Quantitative comparison of three commonly used treatments for navicular syndrome in horses

Mike J. Schoonover, DVM, MS; Henry W. Jann, DVM, MS; Margaret A. Blaik, DVM

Objective—To quantitatively compare 3 commonly used treatments for navicular syndrome (NS) in horses: heel-elevation shoeing alone, heel-elevation shoeing and phenylbutazone administration, heel-elevation shoeing and injection of the distal interphalangeal joint (DIPJ) with triamcinolone acetonide (TA), and all 3 treatments in combination.

Animals—12 horses with NS.

Procedure—A force plate was used to measure baseline peak vertical ground reaction force (PVGRF) of the forelimbs. Each horse's forelimbs were shod with 3° heel-elevation horseshoes; PVGRF was measured 24 hours and 14 days after shoeing. Fourteen days after shoeing (following data collection), phenylbutazone (4.4 mg/kg, IV, q 12 h) was administered (5 treatments). Two hours after the fifth treatment, PVGRF was measured; TA (6 mg) was injected into the DIPJ of the forelimb that generated the lower baseline PVGRF. Fourteen days later, PVGRF was measured. Phenylbutazone was administered as before, and PVGRF was measured. Percentage body weight of force (%BWF) was calculated from PVGRF measurements and used for comparisons.

Results—14 days after shoeing, mean %BWF in both forelimbs significantly increased from baseline; additional administration of phenylbutazone significantly increased %BWF applied from the more lame forelimb. Compared with shoeing alone, there was no significant change in %BWF after injection of the DIPJ with TA in shod horses.

Conclusions and Clinical Relevance—Heel-elevation shoeing alone and in combination with phenylbutazone administration quantitatively decreased lameness in horses with NS. Although not significant, additional DIPJ injection with TA resulted in further quantitative decrease in lameness, compared with that achieved via shoeing alone. (*Am J Vet Res* 2005;66:1247–1251)

Navicular syndrome is a common cause of lameness that affects many horses of all activity groups. It is a poorly understood, incurable, degenerative condition of the distal sesamoid (navicular) bone and supporting soft tissue structures.[1-4] Since the recognition of navicular syndrome in 1752, many attempts to define the exact pathogenesis have been made; however, navicular syndrome has never been experimentally reproduced in horses.[3] Poor conformation, excessive training or use, and improper trimming of hooves or shoeing have all been implicated as predisposing factors to development of navicular syndrome in horses.[1,2,5] Although the cause remains unclear, 2 main theories of pathogenesis have evolved: abnormal biomechanical function (biomechanical trauma) and vascular compromise.

Prior to the mid 1980s, diagnosis was routinely made on the basis of clinical signs, which classically consisted of a bilateral forelimb lameness that improved with palmar digital perineural anesthesia or distal interphalangeal joint anesthesia.[6,7] Recent reports[1,8,9] emphasize the use of radiography, nuclear scintigraphy, computed tomography, and magnetic resonance imaging to accurately and definitively diagnose navicular syndrome in horses. Traditionally, subjective lameness evaluations have been the only way to determine clinical lameness and treatment efficacy. However, with the development of quantitative gait analysis technology such as force plates, lameness can now be evaluated in an objective fashion.[10-14] A force plate is able to measure the maximal vertical ground reaction force generated by each limb as it strikes the plate when a horse is in motion. Peak vertical ground reaction force has been found to be inversely correlated to the degree of lameness when normalized to body weight.[10,11]

Many treatments, such as controlled exercise, corrective shoeing, various medical and surgical treatments, and acupuncture, have been advocated to manage this painful condition, but the therapeutic benefits have been inconsistent.[1,4,5,15-22] Nevertheless, most practitioners agree that some type of corrective shoeing is the basis for treatment and other treatment options should be used in conjunction.[1] Correction of any preexisting hoof abnormalities (eg, hoof imbalance) is the first goal. Several shoeing techniques have been employed in an attempt to improve lameness of horses with navicular syndrome. The most common of these involves raising the hoof angle via elevation of the heel. Heel elevation decreases the tension of the deep digital flexor tendon, resulting in a decrease of the compressive force exerted on the navicular bone.[23,24] Also, extension of the shoe outside the hoof wall at the quarters and heel and beyond the caudal extent of the heel provides additional heel support and decreases biomechanical forces on the navicular region.[25]

Received April 12, 2004.
Accepted October 19, 2004.
From the Department of Veterinary Clinical Sciences, College of Veterinary Medicine, Oklahoma State University, Stillwater, OK 74078. Dr. Schoonover's present address is Interstate Equine Services, 2536 S Ladd Ave, Goldsby, OK 73093. Dr. Blaik's present address is the Department of Small Animal Clinical Sciences, College of Veterinary Medicine, University of Florida, Gainesville, FL 32610-0126.
The authors thank Dr. Mark Payton for statistical guidance.
Address correspondence to Dr. Schoonover.

Medical management of horses with navicular syndrome most commonly includes administration of **nonsteroidal anti-inflammatory derivatives (NSAIDs)**.[1,26,27] In clinical practice, phenylbutazone is the NSAID that is most widely used to provide musculoskeletal analgesia. For horses with navicular syndrome, phenylbutazone may only be necessary to break the pain cycle while the horses adapt to corrective shoeing. However, some horses may require additional administration of phenylbutazone intermittently (often in association with performance or athletic events), and severely lame horses may need continuous treatment to maintain normal daily function.

Intrasynovial injection of corticosteroids has been widely used to treat lameness in horses. Corticosteroids reduce the volume and increase the viscosity of synovial fluid and stabilize chondroblasts.[28] Although the **distal interphalangeal joint (DIPJ)** and the podotrochlear (navicular) bursa in horses have no direct communication,[29] injection of corticosteroids into either of these synovial structures has been advocated to manage navicular syndrome.[20] Substances injected into the DIPJ have been detected in the fluid and synovium of the navicular bursa and in the medullary cavity of the navicular bone[30,31]; moreover, the administration of local anesthetic solution into the navicular bursa can alleviate lameness originating from the DIPJ within 20 minutes.[32] Results of in vivo studies[33,34] in horses have indicated that intrasynovial administration of the corticosteroid triamcinolone acetonide decreases lameness and improves synovial membrane and articular cartilage variables in treated joints, compared with findings after administration of placebo.

The purpose of the study reported here was to quantitatively compare 3 commonly used treatments for navicular syndrome in horses: heel-elevation shoeing alone, heel-elevation shoeing and phenylbutazone administration, heel-elevation shoeing and injection of triamcinolone acetonide in the DIPJ, and all 3 treatments in combination. From clinical experience, our hypothesis was that the method of heel-elevation shoeing used in this study would quantitatively decrease lameness (determined as an increase in mean **percentage body weight of force [%BWF]** from baseline values) of the forelimbs of horses with navicular syndrome. We also hypothesized that, in combination with this shoeing technique, phenylbutazone administration or injection of triamcinolone acetonide into the DIPJ would further decrease lameness (determined as a further increase in mean %BWF from baseline values) of the forelimbs of horses with navicular syndrome.

Materials and Methods

Inclusion criteria—Horses evaluated at the Oklahoma State University Boren Veterinary Medical Teaching Hospital for forelimb lameness displaying clinical and radiographic evidence of navicular syndrome were considered for this study. Clinical evidence of navicular syndrome was defined as signs of forelimb heel-area pain elicited bilaterally by use of hoof testers, accompanied by bilateral forelimb lameness that improved following palmar digital perineural anesthesia of the limbs. Initial lameness was evaluated subjectively by use of the 5-point scale devised by the American Association of Equine Practitioners.[35] Standard navicular radiographic views (ie, lateromedial, 60° dorsoproximal-palmarodistal oblique, and 45° palmaroproximal-palmarodistal oblique views) of both forelimbs were obtained, and each navicular bone was scored by one of the authors (MAB) on a scale[36] of 0 to 4. Any horse assigned a combined score of ≥ 2 was considered to have radiographic evidence of navicular syndrome. Because of their dispositions or behaviors, certain horses were considered unsuitable for shoeing or force plate data collection; those horses were excluded from the study. Participation in the research trial was requested from the owner of each horse that met the aforementioned selection criteria, and a signed client consent form was obtained from the owners who agreed. The study was approved by the Oklahoma State University Institutional Animal Care and Use Committee.

Animals—Twelve horses (8 geldings and 4 mares) were included in the study; the mean ± SD age of the horses was 10 ± 3.9 years. According to the owners, the duration of lameness ranged from 1 month to 2 years.

Quantitative assessment of force—The peak vertical ground reaction force generated by the forelimbs was measured by trotting each horse across a floor-mounted piezoelectric force plate[a] at 2.50 to 2.90 m/s. This velocity was measured by use of a millisecond timer and 2 photoelectric switches[b] set 3 m apart. The peak vertical ground reaction force was measured initially in Newtons, converted to kilograms of force, and finally normalized to body weight (%BWF) by use of computer software.[c] The %BWF values were then used for comparisons among treatments. Six valid strikes to the force plate were averaged to obtain the mean %BWF generated by each forelimb at each data collection session.

Experimental design—Data for each forelimb were collected at 6 different sessions. At the first session, the baseline mean %BWF was obtained prior to any treatment. At this data collection session, the forelimb that generated the lower %BWF was designated as the **lame forelimb (LFL)** and the forelimb that generated the higher %BWF was designated as the **contralateral forelimb (CFL)** for the duration of the study. All 4 hooves of each horse were then trimmed and balanced. Wide web aluminum horseshoes (3° wedge)[d] were applied to the fore feet and steel flat horseshoes[e] were applied to the hind feet with nails by one of the authors (HWJ). Measurements have revealed that the aluminum shoes are 57% lighter and have a 27% increase in surface area, compared with comparable flat steel shoes.[e] Special emphasis was placed on the heel area, and so the bar of the shoe extended 3 to 4 mm abaxial to the hoof wall caudal to the last nail and 10 to 12 mm beyond the caudal-most extent of the heel.

The second data collection session occurred 24 hours after shoeing to evaluate the immediate response to heel elevation. An adaptation period of 2 weeks was chosen to evaluate the effects of heel-elevation shoeing alone; consequently, mean %BWF was determined at the third data collection session 14 days after shoeing. Subsequent to this data collection, phenylbutazone (4.4 mg/kg, IV, q 12 h) was administered (5 treatments); this is considered the maximum short-term dose of phenylbutazone.[37] Two hours after the last phenylbutazone treatment, the mean %BWF was determined at the fourth session to evaluate the combined effect of heel-elevation shoeing and phenylbutazone administration. Immediately after the fourth data collection session, the DIPJ of the LFL was injected with 6 mg of triamcinolone acetonide. After a period of 2 weeks, the mean %BWF was determined at the fifth session to evaluate the combined effect of heel-elevation shoeing and injection of the DIPJ with triamcinolone acetonide.

Although intra-articular injection of corticosteroids into the DIPJ is routinely performed bilaterally, only the DIPJ of the LFL was injected in this study. Because an interval of 2 weeks elapsed after injection of the DIPJ with triamcinolone acetonide, any significant change in %BWF at this time could have been attributed to the additional period of adaptation to shoeing rather than to treatment with triamcinolone acetonide. Therefore, only 1 DIPJ was injected to determine which treatment was responsible for any detected change in %BWF. After the fifth data collection session, phenylbutazone (4.4 mg/kg, IV, q 12 h) was again administered for 5 treatments; 2 hours after the last NSAID injection, mean %BWF was determined at the sixth and final data collection session to evaluate the effect of all 3 treatments in combination. In the experience of our group, results of force plate analyses have indicated that the mean %BWF generated by the forelimbs of horses with navicular syndrome does not change day-to-day or week-to-week over a 3-week period. Therefore, the degree of quantitative lameness of horses with navicular syndrome was not expected to change during this study.

Data analyses—Because navicular syndrome is a bilateral condition, data for each forelimb were collected and analyzed separately for improvement in the respective limb. Data collected 24 hours and 14 days after heel-elevation shoeing were compared with baseline data to detect significant changes in mean %BWF. All other data were compared with data collected 14 days after heel-elevation shoeing. Statistical analyses were performed by use of computer software[f]; a repeated-measures ANOVA technique was applied separately for each forelimb on the sample population (group) and individual horse levels. Effects of treatment were analyzed by use of a least-squares means statement. Values of $P \leq 0.05$ were considered significant.

Results

Population results—Baseline and treatment mean %BWF values of the sample population were compared (**Figure 1**). Twenty-four hours after the application of heel-elevation shoes, mean %BWF for either forelimb did not change significantly from baseline values. However, after a 14-day adaptation period, heel-elevation shoeing resulted in significantly increased mean %BWF for both forelimbs, compared with baseline values. The additional administration of phenylbutazone to horses fitted with heel-elevation shoes significantly ($P < 0.001$) increased the mean %BWF of the LFL, compared with values obtained 14 days after heel-elevation shoeing. An increase in the mean %BWF was also detected in the CFL, although this value was not significantly ($P < 0.25$) different from that determined 14 days after heel-elevation shoeing alone. When compared with data collected 14 days after shoeing alone, the additional administration of triamcinolone acetonide in the DIPJ of the LFL failed to result in significant improvement in the mean %BWF of either limb ($P = 0.29$ for LFL and 0.88 for CFL data). When compared with data obtained 14 days after shoeing, application of all 3 treatments in combination provided a significant ($P < 0.001$) increase in mean %BWF of the LFL; the mean %BWF value of the CFL also increased but not significantly ($P \leq 0.48$). For both limbs, the values of mean %BWF achieved after application of all 3 treatments were similar to those achieved through shoeing and administration of phenylbutazone.

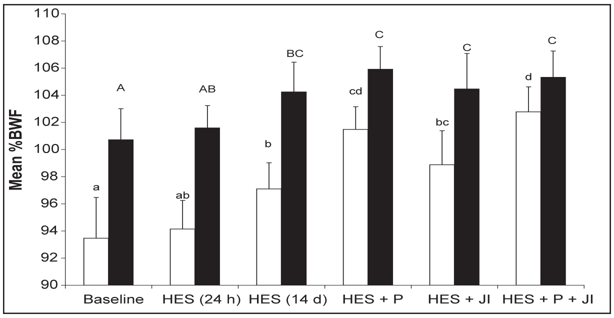

Figure 1—Mean force (+ SEM) expressed as mean percentage of body weight (%BWF) generated by the forelimbs of 12 horses with navicular syndrome prior to (baseline) and after heel-elevation shoeing (HES) alone (24 hours and 14 days after application), HES and treatment with phenylbutazone (HES + P), HES and injection of triamcinolone acetonide in the distal interphalangeal joint (HES + JI), and all 3 treatments in combination (HES + P + JI). By use of baseline force plate data, the forelimb that generated the lower %BWF was designated as the lame forelimb (white bars) and the forelimb that generated the higher %BWF was designated as the contralateral forelimb (black bars) for the duration of the study. a-d,A-C—Values with the same letter designation (upper- or lowercase) are not significantly ($P > 0.05$) different.

Individual results—Twenty-four hours after the application of heel-elevation shoes, there were significant increases in the mean %BWF value of the LFL of 3 horses, compared with baseline values, whereas 3 other horses had significant increases in the mean %BWF value of the CFL. For each limb, mean %BWF values either were not increased or had decreased 24 hours after application of the therapeutic shoes in 9 horses. After a 14-day adaptation period, heel-elevation shoeing significantly increased mean %BWF of the LFL from the baseline value in 9 of the 12 horses; mean %BWF of the CFL was significantly increased from the baseline value in 6 horses. Compared with effect of shoeing alone, the additional administration of phenylbutazone further increased the mean %BWF value of the LFL in 8 of the 12 horses and increased the mean %BWF value of the CFL in 5 horses. In horses fitted with heel-elevation shoes, the injection of triamcinolone acetonide into the DIPJ of the LFL significantly increased the mean %BWF of the LFL in 6 horses and increased the mean %BWF of the CFL in 3 horses, compared with the values achieved 14 days after shoeing alone. Compared with data collected 14 days after shoeing, all 3 treatments in combination resulted in a significant increase in mean %BWF of the LFL in 9 horses and an increase in mean %BWF of the CFL in 2 horses.

Discussion

Inappropriate or inadequate foot care is a common finding in horses with navicular syndrome. Long toes, underrun heels, and hoof imbalance can put excess strain on the navicular apparatus. Shoes that are too small or that do not extend to or beyond the caudalmost extent of the heel do not provide appropriate support.[6] In the present study, the shoes were fitted in a manner that ensured maximum support to the heel. The wide web of these shoes provides additional surface area and decreases the force per unit area of ground contact; furthermore, the aluminum shoes are lightweight, which decreases inertial kinetic forces on the distal portion of the limb. Although the %BWF value increased from baseline in only 3 of the 12 horses at 24 hours after therapeutic shoeing, most horses in our study had significant increases in %BWF of their forelimbs after the 14-day adaptation period, which indicates improvement in lameness with time. This supports the suggestion that an adaptation period after therapeutic shoeing is necessary to achieve relief from the inciting painful stimuli in horses.

Results of the present study indicate that horses with navicular syndrome may significantly increase the mean %BWF generated by their forelimbs 14 days after being shod in the described manner. The data support the biomechanical theory of navicular syndrome pathogenesis, and heel elevation decreases pain in the foot by reducing the pressure applied on the navicular bone. In our study, mean %BWF did not change or significantly decreased in some of the horses as a result of application of this shoeing technique. This finding is consistent with responses to other therapeutic shoeing methods, but a longer adaptation period may be necessary to fully recognize the benefit of this heel-elevation shoeing technique.[1,15,16] Other therapeutic shoeing techniques for treatment of navicular syndrome that do not use the heel-elevation principle (eg, application of egg-bar shoes or natural balance shoes) may have benefited these horses; however, horses shod with flat shoes have an increased maximal force exerted on the navicular bone by the deep digital flexor tendon, compared with unshod horses.[23,24]

The addition of phenylbutazone administration to the described method of shoeing further improved the mean %BWF of 8 horses. The musculoskeletal analgesic properties of NSAIDs are well documented. At the dosage of phenylbutazone (4.4 mg/kg, q 12 h) used in the present study, a typical 500-kg horse would receive approximately 2 g of phenylbutazone at each treatment. This dosage was chosen to provide maximum anti-inflammatory response in a short period, similar to the administration of phenylbutazone in association with athletic performance. However, in 1 report,[38] it is suggested that a lower dosage (4.4 mg/kg, q 24 h) may be as effective and reduce the potential for development of toxic side effects.

Although the quantitative lameness data obtained from the 12 horses in our study indicated no significant difference in mean %BWF 14 days after injection of the DIPJ with triamcinolone acetonide, compared with data obtained 14 days after shoeing alone, there was an increase in %BWF of the LFL in 6 horses. However, the other 6 horses either had no change or a decrease in %BWF of the LFL at 14 days after that treatment, compared with data obtained 14 days after shoeing. One report[20] advocates injection of corticosteroids in combination with hyaluronate directly into the navicular bursa of horses that are refractory to other treatments. Administration of hyaluronate in combination with corticosteroids has been shown to be more beneficial for the treatment of joint disease than administration of corticosteroids alone,[28] and such treatment may have further benefited the horses in the present study.

Therapeutic shoeing in some fashion is considered by many practitioners to be the basis of treatment of navicular syndrome in horses. The present study was conducted in such a way that all treatment modalities included and therefore were dependent on therapeutic shoeing. Changing the sequence with which the different treatments were applied might have provided different results. For instance, either the administration of phenylbutazone or injection of the DIPJ with triamcinolone acetonide (or the combination of these 2 treatments) without the application of therapeutic shoeing might have resulted in a quantitative change in mean %BWF of the horses. In addition, combinations of other therapeutic shoeing methods and other medical and surgical treatments may quantitatively alter the degree of lameness of horses with navicular syndrome.

The results of the present study indicate that application of the described method of 3° heel-elevation shoeing alone and in combination with IV administration of phenylbutazone may quantitatively decrease lameness in horses with navicular syndrome. Although the mean %BWF after injection of the DIPJ with triamcinolone acetonide was not significantly different from the value after shoeing alone in the horses of the present study, administration of that treatment in conjunction with 3° heel-elevation shoeing may offer further quantitative improvement in lameness in individual horses with navicular syndrome. However, some horses may be refractory to these treatment methods and require other interventions such as alternate therapeutic shoeing techniques or injection of the navicular bursa with corticosteroids or hyaluronate to quantitatively decrease lameness associated with navicular syndrome.

---

a. Piezoelectric biomechanics force plate system (type 9287920311), Kistler, Amherst, NY.
b. Infrared photoelectric sensor, model #49-551A, Radioshack Corp, Fort Worth, Tex.
c. Bioware software, version 3.22, type 2812A1-3, Kistler, Amherst, NY.
d. Elite competition shoe—3° wedge, Victory Racing Plate Co, Baltimore, Md.
e. St Croix Lite, St Croix Forage, Forest Lake, Minn.
f. PC SAS, version 8.2, SAS Institute, Cary, NC.

References

1. Stashak T. Navicular syndrome (navicular disease). In: White NA, Moore JN, eds. *Current techniques in equine surgery and lameness*. 2nd ed. Philadelphia: WB Saunders Co, 1998;537–544.
2. Pool RR, Meagher DM, Stover SM. Pathophysiology of navicular syndrome. *Vet Clin North Am Equine Pract* 1989;5:109–129.
3. Dyson SJ. Navicular disease and other soft tissue causes of palmar foot pain. In: Ross MW, Dyson SJ, eds. *Diagnosis and management of lameness in the horse*. Philadelphia: WB Saunders Co, 2003;286–299.
4. Madison JB, Dyson SJ. Treatment and prognosis of horses with navicular disease. In: Ross MW, Dyson SJ, eds. *Diagnosis and management of lameness in the horse*. Philadelphia: WB Saunders Co, 2003;299–304.
5. Wright IM. A study of 118 cases of navicular disease: clinical features. *Equine Vet J* 1993;25:488–492.
6. Dabareiner RM, Carter GK. Diagnosis, treatment, and farriery for horses with chronic heel pain. *Vet Clin North Am Equine Pract* 2003;19:417–441.
7. Adams OR. Lameness—navicular disease. In: Adams OR. *Lameness in horses*. Philadelphia: Lea & Febiger, 1962;173–181.

8. Trout DR. Soft tissue- and bone-phase scintigraphy for diagnosis of navicular disease in horses. *J Am Vet Med Assoc* 1991;198:73–77.
9. Widmer WR, Buckwalter KA, Fessler JF, et al. Use of radiography, computed tomography and magnetic resonance imaging for evaluation of navicular syndrome in the horse. *Vet Radiol Ultrasound* 2000;41:108–116.
10. Merkens HW, Schamhardt HC. Evaluation of equine locomotion during different degrees of experimentally induced lameness. I: lameness model and quantification of ground reactive force patterns on the limbs. *Equine Vet J Suppl* 1988;6:99–106.
11. Merkens HW, Schamhardt HC. Evaluation of equine locomotion during different degrees of experimentally induced lameness. II: distribution of ground reactive force patterns of the concurrently loaded limbs. *Equine Vet J Suppl* 1988;6:107–112.
12. McLaughlin RM Jr, Gaughan EM, Roush JK, et al. Effects of subject velocity on ground reactive force measurements and stance times in clinically normal horses at the walk and trot. *Am J Vet Res* 1996;57:7–11.
13. Barr ARS, Dow SM, Goodship AE. Parameters of forelimb ground reaction force in 48 normal ponies. *Vet Rec* 1995;136:283–286.
14. Schamhardt HC, Merkens HW. Quantification of equine ground reaction force patterns. *J Biomech* 1987;20:443–446.
15. Ostblom LC, Lund C, Melsen F. Navicular bone disease: results of treatment using egg-bar shoeing technique. *Equine Vet J* 1984;16:203–206.
16. Turner TA. Shoeing principles for the management of navicular disease in horses. *J Am Vet Med Assoc* 1986;189:298–301.
17. Coffman JR, Johnson JH, Tritschler LG, et al. Orgotein in equine navicular disease: a double blind study. *J Am Vet Med Assoc* 1979;174:261–264.
18. Turner AS, Tucker CM. The evaluation of isoxsuprine hydrochloride for the treatment of navicular disease: a double blind study. *Equine Vet J* 1989;21:338–341.
19. Denoix JM, Thibaud D, Riccio B. Tiludronate as a new therapeutic agent in the treatment of navicular disease: a double-blind placebo-controlled clinical trial. *Equine Vet J* 2003;35:407–413.
20. Dabareiner RM, Carter GK, Honnas CM. Injection of corticosteroids, hyaluronate, and amikacin into the navicular bursa in horses with signs of navicular area pain unresponsive to other treatments: 25 cases (1999–2002). *J Am Vet Med Assoc* 2003;223:1469–1474.
21. Wright IM. A study of 118 cases of navicular disease: treatment by navicular suspensory desmotomy. *Equine Vet J* 1993;25:501–509.
22. Jackman BJ, Baxter GM, Doran RE, et al. Palmar digital neurectomy in horses: 57 cases (1984–1990). *Vet Surg* 1993;22:285–288.
23. Willemen MA, Savelberg HH, Barneveld A. The effect of orthopaedic shoeing on the force exerted by the deep digital flexor tendon on the navicular bone in horses. *Equine Vet J* 1999;31:25–30.
24. Wilson AM, McGuigan MP, Pardoe C. The biomechanical effects of wedged, eggbar and extension shoes in sound and lame horses. *Proc Am Assoc Equine Pract* 2001;47:339–343.
25. Turner TA. Diagnosis and treatment of navicular disease in horses. *Vet Clin North Am Equine Pract* 1989;5:131–143.
26. Turner TA. "Navicular disease" (navicular syndrome). In: Colahan PT, Mayhew IG, Merritt AM, et al, eds. *Equine medicine and surgery*. 5th ed. St Louis: Mosby Year Book Inc, 1999;1513–1520.
27. McIlwraith CW, Frisbie DD, Kawcak CE. Nonsteroidal anti-inflammatory drugs. *Proc Am Assoc Equine Pract* 2001;47:182–187.
28. Owen RR. Intra-articular corticosteroid therapy in the horse. *J Am Vet Med Assoc* 1980;177:710–713.
29. Jann H, Henry G, Berry A, et al. Arthrographic observations of the equine distal interphalangeal joint (Articulationes interphalangeae distalis manus) and navicular bursa (Bursa podotrochlearis). *Anat Histol Embryol* 1991;20:30–36.
30. Schumacher J, Schumacher J, Gillette R, et al. The effects of local anaesthetic solution in the navicular bursa of horses with lameness caused by distal interphalangeal joint pain. *Equine Vet J* 2003;35:502–505.
31. Keegan KG, Wilson DA, Kreeger JM, et al. Local distribution of mepivacaine after distal interphalangeal joint injection in horses. *Am J Vet Res* 1996;57:422–426.
32. Bowker RM, Rockershouser SJ, Vex KB, et al. Immunocytochemical and dye distribution studies of nerves potentially desensitized by injections into the distal interphalangeal joint or the navicular bursa of horses. *J Am Vet Med Assoc* 1993; 203:1708–1714.
33. Kawcak CE, Norrdin RW, Frisbie DD, et al. Effects of osteochondral fragmentation and intra-articular triamcinolone acetonide treatment on subchondral bone in the equine carpus. *Equine Vet J* 1998;30:66–71.
34. Frisbie DD, Kawcak CE, Trotter GW, et al. Effects of triamcinolone acetonide on an in vivo equine osteochondral fragment exercise model. *Equine Vet J* 1997;29:349–359.
35. AAEP lameness scale: American Association of Equine Practitioners. Definition and classification of lameness. In: *Guide for veterinary service and judging of equestrian events*. 4th ed. Lexington, Ky: American Association of Equine Practitioners, 1991;19.
36. Dik KJ, van den Broek J. Role of navicular bone shape in the pathogenesis of navicular disease: a radiographic study. *Equine Vet J* 1995;27:390–393.
37. Plumb DC. *Veterinary drug handbook*. 2nd ed. Pocket edition. Ames, Iowa: Iowa State University Press, 1995;542–544.
38. Hu HH, MacAllister CG, Payton ME, et al. Evaluation of the analgesic effects of phenylbutazone administered at a high or low dosage in horses with chronic lameness. *J Am Vet Med Assoc* 2005;226:414–417.