Title: Fédération Equestre Internationale (FEI) endurance events: Riding speeds as a risk factor for failure to qualify outcomes (2012-2015)

Authors: E.D. Bennet, T.D.H. Parkin

PII: S1090-0233(18)30130-8
DOI: https://doi.org/10.1016/j.tvjl.2018.04.012
Reference: YTVJL 5149

To appear in:

Accepted date: 18-4-2018

Original Article

Fédération Equestre Internationale (FEI) endurance events: Riding speeds as a risk factor for failure to qualify outcomes (2012-2015)

E.D. Bennet *, T.D.H. Parkin

School of Veterinary Medicine, University of Glasgow, Glasgow, G61 1QH, United Kingdom

* Corresponding author. Tel.: +44 141 330 3851.
E-mail address: Euan.Bennet@glasgow.ac.uk (E.D. Bennet).

Highlights

- The effect of riding speed on elimination of horses in Fédération Equestre Internationale endurance events was studied.
- Faster riding speeds, especially during stages ('loops') 1 and 2, were associated with deleterious outcomes.
- Sudden drops in riding speed during loop 3 were associated with an increased likelihood of elimination.
- There may be an opportunity for real-time risk analysis during endurance rides.

Abstract

This study examined the association between riding speed and elimination in Fédération Equestre Internationale (FEI) endurance events. A total of 35,061 horse starts from 1 July 2012 to 31 December 2015 were included in a multivariable logistic regression model containing 25 different risk factors. Riding speeds in individual stages ('loops') were included as individual risk factors in studying the progress of horses through loops 1 to 3 of each endurance ride. The possibility of real-time, 'mid-ride' predictive modelling was explored by modelling both riding speeds and sudden changes in speed between loops as potential risk factors. Faster riding speeds, especially during loops 1 and 2, were associated with deleterious outcomes. Furthermore, sudden drops in riding speed during loop 3 were associated with an increased likelihood of elimination.

Keywords: Equine endurance; Riding speed; Failure to qualify; Lameness; Metabolic problems

Introduction

Endurance riding has enjoyed rising popularity in recent years, but one potential consequence of this has been increased competitiveness. Fédération Equestre Internationale (FEI) results over recent decades show that riding speeds are rising worldwide (Coombs and Fisher, 2012; Nagy et al., 2012). Riding speeds may be associated with an increased risk of deleterious outcomes for horses, but this hypothesis has yet to be fully explored in an epidemiological study. Previously, only very specific data, such as 'average riding speed of the ride winner', has been included in published studies; this is perhaps useful to indicate the pace of the runners, but it is not representative of every horse, particularly those that were eliminated. In the absence of studies focussed on detailed average speed data, the previous focus in the literature has been given to more general epidemiological studies (Nagy et al., 2010; Fielding et al., 2011; Nagy et al., 2014a, b), examination of training regimens (Bolwell et al., 2015) and predictive modelling using data gathered at veterinary inspections (Younes et al., 2015).

This paper presents the results of a large scale study of global endurance rides with the inclusion of individual riding speeds. The aim of this study was to use a multivariable model to assess associations between riding speeds and related risk factors, and deleterious outcomes affecting endurance horses. It was hypothesised that specific combination of horse, rider, and ride-level factors would be dominant in terms of risk exposure, and that individual riding speed would be a significant risk factor. Furthermore, it was hypothesised that sudden drops in riding speed at different stages (loops) could be predictive of deleterious outcomes later in a ride.

Materials and methods

Since 2010, the FEI has built up a (publicly-accessible) database of information containing outcomes and details of horses and riders in each FEI level endurance ride. This paper reports part of an overarching project known as the Global Endurance Injuries Study (GEIS) which, as a direct collaboration between the FEI and the University of Glasgow, United Kingdom, granted access to the complete raw data set behind the endurance database. The data sample from the GEIS used in this study contained a comprehensive record of every horse start in every Concours de Raid d`Endurance International (CEI) event worldwide from 1 January 2010 to 31 December 2015. One of the recorded factors in the GEIS was the individual riding speed for each loop of a ride in which a horse participated.

The FEI endurance rules state that rides must be split into three to six loops, with horses being subject to veterinary examination before the start of the ride and at the end of each loop. To successfully complete a ride and record a result outcome (coded as R), horses must pass a final veterinary inspection. Other potential ride outcomes described by the rules are: (1) Retired (RET): riders have the option to retire from a ride after successfully passing a veterinary inspection; (2) disqualified (DSQ): a breach of rules occurred; (3) eliminated (EL): the horse did not complete a loop; (4) finished, not ranked (FNR): the horse completed the ride but took longer to finish than the specified time limit; (5) withdrawn (WD): the horse did not turn up for the event, or otherwise did not start the ride; (6) failure to qualify (FTQ): the horse failed to pass a veterinary inspection; FTQ outcomes must be accompanied by a reason for the outcome, such as ‘irregular gait’ (GA), ‘minor injury’ (MI) or ‘metabolic’ (ME).

Outcomes were sorted into ‘results’, ‘retired’, ‘FTQ LA’, ‘FTQ ME’ and ‘other’. The category ‘other’ included outcomes DSQ, FNR and WD, none of which were considered to be deleterious. Two negative outcomes were assessed: (1) FTQ LA, for which the cases were only those horses that failed to qualify because of lameness, i.e. irregular gait (GA in the FEI description); and (2) FTQ ME, for which the cases were only those horses that failed to qualify because of metabolic problems.

Data selection

For result outcomes, the GEIS speed data were complete. For horse starts that did not successfully complete their ride, some or all of their average speed data were not recorded in the database. Reasons for absent speed data were: (1) in the early years of the database (until mid-2012), eliminated horses did not have their riding speeds recorded in the GEIS for any loop, even loops that were completed successfully; and (2) if a horse was removed from the field during a loop or otherwise was unable to complete a loop, then it did not have a time recorded for that loop. Of the 46,950 horse starts from 1 July 2012 to 31 December 2015, 45,047 (96.0% of horse starts in the cohort) had loop 1 speed recorded, 40,994 (87.3%) had loop 2 speed recorded and 35,061 (74.7%) had loop 3 speed recorded. The majority of the incomplete data in loop 3 related to horses eliminated during loops 1 and 2.

The final dataset selected for analysis included all 35,061 horse starts from 1 July 2012 to 31 December 2015 for which the average speed data was recorded for all three loops. This cohort selection ensured that, for every horse start included, the data relating to every risk factor studied was complete (since every ride included at least three loops). Loop speeds were categorised by quartiles of the data, defined as ‘fast’ (top quartile), ‘medium’ (middle two quartiles) or ‘slow’ (lowest quartile). Twenty-five potential risk factors were considered in the multivariable models (Table 1). The FEI classifies nine geographic regions as described in Table 1 and reference therein. Appropriate mandatory rest periods (MRPs) were calculated for each applicable horse start, based on the distance completed in the previous ride, according to the 2015 rules.

Multivariable logistic regression models were constructed using a bespoke code in MATLAB 2016b (MathWorks) to study potential risk factors associated with deleterious outcomes (FTQ LA, and FTQ ME). Risk factors rejected at the univariable and multivariable stage were tested for confounding in the final model. The goodness-of-fit of each model was tested using the Hosmer-Lemeshow test with 10 degrees of freedom. Biologically plausible combinations of risk factors were tested for second-order interactions in the final model. The final model was tested for clustering by including horse starts as a random element. In the cohort of horse starts studied, 13,863 unique horses accounted for 35,061 horse starts. The median number of horse starts per individual horse was two. The standard deviation of the random effect (ρ) associated with individual horses was $\rho < 0.001$.

Results

Table 2 shows the number of records, average riding speeds and average loop distances for each of loops 1-6, for each of the three most popular ride distance categories (80, 120 and 160 km).

Failure to qualify due to lameness outcomes

Table 3 shows the significant ($P < 0.05$) results of the multivariable model for FTQ LA outcomes. At ride level, associations were found between region group VII (North Africa/Middle East) and decreased odds of FTQ LA (Odds ratio, OR 0.53) compared to region group I (Western/Southern Europe). Compared to rides of distance 80 km, horses starting in rides of 90 km were less likely to be categorised as FTQ LA (OR 0.63), while horses in rides of 160 km had an increased likelihood of being categorised as FTQ LA (OR 1.92). Field sizes of 29-59 horses were associated with an increased odds ratio (OR 1.18) compared to fields with fewer than 15 horses, but no statistically significant associations were found for other field sizes.

At horse level, horses >11 years of age had an increased odds (OR 1.1) of being categorised as FTQ LA compared to horses <7 years of age. Compared to horses with a previous ride distance of

80 km, horses which previously completed ≥90 km were at increased likelihood of being categorised as FTQ LA (OR 1.29 for previous ride distance 90-110km, OR 1.22 for previous ride distance of 120km or greater). Horses with a previous ride outcome of FTQ LA had an increased odds of another FTQ LA (OR 1.14), but a decreased odds of FTQ ME (OR 0.75), compared to horses which completed their previous ride successfully. Compared to horses who returned to competition more than 30 days after their mandatory rest period had expired, horses with less than 1 day over MRP were at increased odds of FTQ LA (OR 1.32). An association was also found for horses who had 3-9 days over MRP since their last competition, with OR 1.2.

At rider level, riders with three or more FTQ LA outcomes (OR 1.35 for riders with exactly three previous FTQ LAs, OR 1.14 for riders with four or more) or one FTQ ME (OR 1.09) in their history had increased odds of FTQ LA. The recent history of a horse also contributed to significant associations; compared to horses that had not been ridden in any FEI events in the previous 120 days, horses with any number or rides in the last 120 days had an increased odds of FTQ LA, with the OR increasing as the number of rides in that period increased – from OR 1.21 for horses with one previous ride to OR 1.79 for horses with three previous rides. Horses that had competed in an FEI event within the last 365 days had an increased odds of FTQ LA compared to horses with no rides in that period, with a lower OR for horses with two (OR 1.28) or three (OR 1.17) rides compared to those with a single ride (OR 1.34). Horses with four rides in the previous year had a slightly increased odds of FTQ LA (OR 1.23) compared to horses with three rides.

Horses ridden at speeds greater than 19.5 km/h in loop 2 were at increased odds of FTQ LA (OR 1.24) compared to those ridden at less than 15.3 km/h. In loop 3, horses ridden at greater than 19.7 km/h were at decreased odds of FTQ LA (OR 0.79) compared to those ridden at less than 14.8 km/h. The only second order interaction term retained in the final model was region group VII and fast riding during loop 2, with an OR of 1.12.

Failure to qualify due to metabolic problems

Table 4 shows the significant ($P < 0.05$) results of the multivariable model for FTQ ME outcomes. Associations were found between region group VII and an increased odds of FTQ ME (OR 1.47) compared to region group I, while region group IX had a reduced odds of FTQ ME with OR 0.43. Compared to ride distances of 80 km, horses ridden distances of 100-120 km had an increased odds of FTQ ME, with OR 1.89 for 100km rides, OR 5.32 for 110km rides, and OR 1.74 for 120km rides. Horses > 11 years of age (OR 1.45 compared to <7 years of age) and male riders (OR 1.42 compared to female riders) also had an increased odds of FTQ ME. Horses that waited 24-30 days over MRP after their previous FEI ride before competing again had an increased odds of FTQ ME, with OR 1.45 compared to those that waited > 30 days over MRP.

Rider history was associated with an increased odds of FTQ ME; riders with one or more previous FTQ MEs had an increased likelihood of the same outcome, with the OR increasing significantly between 1 (OR 1.34), 2 (OR 1.59), 3 (OR 1.55), and ≥4 previous FTQ MEs (OR 1.78). The recent ride history of the horse was also significant in that the number of rides in the last 240 days was associated with increased likelihood of FTQ ME. Horses with one (OR 1.17) or two (OR 1.27) FEI rides were at increased odds compared to horses with zero or more than two FEI rides during that period.

Compared to horses ridden at less than 15.6 km/h in loop 1, horses ridden at speeds greater than 19.7 km/h were at increased odds of FTQ ME with OR 2.2. Tracking the change in speeds as horses progressed through loops 1 to 3, horses which were ridden ‘slowly’ (less than 16 km/h) in loop 3 after being ridden at ‘fast’ (greater than 20 km/h) or at ‘medium’ speeds (16-20 km/h) in loops 1 and 2 had an increased odds of FTQ ME compared to horses ridden ‘slowly’ throughout. Horses ridden more consistently at ‘medium’ or ‘fast’ speeds were at reduced odds of FTQ ME compared to slower horses. Horses ridden at medium/medium/slow speeds in loops 1/2/3 respectively had an OR of 2.1, fast/fast/slow horses an OR of 2.29, and medium/fast/slow horses an OR of 5.09. Horses ridden with a profile of medium/medium/fast had an OR of 0.65, fast/medium/fast horses had an OR of 0.37, and horses ridden consistently fast in all three loops had an OR of 0.5.

Discussion

The results of this study demonstrate the possibility of building a predictive model that combines ride level risk factors with horse and rider history, and 'in-ride' factors, such as riding speed, which could provide information about which horses may require additional attention at veterinary inspections.

Variations in OR were found in different regions. One regional difference was individual riding speed; for example, 58.6% of region VII horses were ridden 'fast' compared to the global average, while for the rest of the world this proportion was 16.3%.

The OR for FTQ LA outcomes were increased in rides of 160 km compared to rides of 80 km, while the OR for FTQ ME outcomes were increased in rides of 120 km compared to rides of 80 km. Although there were relatively small numbers of cases and controls, ride distances of 90 km were associated with decreased odds of FTQ LA, while 100 km and 110 km distances were associated with increased odds of FTQ ME. A linear association between longer distances and increased odds of injury has been reported in endurance rides in the USA (Fielding et al., 2011) and in Thoroughbred racing (Parkin et al., 2004; Perkins et al., 2005; Boden et al., 2007). In other studies of endurance rides (Nagy et al., 2010, 2014b), there were no significant associations between ride distance as a continuous variable and the odds of FTQ. Without significant associations for 120 km rides (for FTA LA outcomes) or 160 km rides (for FTQ ME outcomes), it is difficult to identify any linear trend here. On average, horses were ridden faster in rides of 120 km than in rides of 160 km, which could explain the associations for FTQ LA outcomes. Similarly, horses with longer previous rides were more likely to be categorised as FTQ LA. This could be related to the physical toll that endurance takes on the musculoskeletal system of the horse, as well as general metabolic fatigue.

Rest periods between competitions were significant for both FTQ LA and FTQ ME outcomes. In both cases, fewer days over MRP between competition were associated with increased odds of FTQ. The increased odds of FTQ LA associated with horses who returned to competition less than one day after their mandatory rest period expired is an indication that the introduction of MRPs in 2014 has had the intended effect. No associations were found for horses with a rest period of 1-2 days over MRP (i.e. those horses returning to competition immediately after their MRP expired). Horses who returned within 3-9 days of the end of their MRP were associated with increased odds of FTQ LA. Horses with 24-30 days over MRP were at increased odds of FTQ ME compared to horses with more than 30 days over MRP. No significant associations were found for other rest periods.

The results for ‘number of rides in the last 120 (365) days’ show that fewer rides for the horse over short periods are generally associated with lower odds. Additionally, over a period of one year, horses with any number of previous competitions (up to four in these data) were associated with increased odds of FTQ LA compared to horses with no competitions in the previous year.

No associations were found for the risk factor of ‘horse’s previous experience of 120 km+ rides’, for either FTQ LA or FTQ ME outcomes. Previous studies of endurance rides (Nagy et al., 2014b) and Thoroughbred racing (Georgopoulos and Parkin, 2016) have found experienced horses to be associated with reduced odds of deleterious outcomes compared to horses that were inexperienced (in endurance) or less experienced (in racing).

Compared to horses that successfully completed their last ride, horses that experienced an FTQ LA outcome were more likely to experience another FTQ LA outcome and less likely to experience an FTQ ME outcome, and vice versa. Previous studies of Thoroughbred racing have demonstrated that the number of previous injuries incurred is associated with an increased future likelihood of injury (Georgopoulos and Parkin, 2016). Horses who experience an FTQ outcome have an additional mandatory rest period they must complete before competing again. These results suggest that the benefit of the extended rest period applies to all types of FTQ, not just the type of FTQ which resulted in the rest period.

Riders who had experienced previous FTQs were more likely to sustain the same type of FTQ (LA or ME) again in future rides. This potentially indicates that less-skilled riders will continue to make the same mistakes. Repeat same-combination pairs of horse and rider were infrequent (in the cohort of 35,061 horse starts studied, there were 16,087 returning combinations compared to 27,499 returning horses and 31,953 returning riders), although in these cases, rider history and horse history would have a more complex contribution to make to overall risk exposure.

Fast riding speeds in loops 1 and 2 were associated with increased odds of FTQ ME and FTQ LA outcomes, respectively. Going too fast during the first stage of a ride could fatigue the horse and lead to metabolic problems at any subsequent stage. Similarly, the aggravation of bone or ligament damage over time from riding fast, or recurrence of a pre-existing condition, could lead to physical problems during the ride (Estberg et al., 1996, 1998; Williams et al., 2001; Parkin et al., 2005; Henley et al., 2006). With regard to FTQ LA outcomes, it seems counterintuitive that horses ridden at speeds greater than 19.5 km/h (loop 2) and 19.7 km/h (loop 3) were associated with lower OR than horses ridden at less than 15.3 km/h (loop 2) and 14.8 km/h (loop 3), respectively. An answer to this is partially delivered by the subsequent results for changes in riding speeds over loops 1 to 3; horses ridden slowly in loop 3 after riding fast (or at medium speeds) in loops 1 and 2 were more likely to FTQ than horses ridden consistently slowly. It could be the case that, by loop 3, the highest risk and fastest ridden horses have either already FTQ, or have slowed to the point that their loop 3 speed is significantly lower than their loop 1 and 2 speeds. For FTQ ME outcomes, horses ridden consistently at medium or fast speeds are less likely to FTQ than horses ridden consistently slowly. This leads to the hypothesis that, for well-prepared horses able to maintain a consistent speed appropriate for the horse and the ride conditions, a skilled rider will be able to safely complete the ride. However, the less well-prepared and less skilled combinations of horse and rider were perhaps less able to progress and finish successfully. This allows for the possibility of two 'real-time' risk factors that can be used during rides; early high loop speeds coupled with any sudden changes in riding speed between loops could signal to veterinarians that additional attention is required, i.e. these horses are at increased risk of imminent FTQ.

This study was intended to take as wide a view as possible of the available data, and as such included rides of all distances. However, it is important to note that loop 3 can be very different in terms of tactics and speed, depending on the total ride distance; in an 80 km ride, loop 3 usually will be the final loop, whereas in a 160 km ride, loop 3 might not even cover the halfway point. There is scope for further in-depth investigations of distance-specific cohorts, including further study with more specific groups of horse starts stratified by ride distance.

The riding speeds recorded in the GEIS have been calculated using the total loop times, including recovery time. This means that the recorded speeds are likely to be less than the actual speeds ridden by the horses. The results of the present study therefore probably underestimate the impact of fast riding speeds.

Terrain, going (condition of the course surface) and weather on the day undoubtedly play a part in limiting or allowing certain levels of speed. At the time of this study, such information was unavailable on the global scale. Another limitation of the study is that the GEIS contains only FEI level rides, such that every horse has taken part in sufficient national level rides to qualify for elite endurance competition. For many horses, the FEI rides recorded in the GEIS will represent only part of their calendar of rides. Despite this limitation, the present study has produced results relating to horse and rider history which are statistically significant and have plausible physical explanations. Ultimately, decisions during veterinary inspections are subjective and are dependent on the veterinary delegates acting upon the available information.

Conclusions

This detailed study of individual riding speeds in FEI endurance events has shown that fast riding speeds are a significant risk factor associated with negative outcomes for horses. In particular, riding 'fast' in the early stages of a ride (loops 1 and 2) was associated with an increased risk of FTQ ME. Furthermore, sudden drops in riding speed from 'fast' in loops 1 and 2 to 'slow' in loop 3 were associated with an increased likelihood of FTQ. This provides the opportunity to use predictive modelling 'in-ride' to estimate the real-time risk experienced by a cohort of horses.

Conflict of interest statement

None of the authors of this paper have a financial or personal relationship with other people or organisations that could inappropriately influence or bias the content of the paper.

Acknowledgements

The authors gratefully acknowledge the support of the FEI, which funded this research.

References

Boden, L.A., Anderson, G.A., Charles, J.A., Morgan, K.L., Morton, J.M., Parkin, T.D. H., Clarke, A.F., Slocombe, R.F., 2007. Risk factors for Thoroughbred racehorse fatality in flat starts in Victoria, Australia (1989-2004). Equine Veterinary Journal 39, 430-437.

Bolwell, C.F., Rogers, C.W., Rosanowski, S.M., Weston, J.F., Gee, E.K., Gordon, S.J.G., 2015. Cross-sectional survey of the management and training practices of endurance horses in New Zealand: A pilot study. Journal of Veterinary Science 35, 801-806.

Coombs, S.L., Fisher, R.J., 2012 Endurance riding in 2012: Too far too fast? The Veterinary Journal 194, 270-271.

Estberg, L., Stover, S.M., Gardner, I.A., Johnson, B.J., Case, J.T., Ardans, A., Read, D.H., Anderson, M.L., Barr, B.C., Daft, B.M., et al., 1996. Fatal musculoskeletal injuries incurred during racing and training in Thoroughbreds. Journal of the American Veterinary Medical Association 208, 92-96.

Estberg, L., Stover, S.M., Gardner, I.A., Johnson, B.J., Jack, R.A., Case, J.T., Ardans, A., Read, D.H., Anderson, M.L., Barr, B.C., et al., 1998. Relationship between race start characteristics and risk of catastrophic injury in thoroughbreds: 78 cases (1992). Journal of the American Veterinary Medical Association 212, 544-549.

Fielding, C.L., Meier, C.A., Balch, O.K., Kass, P.K., 2011. Risk factors for the elimination of endurance horses from competition. Journal of the American Veterinary Medical Association 239, 493-498.

Georgopoulos, S.P., Parkin, T.D.H., 2016. Risk factors associated with fatal injuries in Thoroughbred racehorses competing in flat racing in the United States and Canada. Journal of the American Veterinary Medical Association 249, 931-939.

Henley, W.E., Rogers, K., Harkins, L., Wood, J.L.N., 2006. A comparison of survival models for assessing risk of racehorse fatality. Preventive Veterinary Medicine 74, 3-20.

Nagy, A., Dyson, S.J., Murray, J.K., 2012. A veterinary review of endurance riding as an international competitive sport. The Veterinary Journal 194, 288-293.

Nagy, A., Murray, J.K., Dyson, S., 2010. Elimination from elite endurance rides in nine countries: A preliminary study. Equine Veterinary Journal 42 (Suppl. 38), 637-643.

Nagy, A., Murray, J.K., Dyson, S.J., 2014. Descriptive epidemiology and risk factors for eliminations from Federation Equestre Internationale endurance rides due to lameness and metabolic reasons (2008-2011). Equine Veterinary Journal 46, 38-44.

Nagy, A., Murray, J.K., Dyson, S.J., 2014. Horse-, rider-, venue- and environment-related risk factors for elimination from Federation Equestre Internationale endurance rides due to lameness and metabolic reasons. Equine Veterinary Journal 46, 294-299.

Parkin, T.D.H., Clegg, P.D., French, N.P., Proudman, C.J., Riggs, C.M., Singer, E.R., Webbon, P.M., Morgan, K.L., 2004. Race- and course-level risk factors for fatal distal limb fracture in racing Thoroughbreds. Equine Veterinary Journal 36, 521-526

Parkin, T.D.H., Clegg, P.D., French, N.P., Proudman, C.J., Riggs, C.M., Singer, E.R., Webbon, P.M., Morgan, K.L., 2005. Risk factors for fatal lateral condylar fracture of the third metacarpus/metatarsus in UK racing. Equine Veterinary Journal 37, 192-199.

Perkins, N.R., Reid, S.W.J., Morris, R.S., 2005. Risk factors for injury to the superficial digital flexor tendon and suspensory apparatus in Thoroughbred racehorses in New Zealand. New Zealand Veterinary Journal 53, 184-192.

Williams, R.B., Harkins, L.S., Hammond, C.J., Wood, J.L.N., 2001. Racehorse injuries, clinical problems and fatalities recorded on British racecourses from flat racing and National Hunt racing during 1996, 1997 and 1998. Equine Veterinary Journal 33, 478-486.

Younes, M., Robert, C., Cottin, F., Barrey, E., 2015. Speed and cardiac recovery variables predict the probability of elimination in equine Endurance events. PLoS One 10.

Table 1 Risk factors used in the multivariable models.

Risk factor	Categorisation	Notes
Year	Categorical	2012 to 2015
Region group[a]	I-IX (Roman numerals)	Each group is a geographical area as defined by the Fédération Equestre Internationale, approximately corresponding to: I: Western/Southern Europe; II: Northern/Eastern Europe; III: Russia/Western Asia; IV: North America; V: Central America; VI: South America; VII: North Africa/Middle East; VIII: Oceania/Asia; IX: Sub-Saharan Africa
Ride distance	Categorical	Event distances are 80 to 160 km
Field size	Quartiles	No limits in regulations
Horse sex	Binary	Only difference found between ‘stallion’ and ‘not stallion’
Horse age	Quartiles	Horse age on day of ride
Rider sex	Binary	
Rider age	Quartiles	Rider age on day of ride
Horse experience of rides > 120 km	Binary	Had the horse ridden > 120 km in one event before?
Distance of previous ride	Categorical	Categories correspond to Fédération Equestre Internationale rules for rest periods
Outcome of previous ride	Categorical	Either ‘result’, FTQ LA, FTQ ME, or ‘other’
Days since previous ride	Categorical	Relative to mandatory rest period applicable according to the 2015 rules
Horse previous FTQ LA	Categorical	Previous FTQ LA outcomes in career
Horse previous FTQ ME	Categorical	Previous FTQ ME outcomes in career
Rider previous FTQ LA	Categorical	Previous FTQ LA outcomes in career
Rider previous FTQ ME	Categorical	Previous FTQ ME outcomes in career
Rides in last 60 days	Categorical	Horse number of CEI rides in last 60 days
Rides in last 120 days	Categorical	Horse number of CEI rides in last 120 days
Rides in last 240 days	Categorical	Horse number of CEI rides in last 240 days
Rides in last 365 days	Categorical	Horse number of CEI rides in last 365 days
Loop 1 speed	Quartiles	Horse individual riding speed in loop 1
Loop 2 speed	Quartiles	Horse individual riding speed in loop 2
Loop 3 speed	Quartiles	Horse individual riding speed in loop 3
Sudden change in speed, loops 1-2	Categorical	Riding speed (fast, medium, or slow) in loop 1 and loop 2
Sudden change in speed, loops 1-3	Categorical	Riding speed (fast, medium, or slow) in loop 1, loop 2 and loop 3

FTQ LA, failure to qualify due to lameness; FTQ ME, failure to qualify due to metabolic problems; CEI, Concours de Raid d`Endurance International.
[a] See: https://data.fei.org/NFPages/NF/Search (accessed 27 July 2017).

Table 2 Number of records, average riding speeds (1 standard deviation range)[a] and average loop distances (1 standard deviation range) for each ride loop, split by total ride distance category.

	Loop 1	Loop 2	Loop 3	Loop 4	Loop 5	Loop 6
80 km rides						
Number of records	26239	24048	20984	2700	29	-[b]
Speed (km/h)	17.7 (14.3-21.1)	17.1 (13.6-20.6)	17.8 (13.2-22.4)	17.6 (12.7-22.5)	16 (12.5-19.6)	-
Loop distance (km)	33.7 (28.6-38.8)	26 (21.3-30.7)	19.6 (16.3-23)	17.1 (14.4-19.8)	19 (19-19)	-
120 km rides						
Number of records	30814	28603	25429	21650	8959	33
Speed (km/h)	18.6 (14.8-22.4)	18.3 (14.5-22.2)	17.2 (13.4-21)	17 (12.5-21.4)	17.9 (12.6-23.3)	12.9 (6.4-19.5)
Loop distance (km)	35 (30.7-39.3)	31 (26.4-35.6)	26.7 (21.6-31.8)	21.3 (17.9-24.8)	18.4 (15.7-21)	18.0 (14.3-21.7)
160 km rides						
Number of records	8662	8164	7395	6494	5528	3787
Speed (km/h)	17.7 (14.3-21.1)	17.9 (14.7-21.1)	17 (13.8-20.2)	16 (12.9-19.1)	16 (12.1-19.8)	16.2 (11.7-20.8)
Loop distance (km)	36.5 (32.4-40.6)	32.3 (27.2-37.4)	30.6 (25.6-35.7)	27 (22.7-31.2)	21.5 (17.8-25.2)	19.5 (17.2-21.8)

[a] Riding speeds distributions are generally close to normal, therefore one standard deviation range either side of the mean corresponds to the full width at half maximum of the distribution.
[b] Not applicable.

Table 3 Multivariable model results showing the significant (*P* < 0.05) risk factors affecting all horse starts from 1 July 2012 to 31 December 2015 with speed data recorded in loops 1, 2 and 3, for all failure to qualify (FTQ) due to lameness outcomes.

FTQ LA outcomes	Cases	Controls	Odds ratio	95% Confidence interval	*P* value
Region group					
I	1980	11841	Reference	-	-
VII	718	7367	0.53	0.37-0.69	< 0.001
Ride distance (km)					
80	688	10939	Reference	-	-
90	251	3653	0.63	0.49-0.77	< 0.001
160	874	2797	1.92	1.83-2.02	< 0.001
Field size (number of horses)					
< 15	1043	7980	Reference	-	-
29-59	1178	7489	1.18	1.1-1.25	< 0.001
Horse age (years)					
< 7	128	1734	Reference	-	-
> 11	971	6080	1.1	1.02-1.18	0.025
Previous ride distance (km)					
≤ 80 km	875	7208	Reference	-	-
90 to 110 km	565	3602	1.29	1.18-1.4	< 0.001
120 km	1566	9370	1.22	1.13-1.31	< 0.001
> 120 km	714	3599	1.22	1.1-1.33	< 0.001
Horse outcome of last ride					
Result	3251	24883	Reference	-	-
FTQ LA	750	4657	1.14	1.04-1.23	0.007
FTQ ME	154	1366	0.75	0.58-0.93	0.002
Days over mandatory rest period since last ride					
< 1	176	722	1.32	1.13-1.51	0.005
3-9	225	1098	1.2	1.05-1.36	0.021
> 30	3075	25474	Reference	-	-
Rider number of previous FTQ LA					
0	936	9327	Reference	-	-
3	445	2525	1.35	1.24-1.46	< 0.001
4+	1618	10014	1.14	1.06-1.21	< 0.001
Rider number of previous FTQ ME					
0	2410	19382	Reference	-	-
1	924	6007	1.09	1.01-1.17	0.034
Number of rides in last 120 days					
0	1945	18895	Reference	-	-
1	1656	9582	1.21	1.13-1.29	< 0.001
2	475	2099	1.56	1.43-1.69	< 0.001
3	73	293	1.79	1.52-2.07	< 0.001
Number of rides in last 365 days					
0	755	10236	Reference	-	-
1	1258	8569	1.34	1.23-1.44	< 0.001
2	1193	6788	1.28	1.16-1.39	< 0.001
3	636	3582	1.17	1.03-1.3	0.023
4	241	1227	1.23	1.05-1.41	0.021
Average riding speed in loop 2					
< 15.3 km/h	828	7842	Reference	-	-
> 19.5 km/h	1127	7690	1.24	1.13-1.35	< 0.001
Average riding speed in loop 3					
< 14.8 km/h	1042	7728	Reference	-	-
> 19.7 km/h	858	7794	0.79	0.69-0.89	< 0.001
Riding speed change in loop 1-3[a]					
Slow/Slow/Slow	442	3850	Reference	-	-
Slow/Medium/Slow	144	748	1.28	1.08-1.47	0.013
Medium/Medium/Slow	264	1514	1.29	1.15-1.44	< 0.001
Medium/Medium/Medium	1204	7850	1.13	1.05-1.22	0.004
Interactions terms					
Group VII x > 19.5 km/h in loop 2	514	3730	1.7	1.5-1.9	< 0.001

FTQ LA, failure to qualify due to lameness; FTQ ME, failure to qualify due to metabolic problems.
[a] 'Slow' riding speed defined as less than 16km/h in a given loop. 'Medium' riding speed defined as 16-20km/h. 'Fast' riding speed defined as greater than 20 km/h.

Table 4 Multivariable model results showing the significant (*P* < 0.05) risk factors affecting all horse starts from 1 July 2012 to 31 December 2015 with speed data recorded in loops 1, 2 and 3, for all failure to qualify (FTQ) due to metabolic problems outcomes.

FTQ ME outcomes	Cases	Controls	Odds ratio	95% confidence interval	*P* value
Region group					
I	470	13351	Reference	-	-
VII	638	7447	1.47	1.33-1.61	< 0.001
IX	25	1644	0.43	0.03-0.84	< 0.001
Ride distance (km)					
80	234	11393	Reference	-	-
100	95	1073	1.89	1.65-2.12	< 0.001
110	16	44	5.32	4.69-5.95	< 0.001
120	835	12772	1.74	1.63-1.86	< 0.001
Horse age (years)					
< 7	57	1805	Reference	-	-
> 11	450	6601	1.45	1.34-1.57	< 0.001
Rider sex					
Female	461	15309	Reference	-	-
Male	1098	18193	1.42	1.3-1.55	< 0.001
Days over mandatory rest period since last ride					
24-30	82	1040	1.45	1.21-1.69	0.002
> 30	1119	27430	Reference	-	-
Rider number of previous FTQ ME					
0	746	21046	Reference	-	-
1	357	6574	1.34	1.21-1.47	< 0.001
2	196	2818	1.59	1.43-1.76	< 0.001
3	94	1331	1.55	1.32-1.78	< 0.001
4+	166	1733	1.78	1.6-1.97	< 0.001
Number of rides in last 240 days					
0	542	14819	Reference	-	-
1	580	11414	1.17	1.05-1.29	0.009
2	314	5417	1.27	1.13-1.42	0.001
Average riding speed in loop 1 (km/h)					
< 15.6	242	8587	Reference	-	-
> 19.7	674	8193	2.2	2.05-2.35	< 0.001
Riding speed change in loops 1-3[a]					
Slow/Slow/Slow	113	4179	Reference	-	-
Medium/Medium/Slow	124	1654	2.1	1.9-2.3	< 0.001
Medium/Medium/Fast	33	1778	0.65	0.29-1	0.016
Medium/Fast/Slow	11	71	5.09	4.44-5.75	< 0.001
Fast/Medium/Fast	17	582	0.37	-1.01	< 0.001
Fast/Fast/Slow	39	147	2.29	1.9-2.68	< 0.001
Fast/Fast/Fast	297	4540	0.5	0.33-0.67	< 0.001

FTQ ME, failure to qualify due to metabolic problems; FTQ LA, failure to qualify due to lameness.
[a] 'Slow' riding speed defined as less than 16km/h in a given loop. 'Medium' riding speed defined as 16-20km/h. 'Fast' riding speed defined as greater than 20 km/h.