Risk factors associated with fatal injuries in Thoroughbred racehorses competing in flat racing in the United States and Canada

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OBJECTIVE
To identify risk factors associated with fatal injuries in Thoroughbred racehorses in the United States and Canada.

DESIGN
Retrospective study.

ANIMALS
1,891,483 race starts by 154,527 Thoroughbred racehorses at 89 racetracks in the United States and Canada from 2009 to 2013.

PROCEDURES
Data were extracted from the Equine Injury Database, which contained information for 93.9% of all official flat racing events in the United States and Canada during the 5-year observation period. Forty-four possible risk factors were evaluated by univariate then multivariable logistic regression to identify those that were significantly associated with fatal injury (death or euthanasia of a horse within 3 days after sustaining an injury during a race).

RESULTS
3,572 race starts ended with a fatal injury, resulting in a period incidence rate of 1.9 fatal injuries/1,000 race starts. Twenty-two risk factors were significantly associated with fatal injury. Risk of fatal injury was greater for stallions than for mares and geldings and increased as the number of previous nonfatal injuries and race withdrawals and level of competitiveness (eg, horse's winning percentage and race purse) of the horse or race increased.

CONCLUSIONS AND CLINICAL RELEVANCE
Results identified several risk factors associated with fatal injuries in Thoroughbred racehorses. This information can be used as a guideline for the identification of racehorses at high risk of sustaining a fatal injury and in the design and implementation of preventative measures to minimize the number of fatal injuries sustained by horses competing in flat racing in the United States and Canada. (*J Am Vet Med Assoc* 2016;249:931–939)

Limited research was conducted to quantify risk factors associated with race injuries in racehorses until the 1990s. Injuries were generally attributed to bad racetrack conditions, typically on the basis of opinion or hearsay rather than objective facts.[1] Furthermore, associations between various risk factors and injuries were usually evaluated with only univariable analyses, and the use of multivariable techniques that can account for confounding was largely neglected. Age,[2–6] sex,[2,3,7,8] race distance,[4,5,7,9–12] racetrack surface type and conditions,[4,6,10,11,13] race type,[3–6,12,14] field size (number of horses in race),[10,11] season,[5] prior racing history,[4,5,7,9–11] distance galloped during training,[5,9,13,15–18] exercise history,[11,13,16,18] prerace inspection by regulatory veterinarians,[19] and horseshoe characteristics[20,21] have been associated with fatal injuries in Thoroughbred racehorses in previous studies.

The Jockey Club was established in New York in 1894.[22] Its mission is to improve Thoroughbred breeding and racing primarily in the United States, Canada, and Puerto Rico.[22] In 2008, The Jockey Club initiated the EID.[22] The purpose of the EID is to identify the frequency, types, and outcomes of racing injuries in Thoroughbred racehorses competing in flat racing in a standardized format so that valid statistics can be generated in the hope that factors associated with specific injuries can be identified and appropriate measures implemented to prevent such injuries and improve the safety of Thoroughbred racing.[22] The EID contains information for most Thoroughbred races that take place in the United States and Canada and serves as a near-census collection of available data. Despite differences in geography and Thoroughbred racing practices among countries and racing jurisdic-

ABBREVIATIONS

AIC	Akaike Information Criterion
EID	Equine Injury Database
SDFT	Superficial digital flexor tendon

tions, we believe that the EID database can be used to identify risk factors associated with fatal injuries, and that information can be used to improve racing conditions in the United States and Canada as well as other Thoroughbred racing jurisdictions.

The purpose of the study reported here was to identify risk factors associated with fatal injuries in Thoroughbred racehorses competing in flat racing in the United States and Canada. Specific factors such as age, sex, race distance, racetrack surface type and conditions, race type, field size, and prior racing history that were associated with fatal injuries in racehorses in previous studies[2–21] were evaluated by use of multivariable analysis.

Materials and Methods

Data collection

Data were obtained from the EID for the 5-year period from 2009 through 2013. Race start data were provided by The Jockey Club and included information for all racetracks that voluntarily contributed data to the EID during the years of interest. The race starts reported to the EID represented the starts for 93.9% of all official Thoroughbred racing events in the United States and Canada during the 5-year observation period. Injury reports were submitted to the EID by veterinarians at the participating racetracks. The EID database also contained information for approximately 11,000 anonymized trainers and 3,000 anonymized jockeys associated with the recorded races, which enabled us to analyze trainer- and jockey-related risk factors. Because the EID did not contain information regarding extent of training exercise, we used the number of races started by a horse prior to the race of interest as a proxy for cumulative training exercise. Also, the EID did not contain information regarding prerace inspection by regulatory veterinarians; therefore, we used the number of times a horse had been withdrawn from a race (scratched) prior to the race of interest as the proxy for prerace regulatory inspection.

Data analysis

The unit of analysis for the study was race start. For each race start, horses that died or were euthanized within 3 days after sustaining an injury during a race (ie, fatal injury) were classified as cases and all other horses were classified as controls. All official race starts were used to calculate historical information for each horse, but only the 1,891,483 official starts from the racetracks that voluntarily reported injuries to the EID were used in the regression analyses. The outcome of interest, or outcome variable, for all regression analyses was fatal injury. Forty-four plausible risk factors, or independent variables, for fatal injury were selected for consideration in our analysis. Initially, the respective associations between each risk factor and the outcome variable were assessed by use of univariate logistic regression. Only horses that had been competing in flat racing for at least 6 months were included in the analyses to assess risk factors that summarized historical racing information prior to the race of interest; this facilitated the assessment of those relationships because data for horses that had only begun racing within the preceding 6 months were excluded from those analyses.

Risk factors with values of $P < 0.20$ on univariate analysis were eligible for inclusion in a multivariable logistic regression model. A threshold of $P < 0.20$ was chosen to prevent exclusion of a potentially significant risk factor that only becomes evident when a confounder has been controlled for in a multivariable analysis.[23] An automated stepwise selection process was used to build the multivariable model. Potential confounders were identified by use of a forward bidirectional elimination approach and assessment of the AIC. The AICs for competing models were compared, and the model with the lowest AIC was preferred.[24] Only risk factors with values of $P < 0.05$ were retained in the final model.

The potential effect of horse in the data analyses was evaluated by creating a mixed-effects model that included horse as a random effect. Results were nearly identical (< 0.01 change in ORs and no meaningful changes in *P* values) to results obtained with models that did not include random effects. Therefore, only results for models based on race starts without inclusion of horse as a random effect are reported.

Results

Between 2009 and 2013, Thoroughbred flat races took place at 144 racetracks, of which 37 had < 1,000 race starts recorded during the observation period. Collectively, data were extracted from the EID for 154,527 Thoroughbred racehorses that competed in 234,577 races at 89 racetracks. Those horses accounted for 1,891,483 race starts, of which 3,572 resulted in a fatal injury; thus, there were 1.9 fatal injuries/1,000 race starts. Univariate logistic regression results of the respective associations between the selected risk factors and the incidence of fatal injury for all horses **(Table 1)** and only those horses that had been competing in flat racing for ≥ 6 months **(Table 2)** were summarized.

The final multivariable logistic regression model for all horses included 17 risk factors **(Table 3)**. Horse-related risk factors included sex, age at first race start, whether the race was the horse's first race start, finish percentage (finish position/field size; eg, a horse that finishes fourth in a field of 8 would have a finish percentage of 50%, whereas a horse that finishes eighth in a field of 8 would have a finish percentage of 100%) in previous race, whether the horse has been placed by an association or regulatory veterinarian on the vet list (on vet list), number of previous injuries, number of previous scratches, and odds rank in the race (a horse with an odds rank of 1 is the horse favored to win the race). The risk of a fatal injury was increased for stallions, compared with that for mares and geldings. The risk of a fatal

Table 1—Results of univariate logistic regression for assessment of risk factors associated with fatal injuries in Thoroughbred racehorses competing in flat racing in the United States and Canada during the 5-year period from 2009 to 2013.

Risk factor	Control	Case	OR (95% CI)	*P* value
Sex				
Mare or gelding	1,648,276 (87)	2,986 (84)	Referent	—
Stallion	239,635 (13)	586 (16)	1.35 (1.24-1.48)	< 0.001
Age (y)	4.516 (4.514–4.519)	4.596 (4.546–4.646)	1.034 (1.013–1.056)	0.002
Age at first race start (y)	3.428 (3.426–3.429)	3.514 (3.473–3.554)	1.055 (1.029–1.082)	< 0.001
Country				
Canada	155,510 (8)	188 (5)	Referent	—
United States	1,732,401 (92)	3,384 (95)	1.616 (1.395–1.872)	< 0.001
On vet list				
No	1,877,766 (99)	3,531 (99)	Referent	—
Yes	10,145 (1)	41 (1)	2.149 (1.579–2.926)	< 0.001
First race start				
No	1,740,519 (92)	3,375 (94)	Referent	—
Yes	147,392 (8)	197 (6)	0.689 (0.597–0.796)	< 0.001
Field size (No. of horses)	8.521 (8.519–8.524)	8.548 (8.486–8.611)	1.007 (0.990–1.024)	0.404
Finish percentage of previous race (%)	54.047 (54.025–54.069)	52.470 (51.963–52.977)	0.993 (0.991–0.995)	< 0.001
No. of months in racing	13.254 (13.237–13.274)	13.178 (12.780–13.576)	0.100 (0.997–1.002)	0.711
No. of previous injuries	0.0242 (0.0240–0.0244)	0.0414 (0.0343–0.048)	1.612 (1.388–1.872)	< 0.001
No. of previous scratches	1.246 (1.243–1.248)	1.369 (1.304–1.434)	1.030 (1.015–1.046)	< 0.001
Odds at start of race	17.571 (17.541–17.602)	15.266 (14.642–15.890)	0.994 (0.992-0.996)	< 0.001
Odds rank in race	4.761 (4.757–4.765)	4.375 (4.287–4.463)	0.946 (0.934–0.958)	< 0.001
Starting (post) position	4.761 (4.757–4.765)	4.801 (4.712–4.890)	1.006 (0.993–1.018)	0.374
Low purse race (≤ $7,500)				
No	1,585,978 (84)	3,029 (85)	Referent	—
Yes	301,933 (16)	543 (15)	0.942 (0.859–1.032)	0.197
Purse ($)	23,905 (23,920–23,989)	21,011 (19,467–22,555)	0.998 (0.997–0.999)	0.001
Change in purse since previous race				
No change	851,954 (45)	1,528 (43)	Referent	—
Decrease	438,357 (23)	959 (27)	1.220 (1.125–1.322)	< 0.001
Increase	382,306 (20)	693 (19)	1.011 (0.924–1.106)	0.817
Sharp decrease	116,107 (6)	223 (6)	1.071 (0.930–1.233)	0.340
Sharp increase	99,187 (5)	169 (5)	0.950 (0.810–1.114)	0.527
Race distance (fur)	6.703 (6.701–6.705)	6.559 (6.515–6.603)	0.919 (0.896–0.943)	< 0.001
First start with new trainer				
No	1,710,891 (91)	3,155 (88)	Referent	—
Yes	177,020 (9)	417 (12)	1.277 (1.153–1.415)	< 0.001
Training with first trainer				
No	826,388 (44)	1,737 (49)	1.216 (1.134–1.298)	< 0.001
Yes	1,061,523 (56)	1,835 (51)	Referent	—
Time with same trainer (mo)	6.368 (6.356–6.379)	5.542 (5.300–5.784)	0.986 (0.982–0.991)	< 0.001
No. of days between race starts since change of trainer	3.144 (3.085–3.204)	1.979 (0.526–3.432)	0.999 (0.998–1.000)	0.097
First start with new jockey				
No	914,758 (48)	1,639 (46)	Referent	—
Yes	973,153 (52)	1,933 (54)	1.109 (1.038–1.184)	0.002
Time with same jockey (mo)	0.845 (0.842–0.848)	0.785 (0.726–0.844)	0.985 (0.968–1.002)	0.083
Racetrack surface				
Synthetic	235,878 (12)	289 (8)	Referent	—
Off-dirt*	248,168 (13)	528 (15)	1.737 (1.504–2.005)	< 0.001
Dirt	1,152,404 (61)	2,350 (66)	1.664 (1.473–1.881)	< 0.001
Turf	251,461 (13)	405 (11)	1.315 (1.130–1.529)	< 0.001

Values for controls and cases were the mean (95% CI) or the number (%) of horses for all race starts. Data were obtained from the EID. A fatal injury was defined as an injury sustained during a race that resulted in the euthanasia or death of the horse within 3 days. There were 1,891,483 official race starts by 154,527 horses; 3,572 starts resulted in a fatal injury (cases), all other starts were considered controls. On vet list refers to horses that were placed by a veterinarian on the vet list and entered a race while on the list. Finish percentage in previous race was calculated as the finish position of a horse/field size of the previous race (ie, a horse that finished fourth in a field of 8 would have a finish percentage of 50%, whereas a horse that finished eighth in a field of 8 would have a finish percentage of 100%). Within a variable and category (control or case), percentages may not total 100 because of rounding.

*Dirt in any nonfast (sloppy or muddy) condition.

— = Not applicable. CI = Confidence interval.

injury also increased if the horse was on the vet list and as its number of previous injuries and scratches increased. Protective horse-related risk factors (factors that decreased the risk of fatal injury) included first race start and odds rank in race (risk decreased as horses become less favored to win). The risk of fatal injury also decreased as the finish percentage in the previous race increased. Racetrack-related risk

Table 2—Results of univariate logistic regression for assessment of risk factors associated with fatal injuries for the horses of Table 1 that had been racing for ≥ 6 months.

Risk factor	Control	Case	OR (95% CI)	*P* value
Sex				
Mare or gelding	1,078,244 (90)	1,945 (86)	Referent	—
Stallion	117,862 (10)	311 (14)	1.463 (1.298–1.649)	< 0.001
Age (y)	4.942 (4.940 to 4.945)	5.001 (4.940 to 5.062)	1.028 (0.999–1.057)	0.055
Age at first race start (y)	3.328 (3.326 to 3.330)	3.410 (3.362 to 3.457)	1.061 (1.025–1.097)	0.001
Country				
Canada	94,696 (8)	105 (5)	Referent	—
United States	1,101,410 (92)	2,151 (95)	1.761 (1.448–2.143)	< 0.001
On vet list				
No	1,188,425 (99)	2,229 (99)	Referent	—
Yes	7,681 (1)	27 (1)	1.874 (1.281–2.741)	0.001
Field size (No. of horses)	8.394 (8.390 to 8.397)	8.465 (8.388 to 8.541)	1.019 (0.998–1.042)	0.079
Finish percentage in previous race (%)	53.205 (53.183 to 53.227)	51.418 (50.925 to 51.912)	0.988 (0.984–0.991)	< 0.001
No. of months in racing	19.658 (19.639 to 19.678)	19.376 (18.911 to 19.840)	0.998 (0.994–1.001)	0.223
No. of previous injuries	0.0357 (0.0353 to 0.0361)	0.0603 (0.0497 to 0.0709)	1.600 (1.368–1.871)	< 0.001
No. of previous scratches	1.775 (1.773 to 1.779)	1.915 (1.822 to 2.007)	1.027 (1.009–1.044)	0.003
No. of race starts by horse				
< 30 d prior to race	0.837 (0.835 to 0.838)	0.758 (0.731 to 0.785)	0.845 (0.795–0.899)	< 0.001
30–60 d prior to race	0.966 (0.965 to 0.967)	0.100 (0.969 to 1.031)	1.053 (1.001–1.108)	0.047
61–90 d prior to race	0.868 (0.867 to 0.870)	0.954 (0.922 to 0.987)	1.134 (1.080–1.192)	< 0.001
91–180 d prior to race	2.198 (2.195 to 2.201)	2.502 (2.432 to 2.572)	1.098 (1.073–1.123)	< 0.001
No. of race starts by trainer				
< 30 d prior to race	19.757 (19.717 to 19.797)	19.778 (18.923 to 20.634)	1.000 (0.998–1.002)	0.963
30–60 d prior to race	17.160 (17.122 to 17.197)	17.204 (16.398 to 18.010)	1.000 (0.998–1.002)	0.920
61–90 d prior to race	16.090 (16.052 to 16.128)	16.059 (15.231 to 16.888)	1.000 (0.998–1.002)	0.946
91–180 d prior to race	42.091 (41.984 to 42.197)	42.476 (40.179 to 44.772)	1.000 (0.999–1.001)	0.759
No. of trainer wins				
< 30 d prior to race	3.061 (3.052 to 3.070)	3.075 (2.879 to 3.271)	1.001 (0.992–1.009)	0.898
30–60 d prior to race	2.684 (2.676 to 2.692)	2.740 (2.558 to 2.921)	1.002 (0.994–1.011)	0.574
61–90 d prior to race	2.528 (2.520 to 2.537)	2.580 (2.392 to 2.769)	1.002 (0.994–1.011)	0.602
91–180 d prior to race	6.644 (6.621 to 6.667)	6.840 (6.329 to 7.350)	1.001 (0.998–1.004)	0.469
Winning percentage				
< 30 d prior to race	0.0858 (0.0854 to 0.0862)	0.0926 (0.0810 to 0.1042)	1.096 (0.944–1.272)	0.228
30–60 d prior to race	0.0945 (0.0941 to 0.0949)	0.1234 (0.1109 to 0.1359)	1.423 (1.242–1.630)	< 0.001
61–90 d prior to race	0.0854 (0.0850 to 0.0858)	0.1097 (0.0979 to 0.1215)	1.385 (1.201–1.598)	< 0.001
91–180 d prior to race	0.0972 (0.0968 to 0.0976)	0.1208 (0.1118 to 0.1298)	1.642 (1.374–1.962)	< 0.001
Mean speed during previous race (m/s)	16.210 (16.208 to 16.213)	16.259 (16.197 to 16.321)	1.033 (0.995–1.072)	0.086
Mean change in speed from previous race (m/s)	–0.006 (–0.009 to –0.003)	0.020 (–0.066 to 0.107)	1.008 (0.985–1.032)	0.482
Time since previous start (d)	43.639 (43.517 to 43.762)	41.843 (38.902 to 44.784)	0.9995 (0.9989–1.0002)	0.212
Odds at start of race	16.947 (16.910 to 16.984)	14.347 (13.610 to 15.084)	0.993 (0.990–0.995)	< 0.001
Odds rank in race	4.691 (4.686 to 4.696)	4.291 (4.183 to 4.400)	0.942 (0.927–0.958)	< 0.001
Starting (post) position	4.698 (4.693 to 4.703)	4.773 (4.662 to 4.884)	1.011 (0.995–1.027)	0.178
Low purse race (≤ $7,500)				
No	982,380 (82)	1,893 (84)	Referent	—
Yes	213,726 (18)	363 (16)	0.881 (0.788–0.986)	0.028
Purse ($)	22,683 (22,574 to 22,792)	19,014 (17,989 to 20,038)	0.997 (0.995–0.998)	< 0.001
Change in purse since previous race				
No change	492,517 (41)	905 (40)	Referent	—
Decrease	299,774 (25)	641 (28)	1.164 (1.052–1.288)	0.003
Increase	263,620 (22)	471 (21)	0.972 (0.870–1.087)	0.622
Sharp decrease	77,497 (6)	141 (6)	0.990 (0.829–1.183)	0.913
Sharp increase	62,698 (5)	98 (4)	0.851 (0.690–1.048)	0.129
Race distance (fur)	6.792 (6.790 to 6.794)	6.589 (6.533 to 6.644)	0.889 (0.861–0.978)	< 0.001
First start with new trainer				
No	1,063,968 (89)	1,938 (86)	Referent	—
Yes	132,138 (11)	318 (14)	1.321 (1.173–1.488)	< 0.001
Training with first trainer				
No	739,211 (62)	1,523 (68)	1.284 (1.176–1.403)	< 0.001
Yes	456,895 (38)	733 (32)	Referent	—
Time with same trainer (mo)	9.057 (9.041 to 9.074)	7.647 (7.297 to 7.998)	0.981 (0.976–0.986)	< 0.001
No. of days between race starts since change of trainer	4.162 (4.068 to 4.255)	1.932 (–0.346 to 4.209)	0.999 (0.998–1.000)	0.043
First start with new jockey				
No	518,291 (43)	946 (42)	Referent	—
Yes	677,815 (57)	1,310 (58)	1.059 (0.974–1.151)	0.180
Time with same jockey (mo)	1.050 (1.046 to 1.055)	0.930 (0.841 to 1.018)	0.978 (0.960–0.997)	0.021
Racetrack surface				
Synthetic	131,402 (11)	150 (7)	Referent	—
Off-dirt*	162,002 (14)	353 (16)	1.909 (1.577–2.311)	< 0.001
Dirt	739,765 (62)	1,500 (66)	1.776 (1.502–2.101)	< 0.001
Turf	162,937 (14)	253 (11)	1.360 (1.111–1.665)	0.003

There were 1,198,362 official race starts by 101,256 horses that had been racing ≥ 6 months; 2,256 starts resulted in a fatal injury (cases), and all other starts were considered controls. Winning percentage was calculated as the number of wins/number of race starts. ***See*** Table 1 for remainder of key.

Table 3—Final multivariable model for the horses of Table 1.

Risk factor	OR (95% CI)	*P* value
Intercept	0.0024 (0.0018–0.0032)	< 0.001
Age at first race start (per y)	1.076 (1.049–1.104)	< 0.001
Sex		
Mare or gelding	Referent	—
Stallion	1.430 (1.305–1.566)	< 0.001
Country		
Canada	Referent	—
United States	1.376 (1.185–1.598)	< 0.001
On vet list		
No	Referent	—
Yes	1.766 (1.292–2.413)	< 0.001
First race start		
No	Referent	—
Yes	0.633 (0.529–0.743)	< 0.001
Finish percentage in previous race (per 1%)	0.993 (0.991–0.995)	< 0.001
No. of previous injuries (per injury)	1.550 (1.332–1.804)	< 0.001
No. of previous scratches (per scratch)	1.029 (1.013–1.046)	< 0.001
Odds rank in race (per rank)	0.966 (0.953–0.980)	< 0.001
Low purse race (≤ $7,500)		
No	Referent	—
Yes	0.830 (0.752–0.916)	< 0.001
Purse (per $1,000)	0.998 (0.997–1.000)	0.022
Change in purse since previous race		
No change (between –$1,000 and +$1,000)	Referent	—
Moderate decrease ($1,000–$15, 000 decrease)	1.135 (1.042–1.236)	0.004
Moderate increase ($1,000–$15,000 increase)	0.941 (0.856–1.035)	0.212
Large decrease (> $15,000 decrease)	1.057 (0.912–1.225)	0.464
Large increase (> $15,000 increase)	1.034 (0.861–1.242)	0.717
Race distance (per furlong)	0.916 (0.892–0.940)	< 0.001
Time with same trainer (per mo)	0.983 (0.979–0.988)	< 0.001
No. of days between race starts since change of trainer (per d)	0.999 (0.998–1.000)	0.014
First start with new jockey		
No	Referent	—
Yes	1.076 (1.003–1.154)	0.042
Racetrack surface		
Synthetic	Referent	—
Off-dirt*	1.582 (1.367–1.830)	< 0.001
Dirt	1.524 (1.345–1.726)	< 0.001
Turf	1.295 (1.110–1.512)	0.001

See Table 1 for key.

factors included country where the race took place, racetrack surface, race distance, and race purse. The risk of a fatal injury was increased for horses that raced on racetracks in the United States, compared with racetracks in Canada, and on tracks with a turf, dirt, or off-dirt (dirt in any nonfast [sloppy or muddy] condition) surface, compared with tracks with a synthetic surface. The risk of a fatal injury decreased as the race distance and purse increased. Trainer-related risk factors included time with the same trainer and number of days between races after a change in trainer. Both of those factors were protective; the risk of fatal injury decreased as the number of months the horse was trained by the same trainer increased and as the number of days between races after a change in trainer increased. The only jockey-related risk factor included in the final model was first start with a new jockey; the risk of a fatal injury for a horse in its first race with a new jockey was greater than that for a horse in a race in which it was ridden by a jockey who had ridden it in previous races.

The final multivariable logistic regression model for only those horses that had been competing in flat racing for ≥ 6 months also included 17 risk factors **(Table 4)**. Risk factors included in both final multivariable models (ie, the models for all horses and only horses that had been racing for ≥ 6 months) included age at first race start, sex, country where race took place, on vet list, finish percentage in previous race, number of previous injuries, number of previous scratches, odds rank in race, race purse, race distance, time with same trainer, number of days between races after a change in trainer, and racetrack surface. The respective effects (increase or decrease risk of fatal injuries) of those risk factors were the same for both models. Risk factors included in the final model for horses that had been racing for ≥ 6 months but not in the final model for all horses were number of race starts prior to the race of interest and the winning percentage (number of wins/number of race starts). The risk of a fatal risk injury increased as the winning percentage up to 180 days before the race of interest increased. Interestingly, the risk of a fatal in-

Table 4—Final multivariable model for the horses of Table 2.

Risk factor	OR (95% CI)	*P* value
Intercept	0.002 (0.001–0.003)	< 0.001
Age at first race start (per 1 y)	1.078 (1.041–1.116)	< 0.001
Sex		
Mare or gelding	Referent	—
Stallion	1.544 (1.366–1.744)	< 0.001
Country		
Canada	Referent	—
United States	1.304 (1.066–1.594)	0.010
On vet list		
No	Referent	—
Yes	1.526 (1.038–2.243)	0.032
Field size	1.060 (1.035–1.085)	< 0.001
Finish percentage in previous race (per 1%)	0.991 (0.987–0.996)	< 0.001
No. of previous injuries	1.550 (1.323–1.815)	< 0.001
No. of previous scratches	1.020 (1.002–1.039)	0.032
Odds rank in race	0.951 (0.934–0.968)	< 0.001
Low purse race (≤ $7,500)		
No	Referent	—
Yes	0.817 (0.725–0.922)	0.001
Purse (per $1,000)	0.996 (0.994–0.998)	0.001
No. of race starts		
< 30 d prior to race	0.801 (0.748–0.857)	< 0.001
61–90 d prior to race	1.080 (1.023–1.140)	0.006
91–180 d prior to race	1.064 (1.038–1.092)	< 0.001
Race distance (per fur)	0.895 (0.865–0.925)	< 0.001
Time with same trainer (per mo)	0.985 (0.980–0.990)	< 0.001
No. of days between race starts since change of trainer (per d)	0.998 (0.997–0.999)	0.002
Winning percentage (per 1%)		
31–60 d prior to race	1.248 (1.084–1.437)	0.002
91–180 d prior to race	1.227 (1.007–1.494)	0.042
Racetrack surface		
Synthetic	Referent	—
Off-dirt*	1.752 (1.442–2.128)	< 0.001
Dirt	1.618 (1.363–1.920)	< 0.001
Turf	1.322 (1.075–1.627)	0.008

See Table 2 for key.

jury decreased as the number of race starts within 30 days before the race of interest increased but increased as the number of race starts within 61 to 180 days before the race of interest increased.

Discussion

Results of the present study suggested that the risk for fatal injuries (euthanasia or death of a horse within 3 days after sustaining an injury during a race) in Thoroughbred racehorses that competed in flat racing in the United States and Canada during the 5-year period of 2009 to 2013 was increased for horses that were examined by a veterinarian immediately before a race (on vet list) or had sustained a previous injury. Racing a horse that was on the vet list was one of the risk factors with the highest magnitude of effect in the present study. Additionally, the risk that a horse would sustain a fatal injury increased approximately 3% for each scratch (withdrawal from a race). Those findings concur with the results of another study[19] in which horses identified as being at risk by regulatory veterinarians during prerace examinations were 5 to 14 times as likely to sustain a musculoskeletal injury or injury of the suspensory or SDFT as horses that were identified as not at risk by regulatory veterinarians during prerace examinations.

In the present study, the risk of a fatal injury was greater for stallions than for mares and geldings. Results of a case-control study[25] of deceased Thoroughbred racehorses in California indicate that stallions are more likely than mares and geldings to fracture the proximal sesamoid bones of the forelimb. Greater than 80% of the fatal injuries assessed in the present study were fractures. Stallions are also at greater risk of sustaining a catastrophic musculoskeletal injury,[3] nonfatal SDFT injury,[26] or indeed any form of fatal injury,[2] compared with mares and geldings. Interestingly, results of a case-control study[27] involving Thoroughbred racehorses in Australia suggest that sex is not significantly associated with serious musculoskeletal injures. However, the investigators of that study[27] compared the incidence of serious musculoskeletal injures between males and females; it is possible the results were confounded, or biased, by the inclusion of geldings with stallions in the male category.

Successful racehorses appeared to be at an increased risk of fatal injury in the present study. Races with a purse < $7,500 appeared to be protective against fatal injury, although the risk of fatal injury appeared to decrease as the race purse increased. Races with a low (< $7,500) purse might have been a proxy for the quality of racehorses or lack of competitiveness in those races, which may explain their apparent protective effect against fatal injury. Another indicator that successful and competitive horses are at increased risk of fatal injury is the apparent protective effect of the odds rank; the risk of fatal injury decreased as the odds rank for a horse increased (ie, as the horse became less favored to win). In the case-control study[27] of Thoroughbred racehorses in Australia, the risk of serious musculoskeletal injury also increased as the competitiveness or race purse increased.

In the present study, the risk of a fatal injury decreased as the number of race starts for a horse within 30 days prior to the race of interest increased, but increased as the number of race starts for a horse increased within 61 to 90 and 91 to 180 days before the race of interest. This finding suggested that the risk of fatal injury increases for horses with a > 1-month break between races, and is consistent with results of another study[19] in which the risk of a horse sustaining a nonfatal SDFT injury increased 8-fold after a > 2-month break in racing. Results of another study[28] also indicate that the risk of an SDFT or suspensory apparatus injury was greater for horses with no race starts than for horses with multiple race starts. Investigators of a case-control study[17] of Thoroughbred racehorses in California reported that the risk of a fatal skeletal injury was increased as the cumulative exercise and race distance during the 2 months prior to the race of interest increased. The number of workouts, or exercise sessions, for racehorses is positively associated with the risk of proximal sesamoid bone fractures.[25] The EID did not include information regarding the extent of training or exercise for individual horses evaluated in the present study, but the number of race starts during certain periods (eg, 61 to 90 days and 91 to 180 days prior to the race of interest) could be used as a proxy measure for cumulative exercise, in which case our findings are similar to those of the other studies[17,25] in which the risk of injury increased as cumulative exercise increased. Another interesting finding of the present study was that the risk of fatal injury decreases as the time that a horse is trained by the same trainer increases.

Racetrack surface was also associated with the risk of fatal injuries in the Thoroughbred racehorses of the present study. Compared with racetracks with synthetic surfaces, the risk of fatal injury was greatest for racetracks with off-dirt and dirt surfaces followed by racetracks with turf surfaces. That finding was consistent with the results of another study[29] in which the race-associated fatality rate for racehorses in California was greatest for dirt tracks followed by turf and then synthetic tracks. In that study,[29] the race-associated fatality rate for racetracks with dirt surfaces was significantly greater than that for racetracks with synthetic surfaces but did not differ significantly from that for racetracks with turf surfaces, and the fatality rate for racetracks with turf surfaces did not differ significantly from that for racetracks with synthetic surfaces. The reason we were able to identify a statistical difference between synthetic and turf surfaces in the present study is likely a reflection of the large cohort available for analysis, which provided substantially greater power than the smaller study population in that other study.[29] In the present study, as in a previous study,[1] the risk of fatal injury on racetracks with dirt surfaces was significantly greater than that for racetracks with turf surfaces but did not differ significantly from that for racetracks with off-dirt surfaces.

The risk of fatal injury decreased as race distance increased and field size decreased in the present study. Results of a case-control study[10] of fatal fractures in the distal portion of the limbs of Thoroughbred racehorses in the United Kingdom also indicate a positive association between the risk of fatal injury and field size; however, unlike the present study, there was a positive association between risk of fatal injury and race distance. The reason for the discrepancy in the nature of the association between risk of fatal injury and race distance between that study[10] and the present study is most likely associated with differences in distance ranges for flat races in the United Kingdom, compared with the distance ranges for flat races in the United States and Canada. Thoroughbred flat races in the United States and Canada tend to be shorter than those in the United Kingdom. Consequently, races in the United States and Canada are run at a faster pace than races in the United Kingdom, and that fast pace likely contributed to the negative association between risk of fatal injury and race distance observed in this study.

Investigators of multiple studies[10,15,17,19,27,28] have reported a positive association between age and injury risk in Thoroughbred racehorses. Although age was eligible for inclusion in the multivariable models of the present study, it was not maintained in the final models, likely because of multicollinearity. Age was highly correlated with age at first race start, first race start, and number of previous injuries; however, correlation does not imply causation and inclusion of age in the models did not substantially improve the information gain.

The incidence rate of fatal injuries in Thoroughbred racehorses competing in flat racing at 89 tracks in the United States and Canada during the 5-year period from 2009 to 2013 was 1.9/1,000 race starts. That incidence rate was fairly consistent with the incidence rates for fatal musculoskeletal injuries in Thoroughbred racehorses reported in other US studies,[17,12,30,31] (1.2 to 1.96 fatal or catastrophic injuries/1,000 race starts) and a South African study[32] (1.4 catastrophic injuries/1,000 race starts). The incidence rate of fatal and nonfatal injuries in Thoroughbred racehorses was 3.18/1,000 race starts in a study[33] that involved 27 racetracks in Minnesota from 1987 to 1992; unfortunately, the number of fatal injuries was not reported separately from the number of nonfatal injuries in that study. Regardless, the incidence rates of fatal injuries in Thoroughbred racehorses in the United States appear to be much higher than those for racehorses in the United Kingdom[13,34,35] (0.38 to 0.9 fatal injuries/1,000 race starts) and Australia[36,37] (0.3 to 0.44 fatal injuries/1,000 race starts). Moreover, the incidence rates within each jurisdiction, or country, have remained fairly constant since the 1980s.

To our knowledge, the present study was the first to extensively evaluate data obtained from the EID. The data evaluated in the present study represented 93.9% of all official Thoroughbred racing events in the United States and Canada during the 5-year observation period. Therefore, we are confident that our results are unbiased effect estimates for the risk factors evaluated because the data for the approximately 6% of racing events that were not reported to the EID represent a small source of bias.

It is important to note that we did not make any attempt to differentiate the causes of fatal injury in the present study. Risk factors vary among types of fractures,[13,25] and it is likely that some of those risk factors were not identified in the present study. The types of injuries sustained and the reason for euthanasia have been accurately reported to the EID only recently. Thus, future analyses will be able to use more specific outcome variables to identify risk factors associated with the most common reasons for euthanasia of Thoroughbred racehorses following race-induced injuries.

We concede that statistical significance does not necessarily translate to clinical significance. Although we identified several risk factors that were significantly associated with fatal injuries in Thoroughbred horses competing in flat racing, it is important to point out that the vast majority (1,887,911/1,891,483 [99.8%]) of race starts evaluated in the present study did not result in a fatal injury. Because of the extremely large number of race starts evaluated and the resulting high statistical power of this study, the magnitude of effect for some of the risk factors was very small, and this should be considered during discussions regarding the selection and implementation of measures expected to have the greatest effect on minimizing the number of horses that sustain fatal injuries during flat races in the United States and Canada. Nevertheless, the results of the present study can be used as a guideline for the identification of racehorses at high risk of sustaining a fatal injury during a race.

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From this month's *AJVR*

An attempt to detect lameness in galloping horses by use of body-mounted inertial sensors

Marco A. F. Lopes et al

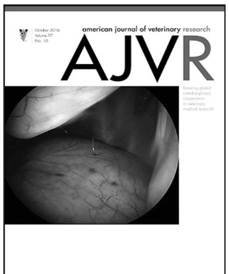
OBJECTIVE
To evaluate head, pelvic, and limb movement to detect lameness in galloping horses.

ANIMALS
12 Thoroughbreds.

PROCEDURES
Movement data were collected with inertial sensors mounted on the head, pelvis, and limbs of horses trotting and galloping in a straight line before and after induction of forelimb and hind limb lameness by use of sole pressure. Successful induction of lameness was determined by measurement of asymmetric vertical head and pelvic movement during trotting. Differences in gallop strides before and after induction of lameness were evaluated with paired-sample statistical analysis and neural network training and testing. Variables included maximum, minimum, range, and time indices of vertical head and pelvic acceleration, head rotation in the sagittal plane, pelvic rotation in the frontal plane, limb contact intervals, stride durations, and limb lead preference. Difference between median standardized gallop strides for each limb lead before and after induction of lameness was calculated as the sum of squared differences at each time index and assessed with a 2-way ANOVA.

RESULTS
Head and pelvic acceleration and rotation, limb timing, stride duration measurements, and limb lead preference during galloping were not significantly different before and after induction of lameness in the forelimb or hind limb. Differences between limb leads before induction of lameness were similar to or greater than differences within limb leads before and after lameness induction.

CONCLUSIONS AND CLINICAL RELEVANCE
Galloping horses maintained asymmetry of head, pelvic, and limb motion between limb leads that was unrelated to lameness. (*Am J Vet Res* 2016;77:1121–1131)



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