Risk factors for and outcomes of noncatastrophic suspensory apparatus injury in Thoroughbred racehorses

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Objective—To evaluate effects of toe grabs, exercise intensity, and distance traveled as risk factors for subclinical to mild suspensory apparatus injury (SMSAI) in Thoroughbred racehorses and to compare incidence of severe musculoskeletal injury (MSI) in horses with and without SMSAI.

Design—Nested case-control study.

Animals—219 Thoroughbred racehorses racing or in race training.

Procedure—Racehorses were examined weekly for 90 days to determine incidence of suspensory ligament injury and monitor horseshoe characteristics. Every horse's exercise speeds and distances were recorded daily. Conditional logistic regression was used to compare exposure variables between incident case (n = 25) and selected control (125) horses. Survival analysis was used to compare time to MSI for horses with (n = 41) and without (76) SMSAI.

Results—The best-fitting logistic model for the data included age (< 5 vs ≥ 5 years old), toe grab height the week of injury (none vs very low, low, regular, or Quarter Horse height), and weekly distance the week preceding injury (miles). Although the 95% confidence intervals for all odds ratios included 1, the odds for SMSAI appeared to increase with the presence of a toe grab, higher weekly distance, and age ≥ 5 years. Horses that had SMSAI were significantly more likely to have a severe MSI or severe suspensory apparatus injury than were horses that did not.

Conclusions and Clinical Relevance—Results suggest that pre-existing SMSAI is associated with development of severe MSI and severe suspensory apparatus injury. Modifying training intensity and toe grab height for horses with SMSAI may decrease the incidence of severe MSI. (J Am Vet Med Assoc 2001; 218:1136–1144)

Musculoskeletal injuries (MSI) are the most common conditions afflicting racehorses. Such injuries range from mild conditions associated with barely discernible lameness to severe damage necessitating euthanasia. Catastrophic (fatal) injuries are uncommon, whereas mild to moderate injuries affect many horses. Outcome varies with severity of the injury, but may include training remission, poor performance, change of career, retirement from competition, and euthanasia. Musculoskeletal injuries are more common in the forelimbs than in the hind limbs, and one of the most common sites of catastrophic injury involving the forelimbs of racehorses is the suspensory apparatus (suspenso ligament and its branches, proximal sesamoid bones, and distal sesamoidean ligaments). A catastrophic suspensory apparatus injury (SAI) involves failure of the suspensory apparatus, so that the metacarpophalangeal joint is no longer supported by the suspensory apparatus. A severe SAI (SSAI), on the other hand, involves failure of only a portion of the suspensory apparatus, with some support structures of the metacarpophalangeal joint remaining intact; horses with SSAI are severely lame. A mild SAI causes discernible lameness, but does not involve structural failure. A subclinical SAI involves inflammation of the structures comprising the suspensory apparatus, but the damage is not severe enough to cause discernible lameness.

Epidemiologic studies have identified multiple risk factors for mild to catastrophic MSI in racehorses, including recent accumulation of high-speed work, recent return from lay-up, type or class of race (eg, claiming or maiden), racetrack, distance of race, summary assessment of risk determined from a prerace physical inspection, higher Beyer's numbers, decreased exercise during the month preceding injury, abnormality of the suspensory ligament detected during a prerace physical examination, stumbling during a race, physical interaction during a race, change in the lead limb during the 12 seconds preceding an injury, horse age ≥ 5 years, hoof balance, and presence of toe grabs. Three of these studies specifically addressed SAI. In 1 study, the presence and height of toe grabs were associated with increased odds of catastrophic suspensory apparatus failure, and the presence of a rim on the shoes worn by the horse was associated with decreased odds of catastrophic suspensory apparatus failure. Only horses that had died for any reason were included in that study, and most horses died of catastrophic MSI. The other 2 studies included live racehorses and assessed mild, severe, and catastrophic injuries as a single group. The likelihood of a mild to catastrophic SAI of the forelimb was associated with a summary assessment of risk determined from a prerace physical inspection, a change in lead limb during the 12 seconds preceding the injury, an abnormality of the suspensory ligament detected dur-
ing a prerace physical inspection,13,15 horse age ≥ 5 years,13 racetrack,1 race number ≤ 6,1 claiming price ≤ $25,000,13 race distance ≤ 7 furlongs,15 and an abnormality of the metacarpophalangeal joint detected during a prerace physical inspection.13 One study15 found that an increase in distance from the preceding race was associated with a decrease in the likelihood of a mild to catastrophic SAI of the forelimb.

We hypothesized that severe and catastrophic SAI result from mild to moderate damage accumulated over time at a rate greater than the healing capacity of the tissue, a process similar to that documented for humeral fractures.16 The finding that prerace suspensory ligament and metacarpophalangeal joint abnormalities are associated with mild to catastrophic SAI13,15 supports this hypothesis. To our knowledge, there are no published studies of risk factors for subclinical SAI in horses, nor have outcomes of horses with subclinical to mild SAI (SMSAI) been reported. However, causal factors for SMSAI are assumed to be the same as those for severe injuries, and a potential outcome of preexisting SMSAI is assumed to be severe or catastrophic SAI. In addition, because metacarpophalangeal joint abnormalities can occur in conjunction with SAI, and because a previous study5 reported that catastrophic suspensory apparatus failure and fracture of the condyle of the third metacarpal bone frequently occurred together and a second study21 reported that palpable metacarpophalangeal joint abnormalities were associated with severe to catastrophic SAI, condylar fracture of the third metacarpal bone (CDY) should also be considered a potential outcome for horses with SMSAI.

Horse shoe design affects the interface between the hoof and the ground, and alterations of this interface can affect gait mechanics.17 Toe grabs are steel traction devices that extend distally from the toe of a horse-shoe. A toe grab may raise the toe above the ground surface, thus simulating a lower hoof angle,5 which likely affects traction with the race surface. A toe grab may also act as a fulcrum to create mediolateral instability (wobble) at the toe, thus affecting hoof balance and stability. Hoof angle and balance affect the kinetics and kinematics of gait,10,20 and presumably affect loads experienced by the suspensory apparatus.21 More microdamage is believed to occur as more load is placed on the altered support system. Because load bearing is also related to exercise intensity and distance traveled, increases in intensity and distance are expected to contribute to injury. The purposes of the study reported here were to evaluate the simultaneous effects of toe grabs, exercise intensity, and distance traveled as risk factors for SMSAI and to evaluate incidence of severe MSI, particularly CDY and SSASI, in horses with and without SMSAI. We hypothesized that distance accumulated at high speeds while using toe grabs would increase the risk of SMSAI and that horses with SMSAI would have an increased risk of SSASI.

Materials and Methods

Study population—Thoroughbred racehorse trainers who had horses entered in races at the Santa Anita and Hollywood Park racetracks during the winter of 1998 were recruited to participate in the study by veterinarians practicing at the racetrack. To be eligible for participation, a trainer must have planned to have horses in training for the duration of the meets and to stable the horses at Santa Anita or Hollywood Park (horses stabled at either racetrack were eligible to race at both tracks). Approximately 250 trainers had horses in training at either track. Twenty-two trainers at Santa Anita and 23 at Hollywood Park (45/250; 18%) fit the criteria for inclusion and were willing to enroll horses in the study. To minimize unmeasured trainer effects, improve generalizability of findings, and prevent trainers with large stables from affecting study results disproportionately, no more than 5 horses were selected from each trainer. Trainers with fewer than 5 horses in training or who offered fewer than 5 horses for inclusion in the study contributed between 2 and 4 horses each. Approximately 90% of trainers allowed participating horses to be systematically selected from the trainer’s stable. Systematic random sampling was accomplished by dividing the number of horses in a trainer’s stable by 5 to get k, then arbitrarily selecting the horse in 1 of the first k stalls, and horses in every kth stall thereafter. The remaining trainers selected the horses that participated. Horses that were unable to race or train because of injury at the start of the study were excluded. At the time of enrollment, the following information was recorded for each horse enrolled: date of birth, sex, and racetrack where stabled. Data collection began on Mar 16, 1998, and concluded on Jun 14, 1998. Because horses that were in the study < 2 weeks contributed no useful information to the study, replacements were sought for horses that left the study during its initial 2 weeks. Of 14 horses that were lost to follow-up from the study during this period (4 were claimed, 1 changed tracks, 2 changed trainers, 4 had an MSI, 2 had non-musculoskeletal injuries, and 1 left for an unknown reason), 8 were replaced with another horse from the same trainer. Additionally, during this time, 2 horses were added by trainers who had not yet provided 5 horses. The number of horses that participated in the study, including the 10 replacements entered in the study after the initial date, was 219. Addition of replacement horses increased the maximum number of horses per trainer to 7, but only 5 horses were actively participating at any given time. One trainer later claimed another study horse, increasing the number of active study participants for this trainer to 6 and the total number of horses remaining in the study to 8. During the study, 1 horse was claimed by a trainer not originally participating in the study. This trainer elected to maintain the horse in the study, thus increasing the number of participating trainers to 46 and decreasing the minimum number of horses per trainer to 1.

Cohort data collection—Two observers (AGE, MBW) were used to collect data. One of the observers (MBW) underwent a training session on physical, horse shoe, and hoof examinations led by 1 of the authors (SMS), using a horse maintained for teaching purposes at the University of California, Davis. Both observers underwent 2 additional training sessions, led by the same author, at Hollywood Park racetrack, using 4 racehorses currently in training. The goal of the training sessions was to standardize the following observations between the 2 observers: structures palpated, positioning of limb for palpation, criteria for categorizing abnormalities, and results of physical, horse shoe, and hoof examinations.

For the first 35 days of the study, all horses stabled at Santa Anita were examined by observer A, and all horses stabled at Hollywood Park were examined by observer B. After completion of the Santa Anita racemeet, many horses originally stabled at Santa Anita were moved to Hollywood Park. Thus, for the remaining 35 days of the study, all horses still stabled at Santa Anita and most of the horses that moved...
from Santa Anita to Hollywood Park were examined by observer A, but 21 horses originally stabled at Santa Anita and belonging to 4 trainers were examined by observer B.

Left and right front limbs of each horse were also palpated weekly by 1 of the 2 observers while the horse was bearing weight on the limb and while the horse was not bearing weight on the limb. When the horse was not bearing weight on the limb, the observer supported the limb at the distal aspect of the metacarpus so the carpal joint was flexed and the metacarpophalangeal joint was relaxed in extension. The suspensory ligament and its branches were palpated, and any evidence of heat (evident, not evident), signs of pain (evident, not evident), swelling (none, mild [local], severe [diffuse]), or abnormal texture (normal [felt uniform throughout structure's length and width], soft [local spot felt soft in comparison to surrounding structure], firm [local spot felt firmer than surrounding structure]) was recorded. The base and apex of the proximal sesamoid bones were palpated and assessed for signs of pain (evident, not evident), signs of swelling, and normal and abnormal texture (evident, not evident).

Trainees were given daily exercise sheets indicating the category (walk, jog, pony, gallop, breeze, race) and corresponding distances (in furlongs) exercised by each horse in the preceding 7 days was a gallop or less. Weekly distances were compared with the database. The database records for study participants were obtained, and race dates and distances were compared with the database. The database was adjusted to correspond to official published race records when discrepancies were found. Races not included in the published race record were deleted.

Variable definition—Exercise intensity and weekly distance were used to summarize weekly training information. Exercise intensity was coded as 2 if the horse had raced during the preceding 7 days, 1 if the horse had breezed but not raced during the preceding 7 days, and 0 if the maximal speed attained during the preceding 7 days was a gallop or less. Weekly distance equaled the sum of the distances in miles traveled by a horse at a breeze or during a race in the preceding week.

Statistical analysis—For incident case and control horses, information on age, sex, toe grab height, rim status, exercise intensity, and weekly distance was obtained for the week of injury and the preceding week. Mantel-Haenszel odds ratios (OR) were generated for the week of injury and the preceding week preceding injury for the following variables: toe grab height, age, sex, exercise intensity, and rim status. Data were stratified on incident case and corresponding controls. For the continuous variable weekly distance, a paired t-test was used to compare mean value for case horses with mean value for control horses. Exposure variables and potential confounding variables that demonstrated a dose-response effect or had P values < 0.30 were chosen for inclusion in multivariable conditional logistic regression modeling. After exposures associated with SMSAI were identified, age was forced into the model to assess confounding associated with age. Adjusted OR and 99% CI were calculated for variables in the final model.

The following outcomes were compared between horses with and without SMSAI by use of y’ tests: any MSI resulting in training remission, SSAI (suspending ligament rupture or proximal sesamoid bone fracture), and CDY. Horses with SMSAI and those without were stratified on age (< 3 vs ≥ 3 years old) and compared by use of Kaplan-Meier product-limit survival methods. Time to SSAI or CDY was compared for the 2 age-stratified groups by use of a generalized Wilcoxon (Breslow) test, with values of P < 0.05 considered significant.

Results

Two hundred nineteen horses began the study, 117 with observer A and 102 with observer B. One hundred thirty-two horses (60%) completed the study.
horses that did not complete the study, 41 (47%) left because of an MSI, 4 (5%) left because of health reasons other than an MSI, 15 (17%) were claimed, transferred, or sold to a trainer not participating in the study, 15 (17%) were transferred to another track, 3 (3%) left because a trainer withdrew from the study, 1 (1%) was retired, and 8 (9%) left for unknown reasons. Attribution attributable to MSI varied substantially by trainer (mean proportion of a trainer's horses that left the study because of MSI, 18.8%; median, 14.3%; range, 0% to 80%).

Age and sex distributions of horses examined by each observer differed (Table 1). Results of palpation and horseshoe assessments also differed between observers. For observer A, 41 of 117 horses were defined as having SMSAI, whereas only 4 of 102 horses for observer B were so defined. Two types of shoes were misclassified as having no toe grabs, rather than having very low toe grabs, by observer B for the initial 45 days of the study. Because of potential inaccuracy of toe grab data for observer B, these data were excluded from analyses. Twenty-one horses switched observers during the study; only observer A data for these horses were included in the analysis.

Incidence of suspensory apparatus injury—Of the 117 observer A horses that began the study, 16 had evidence of suspensory ligament injury on their first physical examination and were considered prevalent cases of SMSAI. Twenty-five additional observer A horses were observed to have developed signs of SMSAI during the study and were considered incident cases of SMSAI. Seventy-six observer A horses had no signs of SMSAI during the study. For the 25 incident cases, time from study onset to SMSAI ranged from 1 to 10 weeks. Incidence of SMSAI was 1 case/214 horse-days of race training.

Outcome of horses—Of the 25 incident cases of SMSAI, 3 (12%) subsequently had a CDY (4, 8, and 9 weeks after SMSAI was first identified), 2 (8%) subsequently had a SSAI (3 and 7.5 weeks after SMSAI was first identified), 1 (4%) subsequently had a SSAI involving a hind limb, 2 (8%) were transferred to trainers or tracks not participating in the study, and 17 (68%) completed the study.

Of the 16 prevalent cases of SMSAI, 1 (6%) had carpal joint surgery, 1 (6%) had bone fragments removed surgically from the metacarpophalangeal joint, 1 (6%) had a severe injury to the superficial digital flexor tendon of 1 forelimb, 1 (6%) developed severe dorsal metacarpal periostitis, 1 (6%) died of a ruptured aorta, and 11 (69%) completed the study.

Of the 76 horses that did not have signs of SMSAI, 1 (1%) developed a CDY, 1 (1%) developed a SSAI, 2 (3%) had carpal joint surgery, 1 (1%) developed severe dorsal metacarpal periostitis, 2 (3%) had a severe injury of the superficial digital flexor tendon in 1 forelimb, 18 (24%) were transferred to trainers or tracks not participating in the study, and 51 (67%) completed the study.

Horseshoe characteristics—Toe grabs were observed on shoes at least once during the course of the study on 111 of 113 (98%) observer A horses, and rims were observed on 60 of 205 (29%) observer A and B horses that remained in the study for more than 14 days. Distribution of toe grab height and rims did not vary significantly with age of the horses (Table 2).

Risk factors for SAI—In univariate analyses (Table 3), horses ≥ 5 years old had higher odds of having an SMSAI, compared with horses ≤ 3 years old, and horses that wore low, regular, or Quarter Horse height toe grabs the week of injury had higher odds of having an SMSAI, compared with horses that did not wear toe grabs that week. Wearing a low, regular, or Quarter Horse height toe grab the week preceding an injury did not significantly increase the odds of having an SMSAI, but P values for these factors were less than the cutoff for inclusion in multivariable analyses. Mean weekly distance at a breeze or racing speed was not significantly different between case and control horses the week preceding an injury or the week of injury.
Variables selected for inclusion in multivariable logistic conditional regression modeling were age, toe grab height the week of injury, toe grab height the week preceding injury, exercise intensity the week preceding injury, and weekly distance the week preceding injury. To improve model fit, variables with 3 categories were collapsed into 2 categories on the basis of results of univariate analyses. Toe grab height was categorized as none versus very low, low, regular, and Quarter Horse height. Exercise intensity was categorized as breeze and slower versus race. Age was categorized as < 5 versus ≥ 5 years old.

The best-fitting model for the data (Table 4) included age (≤ 5 vs ≥ 5 years old) and toe grab height the week of injury (none vs very low, low, regular, and Quarter Horse height) as binary categorical variables and weekly distance the week preceding injury (miles) as a continuous variable. Although the 95% CI for all OR included 1, the odds for SMSAI appeared to increase with the presence of a toe grab, higher weekly distance, and age ≥ 5 years.

Incidence of injuries among horses with SMSAI—The proportion of horses that developed a severe MSI (ie, an MSI that resulted in a training remission) during the course of the study was higher for horses with an SMSAI than for those horses without evidence of SMSAI (Table 5). Similarly, the proportion of horses that developed a CDY appeared higher for horses with SMSAI, compared with those without, the difference was not statistically significant. Horses with SMSAI had shorter times to severe MSI (Fig 1) and to CDY or SSAI (Fig 2) than did horses without SMSAI. After stratification on age (< 5 vs ≥ 5 years), time to CDY or SSAI for horses with and without an SMSAI differed significantly (generalized Wilcoxon test, P = 0.01). Age did not interact with time or SMSAI status to affect time to CDY or SSAI.

Table 3—Results of univariate screening of variables for an association with subclinical or mild suspensory apparatus injury in Thoroughbred racehorses

<table>
<thead>
<tr>
<th>Variable</th>
<th>Category</th>
<th>No. of case horses (%)</th>
<th>No. of control horses (%)</th>
<th>OR</th>
<th>95% CI</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>≤ 3</td>
<td>8 (32)</td>
<td>62 (50)</td>
<td>1.0</td>
<td>Reference</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>5 (20)</td>
<td>30 (24)</td>
<td>1.11</td>
<td>0.27-4.10</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>≥ 5</td>
<td>12 (48)</td>
<td>33 (26)</td>
<td>2.80</td>
<td>0.91-9.58</td>
<td>0.08</td>
</tr>
<tr>
<td>Exercise intensity, week preceding injury</td>
<td>0</td>
<td>9 (36)</td>
<td>46 (37)</td>
<td>1.0</td>
<td>Reference</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>11 (44)</td>
<td>65 (52)</td>
<td>0.76</td>
<td>0.30-1.95</td>
<td>0.76</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>5 (20)</td>
<td>14 (11)</td>
<td>3.49</td>
<td>0.69-25.67</td>
<td>0.25</td>
</tr>
<tr>
<td>Exercise intensity, week of injury</td>
<td>0</td>
<td>6 (24)</td>
<td>28 (23)</td>
<td>1.0</td>
<td>Reference</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>15 (60)</td>
<td>75 (60)</td>
<td>1.04</td>
<td>0.41-2.90</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>4 (16)</td>
<td>21 (17)</td>
<td>0.69</td>
<td>0.08-4.09</td>
<td>1.0</td>
</tr>
<tr>
<td>Rim, week preceding injury</td>
<td>Yes</td>
<td>6 (24)</td>
<td>98 (78)</td>
<td>0.88</td>
<td>0.35-2.41</td>
<td>0.97</td>
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<tr>
<td></td>
<td>No</td>
<td>19 (76)</td>
<td>94 (75)</td>
<td>1.04</td>
<td>0.42-2.81</td>
<td>1.0</td>
</tr>
<tr>
<td>Rim, week of injury</td>
<td>Yes</td>
<td>6 (24)</td>
<td>19 (25)</td>
<td>1.0</td>
<td>Reference</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>19 (76)</td>
<td>94 (75)</td>
<td>1.05</td>
<td>0.42-2.81</td>
<td>1.0</td>
</tr>
<tr>
<td>Toe grab height, week preceding injury</td>
<td>None</td>
<td>3 (12)</td>
<td>27 (22)</td>
<td>1.0</td>
<td>Reference</td>
<td>NA</td>
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<td></td>
<td>Very low</td>
<td>9 (36)</td>
<td>36 (29)</td>
<td>1.27</td>
<td>0.32-6.19</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>Low, regular, or QH</td>
<td>13 (52)</td>
<td>62 (50)</td>
<td>1.99</td>
<td>0.59-8.68</td>
<td>0.47</td>
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<tr>
<td>Toe grab height, week of injury</td>
<td>None</td>
<td>2 (8)</td>
<td>24 (19)</td>
<td>1.0</td>
<td>Reference</td>
<td>NA</td>
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<tr>
<td></td>
<td>Very low</td>
<td>10 (40)</td>
<td>41 (33)</td>
<td>1.38</td>
<td>0.28-10.00</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>Low, regular, or QH</td>
<td>13 (52)</td>
<td>60 (48)</td>
<td>3.67</td>
<td>0.85-24.94</td>
<td>0.16</td>
</tr>
<tr>
<td>Sex</td>
<td>Gelding</td>
<td>12 (48)</td>
<td>58 (46)</td>
<td>1.0</td>
<td>Reference</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td>Sexually intact male</td>
<td>6 (24)</td>
<td>27 (22)</td>
<td>1.00</td>
<td>0.34-2.76</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>7 (28)</td>
<td>40 (32)</td>
<td>0.79</td>
<td>0.28-2.17</td>
<td>0.17</td>
</tr>
</tbody>
</table>

OR = Odds ratio. CI = Confidence interval. NA = Not applicable. QH = Quarter Horse.

Table 4—Estimated coefficients (β), standard errors (SE), odds ratios (OR), and 95% CI for conditional logistic regression analysis of the effect of toe grab height and weekly distance on incidence of subclinical or mild suspensory apparatus injury in 117 Thoroughbred racehorses

<table>
<thead>
<tr>
<th>Variable</th>
<th>β</th>
<th>SE</th>
<th>OR</th>
<th>95% CI</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Toe grab*</td>
<td>1.03</td>
<td>0.79</td>
<td>2.80</td>
<td>0.60-13.06</td>
<td>0.19</td>
</tr>
<tr>
<td>Weekly distance†</td>
<td>0.72</td>
<td>0.58</td>
<td>2.06</td>
<td>0.66-6.44</td>
<td>0.21</td>
</tr>
<tr>
<td>Age (≥ 5 y)</td>
<td>0.83</td>
<td>0.44</td>
<td>2.30</td>
<td>0.96-5.42</td>
<td>0.06</td>
</tr>
</tbody>
</table>

*Toe grab of any height worn during the week of injury. †Distance (in miles) run at a breeze or racing speed during the week preceding injury.
Discussion

Results of the present study suggested that when age was included as a binary variable, time to a MSI of any type and time to a CDY or SSAI specifically were significantly shorter for horses with evidence of preexisting SMSAI than for horses without. This indicated that regardless of age category (< 5 vs ≥ 5 years old), horses with SMSAI were significantly more likely to have a severe MSI of any kind within 90 days of injury, particularly a CDY or a SSAI, than were horses without SMSAI.

Consistent with findings of a previous study, in the present study, evidence of an SMSAI was positively associated with an increased risk of any type of catastrophic severe MSI, not just MSI associated with the suspensory apparatus. Thus, SMSAI may be indicators of musculoskeletal overuse or palpable manifestations of generalized musculoskeletal microdamage occurring at a rate faster than the healing capacity of the affected tissues. Alternatively, horses with a SMSAI may alter gait or limb alignment to decrease load on the injured suspensory apparatus, and these alterations may place increased load on other structures, leading to an increased incidence of severe MSI. Findings of the present study and a previous study do not agree with results of an earlier case-control study in which no significant association was found between palpable suspensory apparatus abnormalities and MSI of structures other than the suspensory apparatus. However, the case-control study evaluated palpation data on the same date as a MSI was identified, whereas the present study evaluated palpation data obtained 1 to 10 weeks prior to injury. Although the proportion of horses with palpable abnormalities of the suspensory apparatus in the previous study that had MSI of other structures on the date of examination may not have been significant, the proportion developing injury over a longer period may have been. Alternatively, the high percentage of MSI that were SSAI or CDY among horses with preexisting SMSAI in the present study may have led to an artificial association between risk factors for SSAI or CDY and all MSI.

During the 3-month period of the present study, 4 (3.4%) of 117 horses developed a CDY. The incidence of CDY in Thoroughbred racehorses is unknown, but CDY is thought to be a common injury. Condylar fractures severe enough to result in euthanasia comprise 17% of fatal MSI in Thoroughbreds, although most CDY (and all CDY in the present study) can be effectively treated with surgery or rest.

In the present study, the risk of CDY appeared to be higher in horses with SMSAI, compared with horses without SMSAI. This indicated that horses with SMSAI were more likely to have a severe MSI of any kind, particularly a CDY or a SSAI, within 90 days of injury.
es without SMSAI, though this association was not statistically significant. Condylar fractures and SAI have previously been shown to occur together. A study\(^5\) of catastrophic injuries in racehorses reported that 16 of 41 (39%) horses with a CDY also had a catastrophic SAI, and that 16 of 79 (20%) horses with a catastrophic SAI also had a CDY. A study\(^5\) of horses with mild to catastrophic SAI found a positive association between detection of an abnormality of the metacarpophalangeal joint during a prerace physical inspection and risk of an SAI. Suspensory apparatus injuries may increase the risk for condylar fracture by affecting gait or the biomechanical loading of the third metacarpal bone in a manner that promotes metacarpal fracture. Such injuries could also be an indicator of accumulated microdamage in other musculoskeletal structures (eg, the third metacarpal bone). Alternatively, SAI and condylar fractures could share the same risk factors. Regardless, it is likely that the etiopathogenesis of these injuries is similar.

Although significant associations were not found, the effect of weekly distance and toe grab height on development of SMSAI suggest that use of toe grabs and longer distances at high speed may be associated with increased risk of SMSAI. Toe grab height and weekly distance fit separately into the model; therefore, wearing a toe grab was, by itself, a risk factor for injury and was not merely a proxy for intensive race training. It is possible that toe grab height and weekly distance may additionally interact with each other to affect the risk of SMSAI, but sample size was too low in the present study to adequately assess such an interaction.

Results of the present study are consistent with results of previous studies\(^6-9\) in which accumulated exercise was a risk factor for MSI. However, findings of the present study and others\(^7-9\) performed in California are not consistent with those of a Kentucky study\(^5\) in which cumulative high-speed exercise had a small negative association with risk of injury. Regional differences in racing surfaces, equine population, racing and training customs, and timed-workout record-keeping may account for this discrepancy. The present study and an earlier study\(^5\) also differ in definitions of exercise covariates (7-day vs 30-day time period) and injury outcomes (SMSAI during training or racing vs appendicular MSI during racing), and these discrepancies may account for differing results. Both training and racing injuries were captured in the present study, whereas the earlier study\(^5\) did not include training injuries.

The strength of association between toe grabs and SMSAI (OR, 2.8) in the present study was weaker than the association between toe grabs and catastrophic suspensory apparatus failure (OR, 6.2 [low toe grab] and 18.0 [regular toe grab]) reported in a previous case-control study.\(^7\) Because diagnosis of SMSAI is likely not as sensitive as diagnosis of catastrophic suspensory apparatus failure, some horses with SMSAI in the present study may have been misclassified as uninjured. Horses misclassified in this way contributed to the population of control horses and may have biased our estimated OR toward 1. Additionally, although age and sex were controlled in the case-control study,\(^3\) the effects of exercise intensity and preexisting injury were not. Some of the risk attributed to toe grabs in the case-control study may have been caused by other factors associated with toe grabs, such as exercise intensity and preexisting injury.

The distribution of horseshoe types that were evident on a typical day during race-training in the present study differed from that reported in a previous study,\(^14\) which described horseshoe types found on 201 Thoroughbred racehorses examined through the California Horse Racing Board Postmortem Program. That study, which grouped flat shoes and “very low toe” shoes in the same category, found that 50.2% of horses were wearing low toe grabs and 37.4% of horses were wearing regular toe grabs, but none were wearing Quarter Horse height toe grabs on front shoes. In contrast, 40.9% of horses wore low toe grabs and 10.4% wore regular or Quarter Horse height toe grabs in the present study. Results may differ because horses that die at racetracks tend to be horses actively racing and, thus, may be more likely to wear toe grabs than horses in the present study, some of which were in the early stages of race training. Alternatively, a recent study\(^7\) that reported positive associations between toe grabs and condylar fractures and suspensory apparatus failures may have influenced trainers to decrease the use and height of toe grabs worn by their racehorses.

A major limitation of this study was a misclassification of toe grab height by one observer. As a result, half of the data obtained was not of adequate quality and could not be used, which decreased the precision of statistical estimates. Other potential limitations also exist. The sensitivity and specificity of palpation for diagnosis of SMSAI are unknown. It is likely that the sensitivity of palpation is low, however, and that some minor injuries were undetected. The specificity was presumably higher, as it seems unlikely that horses with palpable warmth, swelling, or signs of pain associated with the suspensory ligament would be uninjured. Because low test sensitivity biased results toward the null,\(^14\) the OR obtained likely underestimated, rather than overestimated, the risks associated with toe grabs and weekly distance. The analysis was performed a second time with a more restrictive definition of injury to identify cases, assuming that such a definition would lower sensitivity and increase specificity, and results obtained were similar to those reported.

The effects of trainer on estimates of OR for SMSAI could not be examined because of sparse data. It is suspected that identity of the trainer is associated with risk of MSI, and this is supported by the finding in the present study that attrition attributable to MSI varied substantially by trainer. The present study focused on and analyzed changeable factors (exercise and horseshoe practices) that were expected to be associated with SMSAI. Accounting for any remaining trainer effect would most likely increase the variance and, hence, increase the \(P\) values of the reported OR for SMSAI.

Selective loss of horses from the study may have created a selection bias that would have had an unknown impact on estimated OR. The proportion of
horses lost to follow-up in the present study was comparable to that reported in other cohort studies of racehorses. Although horses that left the study presumably differed from those that stayed (eg, less successful horses may have been transferred), reasons for loss unrelated to injury (sale or change of ownership, track, or trainer) should have been unrelated to variables of interest (toe grab height and distance exercised weekly) and thus would not be expected to introduce a selection bias. Horses that left because of injury were not considered lost to follow-up, as they had been followed up until experiencing the outcome of interest.

Inclusion of prevalent cases of SMSAI in survival analyses on the assumption that date of injury was date of entry into the study could have biased time-to-MSI estimates if date of injury was earlier than date of entry into the study. The analysis was repeated using only incident cases of SMSAI, and survival curves for horses with and without SMSAI were again different, with horses with SMSAI significantly more likely to develop MSI, CDY, or SSAI within 90 days of injury.

Forty-one of 117 (35%) horses in the present study had SMSAI during the 90-day study period, resulting in an incidence of 1 case/214 horse-days in race training. Other estimates of the incidence of palpable SAI range from 7.9% of race starts made by horses for which results of a prerace physical examination indicated they were “low-risk” to 37.0% of race starts made by horses for which results of a prerace physical examination indicated they were “high-risk.” These estimates cannot be compared because the denominator of the previous study was race starts, rather than days in race training, and the population of that study did not include horses that were in training but not yet racing. Horses with palpable SAI may be less likely to race, which could lead to an apparently higher incidence of injury in the racehorse population than among those actively racing. Because mild injuries have the potential to develop into severe or catastrophic injuries, and because suspensory apparatus failure is the most common catastrophic MSI among racehorses, the incidence of SMSAI is not surprising.

Subclinical or mild SAI was associated with an increased risk of any type of catastrophic MSI in the present study and, in particular, with increased risk of CDY or SSAI. A recent study concluded that although palpable prerace suspensory ligament abnormalities were associated with an increased risk of all injuries, particularly those of the suspensory apparatus, in the associated race, preventing such horses from racing was not warranted, because the risk of injury in the associated race was low. However, in the present study, horses with palpable SAI were at increased risk of severe MSI, particularly SSAI or CDY, in the 90 days following initial injury, and 45% of horses with SMSAI had a severe MSI within 90 days after the SAI was identified. Identifying horses with SMSAI and suspending or decreasing the intensity of their training regimen should be considered as a means of decreasing the incidence of SSAI, CDY, and other severe MSI in Thoroughbred racehorses. Additional studies with larger sample sizes of the relationship between toe grabs, distance accumulated at racing speed, and incidence of SAI are needed before confidence is gained in the higher risks associated with toe grabs and accumulated high-speed exercise for SAI found in the present study. However, findings of the present study are consistent with those of another study that detected a significantly higher risk of catastrophic SAI associated with toe grabs and with those of a study that detected a significantly higher risk of skeletal fracture associated with high exercise intensity.

References


