

Clinical findings and prognosis of interference injuries to the palmar aspect of the forelimbs in Standardbred racehorses: A study on 74 cases

*Original*

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1 General article

2 **Clinical findings and prognosis of interference injuries to the palmar aspect of the**  
3 **forelimbs in Standardbred racehorses: a study on 74 cases**

4

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14 racehorses.

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19 domain. Explicit informed owner consent for participation in the study was not stated.

20

21 **Summary**

22 **Reasons for performing study:** Information on interference injuries in racehorses is lacking.

23 **Objective:** To describe clinical findings and prognosis of palmar forelimb interference injuries  
24 in Standardbreds.

25 **Study design:** Retrospective cohort study.

26 **Methods:** Records of 74 racehorses sustaining palmar forelimb interference injuries were  
27 studied, 7 during training, 67 during racing. The number of starts before injury, hind shoeing  
28 status, gait penalties, and racing speeds in cases occurring during racing were compared with  
29 negative controls, 67 age, sex and speed category matched horses from the same races. The  
30 number of starts and racing speed in 30 racing days preceding recruitment were compared  
31 with those following recruitment (negative controls) or return to racing (cases). Clinical  
32 aspects and outcome in interference-induced superficial digital flexor (SDF) tendinitis were  
33 compared with 77 horses with overstrain-induced SDF tendinitis.

34 **Results:** In 89% of cases, there was SDF tendinitis and this was associated with a longer  
35 time to return to racing (6 months vs 1 months;  $p < 0.001$ ). The presence of gait penalties  
36 (odds ratio (OR) 11.13; 95% CI 3.74, 41.64;  $p < 0.001$ ) and unshod hind feet (OR=6.26, 95%  
37 CI 2.26, 19.62;  $p < 0.001$ ) increased risk of interference injuries. After recruitment/return to  
38 racing, horses with interference injuries participated in a lower number of races (24 starts *per*  
39 racing day, interquartile range (IQR) 20-32) compared to controls (49, IQR 43-55,  $p < 0.0001$ ).  
40 Interference-induced tendinitis cases ( $n=58$ ) had a shorter time to return to racing (245 +/-  
41 137 days) than overstrain-induced tendinitis cases (331 +/- 118 days,  $p < 0.001$ ).

42 **Main limitations:** Data were collected retrospectively, time of ultrasonographic assessment  
43 varied and health status of the racing controls is unknown.

44 **Conclusions:** SDF tendinitis is common with palmar forelimb interference injuries in  
45 Standardbreds and increases time to return to racing. Interference-induced SDF tendinitis has  
46 a better prognosis than overstrain-induced tendinitis.

47

48 **Introduction**

49 Flying trot is a unique gait adopted by Standardbred racehorses at racing speed, in  
50 which the hindlimbs overstep the forelimbs laterally to sustain a long stride length [1]. At  
51 racing speed, fore and hind hoof trajectories differ during the swing phase of the stride, with  
52 fore hooves projecting more dorsally and less laterally compared to the hind hooves [2].  
53 Interference injuries, i.e. trauma inflicted by one hoof hitting the soft tissues of another leg, are  
54 commonly reported in Standardbred racehorses, and encompass a spectrum of lesions of  
55 varying severity, from simple skin lesions to severe superficial digital flexor (SDF) tendinitis or  
56 laceration.

57 Interference injuries are believed to stem from incoordination [3,4] or muscular fatigue  
58 [5]. Drivers also ascribe these injuries to unexpected interactions with other animals during  
59 racing. Standardbred racehorses are usually equipped with a variety of protective boots to  
60 prevent interference injuries during racing (hind-ankle boots, hind-shin boots and pastern  
61 boots) [5], while forelimb protection is limited to the heels (bell boots) and medial aspect of the  
62 carpus (knee-boots, splint-and-half-knee and knee-and-arm boots). This leaves the palmar  
63 aspect of the metacarpus and the fetlock unprotected. Direct contusion of these regions can  
64 result in interference-induced tendinitis of the SDF, which negatively affects the athletic career  
65 of the animal [7-10]. However, there is no study investigating the relationship between the  
66 occurrence of interference injuries to the palmar aspect of the forelimbs and traumatic  
67 tendinitis of the SDF in Standardbred racehorses.

68 The objectives of our study were to describe the clinical findings associated with  
69 interference injuries affecting the palmar aspect of the forelimbs and to outline their outcome  
70 in a cohort of affected Standardbred racehorses compared to matched controls. Given the  
71 high number of interference-induced SDF tendinitis in our study population, we also included  
72 a group of Standardbred racehorses which had sustained overstrain-induced tendinitis to  
73 compare the outcome of both types.

74

75 **Materials and methods**

76 Case and Control Animals

77 Medical records and long-term follow-up of a cohort of Standardbred racehorses  
78 trained in a single racetrack and experiencing interference injuries at the palmar aspect of the  
79 forelimbs from August 2008 to July 2013 were retrospectively reviewed. Two groups of control  
80 horses were studied. To assess risk factors for the occurrence of interference injuries and  
81 their effect on performances, from an eligible population of 683 horses racing the same  
82 competitions as cases, a negative control group was enrolled. Negative controls were  
83 selected from those horses running the same race that the case injury was sustained that  
84 matched the same age, sex, and speed category of the cases. Where only one eligible control  
85 horse was available, there was no random choice. When 2 or more horses in the same race,  
86 matched on these criteria, one was randomly selected.

87 From an eligible population of 494 horses available in our database, a positive control group  
88 of racehorses sustaining overstrain-induced tendinitis during the study period within the same  
89 age range as cases (from 2 to 8 years) was included (Supplementary item 1).

90 Horse signalment and racing data were obtained from the official racing website<sup>a</sup>. Injury data  
91 (for both interference injuries and overstrain-induced SDF tendinitis) were obtained from our  
92 historical Standardbred racehorses musculoskeletal injury archive, which includes all injuries  
93 that resulted in  $\geq 15$  days of rest [7]. Horses included in this database belong to stables where  
94 first-opinion veterinary care was provided regularly and exclusively by members of our team.

95

96 Interference injuries

97 Interference injuries were defined as self-inflicted sharp skin lacerations or superficial  
98 cuts in target regions of the forelimbs (medial aspect of the carpus, palmar metacarpal region,  
99 palmar aspect of the fetlock, and palmar/medial aspects of the pastern) occurring during  
100 races or fast training and causing an acute lameness (grade  $\geq 3/5$  AAEP scale). Interference  
101 injuries were identified using two methods. First, records of examinations of horses leaving  
102 the racetrack after racing performed by official veterinarians were reviewed and cases of skin  
103 injury were identified. Race video footage was scrutinized in order to exclude injuries caused

104 by other accidental trauma (i.e. contact between horses). Second, clinical reports from the  
105 archives of the equine section of the Veterinary Teaching Hospital of the University of Turin  
106 were assessed for cases with a history of any adverse event occurred during racing or fast  
107 training in the study period. Duplicates were excluded. Cases were confirmed as interference  
108 injury based on clinical descriptions provided by the official report of the treating veterinarian  
109 at the racetrack, interview of drivers, and/or clinical data retrieved from hospital archives.  
110 Diagnosis was supported by digital photos of the injured leg performed at first clinical  
111 examination by one of the investigators. Only horses where training was interrupted for longer  
112 than 15 days were included and this was evaluated by checking training log-books in the  
113 stables.

114 Interference injuries were classified based on their anatomical distribution on the palmar  
115 aspect of the forelimbs in five zones: medial carpal region (zone 1), palmar metacarpal region  
116 (zone 2), digital sheath region identified by the manica flexoria (zone 3), palmar aspect of the  
117 fetlock (zone 4), and palmar aspect of the pastern (zone 5). Soft tissue involvement was  
118 defined based on review of the clinical descriptions of the wound, ultrasonographic findings,  
119 and/or tenoscopic findings. The presence/absence of the following injuries was considered:  
120 skin laceration, trauma to the medial styloid process of the radius, SDF tendinitis or partial  
121 laceration, digital flexor tendon sheath laceration, annular ligament injury, and neurovascular  
122 bundle laceration.

123

#### 124 Ultrasonographic examination and scoring

125 Ultrasonography was performed in every interference injury case with a mobile  
126 system<sup>b</sup>, using a linear probe in B-mode, at the reference veterinary hospital or at the  
127 racetrack by one of two investigators (BR or AB). Transverse and longitudinal scans of both  
128 the injured and contralateral tendons were obtained during weight bearing as previously  
129 described [11]. Briefly, transverse scans of the SDF tendon were obtained at five landmarks  
130 within the metacarpal [12] and pastern regions to assess the tendon cross-sectional area  
131 (CSA) and cross-sectional hypoechogenic area (CSHA) of the lesion, using free image  
132 analysis software<sup>c</sup>. Total cross-sectional area (T-CSA) and total cross-sectional  
133 hypoechogenic area (T-CSHA) were calculated by summing the values of CSA and CSHA

134 measured at all landmarks. The maximal injured zone of the tendon was defined where  
135 maximal CSHA was identified and the CSHA/CSA ratio was determined at this level. The ratio  
136 between CSA of the injured tendon at the maximal injured zone and the corresponding CSA  
137 in the contralateral tendon were determined (CSA/cCSA). In transverse images, lesions were  
138 classified as: superficial/marginal, diffuse, core lesion and longitudinal splits. Longitudinal  
139 scans of the SDFT were obtained at three specific landmarks in the metacarpal region [13] to  
140 assess echogenicity scores. The fibre alignment score was assessed using a 4-points semi-  
141 quantitative scale at the maximal injured zone [11].

142

#### 143 Racing-related risk factors

144 In order to investigate the risk factors for the occurrence of interference injuries, the following  
145 data were collected from the official racing website<sup>a</sup> for both the cases (horses sustaining the  
146 injury during a race) and negative controls: total number of starts from the beginning of the  
147 racing career to the recruitment race, official gait penalties (horses breaking to gallop during  
148 the recruitment race), hindlimbs shoeing status during the recruitment race (shod/unshod).  
149 Racing speed (average speed maintained by the horse over the last 1000 meters of a race,  
150 [m/s]), was assessed as risk factor using speed categories in the group of cases. For this  
151 analysis, horses were classified based on their mean racing speed immediately before the  
152 recruitment race in five different categories: animals performing at  $\geq 78$  s/km (category 1),  $\geq 76$   
153 and  $< 78$  s/km (category 2),  $\geq 74$  and  $< 76$  s/km (category 3),  $\geq 72$  and  $< 74$  s/km (category 4),  
154 and  $< 72$  s/km (category 5).

155

#### 156 Outcome measures

157 Racing information was obtained from the official racing website<sup>a</sup> and used to determine the  
158 time to return to racing in cases and positive controls, defined as the interval in days elapsing  
159 from the injury until the first race post-injury. The number of starts during the 30 racing days  
160 preceding the injury and during the 30 racing days following the return to racing (cases) or the  
161 recruitment race (negative controls) were also acquired from the official website. Two  
162 variables were studied: participation rate and mean racing speed during races. Participation  
163 rate was calculated as the number of horses participating in each of the 30 racing days

164 preceding the injury and following the return to racing (or preceding and following the  
165 recruitment race, for negative controls). Racing speed was the average speed maintained by  
166 the horse over the last 1000 meters of a race [m/s]. In cases and in the positive control group,  
167 information on clinical outcome was obtained by reviewing of clinical archives and by  
168 telephone discussions with 18 drivers. Each horse was assigned to one of three clinical  
169 outcome categories, i.e. returned to racing, recurrence of tendinitis, or definitively retired.

170

### 171 Data analysis

172 Statistical analyses were performed using R libraries<sup>d</sup> and Prism v.7<sup>e</sup>, with an alpha  
173 level set at 0.05. The incidence rate of interference injuries in the population studied was  
174 calculated considering all races performed in the reference racetrack during the study period.  
175 Data distribution was assessed with D'Agostino-Pearson omnibus normality test. Chi square  
176 test and Fisher exact test (with Bonferroni correction for post-tests) were used to examine any  
177 association existing between the anatomical region where interference injuries occur and the  
178 occurrence of tendon injury.

179 To examine risk factors for interference injury, a conditional logistic regression model  
180 comparing cases (only injured during races) and negative controls was employed that  
181 assessed the effect of the variables shod/unshod (binary), official gait penalty yes/no (binary),  
182 total number of starts before the injury (quantitative) and racing speed category (categorical).  
183 Conditional regression analysis was performed introducing the variable pairing as a clustering  
184 random effect in the lme4 library of the R package (the more common clogit library did not  
185 provide convergence of the iterative estimation procedure).

186 To examine the effect of all interference injuries on race performance, mean racing speed in  
187 the 30 races before the injuries was compared to mean racing speed in the 30 races after the  
188 injury using a general linear model (analysis of covariance) in the group of cases. The effect  
189 of interference injury on participation rate was studied with a general linear model (analysis of  
190 covariance).

191 The effect of the injury zone on clinical outcome was assessed with Chi-square test. Kruskal-  
192 Wallis with Dunn's post-tests and Student t-test with Welch correction were used to compare

193 the time to return to racing of cases with interference injuries in different zones and  
194 with/without SDF tendon lesions, respectively.

195 For comparison of the outcome in the sub-group of horses with interference-induced SDF  
196 tendinitis and the positive control group with overstrain-induced SDF tendinitis, Kaplan-Meier  
197 estimator and log-rank (Mantel-Cox) test were used. Time to return to racing was estimated to  
198 be 400 days for horses that had not resumed training before the end of the study period,  
199 based on the fact that Standardbred racehorses experiencing >1 year off from racing do not  
200 generally resume training (retired horses were included in this analysis). Ultrasonographic  
201 features in the interference-induced tendinitis sub-group and the overstrain-induced tendinitis  
202 group were compared using Student t-test or Mann-Whitney test.

203

## 204 **Results**

205         Seventy-four Standardbred racehorses with interference injuries were identified  
206 (median age 4 years, interquartile range (IQR) 3-6; 50 males, 24 females). Sixty-seven (90%)  
207 occurred during racing while 7 (10%) occurred during training. Seventy-seven racehorses with  
208 overstrain-induced SDF tendinitis were included in the positive control group (median age 4  
209 years, IQR 3-6; 47 males, 30 females), while 67 healthy horses constituted our negative  
210 control group (median age 4 years, IQR 3-6; 46 males, 21 females). The incidence rate of  
211 interference injuries at the palmar aspect of forelimbs during racing was 2.8/1000 race starts  
212 during our observation period.

213

### 214 *Clinical description of interference injuries*

215         Interference injuries most commonly occurred in zones 2 and 3, where 39% and 27% of  
216 the lesions were observed, respectively, while 5% of traumas occurred in zone 1, 15% in  
217 zone 4, and 14% in zone 5 (Fig. 1). Lacerations requiring skin suture were detected in 41/74  
218 horses (55%), while small skin lesions not requiring any suture were found in 33/74 animals  
219 (44%). The digital neurovascular bundle was lacerated in 2 animals (3%) and swelling of the  
220 medial aspect of the carpal region was detected in 4 animals (5%), due to blunt trauma at the  
221 level of the medial bony styloid process of the radius (Supplementary item 2). Interference-  
222 induced SDF tendinitis and digital sheath laceration were present, respectively, in 58 (78%)

223 and in 13 (17.5%) cases. Interference-induced annular ligament desmitis was observed in 11  
224 animals (15%), and laceration of the SDF tendon was detected in 8 cases (11%). The  
225 presence of skin lacerations requiring suturing was associated with interference injuries  
226 occurring in specific zones of the forelimbs ( $p < 0.001$ ) and skin lacerations were more  
227 frequently observed in the zone 4 compared to zones 1 ( $p = 0.005$ ) and 2 ( $p = 0.004$ ). Tendinitis  
228 of the SDF tendon was more frequently observed in the zone 2 and 3 compared to zone 1  
229 ( $p < 0.0001$  and  $p = 0.002$ , respectively) and in zone 2 compared to zone 5 ( $p = 0.005$ , Table 1).

230

### 231 Risk factors for interference injuries to the palmar aspect of forelimbs

232 Thirty-five (52%) of the 67 horses with interference injuries sustained during racing and  
233 5 (7%) negative controls were disqualified due to gait penalties. Twenty-nine (43%) horses  
234 with interference injuries during racing and 6 (9%) negative controls were unshod in the  
235 hindlimbs. Considering racing speed categories, 7/67 (16%) of interference injuries occurred  
236 in category 1, 8 (12%) in category 2, 29 (43%) in category 3, 22 (33%) in category 4, and 1  
237 (2%) in category 5.

238 The conditional logistic regression model identified that hindlimb shoeing status and gait  
239 penalties were significant predictors for the occurrence of interference injuries. Risk of  
240 interference injury was decreased with increased number of races (Table 2).

241

### 242 Consequences of interference injury on racing performances

243 Following interference injury, 50/74 horses (68%) resumed training while 24/74 (32%)  
244 was retired from racing. In the horses which resumed training, median time to return to racing  
245 was 152 days (IQR 64-195 days). Within the interference injury group which resumed training,  
246 the time to return to racing was longer in horses with concurrent SDF tendinitis compared to  
247 horses with no SDF tendon involvement (Fig. 2a). Time to return to racing was also affected  
248 by the zone where the interference injury occurred ( $p = 0.003$ , Supplementary item 3). Horses  
249 sustaining interference injuries in zones 3 had longer times to return to racing (median 186  
250 day, IQR 165-276) compared to horses with injuries in zones 1 (median 44 days, IQR 23-127,  
251  $p = 0.03$ ) and 5 (median 73 days, IQR 28-169,  $p = 0.03$ ). In interference injury cases which  
252 resumed training, 17/50 (34%) had recurrence of SDF tendinitis. Clinical outcome was not

253 significantly affected by the region of the interference injury ( $p=0.07$ , Fig. 2b). Within the  
254 interference injury cases, the mean racing speed over 30 racing days before the injury was  
255 similar to the mean racing speed after return to racing (Fig. 3a). However, after  
256 recruitment/return to racing, horses with interference injuries participated in a lower number of  
257 races (24 starts per racing day, interquartile range (IQR) 20-32) compared to controls (49,  
258 IQR 43-55). As such, the post-injury race participation rate (expressed in percentage) was  
259 lower than the post-recruitment race participation rate in the negative control group  
260 ( $p<0.0001$ , Fig. 3b).

261

262 *Comparison of ultrasonographic features and outcome of interference-induced tendinitis and*  
263 *overstrain-induced tendinitis*

264 Interference-induced tendinitis and overstrain-induced tendinitis had different  
265 ultrasonographic features (Supplementary item 4). Superficial ( $p=0.04$ ), diffuse ( $p=0.004$ ), and  
266 longitudinal split lesions ( $p=0.002$ ) were seen more often with interference-induced SDF  
267 tendinitis, while core lesions more commonly found in overstrain tendinitis ( $p<0.0001$ ). The  
268 location of the maximal injured zone varied significantly between the groups ( $p<0.0001$ ), with  
269 overstrain tendinitis more frequently affecting zone 1A ( $p=0.002$ , Supplementary item 5) than  
270 interference-induced SDF tendinitis. There was no difference between the two groups in  
271 terms of echogenicity score ( $p=0.5$ ), fibre alignment score ( $p=0.4$ ), and CSHA/CSA ratio  
272 ( $p=0.07$ ), whereas T-CSA ( $p=0.02$ ) and T-CSHA ( $p=0.01$ ) and CSA/cCSA ratio ( $p=0.009$ )  
273 were significantly smaller in interference-induced SDF tendinitis compared to overstrain-  
274 induced tendinitis (Table 3). The time to return to racing was significantly lower in horses with  
275 interference-induced SDF tendinitis (mean  $\pm$  S.D.  $245\pm 137$  days) compared to those with  
276 overstrain SDF tendinitis ( $331\pm 118$  days,  $p<0.001$ , **Fig. 4**).

277

278 **Discussion**

279           This is the first analytical study of clinical outcomes following interference injury in the  
280 palmar aspects of the forelimbs in Standardbred racehorses. These injuries can influence the  
281 athletic career of racehorses as they are associated with interference-induced SDF tendinitis,  
282 which, based on our data, significantly influences the outcome. SDF tendinitis was more  
283 frequently seen in association with interference injuries in the mid-metacarpal region (zone 2)  
284 and at the digital sheath region (zone 3) rather than the carpal region and palmar aspect of  
285 the pastern. Horses with interference injuries at the digital sheath region had a longer time to  
286 return to racing compared to those with injuries at the proximal metacarpal region and at the  
287 palmar pastern. Interference injuries were more likely to occur in horses racing unshod in the  
288 hind feet and in horses which sustained gait penalties. Based on the results obtained in our  
289 population, a greater number of career starts may slightly decrease the likelihood of an  
290 interference injury occurring.

291           The precise biomechanical aetiology of interference injuries is not well understood.  
292 The lesion distribution pattern that we observed suggests that interference injuries in the  
293 forelimbs most likely result from a toe-impact of the hind hooves hitting the palmar aspect of  
294 the limb, rather than the contralateral fore hoof. At high speed, joint flexion and peak height of  
295 the hind hooves increase during the swing phase of the stride [14], which may increase the  
296 risk of hind hooves reaching the palmar aspect of the forelimbs. Despite higher speed being  
297 reported previously as a possible risk factor for the occurrence of interference injuries in  
298 Standardbred racehorses [5], we did not observe an association between likelihood of injury  
299 and racing speed. Shoeing increases inertia in the distal limb [15] and maximal height of the  
300 flight arc of the foot during the swing phase of the stride [16]. Such shoeing-induced alteration  
301 of gait mechanics might have a protective role in Standardbred racehorses for the occurrence  
302 of this type of injuries. The significant association observed between interference injuries and  
303 gait penalties relating to breaking into a gallop (and out of trot) during racing is noteworthy but  
304 does not prove a cause-effect relationship between those two variables. Further studies are  
305 warranted to explore possible biomechanical determinants of interference injuries.

306           The presence of SDF tendinitis, more frequently detected in zones 2 and 3, was

307 associated with a longer time to return to racing. In the current study, the anatomical site of  
308 interference injuries was not associated with clinical outcome category, but a low number of  
309 interference injuries was observed in the medial carpal region. Horses with interference-  
310 induced SDF tendinitis had a shorter time to return to racing compared to those with  
311 overstrain-induced tendinitis. The different ultrasonographic pattern and the smaller size of  
312 lesions seen with interference-induced SDF tendinitis may explain the shorter time to return to  
313 racing in this group. However, ultrasonographic examination was delayed many days in  
314 interference injury cases when a skin laceration was present which may have introduced bias  
315 in the assessment of echogenicity and longitudinal extension of the lesions [17]. Also, it is  
316 possible factors which were not examined in the current study, such as different therapeutic  
317 strategies adopted in interference-induced and overstrain-induced tendinitis may have  
318 impacted on time to return to racing.

319           Due to the retrospective nature of our study, we could not control for many variables,  
320 which might have introduced a bias into our results. Our inclusion criteria relied on information  
321 available in medical records in a musculoskeletal injuries database. All cases and positive  
322 controls were recruited in a single racetrack and were not randomly selected. We have no  
323 information on the health status of our negative control group, which may introduce a further  
324 source of bias. Nevertheless, we conclude that palmar forelimb interference injuries are  
325 frequently associated with SDF tendinitis. These injuries can negatively influence the athletic  
326 career of racehorses in terms of racing starts but not in terms of racing speed. Compared with  
327 overstrain-induced tendinitis, interference-induced SDF tendon lesions have a shorter time to  
328 return to racing. Further studies are needed to explore the pathogenesis and possible  
329 prevention of this injury.

330

331

332

333 **List of Figure Legends**

334

335 **Figure 1.** Anatomical distribution of interference injuries in 74 Standardbred racehorses. Each  
336 point represents an interference injury. L: lateral; M: medial.

337 **Figure 2.** Prognostic factors with palmar forelimb interference injuries in Standardbred  
338 racehorses. a) The effect of superficial digital flexor tendon involvement in the interference  
339 injury group on time to return to racing. b) The association between anatomical distribution of  
340 interference injuries and clinical outcome. Data are presented as percentage (analysis was  
341 performed on raw data).

342 **Figure 3.** Effect of palmar forelimb interference injuries on athletic performance in  
343 Standardbred racehorses. a) Cases' racing speed before and following injury. Racing day 0 =  
344 race in which injury was sustained. The error bars represent 95% confidence intervals.

345 b) Race participation rate before and following injury in cases and a negative control group.  
346 Cases' post-injury participation rate was lower than negative controls' post-recruitment  
347 participation rate ( $p < 0.0001$ ). Racing day 0 = race in which injury was sustained.

348 **Figure 4.** Kaplan-Meier plot of time to return to racing in Standardbred racehorses with  
349 interference superficial digital flexor tendonitis ( $n = 74$ ) and overstrain-induced superficial  
350 digital flexor tendonitis tendinitis ( $n = 77$ ). SDF: superficial digital flexor

351

352

353 **Manufacturers' details**

354 <sup>a</sup> <http://www.ippicabiz.it>.

355 <sup>b</sup> LOGIQ e, General Electric, UK.

356 <sup>c</sup> ImageJ, U.S. National Institute of Health, Bethesda, MD, USA.

357 <sup>d</sup> R version 3.4.0 ;<http://www.r-project.org>.

358 <sup>e</sup> GraphPad Software, La Jolla, CA, USA.

359

360

361 **References**

362

363 [1] Barrey, E., Auvinet, B., Courouce, A. (1995) Gait evaluation of race trotters using an  
364 accelerometric device. *Equine Vet J* 18 (Suppl), 156-160.

365 [2] Van Weeren, P.R., van der Bogert, A.J., Back, W., Bruin, G., Barneveld A. (1993)  
366 Kinematics of the Standardbred trotter measured at 6,7,8, and 9 m/s on a treadmill, before  
367 and after 5 months of  
368 prerace training. *Acta Anat (Basel)* 146, 81-204.

369 [3] Leleu, C., Cotrel, C. and Barrey, E. (2004) Effect of age on locomotion of Standardbred  
370 trotters in training. *Equine and Comparative Exercise Physiology* 1, 107-117.

371 [4] Vilar, J.M., Spadari, A., Billi, V., Desini, V. and Santana, A. (2008) Biomechanics in  
372 young and adult italian standardbred trotter horses in real racing conditions. *Vet Res Comm*  
373 32, 367-376.

374 [5] Coucoucè-Malblanc A., Hinchcliff K.W. (2014) Veterinary aspects of racing and training  
375 horses used for harness racing. In: Hinchcliff, Kaneps, Geor. *Equine Sport Medicine &*  
376 *Surgery* (2nd Ed). Elsevier, Edinburgh, 1037-1055.

377 [6] <http://www.standardbredcanada.ca> (accessed on 08/10/2016).

378 [7] Bertuglia, A., Bullone, M., Rossotto, F. and Gasparini, M. (2014) Epidemiology of  
379 musculoskeletal injuries in a population of harness Standardbred racehorses in training. *BMC*  
380 *Vet Res* 10, 11.

381 [8] Foland, J.W., Trotter, G.W., Stashak, T.S., McIlwraith, C.W., Turner, A.S., Aanes, W.A.  
382 (1991) Traumatic injuries involving tendons of the distal limbs in horses: a retrospective study  
383 of 55 cases. *Equine Vet J* 23, 422-5.

384 [9] O'Meara, B., Bladon, B., Parkin, T.D., Fraser, B. and Lischer, C.J. (2010) An  
385 investigation of the relationship between race performance and superficial digital flexor  
386 tendonitis in the Thoroughbred racehorse. *Equine Vet J* 42, 322-326.

387 [10] Perkins, N.R., Reid, S.W. and Morris, R.S. (2005) Risk factors for injury to the  
388 superficial digital flexor tendon and suspensory apparatus in Thoroughbred racehorses in  
389 New Zealand. *N Z Vet J* 53, 184-192.

390 [11] Smith, R.K. and McIlwraith, C.W. (2012) Consensus on equine tendon disease:  
391 building on the 2007 Havemeyer symposium. *Equine Vet J* 44, 2-6.

392 [12] Genovese, R.L., Rantanen, N.W., Simpson, B.S. and Simpson, D.M. (1990) Clinical  
393 experience with quantitative analysis of superficial digital flexor tendon injuries in  
394 Thoroughbred and Standardbred racehorses. *Vet Clin North Am Equine Pract* 6, 129-145.

395 [13] Smith, R.K., Cauvin, E.R.J. (2014) Ultrasonography of the metacarpus and  
396 metatarsus. In: *Atlas of Equine Ultrasonography*. Wiley Blackwell, West Sussex, 73-105.

397 [14] Clayton, H.M., Hoyt, D.F., Wickler, S.J., Cogger, E.A., Lanovaz, J.L. (2002) Hindlimb  
398 net joint energies during swing phase as a function of trotting velocity. *Equine Vet J* 34  
399 (Suppl), 235-239.

400 [15] Clayton, H.M., Lanovaz, J.L.; Schamhardt H.C., Willemen, M.A., Colborne, G.L.  
401 (1998) Net joint moments and powers in the equine forelimb in the stance phase of the trot.  
402 *Equine Vet J* 30, 384-389.

403 [16] Willemen, M.A., Savelberg, H.C.C.M., Barneveld, A. (1997) The improvement of the  
404 gait quality of sound trotting warmblood horses by normal shoeing and its effect on the load  
405 on the lower forelimb. *Livestock Prod Sci* 52, 145-153.

406 [17] David, F., Cadby, J., Bosch, G., Brama, P., van Weeren, R. and van Schie, H. (2012)  
407 Short-term cast immobilisation is effective in reducing lesion propagation in a surgical model  
408 of equine superficial digital flexor tendon injury. *Equine Vet J* 44, 570-575.

409

410 **Supplementary information**

411

412 **Supplementary item 1:** Case and control enrollment flow chart

413 **Supplementary item 2:** Clinical presentations of interference injuries. a) Extensive laceration  
414 of the skin on the palmar aspect of the fetlock. b) Swelling of the medial styloid process at the  
415 radial epiphysis.

416 **Supplementary item 3:** Representative ultrasonographic images of marginal split (a), diffuse  
417 (b, c), and superficial (d) lesions of the superficial digital flexor tendon. Injured tendons are  
418 displayed in the right of each panel, while the contralateral tendon is displayed on the left.

419 **Supplementary item 4:** Effect of the injury zone on time to return to racing. Time to return to  
420 racing was significantly affected by the injury zone ( $p=0.003$ , Kruskal-Wallis test). Dunn's  
421 multiple post-tests revealed significant differences between zone 3 and zone 1 and between  
422 zone 3 and zone 5 ( $p=0.03$  for both). Bars represent median and interquartile ranges,  
423 whiskers represent minimum and maximum values.

424 **Supplementary item 5:** Location of the maximal injury zone in interference- and overstrain-  
425 induced tendinitis of the superficial digital flexor tendon. Maximal injury zone was affected by  
426 the group ( $p<0.0001$ , Chi squared test). Post-tests were performed using multiple Fisher  
427 exact tests and Bonferroni correction for multiple comparisons. \*:  $p=0.01$ . SDF: superficial  
428 digital flexor.

429

430 SI Legends – versions for text

431

432 **Supplementary item 1:** Case and control enrollment flow chart.

433 **Supplementary item 2:** Clinical presentations of interference injuries.

434 **Supplementary item 3:** Ultrasonographic images.

435 **Supplementary item 4:** Effect of the injury zone on time to return to racing.

436 **Supplementary item 5:** Location of the maximal injury zone

437

438



440 **Tables**

441

442 **Table 1.** Location and structures involved in palmar forelimb interference injuries in 74

443 Standardbred racehorses.

	Zone 1 (n=4)	Zone 2 (n=29)	Zone 3 (n=20)	Zone 4 (n=11)	Zone 5 (n=10)
<i>Skin laceration requiring suture</i> (n=41)	0 <sup>a</sup>	10 <sup>a</sup>	13	10	8
<i>Superficial digital flexor tendinitis</i> (n=58)	1	27 <sup>b</sup>	14 <sup>b</sup>	9	7 <sup>c</sup>
<i>Digital Sheath injury</i> (n=13)	n.a.	n.a.	10	2	1
<i>Annular Ligament lesion*</i> (n=11)	n.a.	n.a.	n.a.	11	n.a.
<i>Vascular injury*</i> (n=2)	0	0	0	0	2
<i>Laceration of the superficial digital flexor tendon</i> (n=8)	0	1	6	1	n.a.
<i>Bony lesions*</i> (n=4)	4	0	0	0	0

444

445 Legend: n.a. = not applicable. <sup>a</sup>:significantly different from zone 4; <sup>b</sup>:significantly different from  
446 zone 1; <sup>c</sup>:significantly different from zone 2. \*Statistical comparisons were not performed.

447

448 **Table 2.** Conditional logistic regression model for risk factors associated with interference  
 449 injuries to the palmar aspect of forelimbs.

<i>Variable</i>	<i>Cases</i>	<i>Negative controls</i>	<i>Odds ratio</i>	<i>95% confidence intervals for the odds ratios</i>	<i>P value</i>	
<i>Number of races at time of injury</i>	30 ± 30	39 ± 28	0.98	(0.96, 0.99)	<b>0.024</b>	
<i>Hindlimb shoeing status</i>	<i>Shod</i>	38/67	61/67	reference		
	<i>Unshod</i>	29/67	6/67	6.26	(2.26, 19.62)	<b>&lt;0.001</b>
<i>Official gait penalties</i>	<i>Yes</i>	35/67	5/67	11.13	(3.74, 41.64)	<b>&lt;0.001</b>
	<i>No</i>	32/67	62/67	reference		
<i>Racing speed categories</i>						
	<i>Category 1</i>	7/67	n.a.	reference		
	<i>Category 2</i>	8/67	n.a.	1.56	(0.25, 10.41)	0.635
	<i>Category 3</i>	29/67	n.a.	1.35	(0.29, 6.96)	0.709
	<i>Category 4</i>	22/67	n.a.	1.65	(0.34, 8.96)	0.541
	<i>Category 5</i>	1/67	n.a.	3.08	(0.092, 104.6)	0.487

450 Total number of races is expressed as mean ± SD. n.a.: not applicable

451 **Table 3.** Ultrasonographic characteristics of interference-induced and overstrain-induced  
 452 superficial digital flexor tendinitis cases.

	<i>Interference- induced tendinitis (n=58)</i>	<i>Overstrain- induced tendinitis (n=77)</i>
<i>Cross-sectional description of the lesions [N cases]</i>		
<i>Superficial/Marginal</i>	31 (53%)	27 (35%) <sup>a</sup>
<i>Core</i>	4 (7%)	44 (57%) <sup>a</sup>
<i>Diffuse</i>	16 (28%)	6 (8%) <sup>a</sup>
<i>Longitudinal split</i>	7 (12%)	0 <sup>a</sup>
<i>T-CSA of the SDFT [cm<sup>2</sup>]</i>	8.7 (8.4-9.1)	9.4 (9.0-9.8) <sup>a</sup>
<i>T-CSHA of the SDFT [cm<sup>2</sup>]</i>	1.3 (1.1-1.6)	1.9 (1.6-2.2) <sup>a</sup>
<i>CSA/cCSA at the maximal injury zone</i>	1.7 (1.6-1.8)	1.9 (1.8-1.9) <sup>a</sup>
<i>CSHA/CSA at the maximal injury zone [%]</i>	34 (29-39)	38 (34-41)
<i>Fibre alignment score at the maximal injury zone</i>	4 (3-4)	4 (3-4)
<i>Echogenicity score at the maximal injury zone</i>	4 (3-4)	4 (4-4)

453

454 Legend: T-CSA= Total Cross Sectional Area, T-CSHA= Total Cross Sectional Hypoechoic  
 455 Area, CSA/cCSA= Cross Sectional Area/contralateral Cross Sectional Area, CSHA/CSA=  
 456 Cross Sectional Hypoechoic Area/Cross Sectional Area, SDFT= Superficial Digital Flexor  
 457 Tendon. Data are indicated as mean (95% C.I.) with the exception of Fibre alignment and  
 458 Echogenicity scores at the maximal injury zone, expressed as median (25<sup>th</sup>-75<sup>th</sup> percentile).

459 <sup>a</sup>: significantly different from interference-induced tendinitis group.

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461