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Analysis of the Factors Influencing Fractures in Racehorses

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Abstract: The study population comprised 725 Thoroughbred racehorses with fractures over a 5 year period from 2007 through 2011 at the Korea Racing Authority's Seoul racecourse. There were 371 racing-related fractures in horses, accounting for the highest proportion of 51.2% of the fractures, followed by training-related (33.4%) and management-related (14.1%) fractures and fractures defined by pre-qualification inspection factors (1.4%). Fatal injury by racing-related fractures had the highest proportion at 32.8% of all the fractures in the study horses. The proportion of leg fractures was as high as 96.6%; this can be explained by considering the skeletal function of horses and the burden of supporting the body weight. In terms of occurrence by age, among factors for racing-induced fractures in horses, fracture occurrence rate in horses of 3-5 years of age exceeded the average rate of 0.60%. In the analysis of fracture occurrence by sex, geldings were the most frequently affected followed by male and then female horses. In the analysis of factors affecting racing-related fractures, fracture occurrence was considerably high in racehorses in which the burdened weight exceeded the average value. For burdened weight over 54 kg, there was a fracture in 219 of the 371 horses with racing-related fractures and this proportion was relatively high at 59%. When the track surface was muddy or sloppy, the fracture occurrence rate was higher than that during fast, good or humid conditions.

Key words: Factors, fracture, Thoroughbred racehorses, geldings, Korea

INTRODUCTION

Injury of the skeletal system in racehorses may occur in any environment-including before or after a race and is serious, potentially resulting in a fatal injury. According to the Japan Racing Association, 10,203 fractures were diagnosed in 556,705 racehorses during the period 1987-2000, resulting in an overall incidence of 1.83%. The annual incidence of fractures in flat racing during the 14 year period fluctuated between 1.44 and 2.19% (Oikawa and Kusunose, 2005).

Few epidemiological studies have investigated the risk factors for musculoskeletal injury occurring in Thoroughbred racehorses, although this is a major cause of wastage in the racing industry (Verheyen *et al*., 2006b). Intrinsic factors that have most consistently been associated with fracture risk are age, gender, race, anatomical and biomechanical parameters, bone characteristics and physical fitness level. Environmental factors such as the behavioral pattern of the jockey (Ueda *et al*., 1993), the racetrack condition, race distance and burdened weight can also be considered (Bailey *et al*., 1997; Oikawa and Kusunose, 2005).

Depending on each fracture occurrence, factors related to time, race, training and management at the time of the pre-race diagnosis and physical inspection have been surveyed and race-induced skeletal-system injuries have been reported in many studies (Boden *et al*., 2007; Dyson *et al*., 2008; Parkin, 2008; Wilsher *et al*., 2006). However, epidemiological surveys of the factors associated with skeletal-system injury are limited. In this study, each proportion of fracture occurrence was analyzed in addition to race and training-induced factors.

For both humans and animals, bone fractures present an inherent risk in engaging in strenuous physical exercise and athletic activity (Verheyen *et al*., 2006a). The causes of musculoskeletal injuries are multifactorial and different factors may interact with one another (Stover, 2003).

Studies regarding factors associated with fractures have further improved our understanding of equine bone, including its response to work and its mechanisms of failure, track design in relation to injuries, early diagnosis and hence prevention of catastrophic disease and identification of significant risk factors associated with various fractures (Riggs, 2002). By conducting an epidemiological survey and analysis of racehorse fractures in Korea, we intended to minimize fracture occurrence and understand other factors that affect fractures.

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MATERIALS AND METHODS

Racing circumstances in Seoul in Korea: The Korea Racing Authority (KRA) has 2 racetracks (both oval courses with racing in an anticlockwise direction). There are about 2500 Thoroughbred racehorses at the Seoul racetrack which also serves as a training center where approximately 1400 horses are managed regularly. Approximately 1100 races and 12,370 starts take place every year and the total numbers of starts was 61,851 during the study period.

One of the characteristics of the KRA's Seoul racecourse is that all races are flat races with a sand track. Average race participation of horses with racing-related fractures according to their domestic racing career was 15.4 times and average race participation interval was 72 days. Average weight change for the total number of racehorses during the relevant period was ±5.87 kg and average burden weight was 53.5 kg.

Study population and item investigation: Seven hundred twenty-five Thoroughbred racehorses that suffered fractures during training or racing at the KRA's Seoul racecourse during the 5 year period from 2007 through 2011 were surveyed. Diagnosis of fractures was performed using a portable x-ray (VET-20BT, POSCOM, Korea) or ultrasound device (LOGIQ 500 PRO, USA). A fracture was diagnosed if there was complete or incomplete fracture or partial or total fracture of the bone cortex or parenchyma.

The following items were investigated: the fracture rate of racehorses, the degree of fractures in racehorses, analysis of fracture patterns, distribution of fracture occurrence depending on the fracture location (bone or body part) and site and the status of fracture occurrence associated with the horse's body factors (age and gender) and with the racing environment (racing interval, horseback-burdened weight and racetrack condition).

Inclusion criteria and case definition: Cases of fracture were divided into 4 groups depending on the direct cause of fracture or the point in time of fracture recognition: racing-induced (racing-related) fracture, meaning cases that resulted from racing; training-induced (training-related), meaning fractures that occurred with race training; management-induced (management-related) cases, meaning fractures that were unrelated to physical activities such as racing and training and pre-qualification inspection (pre-race physical checkup), meaning fractures that were detected at the pre-race physical inspection for registering of new racehorses.

The annual proportion of fracture was estimated per horse managed and occurrence rates of racing-induced fracture were estimated per horse starts by risk factors. The degree of fracture was classified as follows: mild (necessitating at least 4 months' rest for the horse before the next race), moderate (6 month's rest), severe (6-12 months) and fatal (disqualification or euthanasia). Because the moisture content of the racetrack affects its condition on the day of the race, the racetrack condition was categorized on the basis of moisture content into 5 types: fast, moisture content of 2-5%; good, moisture content of 6-9%; humid, moisture content of 10-14%; muddy, moisture content of 15-19% and sloppy, moisture content of >20%.

RESULTS

The fracture occurrence rate of racehorses that were raised and managed at the KRA's Seoul racecourse is presented in Table 1. The fracture occurrence rate was not even. Annual occurrence rate of fracture was calculated according to the number of managed horses per year. Fracture rates in 2009 of 6.34% and in 2010 of 6.64% were higher than the total 6.00% rate for the 5 year study period. Significant results with the chi-square test meant that the occurrence rate in each year was not equal. It was assumed that the occurrence rate in 2011 (4.52%) was lower than other years. Meanwhile, a total of 371 racing-related fractures were diagnosed in 61,851 runners, resulting in an incidence of 0.60% (371/61,851) per starts.

Fatal injury by racing-induced factors had the highest distribution of 32.8% of the total fractures in horses. Meanwhile, 4 horses (0.6%) out of the 10 horses fractured that were recognized on pre-race physical inspection had a fatal injury. A fatal injury such as race ineligibility or euthanasia was fatal to the life of the racehorse and had a distribution of 61.5% Table 2.

Fractures in racehorses take place by a complex action involving diverse factors. To determine the

Table 1: Annual occurrence rates of fracture in Thoroughbred racehorses at the Seoul racecourse in Korea (2007-2011)

	Years							
Parameters	2007 (n = 2335)*	2008 (n = 2419)	2009 (n = 2336)	2010 (n = 2438)	2011 (n = 2546)	Total (n = 12,074)	χ^2	p-value
Number of horses with fracture	133(5.70**)	167(6.90)	148(6.34)	162(6.64)	115(4.52)	725(6.00)	16.0664	0.0022***

*No. of horses managed each year; ** Occurrence rates relative to horses managed (%); *** p<0.05

Table 2: Fracture degree by cause of fracture or point in time that the fracture was confirmed

Degree of fracture*	Racing-induced	Training-induced	Management -induced	Pre-qualification inspection	Total	χ^2	p-value
Mild	45 (6.2)**	23 (3.2)	20 (2.8)	4 (0.6)	92 (12.7)		
Moderate	61 (8.4)	34 (4.7)	31 (4.3)	1 (0.1)	127 (17.5)		
Severe	27 (3.7)	18 (2.5)	14 (1.9)	1 (0.1)	60 (8.3)	41.9244	0.0001***
Fatal	238 (32.8)	167 (23.0)	37 (5.1)	4 (0.6)	446 (61.5)		
Total	371 (51.2)	242 (33.4)	102 (14.1)	10 (1.4)	725 (100.0)		

*Degree of fracture was classified into 4 classes according to the minimum rest period until the next race participation: mild, rest for <4 months; moderate, rest for about 6 months; severe, rest for 7-12 months and fatal, disqualification of the racehorse or euthanasia; ** Proportion of occurrence distribution by degree and cause of fracture (%); *** p<0.05

Table 3: Analysis of the fracture patterns according to the cause or point in time of recognition of the fracture

Fracture location	Racing-induced	Training-induced	Management -induced	Pre-qualification inspection	Total	χ^2	p-value
Forelimb							
Left side	163 (22.5)*	87 (12.0)	18 (2.5)	2 (0.3)	270 (37.2)	147.788	0.0001***
Right side	180 (24.8)	118 (16.3)	16 (2.2)	2 (0.3)	316 (43.6)		
Both sides	10 (1.4)	6 (0.8)	4 (0.6)	0 (0.0)	20 (2.8)		
Subtotal	353 (48.7)	211 (29.1)	38 (5.2)	4 (0.6)	606 (83.6)		
Hindlimb**							
Left side	7 (1.0)	16 (2.2)	24 (3.3)	5 (0.7)	52 (7.2)		
Right side	10 (1.4)	12 (1.7)	17 (2.3)	1 (0.1)	40 (5.5)		
Both sides	1 (0.1)	0 (0.0)	1 (0.1)	0 (0.0)	2 (0.3)		
Subtotal	18 (2.5)	28 (3.9)	42 (5.8)	6 (0.8)	94 (13.0)		
Other location	0 (0.0)	3 (0.4)	22 (3.0)	0 (0.0)	25 (3.4)		
Total	371 (51.2)	242 (33.4)	102 (14.1)	10 (1.4)	725 (100.0)		

*Proportion of occurrence distribution by fracture pattern and cause of fracture (%); ** In the case of the hind limb, statistical testing was not performed owing to the small number of horses with fracture; *** p<0.05

Table 4: Analysis of the fracture location and site in Thoroughbred racehorses

Location*	Number of fracture cases (%)**
Forelimb	
Scapula	5 (0.7)
Humerus	14 (1.9)
Radius	1 (0.1)
Carpus	220 (30.3)
Metacarpus	124 (17.1)
Fetlock	221 (30.5)
Pastern	7 (1.0)
Hoof	14 (1.9)
Total	606 (83.6)
Hindlimb	
Pelvis	16 (2.2)
Femur	4 (0.6)
Tibia	8 (1.1)
Hock	2 (0.3)
Metatarsus	11 (1.5)
Fetlock	38 (5.2)
Pastern	8 (1.1)
Hoof	7 (1.0)
Total	94 (13.0)
Other	25 (3.4)

*Location: The carpus included the following bones: the distal radius, 3rd carpal, radial carpal , intermediate carpal and accessory carpal. The metacarpus comprised the splint bones and 3rd metacarpal bone. The fetlock included the proximal sesamoid bone and proximal 1st phalangeal bone. The pastern implied the 1st and 2nd phalangeal bones. The hoof meant the pedal bone. The hock comprised the 3rd and central tarsal bones. The metatarsus included the 3rd and 4th metatarsal bones; ** Proportion of occurrence distribution by location of fracture

location of the fracture, an analysis was done depending on the fracture location at the time of diagnosis (Table 3). A total of 83.6% of the leg fractures took place in the forelimb and the incidence in the right forelimb (43.6%) was higher than that in the left forelimb (37.2%).

We analyzed the occurrence distribution in the extremities which accounted for most of the fractures critically affecting the lives of racehorses (Table 4). In the hind limb, there was a very low fracture distribution (13.0%) compared with the forelimb (83.6%).

In terms of occurrence by age among factors affecting racing-induced fractures in horses, the fracture occurrence rate for horses of 3-5 years (0.61-0.69%) exceeded the average rate of 0.60% (Table 5) but the occurrence rate for horses of 6 years (0.18%) was remarkably lower than the total rate. Significant results with the chi-square test meant that the occurrence rate at each age was not equal. It was assumed that the occurrence rate was lower for the 6 year category than other age categories. In the analysis of fracture occurrence by gender, although there was no significant difference, fractures were most frequent in geldings, followed by male and then female horses (Table 6). In the case of gelded horses, fractures occurred in 85 horses out of 13,692 horses. A total of 132 horses had a fracture out of 21,659 male horses and 154 horses had a fracture out of 26,500 female horses.

Besides average times of race participation for racehorses, in cases of above-average value for race participation interval, weight change of racehorses and burden weight during the relevant period, the fracture occurrence distributions were higher than in those horses of average value among race starters (Table 7).

As an environmental factor affecting racing-induced fracture, the racetrack condition was surveyed (Table 8). When the condition of the racetrack surface was muddy or sloppy, the fracture occurrence rate was somewhat high compared with fast, good or humid conditions but there was no significant difference.

Table 5: Incidence comparison of 371 racing-induced fractures associated with the age of the horse

Horse age (years)	(2n = 6212)	(3n = 25,890)	(4n = 17,977)	(5n = 8061)	(6n = 2730)	(≥7n = 981)	Total (n = 61,851)*	χ^2	p-value
No. of horses with fracture	24 (0.39)**	159 (0.61)	124 (0.69)	56 (0.69)	5 (0.18)	3 (0.31)	371 (0.60)	17.8652	0.0031***

*Total number of racing starts during survey; **Fracture occurrence rate per 100 starts (%); *** $p<0.05$

Table 6: Incidence comparison of 371 racing-induced fractures associated with horse gender

Horse gender	Female (n = 26,500)	Male (n = 21,659)	Gelding (n = 13,692)	Total (n = 61,851)*	χ^2	p-value
Number of horses with fracture	154 (0.58) **	132 (0.61)	85 (0.62)	371 (0.60)	0.2900	0.8650

* Total number of racing starts during survey; ** Fracture occurrence rate per 100 starts (%)

Table 7: Analysis of risk factors associated with racing-induced fracture

	Total number of race participations (times)		Racing interval (days)		Horse weight change Relative to previous racing day (kg)			Horseback-burdened weight (kg)	
Range (Factor*)	≤15	≥16	≤72	≥73	≥-6	-5 to +5	≥+6	≤53.5	≥54
Number of horses with fracture	264 (71.2)**	107 (28.8)	328 (88.4)	43 (11.6)	85 (22.9)	223 (60.1)	63 (17.0)	152 (41.0)	219 (59.0)

* Mean value of factors of racehorses participating in races: total number of race participations, 15 times; race participation interval, 72 days weight variation, ±5.87 kg and burden weight, 53.5 kg; ** Occurrence distribution proportion by fracture risk factor (%)

Table 8: Incidence analysis of 371 racing-induced fractures according to the surface of the racetrack

	Racetrack condition*						
Condition	Fast (n = 1930)**	Good (n = 1349)	Humid (n = 872)	Muddy (n = 746)	Sloppy (n = 504)	χ^2	p-value
Number of horses with fracture	117 (6.06)***	94 (6.97)	60 (6.88)	62 (8.31)	38 (7.54)	4.7640	0.3124

Condition* Water content was measured using a previously described method: fast, 2-5%; good, 6-9%; humid, 10-14%; muddy, 15-19% and sloppy, over 20%; ** Number of races during survey; *** Fracture occurrence rate by racetrack condition (%)

DISCUSSION

We surveyed and analyzed reliable data of fracture occurrence status and the main factors affecting the fractures of racehorses raised and managed at KRA. The final objective of this study was not only to prevent fractures in racehorses and possible loss of function due to fracture but also to suggest improvements in race conditions and the race environment.

Despite fluctuations in the managed and fractured horses, occurrence rates did not show an upward tendency. The racing-induced fracture incidence per starts of 0.60% (371/61,851) as mentioned in the above results was slightly >0.38% in the United Kingdom (Pinchbeck *et al*., 2004) and <1.83% in Japan (Oikawa and Kusunose, 2005) and considerably >the incidence rates of musculoskeletal breakdown per starts of 0.24% in Australia (Bailey *et al*., 1997) and the prevalence of horses with racing injuries 0.33% in the USA (Peloso *et al*., 1994).

As shown in Table 2, 55.9% (405/725) of the fractured horses were diagnosed with a fatal injury due to racing or training-induced factors. According to the surveyed data, 51.2% (371 horses) of fracture-diagnosed horses suffered the injury because of racing-induced factors. These results may be explained by the intense competition among the jockeys, the high racing speeds and the condition of the sand track during the race.

Fractures in the forelimbs occurred at a higher rate than those in the hind limbs; this can be explained by the skeletal function of the horse and the greater proportion of the total body weight supported by the forelimbs than hind limbs. Although, there was no significant difference between the left and right distributions of fracture, fractures occurred more frequently in the right than left leg. Martin *et al*. (1988) also the right limb was affected more frequently than was the left limb. It is assumed that this result is closely related to the counterclockwise racing direction of the racecourse at KRA and that, the greater momentum on the right side due to the counterclockwise movement increased the possibility of a fracture occurring in the right leg. The higher prevalence of right-sided third-carpal fractures (60% in the right limb and 40% in the left limb) noted in studies from the USA was assumed to reflect the anticlockwise direction of training and racing tracks (Schneider *et al*., 1988).

The fracture rate in the legs was as high as 96.6% while other fractures including skull or vertebra fractures showed an extremely low rate of 3.4%. Fractures occurred most commonly in the lower forelimb including the fetlock (30.5%) and carpal (30.3%) and metacarpal (17.1%) regions

and the upper hind limb was rarely affected. Fracture of the fetlock is also closely related to the racing direction of the racecourse and this part of the anatomy is sensitive to injury because it has the biggest motion range of the horse skeleton. The high frequency of fractures of the fetlock-the part of the skeleton located at the extremities-proves the phenomenon described above. Management-induced fractures and fractures detected at the pre-race physical inspection did not show a significantly higher fracture occurrence in the forelimb compared with the hind limb. A possible explanation for these different results is that racing- and training-induced fractures occur in actual racing because of the buildup of stress to the legs while management and pre-race inspection are preparation steps prior to an actual race so no stress exists in any of the legs.

Detailed surveys for horse factors and environmental factors that affect racing-induced fractures were performed. Horse factors were classified into 6 categories including age, gender, frequency of race participation, racing interval, weight fluctuation and burdened weight. For environmental factors, we surveyed the racetrack conditions. From the results of the racing-induced fracture survey, the fracture occurrence rate in horses aged 3-5 years exceeded the average rate of 0.60%. This was contradictory to another study. In the other study, horses over 4 years of age were 1.8 times more likely to suffer a fracture than those 4 years old or less (Bailey *et al*., 1997). This is not surprising given that older horses are more likely to have been exposed to a lifetime of greater repetitive microtrauma from racing and training. In addition, bone strength plays a role in the increase of fracture occurrence associated with age. Fracture toughness substantially decreased with a horse's age in quasi-static experiments (Kulin *et al*., 2011). Although, there was no significant difference in fracture occurrence between horses of different age groups in the present study, our contradictory result may be explained by the fact that horses of 3-5 years of age participate more frequently in training and racing than do horses in other age groups in Korea and therefore display a relatively high fracture occurrence due to accumulated fatigue.

Compared with colts and mares, gelding horses showed the highest ratio in the proportion of fracture occurrence by gender but this difference was neither significant nor logical. An explanation for this phenomenon might be that the temperament of male horses remains unchanged for a certain period after castration and that fracture occurrence might increase in gelding horses engaged in racing before the sexual character of the horse has disappeared.

The shorter the race career of a racehorse, the higher the occurrence rate of fracture. It is believed that fractures were induced by the desire for competitive speed and irrational race participation of horses that were not race adapted. In addition, fracture occurrence was higher in racehorses in which the race participation interval was shorter than the average racing interval. This is because both intensive training before the adaptive response is completed and reduced bone strain increase the risk of fatigue damage and bone fatigue is associated with progressive microdamage which is important in the pathogenesis of fractures (Riggs, 2002). Rest and a gradual return to exercise appear to result in complete recovery of horses with incomplete fracture (Kawcak *et al*., 1995). It is believed that the fracture rate was increased because of early return to racing without adequate rest and inappropriate treatment of minor injuries.

In terms of weight fluctuation among horse factors for racing-induced fractures, fracture occurrence in racehorses in the category of average weight fluctuation was recorded as the highest.

CONCLUSION

This finding might be explained by accumulated fatigue due to intensified training and race participation for maintaining and controlling the proper weight of the horse.

The track surface condition has an effect on the risk of fracture injury (Pinchbeck *et al*., 2004). This has already been proven by another thesis. Although our study revealed no significant differences, fracture rates increased with saturated or poor racetrack condition. It is believed that fractures are more likely to occur because of poor landing, sliding and unbalanced composition of sand particles on the racetrack as a result of the increased moisture content.

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