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Risk factors for superficial digital flexor tendinopathy in Thoroughbred racing horses in Japan

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Thoroughbred racehorses are commonly affected with superficial digital flexor (SDF) tendinopathy. This study aimed to identify risk factors for SDF tendinopathy in racing horses. The authors selected racehorses (n=292) with SDF tendinopathy from the medical records of a racetrack. As a risk factor associated with track-related variables, the SDF tendinopathy odds ratio (OR) was significantly high for a sloppy track surface compared with a standard track surface. Regarding risk factors associated with race-related variables, the SDF tendinopathy OR was significantly high in the following cases: when the order of arrival was worse than or equal to the 10th place; when the racehorses started to run a short race and when the racehorses' favourites were worse than or equal to the 8th place. Regarding risk factors associated with racehorse-related variables, the body weight of racehorses with SDF tendinopathy was significantly heavier than that of control horses. When there was a decrease in body weight since previous racing, the SDF tendinopathy OR was significantly high. Regarding risk factors associated with race career-related variables, when the charge in the race distance was short, the SDF tendinopathy OR was significantly high. As a countermeasure to prevent SDF tendinopathy, a sloppy track surface should be avoided during the race by guiding the horse toward to more solid track surface. Selecting long-distance races with slow speed, if possible, could reduce the risk of SDF tendinopathy.

Key words: *racing horse, risk factor, superficial flexor tendinopathy, Thoroughbred*

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Orthopedic diseases account for retirement in 76% of racehorses, of which 46% of cases are because of superficial digital flexor (SDF) tendinopathy, which is caused by microdamage to the SDF tendon with ageing and training load [12]. SDF tendinopathy develops in 6–13% of racehorses during racing [11]. The SDF tendinopathy prevalence in racehorses is 6% in 2-year-olds, 20% in 3-year-olds, 17% in 4-year-olds and 12% in 5-year-olds and older racehorses; the average SDF tendinopathy prevalence is 14% [5]. SDF tendon injuries occur at a rate of 0.94 injuries for every 1,000 race starts among racehorses running on flat track surfaces and at a rate of 0.58 injuries for every 1,000 race starts among racehorses running on turf surfaces. A previous study identified old age, female gender, experience of long-distance and faster races, heavy body weight at the race, firm track surfaces and long careers as high-risk factors for SDF tendinopathy [3–7]. Physical examination revealed swelling, heat and pain. Clinical diagnosis of SDF tendinopathy is made by ultrasonography, and prognosis is evaluated by severity on ultrasonographic findings [1]. Treatment strategies for SDF tendinopathy include shock waves, mesenchymal stem cell injection and platelet-rich plasma injection. However, shock waves are effective in the short term, and their long-term effect seemed less beneficial. Furthermore, mesenchymal stem cell and platelet-rich plasma injections require long-term rest [2, 10].

Even after treatment of SDF tendinopathy, the SDF tendon is replaced by fragile fibrous tissues, and therefore, many racehorses show recurrence of SDF tendinopathy, causing huge economic losses. Therefore, it is important to prevent SDF tendinopathy. Risk factors associated with the development or recurrence of SDF tendinopathy in racehorses, such as race distance, body weight, steeplechase experience and sex, have been identified in various countries. These

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risk factors could be valuable to horse trainers, owners and veterinarians, therefore identifying high-risk horses and adjusting race schedules would minimise injuries. However, such factors vary with race tracks due to differences in track surface, race distance, race interval, or trainer preference. In Japan, for example, flat races conducted in the Japan Racing Association (JRA) are relatively longer-distance races (compared with our data) and include both turf and dirt races. Conversely, non-JRA race tracks, such as those at the Oi Racecourse (Tokyo Metropolitan Racing Association), are used to conduct relatively short-distance races and include only dirt races.

This study aimed to identify the risk factors for SDF tendinopathy from medical records of racehorses afflicted with SDF tendinopathy at the Oi Racecourse.

Materials and Methods

Horses

A total of 292 racehorses diagnosed with SDF tendinopathies between 2011 and 2015 were assessed from the medical records of the Oi Racecourse. The diagnosis of SDF tendinopathy in all the enrolled horses was made using ultrasonography. All racehorses with SDF tendinopathy were diagnosed within 2 days after racing. For each horse, all race records containing data relating to race history prior to the injury were collected from an online database (www.netkeiba.com). In an accordance with the method of a previous study [11], two control horses were matched to each case horse by randomly selecting from horses that were not included as case horses, had the same trainer, had started a race within 6 months of injury in case horses and were of the same age as the case horses. If there was no control horse with the same age as the case horse, the next closest age horse was chosen as the control horse. When a control horse was selected multiple times, the horse was randomly selected to be matched to only one case horse. The race records of control horses with data for the period prior to the selection were collected from an online database (www.netkeiba.com) for analysis (Table 1).

Statistical analysis

The following factors were analyzed in this study: track condition (standard, good, muddy or sloppy), weather at race time (clear, cloudy or raining/snowy), order of arrival, distance of race, favourite, body weight at race time, increase/decrease of body weight from that at the previous race, gender, age, total race distance (not including the race in which the SDF tendinopathy was occurred), mean race distance (not including the race in which the SDF tendinopathy was occurred), charge in race distance since last 3 and 6 races (not including the race in which the SDF tendinopathy was occurred), previous diseases and the number of days since the previous race, as described previously [8, 9, 11]. Horses that never started were not included in the data for increase/decrease of body weight from that at the previous race and the number of days since the previous race. Similarly, horses that started ≤2 or ≤5 times were not included in the data for charge in the race distance since last 3 or 6 races, respectively. The track factors included were the conditions of dirt tracks only and did not include conditions of turf races at the time of injuries (the data of previous turf races were not investigated). Continuous variables were analysed by Student's *t*-test (Microsoft Excel), and the categorical variables were analyzed by the Chi-square test and Fisher's exact test and calculation of the odds ratio (OR; calculated with an online calculator at VassarStats.net). Variables associated with SDF tendinopathy were considered significant risk factors, and $P<0.05$ was considered statistically significant. Multiple logistic regression analysis could not be performed due to the small sample size.

Results

Risk factors associated with track-related variables

A sloppy track surface was associated with a signifi-

Table 1. Descriptive variables of the superficial digital flexor (SDF) tendinopathy case horses and control horses

Variables	Case horses (n=292)	Control horses (n=584)	*P* value
Age (y)	4.0 ± 1.4 (2–9)	3.8 ± 1.3 (2–18)	NS
No. of previous races	18.5 ± 17.2 (0–101)	18.3 ± 15.1 (0–110)	NS
Total race distance (m)	26,446 ± 25,651 (0–148,000)	26,401 ± 22,510 (0–166,000)	NS
Mean race distance (m)	1,378 ± 193 (0–2,034)	1,412 ± 257 (0–2,632)	NS

For continuous variables, data are given as the mean ± SD (range). NS: no significant differences. Total and mean race distances do not include the race in which the SDF tendinopathy was occurred.

cantly higher risk than a standard track surface (OR=1.69; $P<0.01$). No significant differences were identified due to the weather at race time between SDF tendinopathy and control racehorses (Table 2).

Risk factors associated with race-related variables

Regarding risk factors associated with race-related variables, the SDF tendinopathy OR was significantly high in the following cases: (i) when the order of arrival was worse than or equal to the 10th place (OR=2.50; $P<0.01$), (ii) when the racehorses started to run a short race (<1,300 m) (OR=1.45; $P<0.05$) and (iii) when the racehorses' favourites were worse than or equal to the 8th place (OR=1.49; $P<0.05$; Table 3).

Risk factors associated with racehorse-related variables

The body weight of SDF tendinopathy racehorses at the race in which SDF tendinopathy occurred was significantly heavier compared with control racehorses ($P<0.01$). When body weight at race time was ≥470 kg, the SDF tendinopathy OR was significantly high (OR=1.55; $P<0.01$). When the decrease in body weight from that at previous racing was ≥5 kg, the SDF tendinopathy OR was significantly high (OR=1.59; $P<0.05$). Also, the male and gelding horses had the higher SDF tendinopathy ORs (OR=1.35; $P<0.05$ and OR=3.09; $P<0.01$, respectively) compared with the female horses (Table 4). No significant differences were identified due to horse age between SDF tendinopathy and control racehorses (Table 1).

Risk factors associated with race career-related variables

When the charge in the race distance since the last 3 (<4,000 m) and 6 races (<8,000 m) was short, the SDF tendinopathy OR was significantly high (OR=1.40; $P<0.05$ and OR=1.47; $P<0.05$, respectively; Table 5). When the number of days since the previous race was ≥90-days, the SDF tendinopathy OR was significantly high (OR=1.75; $P<0.05$).

Table 2. Track/weather-related risk factors for superficial digital flexor (SDF) tendinopathy

Risk factor for SDF tendinopathy	Case horses (n=292)	Control horses (n=584)	Odds ratio (OR)	*P* value	95% Confidence interval
Track-related variables					
Track conditions					
Standard	137 (47%)	327 (56%)	Refe	-	-
Good	53 (18%)	99 (17%)	1.28	NS	0.87–1.88
Muddy	44 (15%)	76 (13%)	1.38	NS	0.91–2.11
Sloppy	58 (20%)	82 (14%)	1.69	<0.01	1.14–2.50
Weather-related variables					
Fine	155 (53%)	315 (54%)	Refe	-	-
Cloudy	96 (33%)	199 (34%)	0.98	NS	0.72–1.34
Raining/snowy	41 (14%)	70 (12%)	1.24	NS	0.77–1.83

For categorical variables, data are given as numbers (percentages). NS: no significant differences; Refe: reference.

Table 3. Race-related risk factors for superficial digital flexor (SDF) tendinopathy

Risk factor for SDF tendinopathy	Case horses (n=292)	Control horses (n=584)	Odds ratio (OR)	*P* value	95% confidence interval
Race-related variables					
Order of arrival	9.3 ± 3.9	7.2 ± 4.3		<0.01	-
10th place or more	158 (54%)	187 (32%)	2.50	<0.01	1.88–3.34
1st to 9th place	134 (46%)	397 (68%)	Refe	-	
Race of distance (m)	1,385 ± 222	1,447 ± 290		<0.01	-
<1,300 m	131 (45%)	210 (36%)	1.45	<0.05	1.09–1.93
≥1,300 m	161 (55%)	374 (64%)	Refe	-	
Favourite	7.6 ± 3.4	7.0 ± 4.8		<0.05	-
8th or more	146 (50%)	234 (40%)	1.49	<0.05	1.13–1.98
1st to 7th	146 (50%)	350 (60%)	Refe	-	

For categorical variables, data are given as numbers (percentages). For continuous variables, data are given as the mean ± SD. Refe: reference.

Table 4. Horse-related risk factors for superficial digital flexor (SDF) tendinopathy

Risk factor for SDF tendinopathy	Case horses	Control horses	Odds ratio (OR)	*P* value	95% confidence interval
Horse-related variables					
Body weight at race time (kg)	477.8 ± 29	469.7 ± 33		<0.01	-
≥470 kg body weight at race time	178 (60%)	293 (50%)	1.55	<0.01	1.17–2.06
<470 kg body weight at race time	114 (40%)	291 (50%)	Refe	-	
Increase/decrease of body weight (kg) from previous race	0.06 ± 7.57	0.59 ± 5.97		NS	
≥5 kg decrease of body weight	53 (18%)	70 (12%)	1.59	<0.05	1.08–2.34
Otherwise	236 (82%)	495 (88%)	Refe	-	
Sex					
Female	99 (34%)	245 (42%)	Refe	-	
Male	178 (61%)	327 (56%)	1.35	<0.05	1.00–1.81
Gelding	15 (5%)	12 (2%)	3.09	<0.01	1.40–6.84

For categorical variables, data are given as numbers (percentages). For continuous variables, data are given as the mean ± SD. NS: no significant differences; Refe: reference. The horses with no previous race are not included in the data of increase / decrease of body weight (kg) from previous race.

Table 5. Race career-related risk factors for superficial digital flexor (SDF) tendinopathy

Risk factor for SDF tendinopathy	Case horses	Control horses	Odds ratio (OR)	*P* value	95% confidence interval
Race career-related variables					
Charge in running distance since last 3 races	4,195 ± 535	4,375 ± 737		<0.01	-
<4,000 m	93 (36%)	129 (29%)	1.40	<0.05	1.01–1.94
≥4,000 m	162 (64%)	315 (71%)	Refe	-	-
Charge in running distance since last 6 races	8,379 ± 1,379	8,878 ± 3,052		<0.05	-
<8,000 m	83 (38%)	117 (30%)	1.47	<0.05	1.03–2.08
≥8,000 m	133 (62%)	275 (70%)	Refe	-	-
Number of days since previous race	41.8 ± 61.6	33.3 ± 48.7		<0.05	
≥90 days	30 (10%)	35 (6%)	1.75	<0.05	1.05–2.92
<90 days	259 (90%)	530 (94%)	Refe	-	

For categorical variables, data are given as numbers (percentages). For continuous variables, data are given as the mean ± SD. NS: not significant difference; Refe: reference. The horses with <3 previous races are not included in the data of charge in running distance since last 3 races. The horses with <6 previous races are not included in the data of charge in running distance since last 6 races. The horses with no previous race are not included in the data of days since the previous race.

Risk factors associated with previous diseases

No significant differences were identified with respect to history of other diseases between SDF tendinopathy and the control horses (Table 6). And, 0.69% of case horses (2/292) had a history of SDF tendinopathies. However, this information could not be determined for the control horses because of missing data.

Discussion

In this study, a sloppy track surface was associated with a significantly higher risk of SDF tendinopathy than a standard track surface. A previous study reported that the firmer track surface was associated with the higher risk of SDF tendinopathy [8]. In this study, all SDF tendinopathy racehorses started in the flat track-race. A previous study suggested that SDF tendinopathy develops more easily on a dirt track than on a turf track [11]. Such differences between the track types should be investigated in the future. No previous findings would completely match with our data because of the differences between the contents of dirt tracks in Japan and those in foreign countries (sand- vs clay-based tracks).

When racehorses start running short and fast races (<1,300 m), the SDF tendon suffers increased microdamage as a consequence of multiple concussion force experienced during the races due to the increased gait velocity. Thus, such short and fast races can cause an increase in

Table 6. Risk factors associated with previous diseases for superficial digital flexor (SDF) tendinopathy

Risk factor for SDF tendinopathy	Case horses (n=292)	Control horses (n=584)	Odds ratio (OR)	*P* value	95% confidence interval
Risk factors associated with previous disease					
History of tendinitis	2 (0.69%)	0 (0%)	∞	N/A	-
Otherwise	290 (99.31%)	584 (100%)	Refe	-	
History of the other disease	1 (0.34%)	11 (1.84%)	0.17	NS	0.023–1.393
Otherwise	291 (99.66%)	573 (98.16%)	Refe	-	

For categorical variables, data are given as numbers (percentages). Refe: reference; NS: not significant difference; N/A: none applicable.

the micro-tears of SDF tendons, resulting in a higher risk of SDF tendinopathy. In contrast, it is also possible that trainers may intentionally select short-distance races for horses with pre-existing tendon damages/injuries. Hence, it is also possible that horses participate in short-distance races because of potential SDF tendinopathies, which would mean that short-distance are not the cause of them. Therefore, avoiding short-distance races might not directly reduce the risk of SDF tendinopathies. In addition, when the racehorses' favourites were worse than or equal to the 8th place, the poor result of the previous race could have been due to the potential tendon damage that occurred during the previous race. However, worse favourites can be the result of a large number of factors other than SDF tendinopathy. Therefore, this study could not conclude whether such horses with worse favourites are already at a higher risk of SDF tendinopathy and more likely to develop injuries than control horses.

A previous study reported that heavy body weight increases the load on limbs [11]. Our study revealed similar results that showed an increased SDF tendinopathy OR with increased body weight (≥470 kg). Interestingly, in this study, we found that when the body weight decreased compared with the previous race, the SDF tendinopathy OR was significantly high. This result suggested that muscle loss or too much training load before the race also worsens general conditions. Hence, these horses experience muscle fatigue earlier than fit horses, resulting in increased tendon forces toward the end of race and thus a risk of SDF tendinopathy. However, the data for body weight can be conflicting. Decreased body weight could not only be the result of muscle loss or excessive training but also be the result of intentional weight reduction during training to improve race performance. Our study did not include any survey to assess the intent of previous trainings, and our results were not sufficient to draw any conclusions with respect to these arguments.

In our results, males and geldings had significantly higher risks of SDF tendinopathy compared with female horses, in an agreement with previous reports [4, 11]. Such a phenomenon would, in turn, demonstrate that the lowest risk of SDF tendinopathy is in female horses, indicating that the slower gate velocity in female horses could potentially reduce the tendon strains.

When the charge in the race distance (since the last 3 and 6 races) is short, load accumulates in the limbs over a series of short and fast races, inducing SDF tendinopathy. In addition, racehorses that are favourable for short-distance race tend to be used only for short-distance races by trainers, resulting in the short total racing distance. Therefore, it is suggested that SDF tendinopathy is induced by the accumulation of microdamages from short-distance and high-speed races. According to a previous study conducted overseas, the greater the distance, the higher the SDF tendinopathy risk. Such a difference could be due to the differences in race distance between Japan and overseas. However, our investigation was inadequate to confidently draw this conclusion, because our data on race distance included only a narrow range (1,000 and 2,880 m rather than ≥4,000 m).

Our results also revealed that if the number of days since the previous race was ≥90 days, the risk of SDF tendinopathy increased by 1.75 times. However, it is considered that race interval of more than 90 days is not enough to recover from accumulation of microdamage in tendons. Furthermore, a ≥90 days interval is decided by the trainers who suspect subclinical tendon injuries due to gait impairments or anomalies. Hence, these horses may sustain SDF tendinopathies in the following races. We would like to state that, of course, the rest itself does not increase the risk of SDF tendinopathy.

As a countermeasure to prevent SDF tendinopathy, sloppy track surfaces should be avoided during races by guiding horses toward to more solid track surfaces. Short distance with faster races should be avoided, if possible, and selecting long distance with slower speed races could lower the risk of SDF tendinopathy. Further investigations with larger sample sizes are warranted to clarify the positive or negative impact of decreases in body weight and the length of the race interval on the risk of SDF tendinopathy.

References

1. Alzola, R., Easter, C., Riggs, C.M., Gardner, D.S., and Freeman, S.L. 2018. Ultrasonographic-based predictive factors influencing successful return to racing after superficial digital flexor tendon injuries in flat racehorses: A retrospective cohort study in 469 Thoroughbred racehorses in Hong Kong. *Equine Vet. J.* **50**: 602–608. [Medline] [CrossRef]
2. Bosch, G., Lin, Y.L., van Schie, H.T.M., van De Lest, C.H.A., Barneveld, A., and van Weeren, P.R. 2007. Effect of extracorporeal shock wave therapy on the biochemical composition and metabolic activity of tenocytes in normal tendinous structures in ponies. *Equine Vet. J.* **39**: 226–231. [Medline] [CrossRef]
3. Estberg, L., Gardner, I.A., Stover, S.M., Johnson, B.J., Case, J.T., and Ardans, A.A. 1995. Cumulative racing-speed exercise distance cluster as a risk factor for fatal musculoskeletal injury in Thoroughbred racehorses in California. *Prev. Vet. Med.* **24**: 253–263. [CrossRef]
4. Kasashima, Y., Takahashi, T., Smith, R.K.W., Goodship, A.E., Kuwano, A., Ueno, T., and Hirano, S. 2004. Prevalence of superficial digital flexor tendonitis and suspensory desmitis in Japanese Thoroughbred flat racehorses in 1999. *Equine Vet. J.* **36**: 346–350. [Medline] [CrossRef]
5. Lam, K.K.H., Parkin, T.D.H., Riggs, C.M., and Morgan, K.L. 2007. Evaluation of detailed training data to identify risk factors for retirement because of tendon injuries in Thoroughbred racehorses. *Am. J. Vet. Res.* **68**: 1188–1197. [Medline] [CrossRef]
6. Mohammed, H.O., Hill, T., and Lowe, J. 1992. The risk of severity of limb injuries in racing thoroughbred horses. *Cornell Vet.* **82**: 331–341. [Medline]
7. Perkins, N.R., Reid, S.W., and Morris, R.S. 2005. Risk factors for injury to the superficial digital flexor tendon and suspensory apparatus in Thoroughbred racehorses in New Zealand. *N. Z. Vet. J.* **53**: 184–192. [Medline] [CrossRef]
8. Reardon, R.J.M., Boden, L.A., Mellor, D.J., Love, S., Newton, J.R., Stirk, A.J., and Parkin, T.D.H. 2012. Risk factors for superficial digital flexor tendinopathy in Thoroughbred racehorses in hurdle starts in the UK (2001–2009). *Equine Vet. J.* **44**: 564–569. [Medline] [CrossRef]
9. Reardon, R.J.M., Boden, L.A., Mellor, D.J., Love, S., Newton, J.R., Stirk, A.J., and Parkin, T.D.H. 2013. Risk factors for superficial digital flexor tendinopathy in Thoroughbred racehorses in steeplechase starts in the United Kingdom (2001–2009). *Vet. J.* **195**: 325–330. [Medline] [CrossRef]
10. Romero, A., Barrachina, L., Ranera, B., Remacha, A.R., Moreno, B., de Blas, I., Sanz, A., Vázquez, F.J., Vitoria, A., Junquera, C., Zaragoza, P., and Rodellar, C. 2017. Comparison of autologous bone marrow and adipose tissue derived mesenchymal stem cells, and platelet rich plasma, for treating surgically induced lesions of the equine superficial digital flexor tendon. *Vet. J.* **224**: 76–84. [Medline] [CrossRef]
11. Takahashi, T., Kasashima, Y., and Ueno, Y. 2004. Association between race history and risk of superficial digital flexor tendon injury in Thoroughbred racehorses. *J. Am. Vet. Med. Assoc.* **225**: 90–93. [Medline] [CrossRef]
12. Williams, R.B., Harkins, L.S., Hammond, C.J., and Wood, J.L.N. 2001. Racehorse injuries, clinical problems and fatalities recorded on British racecourses from flat racing and National Hunt racing during 1996, 1997 and 1998. *Equine Vet. J.* **33**: 478–486. [Medline] [CrossRef]