The Veterinary Journal 235 (2018) 42–46

Contents lists available at ScienceDirect

The Veterinary Journal

journal homepage: www.elsevier.com/locate/tvjl

Original Article

A retrospective cohort study investigating risk factors for the failure of Thoroughbred racehorses to return to racing after superficial digital flexor tendon injury

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ARTICLE INFO

Keywords:
Equine
Injury
Outcome
Return to racing
Superficial digital flexor tendon

ABSTRACT

A retrospective cohort study was conducted to investigate risk factors for the failure of Thoroughbred racehorses to return to racing after an injury of the superficial digital flexor tendon (SDFT). Successful return was defined as the completion of five or more races after SDFT injury. The official Japan Racing Association (JRA) medical records of racehorses with a core-type SDFT injury were reviewed for clinical variables related to the characteristics of the horse and the severity of SDFT injuries at the time of diagnosis. Data on racing outcomes were obtained from the official JRA racing database. Risk factors were screened using univariable logistic regression and subsequent multivariable model building. Forty-nine of 346 (14.2%) horses successfully returned to racing after SDFT injuries. Multivariable model building revealed that an increase in the total number of injured zones (defined as the total number of zones in which the injured hypoechoic area was observed at the time of ultrasonographic diagnosis of SDFT injury) was associated with an increased risk of failure to return to racing after SDFT injury. Horse characteristics, such as age, body mass and sex, were not associated with a successful return to racing. In the rehabilitation of cases with larger (longer) lesions, more effective and careful medical management may be needed for an improvement in the athletic outcomes.

Introduction

Injuries of the superficial digital flexor tendon (SDFT) are common musculoskeletal lesions in Thoroughbred racehorses, with a prevalence of 11–30%, and remain a significant cause of racehorse wastage (Marr et al., 1993; Williams et al., 2001; Takahashi et al., 2004). Most horses with SDFT injury cannot continue training and racing without an intervening period of rest (Reef, 2001). Although the time out of training ranges from 6 to 26 months, depending on the initial severity of SDFT injury (Marr et al., 1993; Ross et al., 2011), 40–80% of affected horses cannot successfully return to racing; a successful return to racing is defined as a completion of five or more races (Dowling et al., 2000).

Several studies have used ultrasonography to determine the severity of SDFT injury for investigating variables associated with the failure to return to racing (Marr et al., 1993; Genovese et al., 1997; Smith and Cauvin, 2014). Although many studies have used univariable analyses and/or descriptive statistics to determine risk factors, statistical analysis, including assessment of the impact of multiple variables, is important for assessing the relationship between many factors and the event. Furthermore, some studies have demonstrated that serial ultrasonographic evaluations are required during rehabilitation, because prognostic predictions are determined on the basis of ultrasonographic changes in the lesion. Thus, this method cannot be used to determine prognosis at the time of diagnosis.

If objective risk data could be used to determine the prognosis of a tendon injury at the time of diagnosis, it would be possible to prevent the loss of time and money of horse owners, as well as to contribute to the welfare of racehorses, by immediately providing the opportunity for adaptive reuse, for example, for recreation or breeding. The aim of this study was to identify risk factors associated with failure of Thoroughbred racehorses to return to racing after SDFT injury by using multivariable model building to investigate variables related to horse characteristics and severity of SDFT injury at the time of diagnosis.

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https://doi.org/10.1016/j.tvjl.2018.03.003
1090-0233/

Materials and methods

Experimental design

A retrospective cohort study was conducted to determine risk factors associated with failure of Thoroughbred racehorses to return to racing after SDFT injury. All study protocols were approved by the Japan Racing Association (JRA) Equine Research Institute (JRA approval number 28NIKKEI3155; date of approval 15 July 2016).

Horses

The study population consisted of Thoroughbred racehorses registered with JRA Miho Training Centre, which has approximately 2000 stables. Horses sustaining a central core-type SDFT injury, which was determined on the basis of the position of the lesion (Smith and Cauvin, 2014), while training or racing, from 1 January 2008 and 31 December 2012, were eligible for inclusion. Ten JRA official veterinarians were involved in the ultrasonographic diagnosis of all SDFT injuries. All veterinarians attended the same training seminar and used a consensus set of diagnostic criteria, which were specified by veterinarians with >15 years of experience in equine musculoskeletal ultrasonography, to minimise individual diagnostic bias.

Horses with a complete SDFT rupture or with a previous history of SDFT injuries (even in the contralateral limb) were excluded from the study. Horses that were unlisted from registration with JRA within 30 days after diagnosis were also excluded, because we targeted racehorses receiving medical treatment, including enough rest and rehabilitation for the purpose of returning to racing. All information was obtained from official medical records. Horses with missing data in their medical records were excluded.

Clinical variables and outcomes

Eight clinical variables (three horse-related and five injury-related) were used to determine risk factors. Horse-related variables included sex, age and body mass at the onset of SDFT injury; geldings were included in the male category. Injury-related variables included the affected side and four ultrasonographic findings related to the severity of SDFT injury. Horses with bilateral injuries were categorised according to the more severely injured side. Ultrasonographic findings included maximum injury zone (MIZ), cross-sectional area in the MIZ (MIZ-CSA), percentage of the injured hypoechoic area per MIZ-CSA (MIZ-%HYP) and total number of injured zones (TNZ). Zone designations are generally used to determine the anatomical location from the ultrasonographic images of the equine forelimbs (Smith and Cauvin, 2014). The palmar metacarpal regions were categorised into the following seven zones from proximal to distal: 1A, 1B, 2A, 2B, 3A, 3B and 3C. MIZ was defined as the zone with the greatest ratio of injured hypoechoic area to CSA, which was measured using the trace measurement function on a transverse ultrasonographic image. TNZ, which was used as an index of the lesion length in the vertical direction, was defined as the total number of zones in which the injured hypoechoic area was observed at the time of ultrasonographic diagnosis.

MIZ and TNZ were classified into three categories. MIZ was divided into the following three categories based on location: proximal (P: 1A and 1B), middle (M: 2A and 2B) and distal (D: 3A, 3B and 3C). TNZ was divided into the following three categories containing the same number of horses: category 1: TNZ $\leq$ 3; category 2: TNZ = 4; and category 3: TNZ $\geq$ 5.

The outcome variable was a successful return to racing, defined as the completion of five or more races after SDFT injury (Ross et al., 2011). All race records of horses that had sustained SDFT injury were collected from the official JRA racing database.[1]

Data analysis

Continuous data were reviewed using descriptive statistics, and were expressed as minimum, lower quartile, median, upper quartile and maximum. Categorical data were presented as descriptive statistics, including the number and proportion of horses in each category.

Univariable logistic regression was performed to assess which variables were potential risk factors. Variables were age (years), body mass (kg), sex (male vs. female), affected side (right forelimb vs. left forelimb), TNZ (three categories), MIZ (three categories), MIZ-CSA (cm^2) and MIZ-%HYP (%). Crude odds ratios (ORs) and 95% confidence intervals (CIs) were calculated in the univariable logistic regression model. Locally weighted scatterplot smoothing (LOWESS) curves were used for visually assessing whether log-odds of the outcome was linearly associated with the continuous variable (Hosmer et al., 2013b).

Variables were available for inclusion in subsequent multivariable model building if the likelihood ratio test *P* value from the univariable logistic regression analysis was <0.15. The variance inflation factor (VIF) was used to check for multicollinearity. VIF values > 10 were considered to indicate multicollinearity. The final model was built using a combination of forward and backward step-wise procedures. In a likelihood ratio statistical test, variables with a P value < 0.15 were included in the model and those with a P value > 0.15 were used as the cut-off for removal. The Wald test P value was used when comparing variables with the reference and P < 0.05 was considered to be statistically significant. The fit of the final model was assessed using the Hosmer–Lemeshow goodness-of-fit test (Hosmer et al., 2013a). The relationship between the total number of events and the number of retained variables was also checked for reliable analysis, which required at least 10 events per variable (Peduzzi et al., 1996).

An analysis of the receiver operating characteristics (ROC) was used for assessing the sensitivity, specificity and area under the ROC curve (AUC) of the final model. Positive (PPV) and negative predictive values (NPV) were calculated from a contingency table of the retained variable. All statistical analyses were performed using commercially available software (JMP 12, SAS Institute).

Results

In this retrospective cohort study, 346/405 racehorses met the entire inclusion criteria (Fig. 1). The characteristics of the study population and clinical variables are summarised in Table 1. The study population was followed up until December 2016, by which time all horses that had not successfully returned to racing were retired from racing. Forty-nine horses (14.2%) had successfully returned to racing after SDFT injury.

Using univariable logistic regression, TNZ, MIZ-CSA and MIZ-% HYP were identified as potential risk factors (Table 2). LOWESS curves showed that log odds of the outcome were linearly associated with all continuous variables. There was no evidence for multicollinearity in the multivariable model building (all VIF values < 3). These variables were then included in the multivariable step-wise model. After step-wise procedures for final model building, TNZ was the only predictor associated with the failure to successful return to racing after SDFT injury. The OR of the failure to return to racing was significantly higher in TNZ category 3 than in TNZ category 1 (OR 4.08, 95% CI 1.73–11.27; P < 0.001) or TNZ category 2 (OR 2.72, 95% CI 1.06–7.92; P = 0.038) (Table 2). The total number of events (n = 49) for the retained variable was >10. The sensitivity, specificity and AUC were 0.41, 0.84 and 0.67 (95% CI 0.59–0.74), respectively. The PPV for TNZ category 3 vs. category 1 was 0.94 and the PPV for TNZ category 2 vs. category 1 was 0.86. NPVs for TNZ category 3 vs. category 1 and TNZ category 2 vs. category 1 were 0.20. There was no evidence of a lack of fit for the current model; the Hosmer–Lemeshow goodness-of-fit test was 0.68 (P = 0.41).

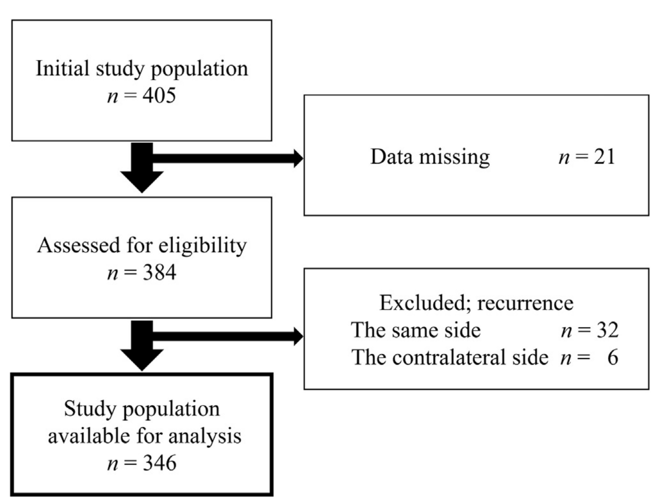

Fig. 1. Flow chart of the study population.

[1] See: http://japanracing.jp/en/ (accessed 25 May 2017).