touched either the ground or the obstacle and the ground at the same time. In this study, falls were identified and recorded by fence judges, who were positioned by each fence to record penalties incurred by each competitor. The fence judges were briefed before the competition on the definition of a horse fall, in order to maximise the probability of correct identification. Falls that occurred on the approach to the fence, as a result of the horse attempting to avoid jumping the fence, were not classified as cases.

Control definition and selection

A control was defined as a jumping effort that did not result in a horse fall. Three control horse and rider pairs were selected randomly from all successful jumping efforts that took place on the same day and at the same competition from which their case was selected. Matching was used to control for the potentially confounding effects of month, weather conditions and geographical location of the event.

Video footage

Video footage was obtained from three sources; Television in Europe Ltd.[1] (TE), Total Recall Videos[2] (TR) and Lucid Dreams Media[3] (LD). TR and LD are commercial companies that make videos of competitors' cross-country rounds that are available to purchase. TE filmed Burghley (CCI 4*) in order to produce television coverage of the cross-country phase. The companies had members of staff positioned at various points around the cross-country course, sometimes in addition to unmanned video cameras that would be left recording for the day. The companies aimed to record all competitors at every fence, but practical issues such as the siting of some fences and changing of equipment and staff meant that some competitors and/or fences were omitted from the recorded footage. The selection of events attended by TR and LD was made on the basis of location and expected financial reward. TR were present at six one-day events (Intro to Intermediate level) within the Midlands region of England, whilst LD attended four CCI 1* and CCI 2* events in England and Scotland that were selected for inclusion in the study.

Video footage was requested for all cases and controls included in the prospective case-control study that had been recorded. Footage was requested to begin at least 5 strides prior to take-off at the fence immediately prior to the 'selected' fence, and to finish at least 3 strides following landing after the 'selected' fence for each horse. 'Selected' fences included fences at which a horse had fallen (case fences) and fences selected randomly for control competitors (control fences).

Footage was available for 169 competitors that had been classified by fence judges as cases (47) and controls (122). The footage was used for two purposes. Firstly, to verify the classification of cases and controls by fence judges. Secondly, to quantify the level of agreement between data collected by questionnaire from cases and controls with data obtained from video footage. Objective variables included the equipment that the riders used for the cross-country phase (spurs, type of bit and type of noseband). Subjective variables included the horse's speed of approach to the selected fence (appropriate, too slow, too fast) and the quality of the previous

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[1] Television in Europe, London.
[2] Total Recall Videos, Northants.
[3] Lucid Dreams Media, Northern Ireland.

jumping effort, which was defined by how well the horse had jumped the previous fence (very well, well, not very well, not at all well).

Classification of cases and controls

The video footage was assessed by one of the authors (JM) to categorise the horse and rider partnerships into cases and controls. The advantages of watching each competitor more than once in slow motion, meant that this classification was taken to be the 'gold standard' with which the fence judges' decisions could be compared. Wherever possible, the author was 'blind' to the classifications provided by the fence judges when viewing the videos; however, some horses and/or riders were recognised in the footage as having been included as a case or a control in the study. Classification of cases and controls by studying video footage frame by frame meant that the horse's position could be compared rigorously to the case definition (i.e. the shoulders and quarters needed to touch the ground or the ground and the obstacle). We believe that the facility to study each horse closely will have minimised any bias from knowledge of the fence judge's classification.

Five jumping efforts were not evaluated, as they could not be viewed clearly on the monitor. Footage was assessed for 164 jumping efforts that had been classified by the fence judges as 122 controls and 42 cases.

Verification of data collected by questionnaire

a. Equipment used

The videotapes were studied to determine the presence or absence of spurs worn by the rider and the type of bit and type of noseband used for the horse. Data relating to these three variables were used, as specific questions relating to the equipment at the selected event were included in the questionnaire. Footage that did not show the equipment clearly was classified as missing data.

b. Speed of approach

From the video footage, a subjective assessment was of each competitor's approach speed to the selected fence (appropriate, too slow, too fast). The assessment was based on the author's knowledge and experience of the suitable speed requirements for different types of fence. Video footage was available and was clearly visible for 40 cases and 113 controls.

c. Quality of previous jumping effort

A subjective assessment was made of the quality of the previous jumping effort, defined by how well the horse had jumped the fence prior to the selected fence. Subjective assessments were made according to the categories used by questionnaire respondents (very well, well, not very well, not at all well). Clear video footage was available for 31 cases and 110 controls.

The analysis of the level of agreement between data provided by the respondent and data obtained from video footage was conducted separately for cases and controls. Classification of cases and controls was on the basis of recruitment into the case-control study. Whilst collecting data relating to the equipment used by competitors from video footage, the author was 'blinded' to the data that had been obtained by questionnaire. As discussed previously, the subjective observations (speed of approach, quality of previous jumping effort) were conducted without knowledge of the case-control classification of horses by the fence judges, wherever possible; however, the outcome of the jumping effort was frequently known in advance of the subjective assessment of speed. This was because subjective assessment of speed was difficult to assess if the tapes were viewed in slow motion. A quantitative measurement of speed was not possible as cases and controls were frequently recruited onto the study at different types of fence, requiring different approach speeds.

Subjective description of the horse falls

The video footage was used to compile a subjective description of the horse falls. All falls were categorised according to the descriptions of events preceding the falls (hit fence with front legs, hit fence with hind legs, hit fence with chest, horse did not hit fence but stumbled and fell on landing). Falls were described by the following additional features: horse took off too close or too far away from the fence, horse appeared to try to refuse the fence, fence involved a take-off and/or landing in water.

Data analysis

The level of agreement between data collected from the video footage and from the questionnaire interview was assessed by use of the Kappa statistic (Win Episcope 2.0, Epidecon). The Kappa statistic (K) expressed the proportion of times agreement was achieved between the data provided by fence judges or riders and the data obtained from video footage (P(A)) compared with the maximum agreement that could be achieved, with a 95% level of confidence. The calculation was corrected for the level of agreement that would be expected by chance (P(E)).

$$K = \frac{P(A) - P(E)}{1 - P(E)}$$

Interpretation of the kappa statistic values were based on the following descriptions: $\geq$0.75 indicated excellent agreement, 0.40-0.74 indicated fair to good agreement and <0.4 indicated poor agreement (Kirkwood and Sterne, 2003). The standard error ($SE_{(0)}$) used to calculate the 95% confidence intervals was based on the null hypothesis that agreement between the two datasets was no better than chance.

Results

Misclassification

Classification was 100% (122/122) accurate for controls and 83% (35/42) accurate for cases. Five of the misclassified cases were horses that stumbled badly and had fallen onto their knees causing their riders to be unseated, but had not fulfilled the case definition that required the horse's shoulders and quarters to touch the ground. The other two cases that had been misclassified were 'rider only' falls, caused by the horse hitting the fence hard; however, neither of these two horses fell onto their knees, shoulders or quarters. Video analysis thus indicated some misclassification of cases (7/42) by fence judges. The footage for the control horses included only one 'awkward' jump, whereby the horse briefly 'straddled' a log fence before continuing on the course without incurring any penalties.

Verification of objective data obtained by questionnaire

Comparisons were made between data collected by telephone interview and equipment viewed on the videotapes. The equipment verified was the presence of spurs worn by the rider and the type of bit and type of noseband used for the horse. Results of the agreement between the datasets are shown in Table 1.

Table 1. Equipment used during the cross-country phase of eventing competitions in Great Britain (2001-2002). The level of agreement between data provided by cases and controls during a telephone interview and data obtained from video footage.

Variable	Number (%) of cases providing identical data to that obtained by video footage	Cases: Kappa Statistic (95% confidence interval)	Number (%) of controls providing identical data to that obtained by video footage	Controls: Kappa Statistic (95% confidence interval)
Spurs	42 (91.3)	0.46** (0.18, 0.73)	115 (95.8)	0.53** (0.35, 0.70)
Type of bit	27 (93.1)	0.87*** (0.63, 1.11)	75 (93.8)	0.87*** (0.72, 1.01)
Type of noseband	20 (60.6)	0.34* (0.19, 0.48)	74 (76.3)	0.52** (0.40, 0.65)

* poor agreement
** fair to good agreement
***excellent agreement

Speed of approach and quality of previous jumping effort

Data provided by riders during the telephone interview with reference to their perceived speed of approach to the selected fence is summarised in Table 2. A poor level of agreement was found between the riders' reporting of their speed of approach to the selected fence and the observer's classification (Table 3).

Due to the subjective nature of the categorical variable of the quality of the previous jumping effort, the original respondent categories used in the telephone interview were collapsed into two categories: very well / well and not very well / not at all well. The level of agreement between the two datasets and the observer was considered to be fair to good for cases and poor for controls (Table 3).

Table 2. Summary of the reporting by cases and controls of their speed of approach to the selected fence, in a study of risk factors for horse falls during the cross-country phase of eventing competitions in Great Britain (2001-2002).

	Number of cases (%)	Number of controls (%)
Appropriate speed	30 (75.0)	106 (93.8)
Too slow	5 (12.5)	5 (4.4)
Too fast	5 (12.5)	2 (1.8)

Table 3. Speed of approach to the selected fence and quality of previous jumping effort during the cross-country phase of eventing competitions in Great Britain (2001-2002). The level of agreement between data provided by cases and controls during a telephone interview and data obtained from video footage.

Variable	Number (%) of cases providing identical data to that obtained by video footage	Cases: Kappa Statistic (95% confidence interval)	Number (%) of controls providing identical data to that obtained by video footage	Controls: Kappa Statistic (95% confidence interval)
Speed of approach to selected fence	28 (70.0)	0.20* (-0.03, 0.43)	104 (92.0)	0.15* (0.02, 0.29)
How well the horse jumped the previous fence	28 (90.3)	0.52** (0.17, 0.87)	99 (90.0)	0.10* (-0.08, 0.29)

* poor agreement

** fair to good agreement

***excellent agreement

Subjective description of horse falls

Factors associated with the 33 correctly classified horse falls that were visible on video footage were summarised (Table 4).

Table 4. Factors associated with 33 horse falls selected for inclusion in a case-control study of risk factors of horse falls in eventing competitions in Great Britain (2001-2002).

Description of horse fall	Number (%) of horse falls	Number (%) of rotational falls	Number (%) of non-rotational falls
Hit fence with front legs	17 (51.5)	3 (37.5)	14 (56.0)
Hit fence with hind legs	3 (9.1)	0 (0.0)	3 (12.0)
Hit fence with chest	9 (27.3)	5 (62.5)	4 (16.0)
Horse stumbled and fell on landing	4 (12.1)	0 (0.0)	4 (16.0)
Total	*33 (100)*	*8 (100)*	*25 (100)*
Additional features of fall, (falls were described by one or more features).			
Took off too close to fence	14 (42.4)	6 (75.0)	8 (32.0)
Took off too far away from fence	2 (6.1)	0 (0.0)	2 (8.0)
Horse tried to refuse	4 (12.1)	1 (12.5)	3 (12.0)
Fence involved taking off and/or landing in water	11 (33.3)	0 (0.0)	11 (44.0)

Discussion

Misclassification of the response variable for a study of horse falls in cross-country competitions was identified by video footage as 17% for cases and 0% for controls. The classification of cases and controls by fence judges was recognised as a possible source of error at the time of study design. Fence judges are unpaid volunteers, many of whom have no previous experience of fence judging. Fence judges may be on duty for up to 9 hours, with no scheduled rest periods. Horses follow each other on the cross-country course at approximately two-minute intervals, with each fence on the course being judged by a pair of fence judges. Factors which may contribute to misclassification include: fatigue and lack of concentration which may have resulted in some fence judges not remembering details of a fall, or perhaps even not witnessing the fall. Due to the length of cross-country courses and the siting of the fences, no practical alternative existed to reliance on fence judges for the identification of cases. As a result, misclassification of the response variable by fence judges was perceived as inevitable and unavoidable.

None of the 122 horses recorded as controls by fence judges had been misclassified. The lack of misclassification of controls was as expected. A fall of horse is a rare event, and thus is likely to be noticed by a fence judge, regardless of a lapse in concentration. Following a fall of horse and/or rider in the study, one or more event officials visited the judges at the fence, to check that all paperwork has been completed correctly, to comply with current health and safety requirements of British Eventing. Therefore, it is considered unlikely that a fall of horse would go unnoticed by the fence judge and/or not be recorded correctly.

Seven cases (17%) from the 42 studied on video were 'rider only' falls that had been misclassified by fence judges as horse falls, possibly as a result of the fence judge not seeing the fall properly. Five of the misclassified horses stumbled onto their knees and appeared to narrowly avoid fulfilling the case definition of a horse fall by falling onto their shoulders and quarters. It is expected that the risk factors associated with the stumbles experienced by these misclassified case horses were similar to the risk factors identified for horse falls by this study; however, the potential effect of the misclassification warrants further investigation. Misclassified cases have implications for the sport, including the production of incorrect statistics suggesting an inflated risk of a horse fall when compared to the true risk of a horse fall. Implications of misclassified horse falls for riders include; riders being prevented from completing the cross-country course, due to the compulsory retirement of any competitor incurring a fall of horse (B.E. Rules, 2001), and their horses' records being marred, which would be of particularly relevance if the horse was for sale.

Verification of equipment used

The level of agreement between data collected by questionnaire and video observation of equipment used during the cross-country phase was classified as poor to excellent for cases (kappa: 0.34-0.87) and fair/good to excellent for controls (kappa: 0.52-0.87) depending on the variable analysed. A high level of agreement had been anticipated because most competitors use the same equipment for every competition. Sources of error may have included inaccurate data collection from video footage. The lack of clarity of some of the footage meant that identification was difficult; however, in an effort to obtain accurate data, missing data were recorded for unclear footage. Despite this, the level of agreement for the type of noseband used on case horses between the two sources of data was poor (kappa <0.40). The reason for the poor agreement is unclear, particularly as the level of agreement between the type of bit and presence of spurs was fair to good (kappa: 0.46-0.87) and similar to the level of agreement identified for data provided by controls (kappa: 0.53-0.87). In addition, data for the variable of type of noseband were obtained from video footage with similar ease to data for the variable of type of bit.

Verification of speed of approach

The speed of approach to a fence has previously been identified as a risk factor for horse falls (Murray et al., 2004b). Competitors who believed they had approached the selected fence at an appropriate speed had a lower risk of falling than riders who reported an approach speed that was too slow (OR=5.0) or too fast (OR=6.3). Murray et al. (2004b) acknowledged that this result should be interpreted with caution as the competitors' retrospective opinion of their speed may have been subject to reporting bias. Subjective verification of the speed of a sample of cases and controls in this paper has indicated that whilst cases (25%) were more likely than controls (6.2%) to report an inappropriate speed, the reported speed of cases and controls had similar and poor agreement with the observed footage (kappa=0.15-0.20). We recognise that whilst our classification of approach speed may have been subjected to observer bias, the poor agreement between riders and observed footage may reflect the difficulty in applying a gold standard to subjective variables. We consider that the previously reported association between an approach speed that was too slow or too fast and an increased risk of a horse fall (Murray et al., 2004b) may be a true association. Indeed, previous research suggests that non-differential misclassification of approach speed is likely to bias the strength of the association with the risk of a horse fall towards the null (Clayton and Hills, 1993; Garcia-Closas et al., 1999) or have little effect on the apparent association (Marshall, 1999).

Verification of quality of previous jumping effort

Case riders reported the quality of their jumping effort at the fence prior to the selected fence with fair to good agreement (kappa=0.52) when compared to the author's assessment of the video footage. The level of agreement between the subjective assessment of the quality of the previous jumping effort by control riders and the author was poor (kappa=0.10). Once again, the low level of agreement for the variable may reflect the lack of a 'gold standard' for subjective data.

Subjective description of the horse falls

Take-off point

Descriptive observations revealed that all eight rotational falls followed the horse hitting the fence with either their front legs (37.5%) or chest (62.5%). These observations support the conclusions of the Transport Research Laboratory (TRL) that rotational falls are caused by the horse hitting the fence between the knees and shoulder or chest (Walcott, 2003).

Fourteen (42.4%) of the 33 falls were associated with the horse taking off too close to the fence; leading to six of the eight (75.0%) rotational falls observed. No rotational falls were associated with the two instances when the horse took off too far away from the fence.

Refusals

Four (12.1%) horses were perceived as trying to avoid jumping the fence at which they fell by refusing or running past the fence. British Eventing changed the rule referring to jumping from a standstill in 2001, so that the maximum height that may be jumped from a standstill without penalty of a refusal was reduced from 50cm to 30cm, in an attempt to improve safety to horses and riders (B.E. rules, 2001). Anecdotally, one of the high profile rider fatalities of 1999 occurred as a result of the horse trying to jump from a standstill, somersaulting over the fence and landing on the rider. One of the four horses perceived on the video footage as trying to refuse the fence somersaulted and fell. Three of the four horses that were assessed as trying to refuse were being ridden towards the fence until the fall was unavoidable and were then seen to fall over the fence. The three riders of these horses were considered to be professional event riders who compete at a high level. Less experienced and/or 'competitive' riders may have incurred a refusal rather than a horse fall, as they might not have ridden the horse forward so strongly, thereby allowing the horse to refuse the fence. Video evidence thus provides some support for the B.E. rule that penalises jumping from a standstill, as four horses fell as a result of trying to stop in front of the fence.

Falls at water fences

Fences requiring a take-off or landing in water have been associated with an increased risk of a horse fall (Murray et al., 2004b), whilst an increased risk of injury to horses that fall has been observed for horses that fall in water as opposed to those that fall on land (Murray et al., 2004a). All 11 falls observed at fences associated with water were classified as non-rotational horse falls. Two of the falls that were seen on video showed the horses travelling along flat ground before being required to jump down a step into water. Both horses appeared not to recognise the fact that the water was there and looked to take another canter stride instead of jumping down the step, failed to prepare for a landing, and consequently, fell. This phenomenon may be similar to a person descending a flight of stairs and thinking that they had reached the bottom, when there was in fact another step. Indeed comments from riders whilst completing the questionnaire drew reference to the fact that there was a lack of difference in the colour of the ground prior to the water and the colour of the water. It is possible that the horses did not see and therefore, did not prepare for a lower landing in water, thus falling. Further research is needed to assess the ability of equine vision to detect the presence and depth of water. Three horses fell at different fences at which the horse was required to jump over a solid obstacle into water. In two instances the horses appeared to be surprised in mid air when they saw the water below, failed to prepare their front legs for landing and consequently fell.

The descriptive observations indicated that 24% (8/33) of falls were classified as rotational falls. The percentage of the sample of horse falls classified as rotational falls in this study was thus similar to the overall rate of 18% (33/180) of falls classified as rotational falls by fence judges in the case-control study of horse falls (Chapter 5). These figures indicate that approximately 1 in every 5 horse falls is expected to be a rotational fall, with the perceived associated increased risk of serious injury or fatality to the rider. The frequency of rotational falls observed in this study, and their anecdotal association with serious injury and fatality to riders, suggests that intervention studies should be conducted with the aim of minimising the risk of this type of horse fall.

This study provides evidence for some misclassification of cases and no misclassification of controls by fence judges. Verification of objective and subjective data collected by questionnaire interview with data obtained from video footage indicated varying agreement for objective variables. The riders' subjective assessment of their speed of approach to a fence had a poor level of agreement with the author's subjective assessment, indicating the difficulty in verifying subjective data.

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CHAPTER SEVEN:

Memory decay and performance-related information bias in the reporting of scores by event riders

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Abstract

We used data from a case-control study investigating risk factors for horse falls in the cross-country phase of eventing in Great Britain (G.B.) to examine evidence for memory decay and information bias. Responses to two questions obtained by telephone for 173 cases and 521 controls were examined for evidence of differential reporting according to the respondent's case-control status and performance in the dressage and cross-country phases of competitions. Information bias was found in the accuracy of reporting dressage penalty scores when analysed as a function of performance level (good / poor). Poor dressage performers were less likely to report accurate dressage scores than good performers. The accuracy of reporting dressage scores decreased as the time between the event and questionnaire completion increased, with no case-control interaction. Competitors who incurred cross-country jumping penalties at the event preceding the selected event reported their cross-country scores with less accuracy when compared with competitors who incurred no penalties. No information bias was found when the reporting of dressage and cross-country scores were analysed as a function of respondent category (case / control).

Keywords: Reporting bias, Memory decay, Risk factors, Horse, Cross-country.

Introduction

Case-control studies are subject to biases arising from differential reporting from cases and controls (Schlesselman, 1982). Differential reporting can result in Type-I or Type-II errors. Type-I errors can occur if cases are more likely than controls to fail to report risk factors - particularly, risk factors with negative associations. Type-II errors can occur if cases are more likely than controls to recall and report risk factors in an attempt to explain the outcome.

Most of the published literature on differential reporting is from the social sciences and human medicine rather than from veterinary medicine. Reporting bias is more likely to take place when respondents believe the exposures to be risk factors (Rockenbauer et al., 2001; Cockburn et al., 2001; Weinstock et al., 1991), although reduced reporting of exposures by cases has been documented (Lindefors-Harris et al., 1991). Reporting bias is exposure-specific because cases can under-report some variables and over-report others (Delgado-Rodriguez et al., 1995; Werler et al., 1989). Other studies have found little or no evidence for differential reporting between cases and controls (Pleiss and Miller, 1979; Holmberg et al., 1996; Mackenzie and Lippman, 1989; Friedenreich et al., 1991; Verkerk et al., 1994).

Information bias due to differential reporting has been attributed to variables such as the respondent's age (Chen and Anthony, 2003) and socio-economic status (Artaria and Henneberg, 2000). Performance-related differential reporting was found in a study by Shepperd (1993), which revealed that poor performers reported inflated Scholastic Aptitude Test scores when compared to high performers. This difference was attributed to poor performers seeking to disguise their lack of ability, because the tendency to inflate their scores reduced when accuracy was rewarded. Krueger and Mueller (2002) revealed that those who obtained low scores on a performance test overestimated their performance relative to others. In contrast, high scorers underestimated their own performance.

Information bias also can result from inaccurate reporting due to time-related memory decay. Injury rates reported by New York farmers were underestimated when recalled >=2 months after the event (Jenkins et al., 2002). In contrast, recall periods of > 2 days lead to considerable under-reporting of infant-diarrhoea morbidity by parents in a study conducted in rural Tamilnadu (Ramakrishnan et al., 1999). Hopwood and Guidotti (1988) concluded that the time period of 6 months led to reporting bias because additional symptoms of toxic exposure were reported retrospectively. Coughlin (1990) summarised results from validation studies and concluded that poor recall can be associated with increased reporting bias in case-control studies.

Reasons for reporting bias include increased memory loss of cases due to concussion (McCrea et al., 2002), motivation to recall exposure variables (Rockenbauer et al., 2001; Bar-Oz et al., 1999) and cases being more reluctant than controls to report. These potential biases were of particular relevance to our study and are discussed below.

Eventing is an equestrian sport in which horse and rider combinations complete three competition phases: dressage, show jumping and cross-country. Most competitions take the format of one-day events or three-day events. Events are graded according to the level of difficulty of the cross-country course. The one-day event levels (in ascending order of difficulty) are: Intro, Pre-novice, Novice, Intermediate and Advanced. Three-day events are rated as 1,2,3, or 4-star, (4-star the highest). At one-day events, each horse and rider combination completes all three phases on the same day, in the order dressage, show jumping, cross-country. At three-day events, competitors complete each phase on a separate day in the order dressage, cross-country and finally show jumping. Penalty points are awarded for each phase. The competition is won by the combination with the lowest total penalty score. Any horse that falls during the cross-country phase is subject to immediate elimination from the competition.

Concussion can result from a fall from a horse (although no published incident rates are available) and associated memory loss varies in length according to the severity of the injury (McCrea et al., 2002). Event riders are likely to have different motivational reasons for accurate reporting compared with subjects investigated within other epidemiological studies. This is because riders are reporting not only their own experiences, but also those of a horse and rider partnership. Many riders will believe that they 'owe it to their horse' to report events accurately - particularly if the horse was injured as a result of a fall at the competition. These competitors tend to think very highly of their horses (as a result of emotional attachment arising from the horse's performance ability, temperament or qualities as a pet), and therefore might be more likely to attribute blame for a fall to themselves rather than to their horses. Conversely, some competitors might have a low opinion of and no emotional attachment to their horse and be more likely to blame the horse for any mistake made by the partnership. Reporting accuracy therefore might be biased by the riders' feelings towards the horses that they were riding.

Cases might have been more reluctant than controls to report risk factors as a consequence of the large amount of negative publicity that surrounded the sport of eventing, following five rider fatalities in 1999. Some cases might have believed that if the study were to identify significant risk factors, then the sport of eventing might face further criticism, unwanted changes or even the sport's demise. The motivation for accurate reporting by event riders is therefore a complex area that might involve factors that are unique to equestrian sports competitors.

We focused on responses to two questions included in a telephone interview for a case-control study investigating risk factors for falls of horses on the cross-country phase in the sport of eventing. Data collection of two explanatory variables (dressage and cross-country performances) were used because they could be verified. We looked for evidence of differential reporting between cases and controls and between good and poor performers. The effect of memory decay was assessed for correct recall of dressage penalty scores.

Potential confounding variables for the study presented here included: rider status (professional or amateur event rider) and event type (one- or three-day event). Rider status was considered to be a potential confounder because professional riders compete more horses and attend more events per year than amateur riders. This could have had the effect of making recall of scores more difficult for professional riders. Event type was viewed as a potential confounder because three-day events are fewer and more prestigious than one-day events. In addition, riders only are permitted to ride a maximum of two horses at a three-day event compared with a maximum of five horses at a one-day event. Therefore, scores may have been more easily recalled from three-day events than from one-day events. We believe this is the first study to investigate reporting bias amongst event riders, and is a unique contribution to the literature - particularly because the respondents were reporting the experiences of a horse and rider partnership. Our purpose was to establish whether information bias was present as a result of differential reporting from cases and controls and from good and poor performers.

Materials and Methods

Study population

Our data were taken from a case-control study of the risk factors for falls of horses in the sport of eventing.

Study design and data collection

The cross-country phases of 120 randomly selected horse trials were attended during the years 2001 and 2002. Cases were horses that fell at a numbered obstacle on the cross-country phase. A "horse fall" was defined as the shoulders and quarters of the horse touching either the ground or the obstacle and the ground at the same time (British Eventing rules, 2001). Individual matching was used to obtain controls from the competition venue matched on the day of the event. The controls were selected using random numbers, from all jumping events that did not result in a horse fall. The case-control study of risk factors was designed to have sufficient power (80%) to detect an odds ratio of 2.0, based on a sample of 194 cases and 582 controls (1:3 ratio). After excluding missing data, information was available for 173 cases and 521 controls. These data were used in the study presented here, to investigate reporting bias and memory decay.

A letter explaining the study was sent to all cases and controls within 3 days of the event. The letter informed the riders of imminent contact by telephone to complete a questionnaire relating to the event and additional areas such as horse and rider training. The telephone questionnaires were administered as soon as possible to each rider selected as a case or control.

Responses from the questions used for this study were validated with information on a database at British Eventing (B.E.), the governing body of the sport in Great Britain. The competition scores in the database were supplied by the B.E. scorers present at the events. (Most scores are reported in an electronic format - minimising errors in data entry.)

Data analysis

The two binary outcome variables were: accuracy of dressage score recall (accurate=0, inaccurate=1) and accuracy of cross-country score recall (accurate=0, inaccurate=1). The four explanatory variables were: time since event, case-control status (respondent category), dressage performance and cross-country performance. These variables were selected on the basis of potential for bias from inaccurate and/or differential reporting. The potentially confounding effects of rider status (professional or amateur event rider) and event type (one- or three-day event) also were considered.

Accuracy of dressage score recall and time since event

The difference between each rider's reported score and actual score provided a measure of the level of accuracy of dressage score recall. Recall accuracy was analysed as a binary variable (accurate=0, inaccurate=1) rather than as a continuous variable because the data were not normally distributed and could not be transformed to a normal distribution.

Dressage scores were awarded in penalty points; therefore, the lower the penalty point score, the better the performance. One-day event dressage tests are marked by a single judge and therefore result in penalty scores that are integers. Three judges are used to mark three-day event dressage tests. The average mark awarded by the judges for a three-day event competitor (rounded to two decimal places) is used to calculate the competitor's dressage score. To allow for differences in reporting style between riders (integers or decimals), a recalled score was considered accurate if it was within 0.5 penalty points of the B.E. database score. Generalised linear mixed models were fitted to the data with the matching variable as the random effect (Armitage et al., 2002). Time since the event was introduced as a fixed effect into the model and considered as a potential explanatory variable. Rider status (professional or amateur event rider), respondent category (case or control) and event type (one- or three-day event) were evaluated as potential confounders.

Accurate dressage-score recall as a function of case-control status and dressage performance

Accurate dressage score was considered as a binary outcome variable in relation to the two binary explanatory variables of case-control status and dressage performance.

To investigate the relationship between dressage performance and accuracy of dressage score recall, the riders were divided into two groups. The groups were based on the dressage score in relation to the median dressage penalty score for the type of event (one- or three-day event). The 'good performers' group included those competitors who had achieved a score equal to or better than (i.e. less than) the median score for their event type. The poor performers consisted of competitors awarded more penalty points than the median score. (The hypothesis was that good dressage performers might have been more likely to report the score they had achieved than poor performers - who might have been tempted to conceal their lack of ability by reporting a better score.) Generalised linear mixed models were used to analyse the relationship between the independent fixed effects of dressage performance (good performers = 0, poor performers = 1) and case-control status with the outcome variable of accurate dressage-score recall. Accuracy of dressage score recall was analysed as a binary variable (accurate = 0, inaccurate = 1). The matching variable was included as the random effect. The potential confounding effects of rider status and event type also were considered.

Accuracy of cross-country penalty recall as a function of cross-country performance and case-control status

Questionnaire respondents were asked to recall their cross-country score at the event prior to the event at which they were selected as a case or a control. The accuracy of recall of cross-country penalty score was considered as a function of the competitor's performance in the cross-country phase at that event and case-control status. The binary outcome variable was the accuracy of the competitor's recalled cross-country penalty score (accurate = 0, inaccurate = 1). The variable was analysed as a binary variable rather than as a continuous variable, because elimination or retirement of a competitor was not recorded as a penalty score. The binary explanatory variable of cross-country performance was the competitor either incurring cross-country jumping penalties or not (no penalties = 0, penalties = 1). Generalised linear mixed models were used to analyse the relationship between the independent fixed effects of cross-country performance and case-control status with the outcome variable of accurate cross-country score recall. The potential confounding effects of rider status (professional or amateur event rider) and event type (one- or three-day event) also were considered.

Models were fitted using the function glmmPQL in the statistical package R (www.r-project.org), and were compared using the likelihood-ratio statistic. Variables with $P \leq 0.05$ were considered to be statistically significant and a change in the regression parameters of $\geq 25\%$ was considered to indicate confounding.

Results

Dressage penalty score recall

Eighty-six percent of riders (596/694) provided a score when asked to recall their dressage score for the selected event. Questionnaires were completed between 1 and 73 days after the event. Dressage scores achieved ranged from 23 to 63.3 penalty points (median=41.0) for one-day event competitors, and from 38.4 to 87.8 (median=60.2) for three-day events. A summary of the accuracy obtained by riders in the recall of their dressage scores is displayed in Table 1.

Table 1. The distributions of the differences between the reported and actual dressage scores, for cases and controls selected from horse and rider combinations at one- and three-day events in Great Britain (2001, 2002).

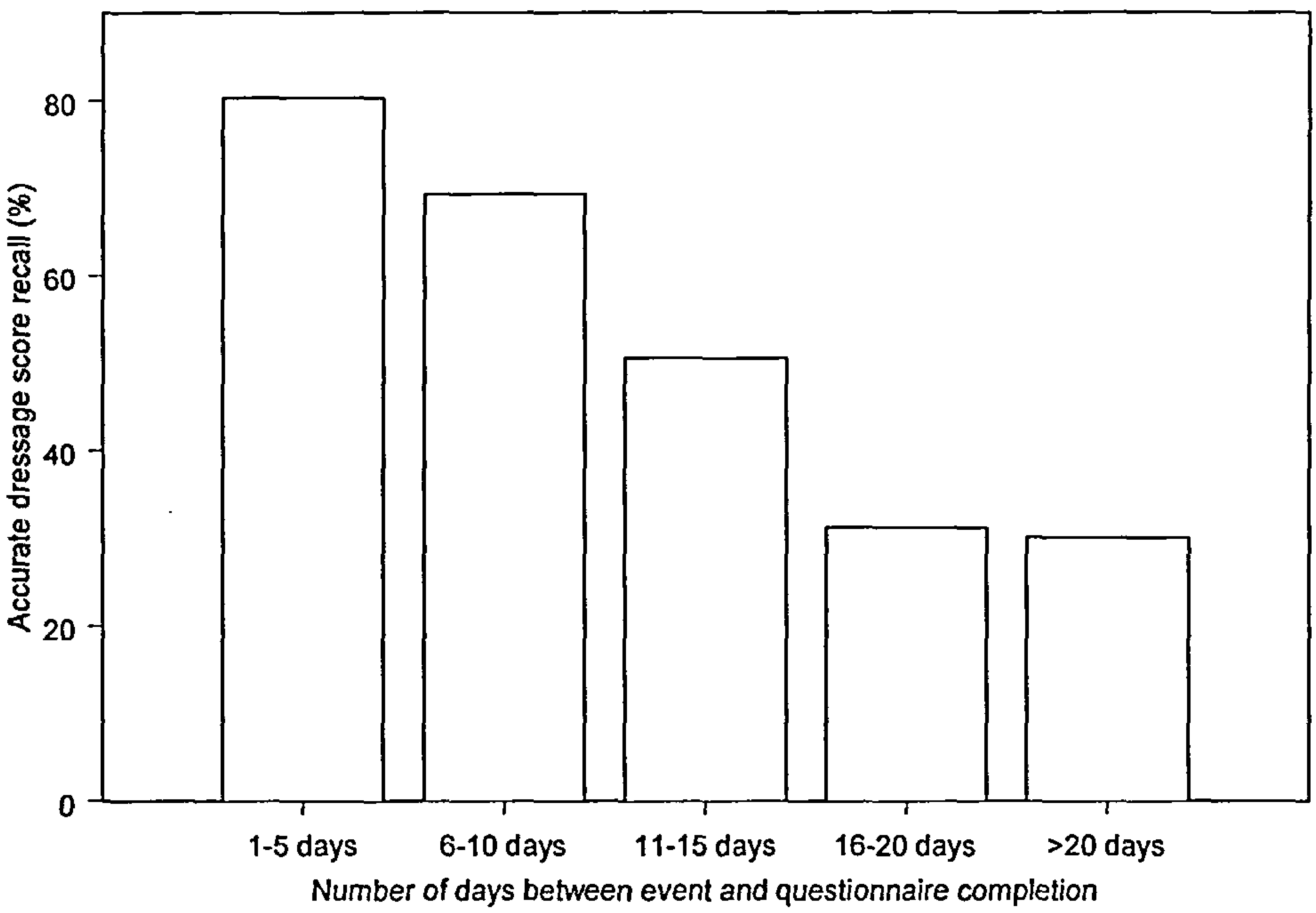
Recalled score minus actual score	Cases (falls) (n=147)		Controls (n= 447)	
	n	%	n	%
≤ -5	8	5.4	18	4.0
> -5 ≤ -3	2	1.4	7	1.6
> -3 ≤ -1	21	14.3	44	9.8
> -1 ≤ +1	115	78.2	362	81.0
>1 ≤ 3	0	0.0	9	2.0
>3	1	0.7	7	1.6

The level of accuracy was represented by reported scores minus the actual scores in penalty points. Riders typically gave a slightly lower (i.e. 'better') dressage penalty-point score than actually was obtained (as indicated by the negative values). The mean (sd) of the difference between reported and actual scores was –0.9 (3.0) for cases (range: -28.4 to +4.6) and –0.5 (2.8) for controls (range: -22.8 to +25.0). The median difference in the scores reported by cases and controls was zero for both groups.

Accuracy of dressage score recall: time since event

The relationship between time since the event and the percentage of respondents with accurate recall is shown in Figure 1 (univariable P<0.0001). Dressage scores were less likely to be reported accurately as the number of days increased between the event and questionnaire completion [b (SE) = 0.05 (0.01)]. No confounding existed between the variables of rider status, case-control status and event type and the response variable of recall accuracy.

Fig. 1. Relationship between accurate dressage penalty score recall and the time since the event for all respondents (cases and controls) in a case-control study of event riders in Great Britain (2001, 2002).



Accuracy of dressage score recall: Dressage performance and case-control status

Riders with dressage scores below the median were less likely to report an accurate dressage score [regression parameter b (SE) = 0.81 (0.18), P<0.0001]. Accurate scores were reported by 31% of good performers, compared with 28% of poor performers. However the mean difference (sd) between reported and achieved scores was -2.45 (5.59) for good performers and -0.70 (7.46) for poor performers; whilst both groups were tending to report 'better' scores than they had achieved, the degree of inaccuracy was greater for good performers. The case-control status of the rider (P=0.48) was not associated with the accuracy of the score reported by the rider. There was no evidence of confounding between the variables investigated.

Accuracy of cross-country penalty recall: Cross-country performance

Competitors incurring cross-country jumping penalties were less likely to supply correct information than competitors who had a penalty-free cross-country round [regression parameter b (SE) = -1.08 (0.30), P<0.0001). The case-control status of the rider was not significantly associated with the outcome variable of accurate cross-country reporting, (P=0.32). There was no evidence of confounding by rider status and event type.

Discussion

This study revealed no case-control information bias, but did show performance-related bias for the reporting of scores. All riders who had experienced horse falls in the study had recovered sufficiently, from any injuries sustained, to complete the telephone questionnaire. Some of the case riders had suffered concussion as a result of their fall and reported an inability to recall events during the time immediately prior to the fall; however, this memory loss did not appear to have affected the recall of the scores under investigation in this study. The nature of the fall and the severity of any injuries sustained by riders appeared to have little effect on their ability to provide accurate responses.

Data collected by telephone questionnaire depends on contacting the subject and arranging a convenient time for completion of the questionnaire. As a result, the time from event to questionnaire completion varied. In some instances, the time was longer than originally anticipated in the study design. With the varying time to questionnaire completion, memory decay that resulted in a reduction in the accuracy of information provided had important implications for the overall project.

The accuracy of dressage score recall decreased by approximately 0.05 penalty points with each day that passed between the event and questionnaire completion. Dressage scores were less likely to be reported accurately as the number of days between the event and questionnaire completion increased ($P<0.0001$). Comparison of our results with published literature of the effect of time on recall was difficult due to the different time scales in each study. Results of previous research were based on comparisons of recall periods of < or > 2 days (Ramakrishnan et al., 1999), 2 months (Jenkins et al., 2002) and 6 months (Hopwood and Guidotti, 1988) since the event of interest. Most of the data presented in this study (98%) were collected between 3 days and 60 days after the event of interest.

Analysis of the accuracy of the dressage scores reported indicated no case-control bias ($P=0.48$). The dressage score is thought to provide a measurement of the training of horse and rider (British Eventing dressage tests). It had been hypothesised that cases might be reluctant to provide information that suggested that inadequate training of horse and/or rider contributed to the cross-country fall. This hypothesis was rejected because a difference was not found in the reporting accuracy of cases and controls. This supports the theory that riders might have been motivated by a sense of responsibility to their horses (or to the sport) to complete the questionnaire accurately.

Poor dressage performers were more likely than good performers to report an inaccurate dressage score. However, further inspection of the data revealed that the scores reported by poor performers were closer (-0.70) to the true score, than the scores reported by good performers (-2.45). Therefore it may be that whilst poor performers were more likely to report inaccurate scores than good performers, the inaccuracy of good performers was greater than that of the poor performers. This is not consistent with the hypothesis that poor performers were endeavouring to 'improve' their score to a greater extent than good performers. The reporting accuracy of good and poor performers needs further investigation to establish the explanation for the differential reporting that was apparent in the recall of dressage scores.

The effect of cross-country performance at the event preceding the selected event did not provide evidence of case-control differential recall (P=0.32). However, competitors incurring cross-country jumping penalties were less likely to report their scores accurately than competitors with penalty-free cross-country rounds (P<0.0001). The relationship between performance level and reporting accuracy was not confounded by the variable of rider status (professional or amateur event rider). No evidence of interaction was found between rider status and performance level - suggesting that any reluctance to report a poor performance is displayed equally by both groups of riders. These findings of differential reporting related to the performance of the respondent are in agreement with the findings of Shepperd (1993) regarding student performance in Scholastic Aptitude Tests. Differential reporting attributable to performance level may be explained partly by the competitive nature of many riders (who might have been reluctant to report a poor performance).

Differential reporting can increase or decrease the odds ratio depending on whether cases over or under report exposure to variables (Rockenbauer et al. 2001; Cockburn et al., 2001; Weinstock et al., 1991; Lindefors-Harris et al., 1991; Delgado-

Rodrigurez et al., 1995; Werler et al., 1989). In our study, cases reported dressage and cross-country scores with a similar level of accuracy as controls - providing evidence that differential reporting was not associated with the case-control status. Case horses were more likely to have been injured at the selected competition than control horses because the latter, by definition, did not fall. Injuries to the horse might have increased the rider's motivation to report events accurately. However, no information was available regarding any injuries sustained by the horses involved in this study. Future research is needed to explore any potential reporting bias attributable to the rider being affected by injuries to the horse. Differential reporting also might depend on the rider's opinion of and emotional attachment to the horse. Although such variables would be difficult to quantify, a solution could be for riders to rate their feelings towards the horse.

In conclusion, this study has provided evidence for information bias as a result of memory decay and performance-related reporting bias of event riders. Poor performers in the dressage and cross-country phases were less likely than good performers to report their scores accurately. No case-control bias was found in the accuracy of reporting dressage and cross-country scores.

Acknowledgements

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CHAPTER EIGHT:

Discussion and conclusion to the thesis

DISCUSSION AND CONCLUSION

The results reported in this thesis provide evidence of risk factors associated with horse falls on the cross-country course of eventing competitions in Great Britain during 2001-2002. The data were analysed initially as a complete dataset. Subsequently the dataset was split and analysed on the basis of event type (one- and two-/three-day events) and fall type (rotational and non-rotational). The results provided information on the effects of course and fence, rider, horse and event-level variables on horse falls within the study in the following categories:

- Horse falls at one-, two- and three-day events (Chapter 3)
- Horse falls at one-day events (Chapter 4)
- Horse falls at two-/three-day events (Chapter 4)
- Rotational horse falls at one-, two- and three-day events (Chapter 5)
- Non-rotational falls at one-, two- and three-day events (Chapter 5)

Different types of event and types of horse fall

Splitting the dataset on the basis of event type (one- and two-/three-day event) and type of fall (rotational and non-rotational) was considered important for the identification of risk factors for distinct groups of horse falls. The additional requirements of completing phases A, B and C prior to the cross-country course for horses competing at two- and three-day events meant that different risk factors might be expected at these events. The two main types of event (one- and two-/three-day events) were therefore separated for the analysis of risk factors associated with event type.

Rotational horse falls were hypothesised to be associated with more serious injuries to the rider when compared to non-rotational falls. Consequently, we considered it important to identify risk factors that were associated with this type of fall. As a result, the dataset was split and analysed on the basis of type of fall (rotational and non-rotational).

A summary of the significant risk factors that were present in two or more of the final multivariable models is provided in Table 1. Two variables were present in four of the five models (fences requiring a landing in water and the combined variable of the angle and spread of the fence). Categorical variables were ordered by ascending odds ratios and the model was rerun to obtain odds ratios used to calculate population proportional attributable risks (PPAR) for all variables associated with an increased risk of a horse fall. The PPAR indicates the impact that a variable has on a population, as the calculation is based on the risk of a horse fall when exposed to a variable (odds ratio) and the frequency of that variable in the dataset. A summary of the PPARs for the risk factors identified in two or more of the multivariable models in provided in Table 2.

Table 1. Variables associated with the risk of a horse fall during the cross-country phase of eventing competitions in Great Britain (2001-2002), which were significant in two or more models. Odds ratios and 95% confidence intervals are displayed.

Model / Variable	All horse falls	One-day event horse falls	Two-/three-day event horse falls	Rotational horse falls	Non-rotational horse falls
Angle and spread					
No angle, <2m	Ref.	Ref.	Ref.	Ref.	
No angle, ≥2m	3.2 (1.7, 6.2)	5.6 (2.3, 13.5)	2.7 (0.9, 7.8)	15.1 (1.8, 126.8)	
Angled fences	4.8 (2.1, 11.2)	6.6 (2.1, 21.4)	3.5 (1.1, 11.5)	20.2 (1.7, 234.0)	
Landing surface					
Firm/good-firm	Ref.				
Good	0.6 (0.3, 1.4)				
Good-soft/ soft/heavy	0.6 (0.1, 3.8)	Land*: Ref.	Land*: Ref.		Land*: Ref.
Water	5.7 (2.1, 15.5)	7.0 (2.3, 21.0)	10.0 (2.1, 48.6)		10.1 (4.3, 23.5)
Take-off surface					
Firm/good-firm	Ref.				
Good	2.3 (1.1, 4.8)				
Good-soft /					Land*: Ref.
soft/heavy	15.6 (2.5, 95.5)	Land*: Ref.			12.2 (3.1, 48.1)
Water	49.8 (10.4, 239.0)	25.0 (5.9, 105.6)			
Previous refusals No	Ref.	Ref.	Ref.		
Yes	23.0 (3.0, 178.1)	10.2 (1.2, 85.6)	11.5 (1.3, 100.4)		
Position					
Didn't know	Ref.	Ref.			2.3 (1.1, 4.7)
First	4.4 (1.4, 13.4)	5.7 (1.6, 20.9)			4.4 (1.1, 18.6)
Second or lower	0.5 (0.2, 0.9)	0.7 (0.3, 1.9)			Ref.
XC lessons (rider) No	Ref.	Ref.			
Yes	1.9 (1.2, 3.1)	2.0 (1.2, 3.6)			
Drop landing					
No	Ref.	Ref.			
Yes	3.4 (1.6, 7.3)	5.6 (2.3, 13.5)			

* A combined 'land' category was created for the ground classified as: firm, good-firm, good, good-soft, soft and heavy. The category of 'water' was compared to the reference category of 'land'.

Table 2: Summary of PPAR for significant variables associated with the risk of a horse fall during the cross-country phase of eventing competitions in Great Britain (2001-2002) in two or more models.

Variable	All horse falls	One-day event horse falls	Two-/three-day event horse falls	Rotational horse falls	Non-rotational horse falls
Angle and spread					
No angle, <2m	0.00	0.00	0.00	0.00	
No angle, ≥2m	0.15	0.17	0.18	0.38	
Angled fences	0.09	0.08	0.09	0.19	
Landing surface					
Good-soft/ soft/heavy	0.00				
Good	0.02				
Firm/good-firm	0.16	Land*: 0.00	Land*: 0.00		Land*: 0.00
Water	0.14	0.15	0.12		0.18
Take-off surface					
Firm/good-firm	0.00				
Good	0.25				
Good-soft /	0.06				
soft/heavy		Land*: 0.00			Land*: 0.00
Water	0.07	0.09			0.08
Previous refusals					
No	0.00	0.00	0.00		
Yes	0.01	0.01	0.02		
Position					
Second or lower	0.00	0.00			0.00
First	0.05	0.07			0.03
Didn't know	0.40	0.22			0.43
XC lessons (rider)					
No	0.00	0.00			
Yes	0.28	0.29			
Drop landing					
No	0.00	0.00			
Yes	0.14	0.18			

* A combined 'land' category was created for the ground classified as: firm, good-firm, good, good-soft, soft and heavy. The category of 'water' was compared to the reference category of 'land'.

Angle and spread of the fence

In four of the five models produced (all falls, one-day event falls, two-/three-day event falls, rotational falls), non-angled fences with a spread of two metres or greater and angled fences with any spread measurement were associated with an increased risk of a horse fall when compared with non-angled fences with a spread of less than two metres. The increased risk of a fall associated with non-angled fences having a base spread of two metres or more (OR=2.7-15.1) may be due to insufficient impulsion of the horse to jump the height and spread of the fence successfully. A logical explanation for the increased risk of falling associated with angled fences (OR=3.5-20.2) is that the horse needs to make additional adjustments at take-off, to ensure that both front legs are raised sufficiently to clear the angled fence. Insufficient impulsion at a wide fence, or failing to raise both front legs sufficiently at an angled fence, could result in the horse hitting the front of the fence at a point between its knees and shoulder. Therefore, a fall at either of these two types of fence could be caused by the horse hitting the fence with its upper forelimbs, thus fulfilling the criteria identified by TRL for initiating a rotational fall (Walcott, 2003). The high PPAR (0.38) attributed to wide, non-angled fences for rotational falls and the PPAR of the variable in other models (0.15-0.18) suggests that the risk associated with these fences should be investigated further through intervention studies. The odds ratio for wide, non-angled fences was surrounded by wide confidence intervals, thus indicating some uncertainty associated with the PPAR estimate for rotational falls at these fences. A potential intervention study would be to reduce the number of wide, non-angled fences and assess the effect on the number of falls, and in particular the number of rotational falls.

Fences requiring a take-off in water

Fences requiring the horse to take-off from water as compared to land were associated with an increased risk of a horse fall in three models (all falls, one-day event falls and non-rotational falls). The strength of the association appeared to be high, with odds ratios ranging from 12.2 to 49.8, although these estimates were imprecise and associated with wide confidence intervals. The increased risk of a horse fall at fences requiring a take-off in water may be may be due to the base of the fence being obscured under water, and / or the drag of the water unbalancing the horse. Examination of the PPARs associated with this variable (0.07-0.09) indicated that these fences did not appear to be associated with a large proportion of the falls in the dataset, as a consequence of their infrequent use on cross-country courses. Therefore, fences requiring a take-off from water should be given less priority than wide, non-angled fences as a method of reducing the number of horse falls.

Fences requiring a landing in water

Within the complete dataset, fences with a landing in water were 5.7 (95% C.I. 2.1, 15.5) times more likely to be associated with a horse fall than fences with landings on firm or good to firm ground (Chapter 3). Combination of the three 'ground' categories into a single 'land' category did not improve the fit of the model significantly. Fences with a landing in water compared to on land were associated with an increased risk of between 7.0 and 10.1 for falls at one-day events, two-/three-day events and non-rotational falls at any type of event, with PPARs for the models ranging from 0.12 to 0.18. The increased risk of a horse fall may be due to the drag of the water unbalancing the horse, or shadows and reflections on the surface of the water that made it difficult for the horse to judge the presence or depth of water.

The analysis of chapter five had limited power to identify variables associated with a small increase or decrease in the risk of a rotational fall, (80% power to detect odds ratios of 3.9 or above). Despite this, the absence of an association between landing in water and rotational horse falls may be a true association, as the analysis of rotational horse falls had sufficient power to detect odds ratios of the magnitude that were identified in other models ($OR \geq 7.0$). The increased risk of a non-rotational horse fall associated with fences with a landing in water and the estimated proportion of falls that were attributed to these fences in the study suggests that they should be considered as an important area for future intervention. Whilst reducing the number of fences requiring a landing in water may not reduce the number of rotational falls, it should be an effective strategy to reduce the overall number of horse falls by reducing the number of non-rotational falls. Further support for an intervention study aiming to reduce the risk of injury to horses was provided by our previous study that revealed that horses that fell in water had an increased risk of injury as compared to horses that fell on land (Murray et al., 2004a).

Previous cross-country refusals and riders who knew they were in the lead

Riders who were aware that they were in first place in the competition prior to the cross-country phase and riders who were clear on the cross-country course prior to the selected fence were identified as being at an increased risk of a horse fall (OR=4.4-5.7) in three models compared with riders who did not know their current position within the competition and riders who had already incurred one or more refusals on the cross-country course. A suggested explanation for the increased risk associated with these two variables is linked to the competitive nature of the sport and of the participating riders. Riders who are currently clear on the cross-country course or who are in the lead in the competition may be more determined to avoid incurring jumping (and time) penalties on the cross-country course than riders who have already had a refusal on the course or who were not in the lead. In a situation where the horse is reluctant to jump or the approach speed or take-off point is inappropriate for the fence, determined riders may ride their horses strongly, using all their resources (voice, legs, whip and spurs) to avoid a refusal, regardless of the potential risks. Determined and competitive riders may thus be more likely to risk a horse fall in situations where less determined riders might incur a refusal. The PPARs estimated for riders who knew that they were in the lead were low (0.05-0.07), reflecting the small number of competitors in this category within the study. Intervention is perceived as impractical (particularly at two- and three-day events) and the PPARs suggest that it would not be an effective strategy for reducing the number of horse falls within the population.

Cross-country lessons

Riders who received cross-country lessons were identified as being at a higher risk of a horse fall in the analysis of all types of event falls (OR=1.9) and one-day event falls (OR=2.0), compared with riders who did not receive cross-country tuition. A suggested reason for this association was that the more motivated and determined riders may have been more likely to receive cross-country lessons in an effort to achieve a good performance, as compared to less motivated riders. Alternatively, these riders may have perceived the need for extra tuition, in order to improve their performance in the cross-country phase. Examination of the data provided some support for this latter suggestion, as riders who received cross-country tuition had been competing in eventing competitions for a median of 4 years, compared with riders who did not receive cross-country tuition and had been competing for a median of 11 years. Despite this, the length of time that a rider had been competing in affiliated eventing competitions was not significantly associated with the risk of a horse fall in the analysis. The PPARs associated with the variable of cross-country tuition was high (0.28-0.29), reflecting the high proportion of case riders within the complete dataset receiving cross-country tuition (99/173). Further research is needed to investigate the increased risk of a horse fall associated with riders who received cross-country tuition within this study before recommendations of intervention can be made.

Drop landing

Fences with a drop landing (i.e. the ground on the landing side was at a visibly lower level than the ground on the take-off side of the fence), were associated with an increased risk of a horse fall at all events (OR=3.4) and at one-day events (OR=5.6) when compared to fences without a drop landing. The suggested explanation for this association was due to an inability by the horse to maintain its balance on landing due to the difference in ground level at take-off and landing. We hypothesised that these horses were likely to have stumbled forwards, resulting in a non-rotational type of horse fall; however, the variable of drop landing did not remain in the final multivariable model for non-rotational horse falls. The apparent lack of an association between drop landings and non-rotational falls needs further investigation, particularly as the classification of falls into rotational and non-rotational horse falls by fence judges was shown to be unreliable and the power of the analysis was low (Chapter 5). Further examination of horse falls occurring at fences with a drop landing is needed to establish the type of falls occurring at these fences and the reasons for these falls. The PPARs associated with fences with a drop landing (0.14-0.18) indicate that reducing the number of these fences on one-day event cross-country courses might be a useful intervention strategy to reduce the number of horse falls.

Speed of approach

The rider's opinion of their speed of approach to the fence was identified as a risk factor for a horse fall in the analysis of the complete dataset in Chapter 3. Riders who perceived that they had approached the selected fence at an appropriate speed had a lower risk of falling than riders who reported an approach speed that was too slow (OR=5.0) or too fast (OR=6.3). Data for the subjective variable of speed of approach to the fence could only be obtained retrospectively and was susceptible to bias from differential reporting by cases and controls. Despite no case-control bias being evident for the variables investigated in chapter 7, reporting bias has been shown to be exposure –specific (Delgado-Rodriguez et al., 1995; Werler et al., 1989). The subjective nature of the variable of speed of approach may have increased its susceptibility to differential reporting as a result of differential case-control motivation to report accurately (Rockenbauer et al., 2001; Bar-Oz et al., 1999). Therefore, this variable was excluded from subsequent analysis (Chapters 4 and 5). In order to obtain a reliable measure of the affect of speed on the risk of falling, a quantitative measurement of speed is needed for the final strides of the approach to the fence. An average speed calculated from the time taken to complete the course would not provide sufficient information, as a competitor who completed the course quickly may have achieved their time by travelling quickly between fences, whilst approaching fences slowly. Further research is needed to investigate the effect of approach speed on the risk of a horse fall to confirm whether, in the absence of potential for reporting bias, it remains a risk factor for horse falls.

Study design

The study reported in this thesis used a matched case-control study design. The use of a case-control study design is recommended as an economical method to investigate risk factors associated with rare outcomes (Beaglehole et al., 1993). The risk of a horse fall was previously estimated in a retrospective study by Singer et al. (2003) as 1 fall per 1160 jumping efforts. Horse falls were confirmed as rare events (1 fall per 2857 jumping efforts) by the prospective study reported in this thesis.

Disadvantages of a case-control study design included the possibility of selection or recall bias. The study was designed to minimise selection bias by the random selection of one- and two-day events. Bias that might have been introduced by the non-random selection of three-day events is likely to have been minimised by the matching of controls to cases. Data collected by questionnaire were obtained retrospectively from riders and consequently had the potential for bias from differential reporting by cases and controls (Schlesselman, 1982; Rockenbauer et al., 2001). The results of the analysis presented in Chapter 7 provided evidence that no case-control response bias was present for the variables investigated (reporting of dressage and cross-country scores). Performance-related response bias was shown to exist for reporting of dressage and cross-country scores. Poor performers were less likely than good performers to report their scores accurately. This bias could have had the effect of masking any effect of performance on the risk of falling. Consequently, for the purposes of analysis we used data from the B.E. website for the dressage and show jumping penalty scores at the selected event, thus eliminating the potential for response bias from these variables.

Matching

A potential limitation of the study was the matching used to select controls. Matching on the variables of venue and day of cross-country competition had the advantages of controlling for the potential confounding effects of month, weather and geographical location of the event. However there were also disadvantages, in particular, if the matching variables were confounders in the source population, then the observed effects in the sampled data may have been biased towards the null (Rothman and Greenland, 1998). In contrast, if the matching variables were not confounders in the source population, but were associated with the exposure, then the observed exposure effect would again be biased towards the null. These biases could have the effect of causing variables that were significantly associated with the risk of falling in the population to be non-significant in the analysis of the sampled data (Rothman and Greenland, 1998). Therefore, caution must be used when interpreting the results of non-significant findings in a matched study, such as the study presented here. Due to potential bias from matching, further research is needed to investigate the association between variables that were non-significant in this study and the risk of falling.

This study did not provide evidence to support an association between specific variables previously hypothesised to have been associated with the risk of a horse fall. In particular, variables such as: combination fences, upright fences and the previous fox-hunting experience of horse and rider were not associated with the risk of a horse fall in this study. Whilst this study has provided no evidence for variables such as fox-hunting experience to be associated with the risk of a horse fall, matching has the potential to bias associations towards the null. An unmatched case-control study design would enable further investigation of these variables.

Matching on competition venue and day of cross-country competition hindered the analysis of the following variables; event type (one-, two- or three-day event), course length, total number of jumps and total number of jumping efforts. In Great Britain, only two CCI 3* and two CCI 4* events took place annually during 2001 and 2002. These four competitions were associated with the longest courses with the greatest number of jumps and jumping efforts, and took place as the only class of eventing competition at their respective venues. Therefore, matching had the effect of creating concordant matched sets for three variables (course length, number of jumps, number of jumping efforts), as controls and cases were recruited onto the study from the same class. Some CCI 1* and CCI 2* competitions were held in conjunction with one-day eventing competitions, but this was rare, creating only two discordant sets for the variable of event type (one- or two-/three-day event). Further analysis, using unmatched controls, is thus needed to establish whether or not the variables of event type, course length, number of jumps and number of jumping efforts are associated with the risk of a horse fall.

Misclassification of cases

Examination of video footage revealed that no controls and 17% (7/42) of cases had been misclassified by fence judges (Chapter 6). Whilst the correct classification of controls was encouraging, the correct identification of cases (horse falls), particularly rotational horse falls, is crucial for the correct identification of risk factors associated with horse falls. Video footage was not available for all cases included in the study, which meant that reanalysing the dataset without the 7 misclassified cases might have introduced bias related to factors such as fence type and siting of the fence. For example, siting of video cameras was partly related to the 'interest' associated with individual types of fence and the number of fences that could be filmed from one camera position. Hence, water fences were always recorded, whereas 'less interesting' fences or fences that were not within sight of any other fences were sometimes not filmed by the companies.

Despite the observed misclassification of cases, the 'stumbles' experienced by many of these horses were very similar to the early stages of many horse falls. The risk factors associated with many of the non-rotational horse falls and the misclassified 'stumbles' are expected to be similar, thus having little effect on the results of the study.

Recommendations for future research

Intervention studies

Observational studies, such as the case-control study reported in this thesis, are useful for generating hypotheses for associations between risk factors and an outcome. Intervention studies are needed to provide unbiased support for associations between risk factors and an outcome by reducing exposure to previously identified risk factors and by assessing the effect of the intervention on the outcome. In addition, the availability and acceptability of an intervention to the population for which it is intended is an important aspect of an intervention study (Beaglehole et al., 1993). We recommend that intervention studies should be used, in particular, to assess the effect of reducing the exposure of competing event horses to the risk factors of non-angled fences with a spread of $\geq$2 metres and fences with a landing in water. Results of these intervention studies can then be used to develop effective methods of reducing the number of horse falls on cross-country courses. The suggested interventions are available to course designers, but the acceptability of the interventions to course designers and riders needs assessing. We anticipate; however, that if the interventions are successful in reducing the number of horse falls and associated injuries then the industry should support the reduced use of wide, non-angled fences and fences with a landing in water.

Testing of models

External validity is essential to obtain an accurate measurement of a model's performance to predict outcomes for other datasets. Previous research has shown logistic regression models to perform better than other modelling methods when used to predict outcomes within different datasets (Terrin et al., 2003). The sensitivity and specificity of the models presented in this thesis were calculated using data from which the models were created. Further information on the external validity of the models reported in this study should be obtained by assessing the predictive capacity of the models on new datasets obtained from events in Great Britain and throughout the world. This would provide useful information on the capacity of the model to predict horse falls in different events, eventing seasons or countries. This would establish whether a need exists for similar studies to be conducted to assess risk factors associated with horse falls in other countries.

Horse, rider and event random effects

An important extension of the work produced in this thesis would be to include an analysis of random effects attributable to the horse, rider and event by fitting mixed models (also known as multilevel models or random-effects models) to the data. Analysis using a mixed model would identify any variation in the risk of a horse fall at an eventing competition that was attributable to factors at the level of the horse, rider or event that had not been measured by fixed covariates. Random effects might include factors such as the genetic make-up and character of the individual horse or rider, the effect of the course designer and the level of prestige associated with different eventing competitions. Mixed models were used to investigate horse-, jockey-, race- and track-level variation in relation to the risk of falling in steeplechase races (Pinchbeck et al., 2002b). A proportion of the variation in the risk of falling in a steeplechase race was attributed to the horse and to the race in Pinchbeck's study.

Examination of the data indicated some duplication of horses and riders, suggesting that inclusion of random effects into the models was warranted. Two horses were recruited onto the study twice as cases, 15 horses that fell were additionally selected as a control and 48 horses were selected two or three times as controls. One hundred and twenty-five riders were recruited onto the study more than once as cases or controls, including 10 riders who incurred two horse falls and one rider who had three horse falls. (The relatively small number of riders competing at three-day events meant that these riders had a high chance of being selected more than once as a control for three-day event cases). Use of a mixed model would determine whether factors associated with individual case horses and riders increased their risk of a horse fall, or whether they were simply 'unlucky'.

Case-case study

The results reported in Chapter 5 provided evidence for factors that were significantly different between cases (rotational or non-rotational falls) and their matched controls. Additional analysis of the data could be conducted using a case-case study design. Case-case studies may be used to compare subgroups (e.g. rotational and non-rotational horse falls), which are likely to have different exposures for the same outcome (e.g. horse falls). This would allow the identification of significant risk factors that are more likely to be associated with rotational falls as compared with non-rotational horse falls. Advantages of a case-case study as compared to a case-control study include a reduction in recall and selection bias (McCarthy and Giesecke, 1999). Intervention strategies based on the results of a case-case study could help to reduce the number of rotational falls; however, there is a risk that it may be at the expense of increasing the number of non-rotational falls. Anecdotally, rider fatalities and serious injuries have been associated with rotational falls; however, little scientific evidence exists to support this theory. The risk of injury to horses and riders as a result of horse falls needs to be determined for the different types of fall (rotational and non-rotational). The potential benefits of reducing the number of rotational falls and the associated risk of serious rider injury or fatality could outweigh the disadvantages associated with increasing the number of non-rotational horse falls.

Psychological risk factors

Previous research has reported that participants in high-risk sports (e.g. paragliding, motor racing, scuba diving, water-skiing) were more likely to be classified as sensation seekers than non-participants (Franques et al., 2003; Freixanet, 1991). An association has also been identified between sensation seekers and risky driving (Jonah, 1997) and the risk of car accidents (Sumer, 2003). In addition, risk-taking behaviour was a predictor for injuries within agricultural settings (Westaby and Lee, 2003). Personality traits such as sensation seeking have thus been associated with participants of high-risk sports and the risk of accident or injury within different environments.

The theory of risk homeostasis (also known as risk compensation theory) proposed by Wilde (1982) suggested that increased dangerous behaviour is used to compensate for safer environments, thus maintaining a constant level of risk for the individual. The theory of risk homeostasis has been studied in the context of road safety, whereby it is proposed that people classified as sensation-seekers are particularly susceptible to maintaining their level of risk, for example by driving faster at night on roads with lighting compared with on roads without lighting (Assum et al., 1999). The homeostasis theory proposed by Wilde (1982) might apply to some event riders who may compensate for 'safer' courses and their increased ability or confidence by riding horses with insufficient experience, riding faster or riding with a less careful approach to fences. The risk associated with the cross-country course is undoubtedly part of the attraction of the sport to many riders and it is thus hypothesised that eventing may attract sensation seekers. A study that evaluated personality traits of riders would provide useful information regarding potential psychological risk factors for horse falls, such as sensation seeking and risk-taking behaviour.

Study of risk factors for rider injury and fatality

There is scope for a study designed to investigate risk factors associated with rider injury in the event of a fall. The wearing of protective helmets and body protectors is compulsory for the cross-country phase and is believed to have reduced the incidence of head injuries in recent years (Moss et al., 2002). Variables such as: rider experience, saddle design, type of helmet and body protector, ground surface, fence type and type of fall (rotational or non-rotational) need to be investigated as potential risk factors for rider injury.

Recommendations to the governing bodies of eventing

The following list details recommendations of interventions, which should be considered with a view to assessment of their effect on reducing the rate at which horses fall on the cross-country phase of eventing competitions. The recommendations are listed in order of importance, based on the number of models in which the variables were found and the size of the PPARs associated with these variables.

- Reduce the number of non-angled fences with a spread of two metres or greater
- Reduce the number of fences with a landing in water
- Reduce the number of fences with a take-off from water
- Warn riders of the dangers of riding 'too competitively' if they are clear or in the lead
- Reduce the number of angled fences
- Reduce the number of fences with drop landings
- Inform riders of the importance of an appropriate speed of approach

Education of riders may be useful in relation to some of the variables identified in this study. In particular, riders should be advised of the increased risk of a horse fall identified for riders who were currently clear on the cross-country course or who knew that they were currently in the lead. Riders should thus be advised of the potential dangers of riding 'too competitively'. Whilst the potential for case-control reporting bias has previously been discussed, inappropriate speed has been hypothesised as a potential risk factor for horse falls. Riders who assessed their speed of approach to the fence as too fast or too slow were associated with an increased risk of a fall compared with riders who believed that their approach speed was appropriate. Education and training of riders of the importance of a correct approach speed and how to achieve this speed might be beneficial to reducing the number of horse falls.

Conclusion

The variables identified in two or more multivariable models as being associated with an increased risk of a horse fall can be separated into two groups. Firstly, there are the variables associated with the competitive nature of the rider. These include: the rider's knowledge of their position, previous refusals on the cross-country course and cross-country tuition received by the rider (presumably in an effort to improve performance). Secondly, a group of variables relating to the fence and ground have been identified as increasing the risk of a horse fall. These variables include: fences with a take-off or landing in water, non-angled fences with a spread of two metres or greater, angled fences and fences with a drop landing. We recommend that the organisations responsible for rules relating to fence design within the sport of eventing in Great Britain, (British Eventing and the F.E.I.) should consider supporting intervention studies that would quantify the effect of modifying exposure to these risk factors, with the aim of reducing the risk of horse falls.

The aim of the study reported in this thesis was to identify variables that increased or decreased the risk of a horse fall during the cross-country phase of eventing competitions in Great Britain during 2001 and 2002. This study has identified risk factors for horse falls, many of which are modifiable. Further research is needed to quantify the effect that reducing exposure to the identified risk factors would have on the rate of horse falls. In addition, the risk of injury to competing event horses and riders needs to be investigated with respect to potential risk factors. The large-scale prospective study reported here is unique to the study of risk factors for eventing horse falls. The results will contribute to the knowledge of those aiming to reduce the risk of horse falls on the cross-country phase of event competitions.

Modification of the risk factors identified in this study should not detract from the challenge and excitement of the cross-country course, the fundamental attraction of the sport to riders and spectators throughout the world.

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