Underrun Heels and Toe-Grab Length as Possible Risk Factors for Catastrophic Musculoskeletal Injuries in Oklahoma Racehorses

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Prevalence of underrun heels in 90 Oklahoma racehorses of different breeds examined postmortem by the Oklahoma Animal Disease Diagnostic Laboratory exceeded 97%. Severity of the underrun heels was significantly greater in racehorses experiencing catastrophic suspensory apparatus injuries than a control group whose deaths were not related to the musculoskeletal system. Lengths of toe grabs were not a significant potential risk factor in catastrophic suspensory apparatus injuries in this study. This research was performed while the authors were employed by the Department of Veterinary Clinical Sciences (Balch, Collier) and the Oklahoma Animal Disease Diagnostic Laboratory (Helman), College of Veterinary Medicine, Oklahoma State University, Stillwater, OK 47078. Authors' addresses: 720 W. 1st Str., Apt. #37, Cheney, WA 99004 (Balch); IDEXX Veterinary Services, 200 Westboro Road Bldg. 20, North Grafton, MA 01536-1895 (Helman); Office of the Dean, College of Agriculture, Forestry, and Natural Resources, University of Hawaii, Hilo, Hawaii 96720 (Collier).

1. Introduction

The California Horse Racing Board Postmortem Program conducted by the California Veterinary Diagnostic Laboratory System provided the first analytic evaluation of horseshoe characteristics and hoof conformation in racehorses experiencing catastrophic injuries. The horseshoe characteristic study[1] examined 201 Thoroughbred racehorses and concluded that the presence and length of toe grabs were statistically related to catastrophic musculoskeletal injury (CMI), suspensory apparatus failure (SAF), and cannon bone condylar fracture (CDY). The hoof size, shape, and balance study[2] examined 95 Thoroughbred racehorses and concluded that increases in ground surface area slightly decreased the frequency of CMI, SAF, and CDY. Additionally, the frequency of SAF increased markedly with the presence of a 10° difference between heel and toe angle.

Obviously, these two studies have important implications to the practice of racehorse hoof trimming and shoeing. However, without collaborating studies done at other racing jurisdictions, the conclusions of the California study remain untested.

The objective of this case-control study was to analyze the shoeing characteristics and hoof conformation of racehorses that died or were euthanized on Oklahoma racetracks. This report specifically

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addresses the effects of dorsopalmar hoof balance and toe-grab length.

2. Materials and Methods

Study Population

The study included 90 racehorses (56 Thoroughbreds, 28 Quarter Horses, 3 Appaloosas, and 3 Paint Horses) examined postmortem by the Oklahoma Animal Disease Diagnostic Laboratory (OADDL) for the Oklahoma Horse Racing Commission between 3 March 1999 and 26 November 2000.

Data Collection

Necropsy data were retrieved from OADDL records, and horses were classified either as non-CMI or CMI based on the catastrophic events that preceded their deaths. Based on necropsy findings, the CMI group was further classified into 1) horses sustaining SAF (rupture of the distal sesamoidean ligaments, suspensory ligament, or fracture of the proximal sesamoids), 2) horses sustaining SAF plus additional fractures (SAF + Fx) that may have included but were not limited to the condylar region of the metacarpus, 3) horses sustaining catastrophic carpal fractures (CCFx), and 4) horses sustaining other catastrophic limb fractures. Controls were the non-CMI horses that died due to reasons unrelated to the appendicular musculoskeletal system.

To facilitate detailed measurement and long-term access to accurate renditions of the hooves, a model of each shod foot was formed using dental plaster following limb transection at the metacarpophalangeal joints. These models were then measured to determine shoe characteristics, shoe placement on the hoof, and hoof conformation.

Characteristics of the horseshoes on both forefeet were identified using techniques developed by Kane et al.[2] Toe grab types were classified as NONE, LOW, REGULAR, or QUARTER HORSE. However, unlike the California study, a fifth category QUEENS PLATE was added to the Oklahoma study because many horses were shod with the toe grab so identified. In addition to classifying the toe grab as NONE, QUEENS PLATE, LOW, REGULAR, or QUARTER HORSE, the lengths of the medial and lateral aspects of the toe grab were measured with mechanical calipers from the ground surface of the shoe to the adjacent ground surface of the toe grabs. These measurements were made independently by two individuals without knowledge of the cause of death and then averaged to provide a single measurement for each toe grab.

The model of each shod hoof was placed in the center of a 25 × 25-cm plastic sheet grooved to fit into a rigid jig. Standardized orthogonal images of the dorsal, lateral, palmar, and medial aspects were obtained using a high-resolution digital camera[a] by sequentially rotating the plastic square in 90° increments. Focal point was centered on the visible edge of the shoe. A final solar view was taken with ground surface of the shoe perpendicular to the camera and focal point centered on the frog. Focal distance was fixed at 50 cm and a calibration ruler was included in each view. Public domain image analysis software[b] was used to determine calibrated angle, length, and area measurements from each image.

For this study, the following three dorsopalmar measurements were recorded. TOE ANGLE was defined by the angle between the solar surface of the wall and the wall at the toe. HEEL ANGLE was defined by the angle formed between the solar surface of the wall and the wall at the heel. SHOE/HEEL ANGLE was defined by the angle formed by a line parallel to the ground surface of the shoe and a line that originated at the most caudal ground portion of the shoe and extended proximally to form a tangent with the heel of the hoof. Measurements were performed without knowledge of the cause of death. A transformed variable, TOE–HEEL ANGLE DIFFERENCE, was created by subtracting the heel angle from the toe angle.

Data Analysis

Each group of case horses, those with CMI, SAF, SAF + Fx, and CCFx, was compared separately with the control group of non-CMI horses. Measurements from the model of the shod hoof from the injured limb were compared to measurements from models of comparable hooves of the non-CMI control group. Separate one-way ANOVA models[c] were used to individually compare the means for each measurement between the case and control horses with significance set at $p < 0.1$. Variables that qualified were used in a final multivariable logistic regression model.[d]

3. Results

The difference between heel and toe angles for 90 left forehooves averaged 16.4° with a standard deviation of 6.1° and ranged between −0.4° to 30.6°. For the 90 right forehooves, the difference averaged 15.6° with a standard deviation of 5.6° and ranged between 5.4° and 30.6°. Only 4 out of 180 hooves demonstrated a difference between heel and toe angles of less than 5°. Fig. 1 plots the frequency and severity of underrun heels.

Of the 90 horses necropsied, 5 horses with catastrophic hindlimb musculoskeletal injuries were excluded from statistical consideration. Of the remaining 85 horses, 62 (73%) were CMI and included 17 (20%) SAF, 7 (8%) SAF + Fx, and 14 (16%) CCFx. The control horses whose deaths were unrelated to the appendicular musculoskeletal system numbered 23 (27%).

Toe-grab length measurements (reported as means and standard deviations) were not significantly different between non-CMI control horses (5.46 ± 2.69 mm) and CMI (5.09 ± 2.65 mm), SAF + Fx (3.93 ± 2.59 mm), CCFx (5.66 ± 2.47 mm), or SAF (4.45 ± 2.65 mm) case horses. Importantly,

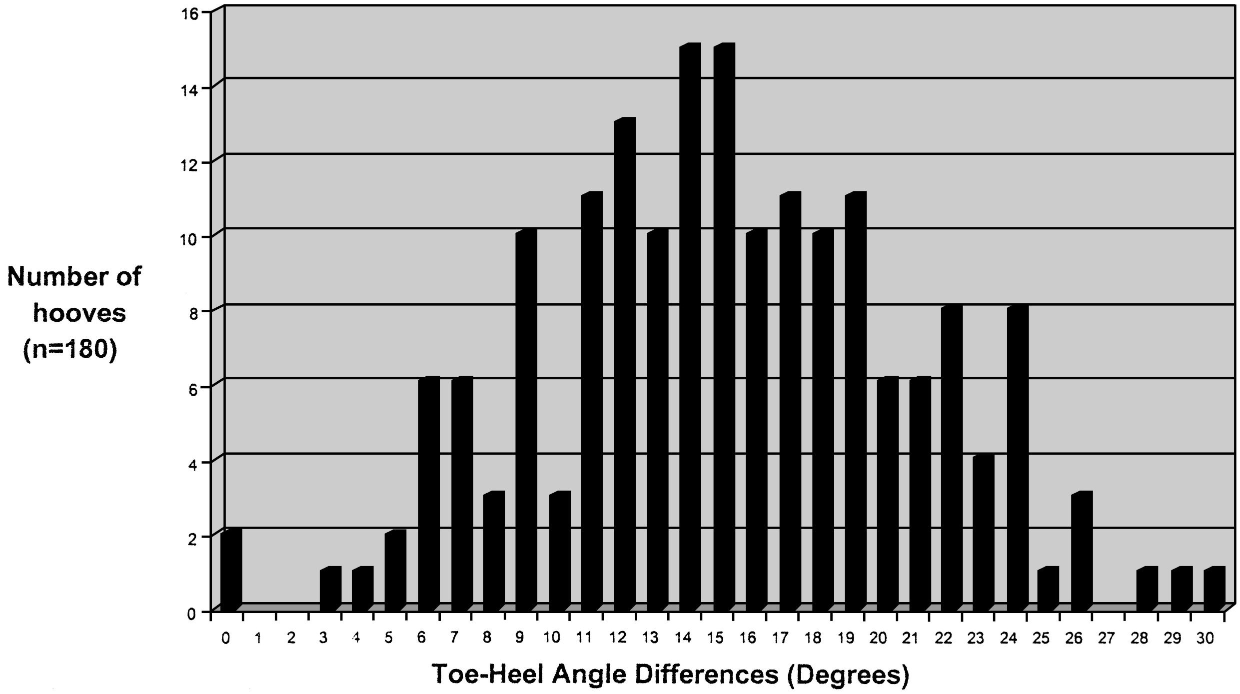

Fig. 1. Frequency of underrun heels of the forehooves in a population of 90 racehorses presented for postmortem examination following euthanasia or death at Oklahoma race tracks in 1999 and 2000.

the differences of the toe-grab lengths between the non-CMI controls and Oklahoma SAF cases were statistically insignificant (power = 0.8 at ∂ 30% or 1.5 mm). Toe angles were very similar across groups: non-CMI controls (54.5 ± 2.9°), CMI (54.0 ± 3.1°), SAF + Fx (53.8 ± 3.1°), CCFx (53.6 ± 2.3°), and SAF (53.8 ± 3.5°). Heel angles differed across groups: non-CMI controls (39.4 ± 6.0°), CMI (36.6 ± 6.8°), SAF + Fx (37.7 ± 8.5°), CCFx (39.4 ± 4.5°), and SAF (32.5 ± 5.7°). Correspondingly, toe–heel angle differences also varied across groups: non-CMI controls (15.1 ± 5.3°), CMI (17.3 ± 6.2°), SAF + Fx (16.1 ± 7.5°), CCFx (14.3 ± 4.4°), and SAF (21.3 ± 5.5°). The shoe/heel angles were very similar across groups: non-CMI controls (39.9 ± 5.5°), CMI (39.5 ± 6.3°), SAF + Fx (38.8 ± 7.7°), CCFx (39.3 ± 4.7°), and SAF (39.9 ± 4.6°).

Comparing non-CMI controls to CMI, SAF + Fx, and CCFx case horses, none of the dorsopalmar measurements were significantly different. However, contrasting the non-CMI controls to the SAF horses, significant variations were present between heel angles ($p < 0.0203$) and toe-heel angle differences ($p < 0.0450$) during the initial one-way ANOVA screening. Logistic regression modeling that contrasted the non-CMI controls to SAF case horses determined that the variations between the heel angles were highly significant (Wald test: $p < 0.0042$; Odds Ratio: 0.82 with 95% Wald Confidence limit of 0.718 to 0.940). Likewise, the variations between the toe–heel angle differences were highly significant (Wald test: $p < 0.0049$; Odds Ratio: 1.24 with 95% Wald Confidence limit of 1.067 to 1.435).

4. Discussion

Underrun heels have been defined as heel angles that are at least 5° lower than toe angles.[3] Underrun heels (also called run-under heels, underslung heels, collapsed heels, and sloping heels) have previously been linked to lameness.[3-6] A 1988 study identified that 26 of 50 sound performance horses had underrun heels.[5] The 1998 California study[1] describing hoof size, shape, and balance of 95 Thoroughbred racehorses did not explicitly determine the prevalence of underrun heels but noted the following means and standard errors for differences between the toe and heel angles: Controls (8.8 ± 0.8°), CMI (10.0 ± 0.5°), SAF (10.1 ± 0.6°), and CDY (9.8 ± 1.7°). Clearly, most of the Thoroughbreds in this California study were underrun as well.

Most importantly, the California study was the first to statistically relate the presence of underrun heels to SAF in a statewide racing jurisdiction. Our study done in Oklahoma supports the same conclusion that increased differences in toe–hoof angles predispose racehorses to SAF. Interestingly, the Odds Ratio for the variable TOE–HEEL ANGLE DIFFERENCE was very similar between racing jurisdictions (Oklahoma: 1.24; California: 1.21). However, unlike the California study, the Oklahoma study found decreasing the heel angle by itself predisposed racehorses to SAF.

The presence of underrun heels may not be synonymous with musculoskeletal disease but is a strong biomechanical predisposition to injury. Hoof tubules in the portion of the heel that is underrun are bent forward, diminishing their ability to resist compression. Concussion is disproportionately concentrated in the heels due to simultaneous reduction in ground surface area and dorsal shift in location. The dorsal shift of ground–contact surface hyperextends the coffin, pastern, and fetlock joints. In turn, this hyperextension increases tensile forces on the palmar aspect of the distal limb and increases compression loading on the dorsal surface of the distal limb.

The prevalence of underrun heels in racing Thoroughbred and Quarter Horses[7] supports the contention that this hoof conformation may be an inherited characteristic that predisposes horses to musculoskeletal disease.[8] This Oklahoma study documents that 97.2% (176 of 180) hooves examined postmortem demonstrated underrun heels. This observation confirms Moyer and Schumacher's 1996 assertion that "the single most frequently encountered abnormal foot configuration is the combination of the underrun (low) heel and long toe."[9] One of the most disturbing aspects of underrun heels is that its extremely high prevalence may lull veterinarians into thinking that the condition is a normal hoof variation rather than a serious pathological deviation.

Perhaps the most interesting part of this study was our inability to confirm the California findings that toe grabs were a potential risk factor for SAF. Because of shoeing and training practices in Oklahoma, aluminum racing shoes were often extremely worn. While toe grabs were classified as NONE, QUEENS PLATE, LOW, REGULAR, or QUARTER HORSE based on shoe markings and grab shape, the toe grab on a new regular shoe could actually be longer than the Quarter Horse toe grab on a severely worn shoe. Measuring the actual length of the toe grab was a technique adapted to remedy the dilemma of excessive wear of toe grabs.

The length of the toe grab did not help to distinguish SAF cases from non-CMI controls. The California study used 201 Thoroughbred racehorses while the Oklahoma study used 85 racehorses of various breeds. While it may be argued that analysis of a larger number of Oklahoma horses would be more likely to confirm the California finding, it should be noted that the average length of the toe grab in the Oklahoma SAF cases was nearly 1 mm *shorter* already than the toe grab in the non-CMI control horses. Interestingly, the trend is in the opposite direction. From a biomechanical perspective, it is reasonable to expect that toe grabs would further hyperextend the distal joints and abnormally load the fetlock.

Potentially, differences between the effects of the toe grabs and their lengths may be associated with variations in flat-track racing in California and Oklahoma. Among the obvious differences is breed: California racehorses were uniformly Thoroughbreds, while Oklahoma racehorses were 62% Thoroughbreds, 31% Quarter Horses, 3% Appaloosas, and 3% Paint Horses. The length of the race is traditionally associated with the breed of the horse. For example, Quarter Horses tend to race much shorter distances than Thoroughbreds. While age was not shown to be an effect in California, the median age of California horses was 4 years and the median age of Oklahoma horses was 3 years. There appears to be differences in types of injuries. In Oklahoma, no horses with cannon bone condylar fracture unrelated to other catastrophic musculoskeletal injuries were identified in this study. In California, 11% (10 of 95) were diagnosed with CDY in the hoof size, shape, and balance study. There may be regional differences in shoeing techniques. For example, Kane et al[1] reported the following means and standard errors for toe angles: Control (50.7 ± 0.5°), CMI (49.7 ± 0.3°), SAF (49.2 ± 0.4°), and CDY (48.4 ± 0.8°). Oklahoma racehorses were routinely trimmed to angles between 3°–5° higher. Interestingly, Kane et al[1] suggest increasing the toe angle to help prevent injury. Almost certainly, there are regional (if not track) differences in track design, soil material, slope, and maintenance.

In summary, underrun heels in 90 Oklahoma racehorses examined postmortem exceeded 97%. The severity of underrun heels was a significant potential risk factor in racehorses with SAF. Surprisingly, the length of toe grabs was not a significant risk factor for SAF in this study. Hopefully, these two state studies will be a clarion call to other states or racing jurisdictions to perform similar case-control studies on racehorses involved in catastrophic injuries. The more universality demonstrated in risk factors, the more likely increased awareness will result in wide spread changes in shoeing techniques in racing horses.

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References and Footnotes

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