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Winter 2024

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ABOUT THE COVER: "Justify" oil on canvas, Scott Kish
https://kishlimitededitions.com/equestrian/

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PRESIDENT'S MESSAGE

together for the horse

Welcome

DEAR MEMBERS,

We truly hope that you had a wonderful holiday season, and cheers to you and yours for a healthy and safe 2024! All of us on the board and working behind the scenes for the National Alliance of Equine Practitioners are quite excited for this coming year and the events we are planning.

The regional wet labs are back due to popular demand! We will be holding one wet lab a month from February through May. The 'Road to Saratoga' course will commence in the Scottsdale, Arizona region in February, then head North to Plymouth, California in March before heading across the country to western Pennsylvania in April and finalizing in the Spring in Canada for May.

The emphasis of each of these wet labs is to bring together farriers, veterinarians and students of these professions to learn in a small setting for an immersive all-day experience with some of the best practitioners in the country. Discussions amongst the clinicians and attendees are always a wonderful part of this experience. I've had the pleasure of seeing new relationships form between practitioners that had not worked together previously, students and seasoned professionals learning a new skill or technique on a live horse that they had always wanted to know, and how the collaboration of learning in a hands-on way brings everyone together. These informal and intellectual meetings truly bring out the best in everyone, and I hope to see you at one of these in 2024!

As a respected member of the NAEP we strive to bring you the very best value that we can in education and wet lab experiences. We realize and understand how busy everyone is, so we are also working on our website currently to make it more user friendly in all aspects. Registration for the Saratoga Equine Practitioners Conference 2024 should be even easier, and we look forward to seeing what you think of the new layout of the website.

It's very important to listen to what our membership and educational sponsors have to say, as it contributes toward the course of the NAEP for the future. I look forward to sharing some of these changes that we are implementing for the 2024 Saratoga Equine Practitioners Conference in our next Horse, Vet & Farrier magazine in the Spring.

Please enjoy this exceptional layout of articles covering a diverse series of topics for this Winter. One of our board members, Dr. Matt Durham, has contributed his knowledge and expertise with others, towards the survey on equine back pain in the horse. We also build upon one of our regional wet lab topics from 2023 on how various ground surfaces and horseshoes affect the hoof of the horse at the walk by Patrick Reilly et al. Thank you to all of our contributing authors, and the exceptional work that you share with our membership.

Together For the Horse.

Sasha Hill, DVM

NAEP President

Survey of equine veterinarians regarding **primary equine back pain** in the United States

By Marianne E. Marshall-Gibson[1*], Matthew G. Durham[2], Kathryn A. Seabaugh[3,4], Valerie J. Moorman[5] and Dora J. Ferris[6]

BACK PAIN IS A COMMON COMPLAINT, clinical finding and performance limiting factor in sport horses. This study sought to gather current veterinary trends in the diagnosis, treatment and management of primary equine back pain in the United States. A 22 question survey was distributed electronically to equine practitioners through AAEP and ACVSMR listservs and through closed social media groups. The survey was open from April 20, 2022 to July 5, 2022. Responses were analyzed using Microsoft excel pivot tables. Ninety-seven survey responses were obtained and analyzed. Respondents reported the clinical signs most frequently relayed to them by the owner/rider/trainer of horses diagnosed with primary back pain were behavioral issues and poor performance. Most common diagnostic tests reported were radiography of the spinous processes, thoraco-lumbar vertebral bodies, and transcutaneous ultrasound of the thoraco-lumbar region. Most common pathologies reported were impinging dorsal spinous processes, degenerative sacro-iliac joint disease, and osteoarthritis in lumbar or thoracic articular process joints. In regards to impinging spinous process ("kissing spine") treatments, 72.2% of respondents recommended surgery only after non-surgical treatments failed, and 14.6% of respondents never recommended surgery. The majority (82%) of respondents reported some level of improvement in clinical signs of primary back pain with rehabilitation alone.

To date, there has been no consensus or discussion about common abnormalities, diagnostic tests, treatments or management options for primary equine back pain in the United States. Results of this survey are a starting point showing current trends in diagnosis, treatment and management of primary equine back pain among equine practitioners in the United States showing 82% of practitioners using rehabilitation as a component of treatment.

INTRODUCTION

Back pain is a common complaint and clinical finding in poorly performing equine athletes, with an estimate of up to 94% of ridden horses experiencing back pain (1). It is typically characterized as either primary (directly related to insults or pathology in the thoraco-lumbo- sacral regions) or secondary (related to compensation for non-primary back injuries or pathologies) back pain (2–4). The etiology of primary back pain can be quite complex, originating from bone, joint, ligament, tendon and muscle injury, or a combination of these (3–5). With increasing availability and affordability of mobile imaging equipment, along with growing continuing education training, equine practitioners have been more readily able to diagnose primary causes of equine back pain. A more accurate diagnosis has led to advances in treatment options as well

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as the widespread incorporation of rehabilitation into the management of affected horses (3–7).

The most reported and commonly diagnosed etiology of primary back pain in horses is impinging spinous processes (ISP) or "kissing spine." The treatment and management of horses with ISP can range from conservative management to more invasive surgical techniques. While the studies describing the surgical treatment of ISPs show favorable results with between 72 and 91% of horses undergoing surgery returning to some level of performance (8–14), there is a surprising lack of literature, systematic reviews or randomized clinical trials, evaluating efficacy of alternative treatment and management options for ISP.

Despite being a common topic discussed among performance horse veterinarians, there is still a general lack of randomized clinical studies and general consensus on best approaches to diagnose, treat, and manage primary equine back pain. This lack of evidence could lead veterinarians toward treatments and management bias based on practitioner preference and possibly geographical location (2).

The study sought to gather current veterinary trends in the diagnosis, treatment and management of primary equine back pain and ISPs in the United States.

MATERIALS AND METHODS

A survey consisting of 22 questions (see Supplementary material) was distributed electronically using Google Forms1 to equine practitioners through the American Association of Equine Practitioners (AAEP) and American College of Veterinary Sports Medicine and Rehabilitation (ACVSMR) listservs and through closed veterinary social media groups: Equine Vet-2-Vet, Equine Lameness Vets, and Women in Equine Practice. Due to the American College of Veterinary Surgeons (ACVS) diplomate contact policy, mass distribution of the survey to this demographic was not able to be performed. Based on the number of equine veterinarians in each group, it is estimated that approximately 3,500 equine veterinarians received access to the questionnaire. The survey was open from April 20, 2022 to July 5, 2022. Responses were analyzed using Microsoft Excel pivot tables. Only fully completed questionnaires were included in the results and each response required a unique identifier to eliminate duplicate responses.

RESULTS

DEMOGRAPHICS

A total of 97 complete survey responses were obtained and analyzed. The regions of the United States represented are shown in Table 1. Primary practice or general practitioners comprised 58% of the respondents while 30% practiced at specialty/s opinion practices or University Teaching Hospitals. Ninety-two percent of respondents represented practices with a predominantly equine (>76% of patients) caseload. The top three breeds reported to be seen by respondents were Warmbloods (90%), Thoroughbreds (88%), and Quarter Horses (84%). Other breeds had minimal representation (<10% each). The disciplines of horses serviced by the respondents based on percentage is shown in Table 2. This table shows a wide variety of disciplines being served by respondents to the current survey, with a slightly higher representation of hunter/jumper and dressage horses.

TABLE 1 Regions of the United States where practitioners predominantly practice.

REGION OF UNITED STATES RESPONDENTS PREDOMINANTLY PRACTICE	# RESPONDENTS
Midwest (OH, IN, IL, WI, MI, MO, IA, MN, KS, NE, SD, ND)	13
Mountain West (MT, WY, ID, CO, UT, NV)	20
Northeast (PA, NY, NJ, CT, MA, RI, VE, NH, ME, DC, DE, MD)	13
Pacific Coast (WA, OR, CA)	11
Southeast (WV, VA, NC, SC, KY, TN, AR, LA, MS, AL, GA, FL)	31
Southwest (OK, TX, NM, AZ)	9
Total	**97**

CLINICAL SIGNS AND DIAGNOSIS OF PRIMARY BACK PAIN

Respondents were asked to characterize the signs of primary back pain in their practice. Forty-eight respondents reported

[1] https://www.google.com/forms/about/

TABLE 2 Percentage of disciplines represented in respondents' practices.

DISCIPLINE	0	<10%	10–25%	26–50%	51–75%	76–99%	100%	TOTAL
AQHA and similar competitions	14	50	21	6	5	1	0	97
Cutting/reining	23	54	16	1	3	0	0	97
Rodeo (team/tie-down/calf roping)	38	36	16	5	2	0	0	97
Working ranch	40	38	14	2	2	1	0	97
Barrel racing	18	40	29	6	3	1	0	97
Eventing	9	37	35	9	4	3	0	97
Endurance	52	40	4	1	0	0	0	97
Hunter/jumper	6	16	26	29	14	5	1	97
Dressage	5	24	39	21	6	2	0	97
Racetrack	60	23	7	3	2	2	0	97
Pleasure/trail	8	29	37	17	5	1	0	97
Polo	62	32	3	0	0	0	0	97
Driving	71	23	1	1	1	0	0	97
Other	78	13	5	0	1	0	0	97

TABLE 3 Frequency of clinical signs reported to respondents by the owner, rider or trainer of horses diagnosed with primary back pain.

COMPLAINT	ALWAYS (100%)	FREQUENTLY (51–99%)	SOMEWHAT FREQUENTLY (26–50%)	INFREQUENTLY (<25%)	NEVER	TOTAL
Bruxism	0	1	16	56	24	97
Tail swishing/altered tail carriage	2	29	39	22	5	97
Aggressive behavior	0	6	28	50	13	97
Bunny hopping gait behind	1	25	42	22	7	97
Difficult transitions	3	35	40	17	2	97
Focal heat	0	1	9	55	32	97
Hindlimb lameness	3	28	33	28	5	97
Forelimb lameness	0	5	20	55	17	97
Difficulty sliding/stopping	2	11	17	38	29	97
Change in jumping style	3	22	32	32	8	97
Kicking out	3	23	40	28	3	97
Unwilling to go forward under saddle	5	30	41	17	4	97
Difficulty when saddling	4	28	46	17	2	97
Difficulty holding canter leads	2	30	43	19	3	97
Difficulty bending	5	21	48	20	3	97
Loss of topline/muscle atrophy	4	23	41	28	1	97
Refusing jumps	1	17	34	38	7	97
Loss of impulsion	5	39	33	18	2	97
Missing lead changes	2	26	43	23	3	97
Girthy/cinchy	2	36	47	12	0	97
Other	1	3	6	14	73	97

between 10 and 25% of patients showing signs of primary back pain, twenty-four respondents reported low (<10%) numbers of patients, eleven respondents reported 26–50% of patients having primary back pain, and fourteen respondents reporting >50% of patients having primary back pain in their practice.

Clinical signs respondents recalled being reported to them by the owner, rider or trainer of horses diagnosed with primary back pain are summarized in Table 3. The most frequently reported clinical signs recalled being relayed to respondents by the owner/rider/trainer of horses diagnosed with primary back pain were behavioral issues and poor performance. Additional responses included sore to back palpation, unwillingness to stand still, or bucking/rearing. Respondents were then asked to evaluate various clinical tests for their perceived value when used to diagnose primary equine back pain. Respondents reported digital pressure over dorsal spinous processes and paraspinal muscles, dynamic mobility/back mobilization exam and ridden exam to have the highest clinical values when diagnosing primary equine back pain (Figure 1).

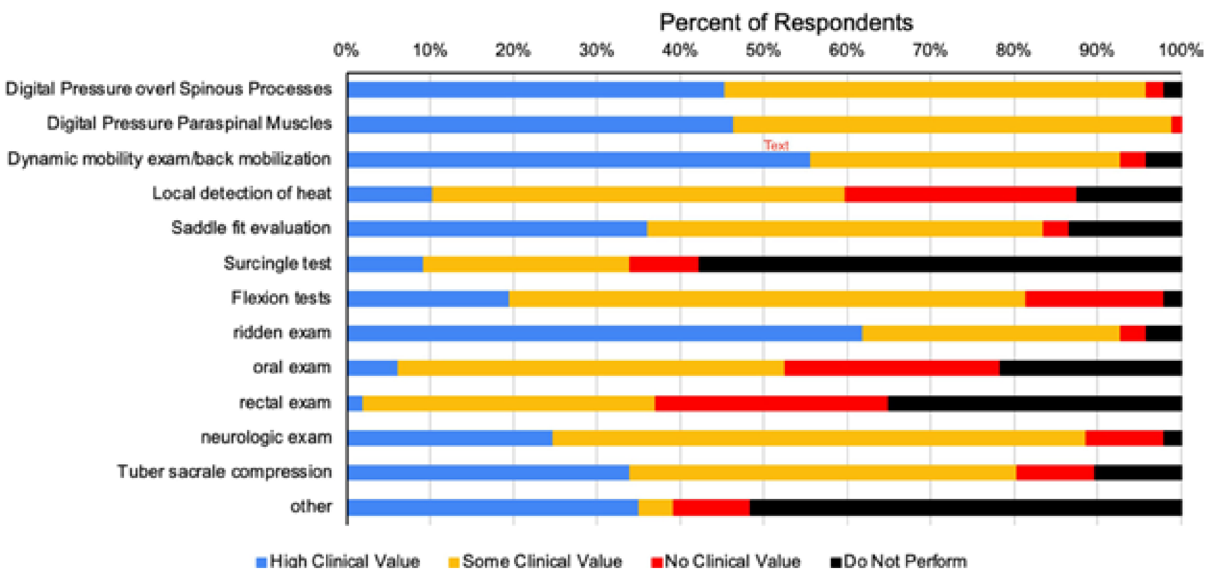

FIGURE 1

Perceived clinical value of various clinical tests performed by respondents to diagnose primary equine back pain.

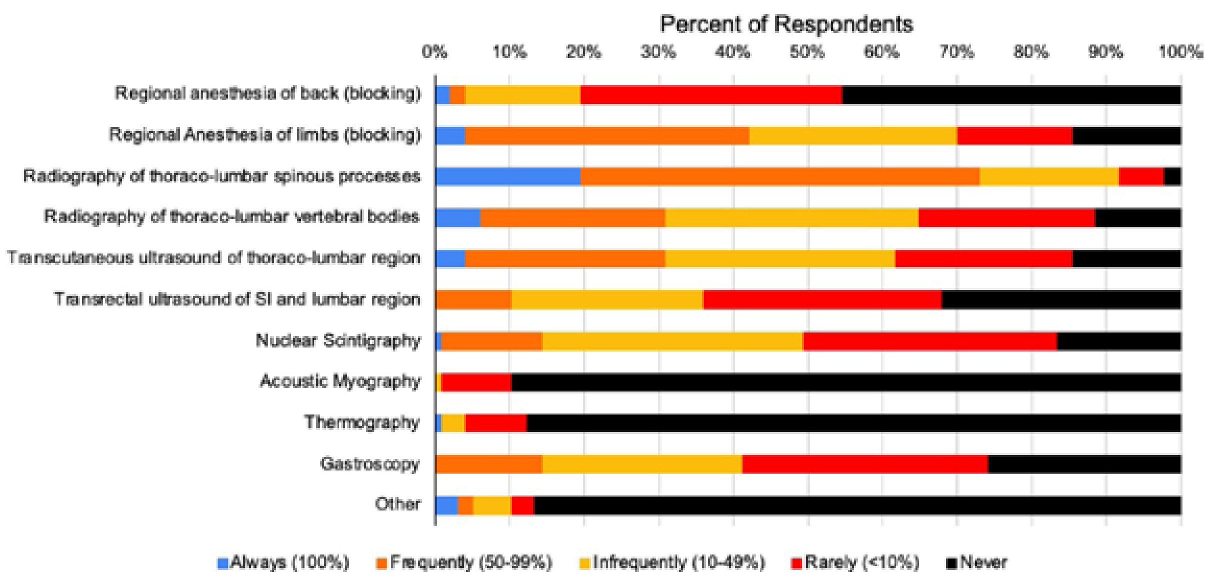

FIGURE 2

Frequency with which respondents use various modalities to diagnose primary equine back pain.

When asked what diagnostic tests respondents used to diagnose primary back pain, the most frequently utilized diagnostic tests were radiography of the spinous processes, thoraco-lumbar vertebral bodies, and transcutaneous ultrasound of the thoraco-lumbar region (Figure 2). Pathologies reported to be seen in patients associated with primary equine back pain are shown in Figure 3. Of the pathologies represented in the survey, 78 respondents reported impinging spinous processes in >10% of patients, 61 respondents reported degenerative sacro-iliac joint disease in >10% of patients, and 55 and 54 respondents primary equine back pain are shown in Figure 3. Of the pathologies represented in the survey, 78 respondents reported impinging spinous processes in >10% of patients, 61 respondents reported degenerative sacro-iliac joint disease in >10% of patients, and 55 and 54 respondents reported osteoarthritis in lumbar or thoracic articular process joints in >10% of patients, respectively.

TREATMENT AND MANAGEMENT OF PRIMARY EQUINE BACK PAIN

The survey asked questions pertaining to the treatment modalities used to manage primary equine back pain. Table 4 shows a summary of the therapies recommended for first line treatment of primary back pain. The most frequently recommended first line therapies included Rehabilitation (44% always recommended), Shockwave (46% frequently recommend), NSAIDs or Chiropractic (45% frequently recommend), and Acupuncture (44% frequently recommend). When asked about the efficacy of various treatment modalities in treating primary equine back pain, respondents reported rehabilitation (64%), shockwave (49%), and local intra- articular injections (43%) to be either always (100%) effective or effective 50–99% of the time (Table 5). The techniques commonly used for injection treatment of primary back pain are summarized in Figure 4. With regards to treating the Sacro-iliac region, image guided injections had a higher reported use (70%) versus non-image guided (12%) injections. Regional injections had similar response rates of 43 and 46% for image guided and non-image guided, respectively.

Respondents were asked which substances they used for local injection treatments of primary back pain (Figure 5). The most frequently reported was corticosteroids (84 responses) followed by Sarracenia purpurea (36 responses). Other responses included lidocaine/local anesthetic (3 responses), Adequan (2 responses), and vitamin B (2 responses).

Additionally, respondents were asked which modalities they recommend for rehabilitation of patients with primary back pain (Figure 6). The most frequently recommended therapies by respondents were Rehabilitation exercises (95%), Acupuncture (82%), Chiropractic (80%), and laser therapy (51%).

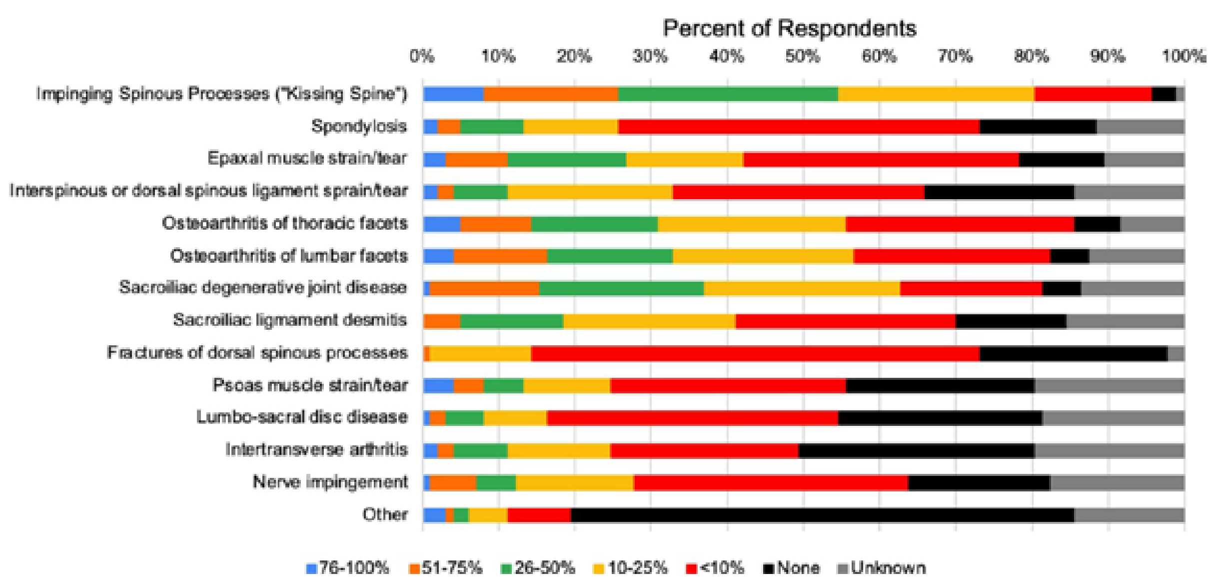

FIGURE 3

Pathologies reported with relative frequency in horses with primary equine back pain.

TABLE 4 Therapies recommended by respondents for first line treatment of primary back pain with relative frequency.

TREATMENT	ALWAYS (100%)	FREQUENTLY (50–99%)	INFREQUENTLY (10–49%)	RARELY (<10%)	NEVER	TOTAL
Local intramuscular injections	3	28	29	21	16	97
Local intra-articular injections	2	37	26	18	14	97
Mesotherapy	3	18	33	15	28	97
Prolotherapy	0	3	5	9	80	97
Shockwave therapy	10	45	18	11	13	97
Bisphosphonates	2	16	25	22	32	97
Non-steroidal anti-inflammatory drugs (NSAIDs) - oral or topical	12	44	22	13	6	97
Surgery (in the case of ISP/“kissing spine”)	2	12	19	40	24	97
Gabapentin	1	9	21	33	33	97
Methocarbamol	7	35	28	20	7	97
Chiropractic	12	44	23	11	7	97
Acupuncture	10	43	28	11	5	97
Laser therapy	4	23	15	30	25	97
Pulsed electro-magnetic field (PEMF)	0	13	20	21	43	97
Functional electrical simulation (FES)	2	4	7	21	63	97
Rehabilitation	43	26	17	9	2	97
Other	6	2	4	1	84	97

TABLE 5 Assessment of efficacy of various treatment modalities for primary equine back pain with relative effectiveness.

TREATMENT MODALITY	ALWAYS EFFECTIVE (100%)	EFFECTIVE (50–99%)	SOMEWHAT EFFECTIVE (10–49%)	INEFFECTIVE (<10%)	DO NOT PERFORM/ RECOMMEND	TOTAL
Local intramuscular injections	3	32	30	9	23	97
Local intra-articular injections	3	39	30	5	20	97
Mesotherapy	2	22	32	9	32	97
Prolotherapy	1	3	7	2	84	97
Shockwave therapy	6	42	25	8	16	97
Bisphosphonates	2	13	36	13	33	97
Non-steroidal anti-inflammatory drugs (NSAIDs) - oral or topical	2	25	51	14	5	97
Surgery (in the case of ISP/ “kissing spine”)	1	31	31	8	26	97
Gabapentin	0	11	23	22	41	97
Methocarbamol	1	23	41	22	10	97
Chiropractic	3	37	37	9	11	97
Acupuncture	4	36	41	7	9	97
Laser therapy	4	18	25	16	34	97
Pulsed electro-magnetic field (PEMF)	1	10	24	15	47	97
Functional electrical stimulation (FES)	2	6	11	7	71	97
Rehabilitation	20	42	24	7	4	97
Other	4	4	2	3	84	97

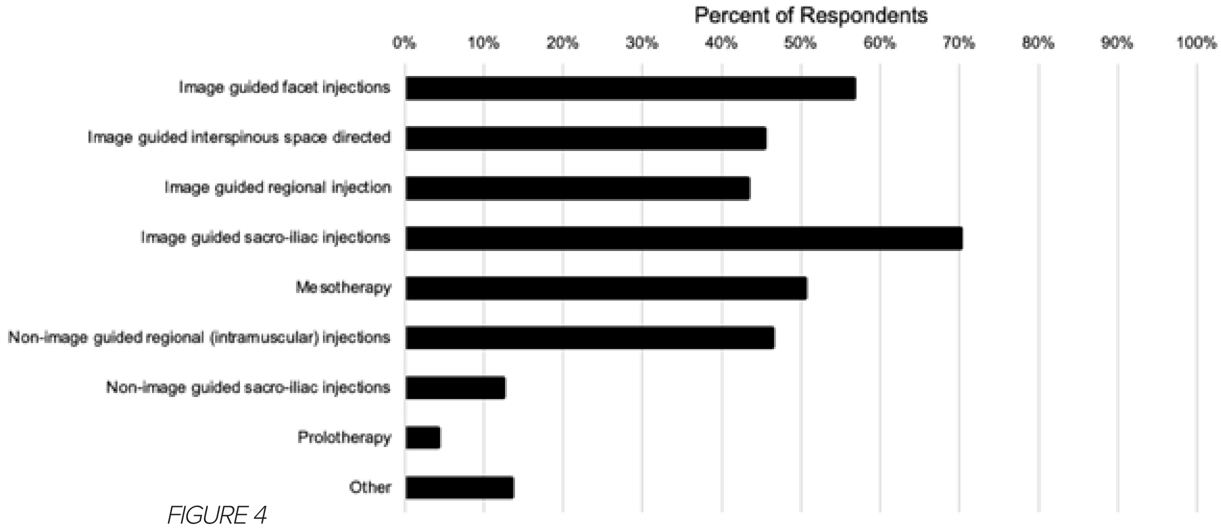

FIGURE 4

Injection techniques used by respondents for treatment of primary equine back pain.

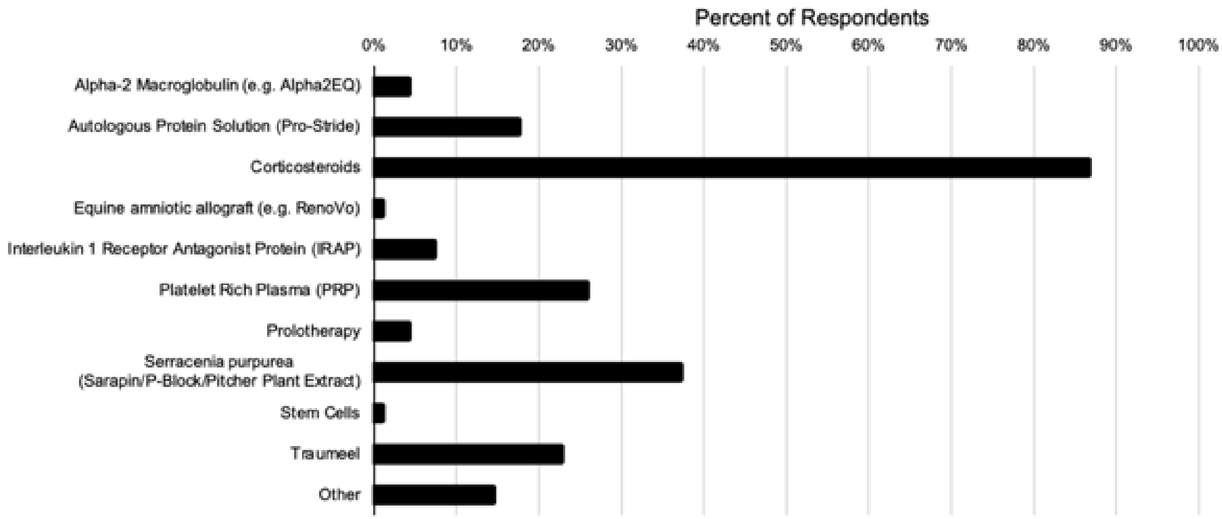

FIGURE 5

Substances used by respondents in primary back pain injection treatments.

TREATMENT AND MANAGEMENT OF IMPINGING SPINOUS PROCESSES

In regards to impinging spinous process ("kissing spine") treatments, 70% of respondents recommended surgery only after non-surgical treatments failed, and 14.6% of respondents never recommended surgery. When surgery was recommended, the majority of respondents (64.6%) left the type of surgical procedure performed for treatment of impinging spinous processes up to the surgeon, while some (16.7%) preferred interspinous ligament desmotomy. Of respondents that had followed horses after ISP surgery (59%), 34% said less than 50% of horses show improvement in presenting clinical signs immediately after surgery. Additionally, 22% of respondents felt 76–100% of horses that had undergone ISP surgery required follow up non-surgical treatments, while only 2% felt horses did not need follow up intervention (Figure 7).

The respondents were asked two questions regarding rehabilitation in the management of horses with ISP. In regards to timing of rehabilitation when horses were undergoing surgery, 49% of respondents said they recommended rehabilitation before surgery, 67% said they recommended rehabilitation after surgery, and 54% they recommended rehabilitation

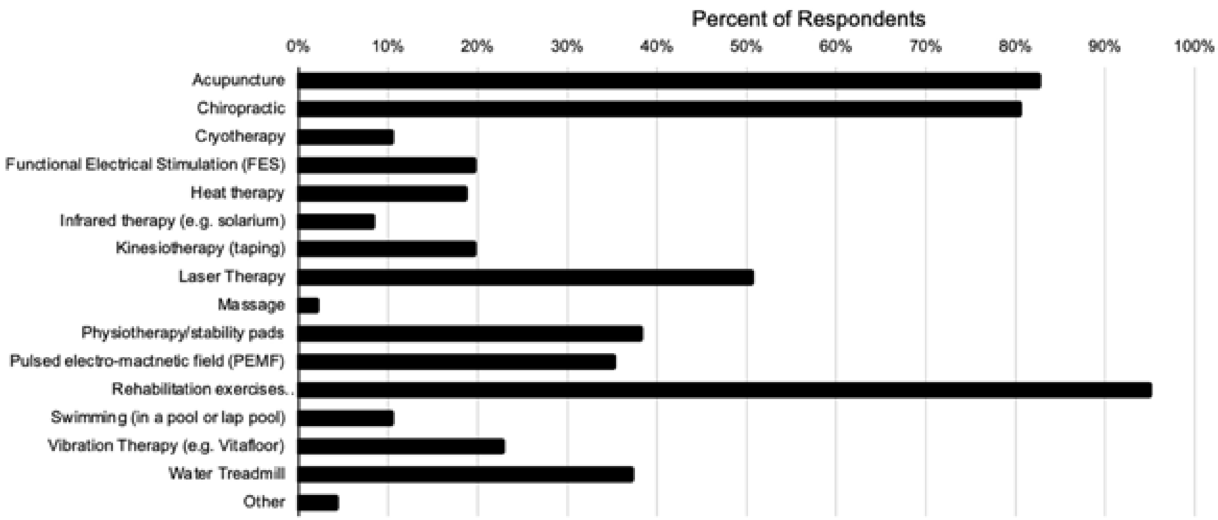

FIGURE 6

Recommended rehabilitation and management modalities by respondents for primary equine back pain.

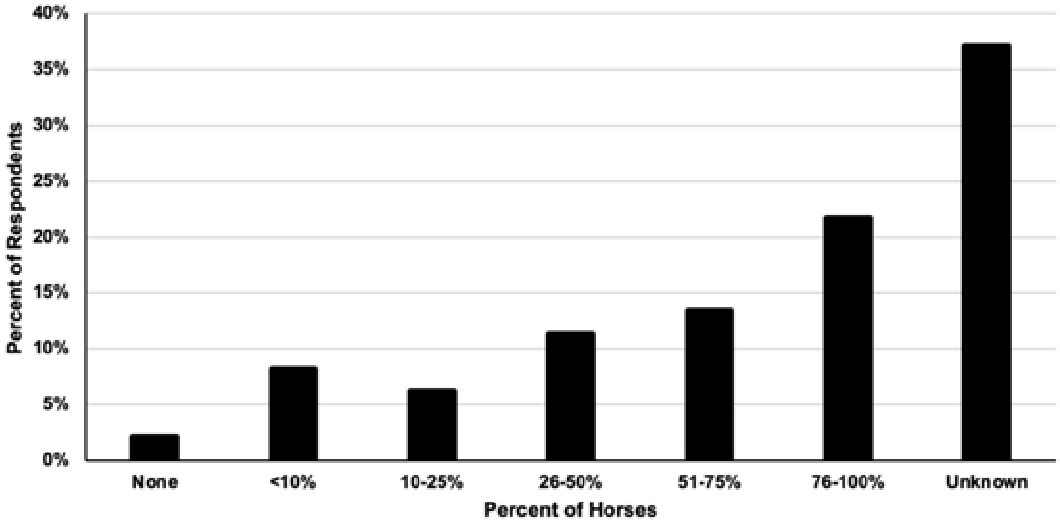

FIGURE 7

Percent of horses that require follow up non-surgical treatments after impinging spinous process surgery in respondents' practices.

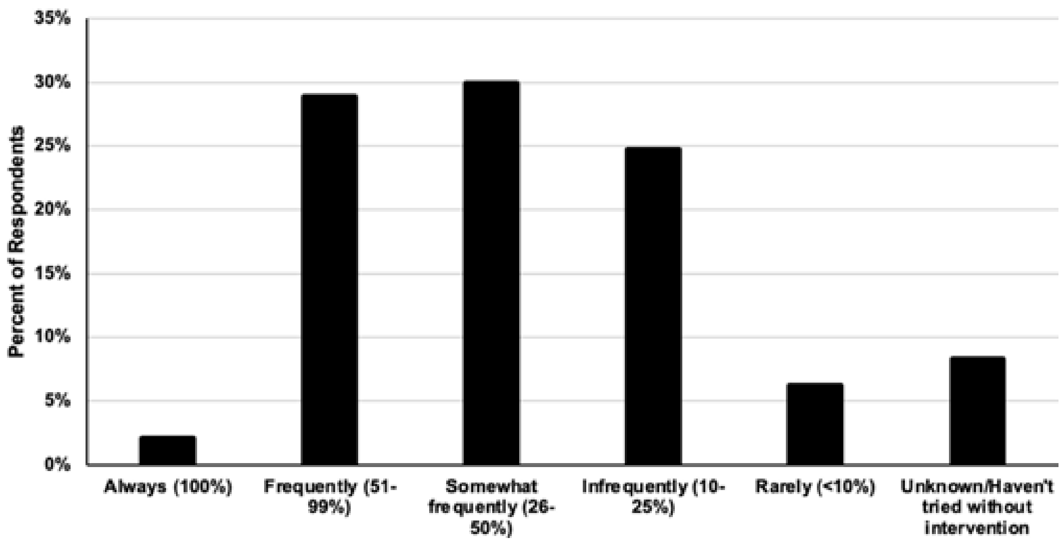

FIGURE 8

Relative frequency respondents see horses that show improvement in clinical signs related to impinging spinous processes with rehabilitation alone (i.e., without medical or surgical intervention).

before and after surgery (respondents were able to choose more than one option for this question). Furthermore, the majority (82%) of respondents reported some level of improvement in clinical signs of primary back pain with rehabilitation alone (Figure 8).

DISCUSSION

The diagnosis, treatment and management of equine back pain has evolved over the past decade with advancements in diagnostic imaging techniques, treatment and management options, and more focused incorporation of rehabilitation. The current survey is the first attempt known by the authors to gather information on current veterinary trends regarding primary equine back pain in the United States.

A limited number of responses were gathered; therefore, a true generalization of trends cannot be made. However, the geographic distribution of respondents is similar to the relative population of equine veterinarians across the United States, indicating a good sampling of current trends (15). A limitation of the survey was respondents represented a variety of equine veterinarians with different experience levels and practice types. In 2011 Haussler et al. reported back pain and associated problems were seen in anywhere from 0.9 to 94% of ridden horses (1). The large variance was expected to be due to veterinarian experience in recognizing and diagnosing primary back pain as well as the breeds being examined as previously demonstrated (5). Likewise, respondents of this survey were not asked about the percentage of performance horse work conducted in their respective practices, nor about their experience or advanced training in diagnosing and treating primary back pain. In addition, breeds represented in the study were mostly limited to Warmbloods, Thoroughbreds and Quarter Horses, hence a generalization to the entirety of the horse population in the United States cannot be made.

When considering clinical signs respondents reported owners riders and trainers associating with primary back pain, they frequently reported non-specific signs of poor performance and behavioral issues similar to previous studies (2, 5). Respondents leaned more towards subjective measures of back palpation and ridden exam to have a high clinical value when diagnosing back pain, while a lower percentage relied on more objective measures like regional anesthesia, which was less popular with veterinarians in the United States than previously reported by European veterinarians (2). Similar to previous findings, most frequently used diagnostic modalities for examination of primary back pain were radiography and ultrasonography, where acoustic myography and thermography were almost never employed

(2). This is likely due to the expense of equipment and lack of validation of the latter modalities in their ability to consistently diagnose back pain.

Consistent with radiography and ultrasonography being the most frequently utilized diagnostic modalities for primary equine back pain, pathologies most frequently associated with primary equine back pain in this survey were those that could be diagnosed with these diagnostic tools: impinging spinous processes, degenerative sacro-iliac joint disease, and osteoarthritis in lumbar and thoracic articular process joints. This is not surprising given the relative availability, versatility, and portability of this type of equipment in the ambulatory setting. Furthermore, in recent years there has been a large increase in training available to equine practitioners utilizing ultrasound and radiology in the diagnosis of axial skeletal issues.

When considering first line treatments for primary equine back pain, respondents recommended non-invasive treatments (shockwave, chiropractic, acupuncture, NSAIDs) and rehabilitation. This is comparable to findings in the human literature which show high success rates in managing chronic back pain with NSAIDs, physical therapy and chiropractic care (7). In contrast to a survey by Wilson in 2018 which reported mesotherapy to be commonly utilized by 87% of their respondents to manage neck and back pain, only 21% of respondents to this survey reported they used this modality >50% of the time. This may be due to the narrow focus of this study to primary back pain vs. inclusion of neck issues. The same reasoning could explain the difference in respondents reporting the use of certain biologic therapies in that study versus this study where very few veterinarians reported the use of IRAP or Stem Cells in the treatment of primary back pain but were more likely to use PRP and similar products. Consistent with the previous survey of European veterinarians (2), corticosteroids were the most frequently reported to be utilized for injectable treatments of primary equine back pain by veterinarians in the United States with 87% of respondents reporting use in this study and 80% of respondents reporting use in the previous study. This is likely due to the relative cost, widespread availability and perceived effectiveness in treatment and management of back pain versus other biologic therapies that have not been effectively studied in this application.

Looking at modalities employed to manage equine neck and back pain, the most common modalities reported to be effective in this study were less invasive modalities of chiropractic, acupuncture, shockwave, and rehabilitation (6). This finding was in line with Wilson's 2018 study asking practitioners which modalities they recommended for equine neck and back pain (6). These modalities frequently fall under the jurisdiction of veterinary medicine in the United States, with some variability in state laws allowing lay people to perform these treatments. Additionally, advanced training in acupuncture, chiropractic and rehabilitation is readily available to veterinarians in the United States through structured certification programs offered by a number of institutions. Therefore, veterinarians in the United States are typically familiar with these modalities and their applications due to an increasing number of veterinarians having certifications in one or more of them.

Following trends of other studies (2, 8–14), impinging spinous processes was the most frequently reported pathology associated with primary equine back pain in this survey. This may be due to the increased availability and portability of digital radiography in the field and general comfort of veterinarians with identifying osteopathic lesions compared to soft tissue abnormalities in the back. Although the literature demonstrates high success rates of horses responding to surgical treatment for ISPs (8–14), 72.2% of respondents to the current survey expressed a reluctance to recommend

surgery as a first line treatment, with a portion (14.4%) opting to never recommend surgery for ISPs. This response may be due to a range of factors including the lack of experience, access to a surgical center and bias. The reluctance or refusal to recommend surgery may account for the large number of respondents reporting the number of horses requiring follow up non-surgical treatments after ISP surgery being unknown. However, respondents to this survey reported the percentage of horses requiring follow up intervention post-surgery due to suspected recurrent back pain as much larger than previously reported (8). Further conclusions could not be drawn as non-surgical interventions were not specifically defined in the survey to differentiate medical treatments vs. rehabilitation modalities, and the definition was left open to interpretation by respondents (Figure 7; Supplementary material). With regards to the effectiveness of rehabilitation in horses with ISPs in the absence of medical or surgical intervention, the respondents reported some proportion of horses not requiring additional therapies to manage their back pain. To the authors' knowledge, this is the first report on the perceived effectiveness of rehabilitation in the absence of medical or surgical intervention in the treatment and management of ISPs by veterinarians.

In conclusion, results of this survey are a starting point showing current trends in diagnosis, treatment and management of primary equine back pain among equine practitioners in the United States. Additional investigations directly comparing the efficacy of the various treatment and rehabilitation modalities used to manage primary equine back pain is warranted given the relative frequency with which certain modalities are utilized or recommended by equine veterinarians. Furthermore, there is a precedent for evaluating the long-term effectiveness of rehabilitation in the absence of surgical or medical intervention in the management of horses presenting with clinical ISPs.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

AUTHOR CONTRIBUTIONS

MM-G conceived and designed the study and was responsible for data collection. MD, KS, VM, and DF contributed to preparing the survey. MM-G and DF contributed to interpretation of data. MM-G drafted the manuscript and all authors edited and revised it critically for content.

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CONFLICT OF INTEREST

DF is employed by Summit Equine Inc.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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SUPPLEMENTARY MATERIAL

The Supplementary material for this article can be found online at: *https://www.frontiersin.org/articles/10.3389/fvets.2023.1224605/ full#supplementary-material*

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Rehabilitation of the Equine Athlete: Tips & Tools to Optimize Recovery

By Sherry A. Johnson, DVM, PhD, DACVSMR

AS PRESENTED at the Saratoga Equine Practitioners Conference, Saratoga Springs, NY September 27-30th, 2023

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INTRODUCTION

Sports medicine and rehabilitation is quickly becoming one of the most progressive and exciting sectors within equine practice. While the human athletic world has embraced the vital role physical therapy and rehabilitation play in the longevity of successful careers, the equine sports medicine community has been slower to identify rehabilitative approaches maximally beneficial for specific diagnoses. Barriers to this progress include lack of universal recommendations regarding the timing, frequency and specific indications of modalities in conjunction with widely varied therapeutic approaches. Whether human or equine, specific rehabilitation goals to decrease pain, improve flexibility, increase strength and restore maximal neuromotor control are ultimately believed to result in recoveries with less convalescence and morbidity. The most effective rehabilitation programs utilize regular, longitudinal patient assessments followed by appropriate adaptation of protocols with both injury-specific and whole-body considerations.

This outline will review various physical modalities and therapeutic exercises commonly employed in the rehabilitation of orthopedic injuries. Appropriate incorporation of any modality or therapeutic exercise into a successful rehabilitation program relies on an accurate diagnosis. Unfortunately, universal recommendations regarding the timing, frequency and specific indications of many of the below-described modalities are still lacking. As further research is able to define specific parameters, significant advancements within the rehabilitation field can be expected.

GENERAL REHABILITATION PLAN CONSIDERATIONS

In the author's experience, physical rehabilitation can be considered to occur in three general phases: 1) Pain mitigation, 2) Mobilization and strengthening, and 3) Athletic preparation with sport-specific considerations. Noteworthy, however, is that the phases are not thought to be completely independent from one another, but rather blended as patient progression (or lack thereof) dictates.

The first phase, dedicated solely to pain mitigation encompasses the more delicate physiotherapeutic techniques

such as icing, compression, TENS therapy, heat and massage with limited amounts of controlled exercise. Goals for this phase of rehabilitation are to reduce swelling (when indicated), break the pain cycle/wind-up and facilitate function so that the second phase of rehabilitation can be pursued more comfortably. The second phase, that of mobilization and strengthening, cultivates the opportunity to more safely mobilize the patient while incorporating various physiotherapeutic aides such as resistance bands, ground poles at various configurations, blood flow restriction training and aquatic therapy. Incorporation of such exercise modifiers allows the clinician to target rehabilitative goals such as improving active range of motion, targeting muscle strength through physiotherapeutic exercises, introducing controlled eccentric loading and stimulating neuromotor control. Some cases may only require elements of phase one with others progressing directly to phase two rehabilitation. The third and final phase of rehabilitation builds upon phase two, but begins to incorporate sport-specific demands that the equine athlete will encounter once they fully return to sport. During phase three, exercise variables such as session length, frequency, speed, carried weight and overall intensity should be gradually introduced while pain mitigation efforts remain minimal. Sport-specific knowledge and awareness of athletic demands is hugely important to building a targeted and appropriate phase three approach. Vigilance and regular re-check evaluations through all phases of rehabilitation remain imperative to identifying set-backs and incorporating pivots (increases or decreases in rehabilitative workload) when necessary. Progression through these phases will vary on a case-by-case basis, with more difficult to manage cases often lagging in phases 1 or 2. Additionally, non-responders may fail phase three rehabilitative approaches, indicating lack of suitability for certain sport intensities. Transparent communication with the owner and trainer to manage expectations, convey case progression and set realistic timelines remain key to successfully managing professional rehabilitation cases.

PHYSICAL MODALITIES

THERMAL THERAPY

Thermal therapy consisting of cryotherapy, heat therapy or a combination thereof (contrast therapy) remains a fundamental cornerstone of many physical therapy programs. Generally speaking, cryotherapy is indicated in acute injuries to reduce pain, swelling and inflammation, while heat therapy is utilized in more chronic conditions to encourage soft tissue extensibility, decrease muscle spasming and increase local blood flow.[1] Methods to apply thermal therapy have been widely developed for use in the equine distal limb, but the equine back and pelvic regions remain challenging due to limitations in anatomic depth of penetration and difficulty in secure application mechanisms.

CRYOTHERAPY

To realize the reported pain modulating benefits of cryotherapy including decreased tissue metabolism, reduction of inflammatory mediators and decreased nerve conduction velocities,[2] tissue temperatures need to be reduced to 10 to 15°C.[3] Cryotherapy of the appendicular skeleton can be accomplished with a variety of commercially available systems, with ice-slurry immersion yielding the quickest decreases in tissue temperature.[4] Cryotherapy can be successfully applied along the back and pelvic regions through the use of cold packs, ice frozen in paper cups or icing blankets that have been recently developed. Optimal dosages (duration and frequency) of cold therapy have yet to be defined, but a general recommendation of cryotherapy application is for 15 to 20 minutes every 2 to 3 hours during the first 48 hours after an acute injury.[3] Although reports of ischemia secondary to cryotherapy (frostbite) are not reported in the veterinary literature, precautions

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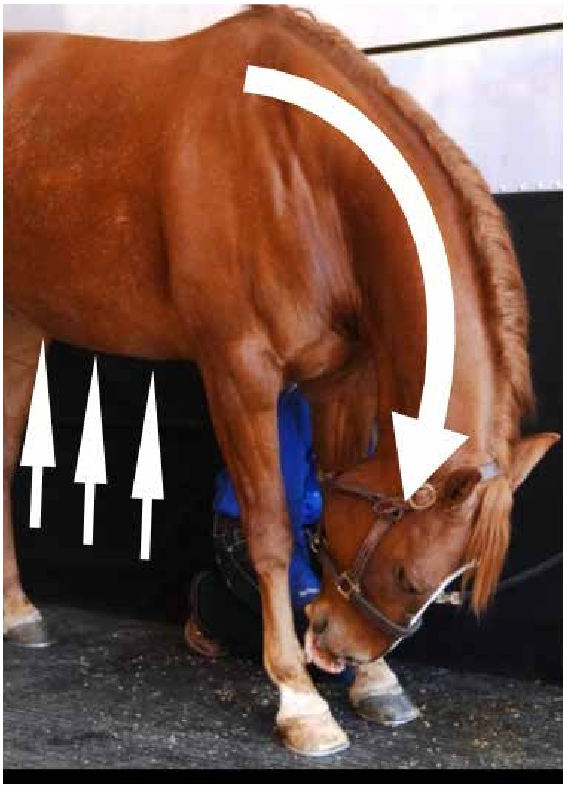
FIGURE 1: **Baited ventral cervical flexion to the level of the front fetlocks, resulting in engagement of the entire cervical spine, postural muscles, core abdominal musculature and the entire thoracolumbar spinal region.**



to avoid superficial cryotherapy-related tissue damage should be taken as temperatures below 10°C are thought to precipitate cellular insult.[3]

HEAT THERAPY

In contrast to increased tissue stiffness properties appreciated with cryotherapy, heat therapy offers the practitioner a means of inducing general muscle relaxation, increasing tissue extensibility and decreasing pain through proposed mechanisms of altered neural receptor metabolic activity.[5] Suggested therapeutic ranges of 40°C to 45°C can be expected to exert physiologic effects whereas temperatures above 45°C may cause tissue damage.[1] Methods of heat application include heating blankets and packs, or other materials that can be heated in a microwave and affixed to the patient. Although clinical effectiveness for superficial heating has yet to be demonstrated, it is often recruited in the both the training and rehabilitation settings prior to exercise as mounted heating lamps (Solarium).

ELASTIC THERAPEUTIC TAPING

Also known as 'kinesiotape,' elastic therapeutic taping is a flexible adhesive product designed for use as an adjunct therapeutic technique for the management of sports-related injuries and musculoskeletal conditions in humans. Manufacturers claim that elastic therapeutic tape provides pain modulation by lifting the skin to allow decompression of the superficial nerve endings and improved blood and lymphatic flow.[6] Current human literature suggests that elastic therapeutic tape may have a small beneficial role in improving cutaneous proprioception, joint range of motion and strength, but further studies are necessary to confirm these findings.[6] A singular equine study evaluating the kinematic and surface EMG effects of kinesiotape of the brachiocephalicus and extensor carpii radialis muscles demonstrated no kinematic differences between "no tape", "with tape", and "post tape."[7] Authors concluded that application of the kinesiotape from muscle (brachiocephalicus and extensor carpii radialis) origin to insertion on the surface of the skin didn't affect the trajectory of the forelimb or muscular activity.[7] In contrast, promising results have been appreciated with preliminary investigations incorporating the use of pre and post application algometry pressure scores (King MR, unpublished data). Equine certification courses are available, but the current level of evidence for its use is largely anecdotal and unsubstantiated. Application of elastic therapeutic tape in the back and pelvic regions is often employed to reduce myofascial restriction and for the purposes of muscle activation or added proprioceptive stimulus. The hair needs to be free of debris, dry and without product (conditioner or fly spray, for example) for the tape to stick, which can be a challenge in even the shortest-haired horses. The tape will typically remain in place for 2-3 days at which time re-application may be warranted.

AQUATIC THERAPY

In the rehabilitation setting, the proposed benefits of aquatic exercise include buoyancy, viscosity and resistance that promote global improvements in muscular timing, strength and neuromotor control.[8] Several options to employ aquatic therapy for the equine athlete are currently available including above ground underwater treadmills, in-ground underwater treadmills and swimming pools (circular or straight).[1] Investigations into the benefits of aquatic therapy for the equine patient have thus far reported subsequent physiologic responses,[9-11] biomechanical effects[12] and its role in mitigating carpal osteoarthritis.[8] Alterations in limb kinematics secondary to varying water depths provides the clinician a means of targeting or sparing flexion/extension joint angles depending on the rehabilitation goals of the

FIGURE 2: **Baited lateral cervical bending to the level of the hind fetlock, resulting in engagement of the entire cervical and thoracolumbar spine.**

specific patient.[13] It was also recently demonstrated that walking slowly (0.8 m/s) on a water treadmill reduced forelimb protraction-retraction range of motion and increased hindlimb protraction-retraction range of motion compared to walking on a dry treadmill at normal speed (1.6 m/s).[14] Based on these findings, authors concluded that forelimb protraction was decreased while hindlimb retraction
was increased during water treadmill exercise, which could be utilized to design rehabilitation programs.[14]

Two studies looking specifically at back and pelvic kinematics during aquatic therapy at varying water depths have been performed.[15-16] When axial rotation, lateral bending and pelvic flexion were evaluated in a population of riding horses, significant increases in rotation and flexion of the back were noted at higher water depths.[15] Additionally, pelvic flexion was significantly increased at higher water levels.[15] Similarly, increases in cranial thoracic extension and thoracolumbar flexion were appreciated in 14 horses walking in high water compared to water at lower depths.[16] Given the resultant spinal and pelvic biomechanical effects of aquatic exercise at varying water depths, the rehabilitation clinician must be mindful that some horses may not tolerate high water levels if pathologic change within the thoracolumbar region results in altered and potentially painful pelvic range of motion. Similar considerations should be given to horses with spinous impingement within the cranial thoracic region as high water depths may exacerbate inappropriate spinal extension.[15]

Lastly, the effects of training on conventional and underwater treadmills on fiber properties and metabolic responses of the superficial digital flexor and gluteal muscles to high-speed exercise in horses was compared.[17] Eight weeks of conventional or underwater treadmill training resulted in only minor changes in type 1 muscle fiber sizes with no effect on muscle metabolic or heart rate responses to standardized exercise tests, leading authors to conclude that training at progressing speeds should be pursued following rehabilitation involving underwater treadmill training.[17] Similarly, the intensity of water treadmill exercise as a function of water height and treadmill speed was recently investigated.[18]

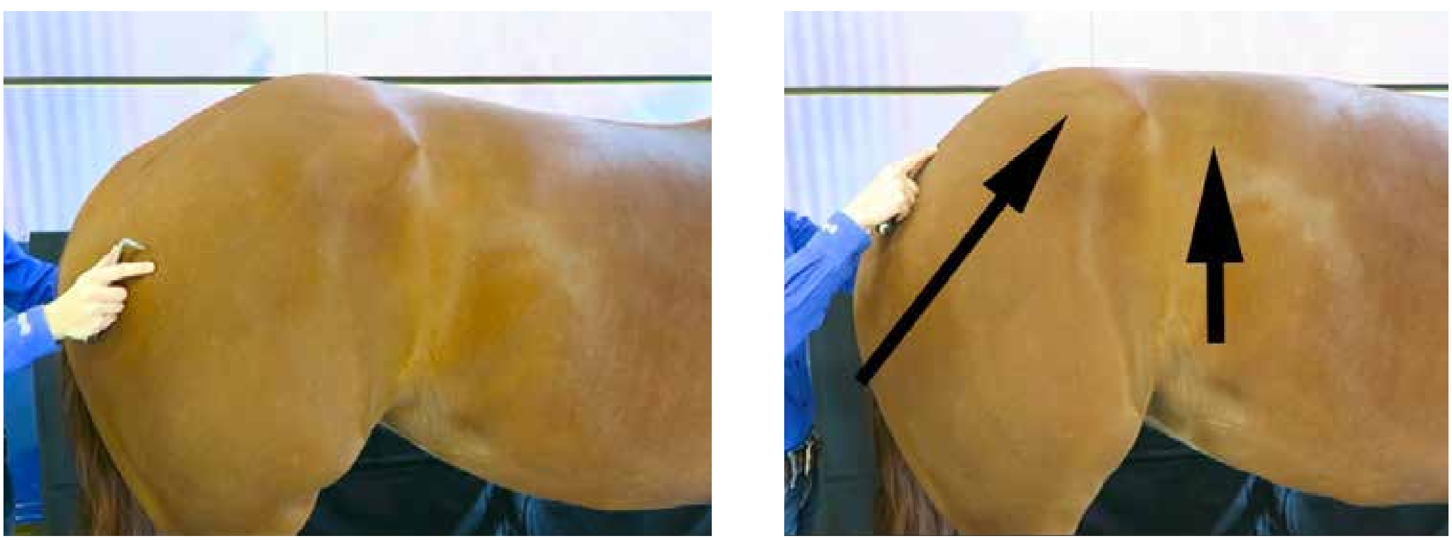


FIGURE 3: **Lumbosacral pre-tuck (left) and mid-stretch (right) demonstrating rotation through the lumbosacral junction, engagement of the iliopsoas muscle and eccentric activation of the longissimus muscle. Note the horse's thoracolumbar and pelvic positions in reference to the black line.**

FIGURE 4: **Sternal pre-lift (left) and mid-stretch (right) demonstrating eccentric activation of the longissimus dorsi, spinalis and intercostalis mucles with simultaneous concentric contraction of the external abdominal oblique. Note the horse's thoracolumbar and pelvic positions in reference to the black line. Ideally, the horse would have lowered it's head and neck simultaneously to facilitate the stretch further.**

Varying water height and speed affects the workload associated with water treadmill exercise, but the conditions investigated were all associated with low intensity exercise. Interestingly, authors noted that water height had a greater impact on exercise intensity than speed.[18] With persistent and exciting interest around various forms of aquatic exercise, further insight into prescription can be expected in the near future.

WHOLE BODY VIBRATION

Of recent interest within the equine community has been the use of low-amplitude, low-frequency mechanical vibration therapy. Although empirically prescribed, perceived benefits reported by owners and horsemen include general relaxation and overall well-being. Acute hematologic and clinical effects of horses undergoing vibration therapy have been recently described, noting no adverse effects following vibration sessions.[19] Within the rehabilitative setting, there has been recent interest in the effects of prolonged vibration therapy on the cross-sectional area and symmetry of the multifidus muscle.[20] A significant increase in multifidus muscle cross-sectional size and symmetry was found following 60 days of twice daily, 30 minute whole body vibration sessions.[20] This study was subsequent to a series of investigations that described cross sectional area differences in horses with clinical signs of back pain and osseous pathologic changes[21] and changes in symmetry following the regular institution of dynamic mobilization exercises.[21] Known for its role in spinal stabilization and postural muscle acuity, development of the multifidus muscle is thought to have potential as an osteoarthritis deterrent.[23-25]

Additional interest has recently surrounded the effects of whole body vibration on hoof growth rate.[26] In this study, ten horses were subject to whole body vibration for 30 minutes, twice daily, five days per week, for 60 days in addition to their regular exercise routine. Authors subsequently noted a significant mean increase in hoof growth after both 30 and 60 days of whole body vibration in comparison to 30-day hoof growth prior to whole body vibration. While this study has given preliminary insight into hoof growth acceleration that may be related to whole body vibration, further studies incorporating a separate control group and standardization of variables including exercise, housing and nutrition are warranted before blanket conclusions can be made.

THERAPEUTIC EXERCISES

Physiotherapeutic exercises aimed at stimulating motor control, flexibility and stability are regularly employed in human physical therapy programs to aid in restoration of improved back and pelvic function. Specifically, the use of such exercises have been shown to reduce both pain and re-injury.[25,27-28] Pursuant to the equine patient, several core strengthening exercises and their role in activating deep epaxial musculature to subsequently improve postural motor control and alter thoracolumbar kinematics have been investigated.[22,29] Both baited and passive exercises offer opportunities to facilitate stretching during dynamic phases and strengthening during static phases of the exercise. Institution of dynamic mobilization exercises over a 3 month time period have been shown to increase both size and symmetry of the multifidus muscle as assessed through longitudinal ultrasonographic evaluation.[22] While blanket recommendations regarding prescription of the below listed exercises is not advised, the stretches listed below offer means through which various regions of the spine and pelvis may be targeted (Figures 1-4).

PROPRIOCEPTIVE STIMULATION

Multiple human studies have demonstrated that individuals with spinal pathology and back pain have reduced muscle CSA leading to loss of function and impairments in postural control and proprioceptive acuity. Human athletes that incorporate core, balance exercises into their rehabilitation programs are significantly less likely to suffer re-injury during a 12-month period following injury, compared to those individuals with similar injuries that did not emphasize core strength (7% re-injury rate in the balance training group versus 29% re-injury rate in the control group).[30] Strengthening, improving proprioception and balance control following injury remains a central focus of human physical therapy programs, and while standardized investigations have yet to focus on equine applications, there are several mechanisms through which neuromotor control can be recruited. Specific to pain and dysfunction of the back and pelvic regions, physical therapy aides such as ground poles, tactile stimulators and incorporation of surface changes offer clinicians passive means of engaging neuromotor control during activities of daily rehabilitation or training. Ground poles when arranged at various distances, heights and configurations can encourage increase in lateral thoracolumbar excursion. Hill work and incorporating backing exercises into hill work can also be used to simultaneously improve muscular strength and challenge proprioceptive acuity.

The use of various training aids within the equine rehabilitation setting has been of recent interest, including the use of a system of elastic bands and Pessoa lines.[31-33] Resistance band training is successfully used in human physical therapy programs to improve core strength and stability, specifically related to the lower back and pelvic regions.[34-36] Commonly referred to as a Theraband, the two-piece equine elastic band system is thought to stimulate core abdominal muscles with the abdominal band and engage hindlimb musculature with the hindquarter band. Its use in horses at a trot was recently investigated and found to reduce mediolateral and rotational movement throughout the thoracolumbar region.[32] Further studies investigating more long-term use and potential mechanistic pathways will help refine its use in the rehabilitation setting. Also pertinent to rehabilitation of the back and pelvic regions are the use of training lines. Pessoa training aids were demonstrated to increase both lumbosacral angles and thoracolumbar dorsoventral excursion when used in horses being lunged at a jog.[33] While further studies are needed to establish specific recommendations regarding use, initial biomechanic effects for targeted rehabilitation are encouraging.

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The influence of different horseshoes and ground substrates on mid-stance hoof orientation at the walk

By Patrick T. Reilly [1], Andrew van Eps [1], Darko Stefanovski [1], Thilo Pfau [2,3]




INTRODUCTION

Therapeutic farriery has been defined as the treatment of diseases of the equine distal limb through trimming or the application of various appliances.[1] The concept of therapeutic farriery is, therefore, not necessarily to balance the hoof but rather to strategically alter the orientation of the hoof to remove mechanical stress from a particular structure determined to be the source of lameness[2] thus aiding in healing.[3] Increasing the dorsal hoof wall angle (either through trimming or the application of a heel-elevating shoe or pad) has been observed to reduce the strain on the deep digital flexor tendon,4,5 but this change in the orientation of the hoof has potentially undesirable consequences, including increasing the load on the heel region of the hoof as well as increasing the strain on the suspensory ligament.[4,5] Kinesiotherapic horseshoeing[3,6] uses horseshoes with a modified ground contact surface in combination with a deformable ground sub- strate to change the mid-stance orientation of the hoof in kinematic events, creating proposed therapeutic benefits while limiting potential adverse mechanical side effects. The literature supporting the use of kinesiotherapic shoeing concepts is limited. Scheffer and Back observed a 1.50-40 forward rotation of the hoof (quantified with an infrared gait analysis system) in horses evaluated at the walk-in sand substrate, and the observed increase in hoof angle was greater in egg bar shoes compared with normal horseshoes.[7] Chateau and Denoix noted a similar finding, observing an increased dorsal hoof wall angle at mid-stance in both normal (2.90) and egg bar shoes (5.10) in a kinematic trial assessed using ultrasonic markers while walking on a soft track.[8] Toe-wide horseshoes were observed to decrease the vertical pressure under a wide-toe shoe compared with a normal shoe in horses walking over a force plate,[9] however, the change in orientation has not been studied for many horseshoes advocated for therapeutic applications. Triaxial accelerometers have been used for inclination measure- ment in several industries, using the constant of gravitational acceleration and a low pass filter for calculating angular position (i.e., orientation) from triaxial acceleration.[10–12] The use of a single triaxial accelerometer has been shown to be an accurate method of acquiring orientation information as compared with a comput- erised pathway in patients with Huntington's disease,[11] but there have been no studies using this equipment to acquire positional information of the equine hoof.

The aim of the current study was to quantify the change in hoof orientation (relative to the ground surface) caused by the application of various horseshoes in walking horses on a variety of ground substrates. We hypothesised that hoof orientation could be measured reliably during static stance (i.e., in the standing horse) or dynamic stance phases (i.e., during locomotion) on the hard ground regardless of horseshoe type. In addition, we hypothesised that horseshoes and deformable ground substrates alter the hoof orientation during the dynamic mid-stance phase in a manner predicted by ground surface modifications of the horseshoe profile and thickness gradient.

MATERIALS AND METHODS

HORSES

Six privately owned horses in active competition were convenience sampled for participation in this study. The primary discipline was dres- sage (n = 4), with the remaining horses competing in eventing (n = 2). These were three Warmbloods, one Thoroughbred, one Standardbred and one Warmblood/Thoroughbred cross. The median age of the horses in this study was 14.5 years old (range 9–18) and the median height was 1.65 m (range 1.62–1.76 m). All horses were observed to be symmetric at the walk through the data collecting process.

HORSESHOES

Six aluminium horseshoes with differing ground surface modifications were applied in random order (Figure 1). Flat (Victory Racing Plate Company); toe-wide, medial-wide; lateral-wide (Grand Circuit Products LLC) flat egg bar shoes and three-degree heel elevated egg bar shoes (KB Horseshoe Company) were used. The toe-wide, medial- wide and later- al-wide shoes were modified to remove the widened section on the narrow branches of the shoe to maximise the ability of the shoe to penetrate the substrate. The feet were trimmed with a visual assessment to promote static alignment of the phalanges in both sagittal and transverse planes. Horseshoes were applied by the same farrier using consistent techniques for the positioning of the horseshoes. The mean dorsal hoof wall angle of the left front hoof was 52.50 (range 510–540) and the mean dorsal hoof wall length was 92 mm (range 83–101 mm).

GROUND SUBSTRATES

The hard substrate consisted of interlocking rubberised bricks with a Shore-A hardness rating of 60. The sand arena consisted of coarse- washed sand approximately 8 cm deep with a compacted stone dust base. The turf was a level grass area.

INSTRUMENTATION

A calibrated 40 g triaxial accelerometer manufactured by Lord Micro- Strain was potted in a silicone elastomeric putty (Smooth-on) a round polyvinyl chloride ring and adhered to the dorsal midline of the left front hoof with a polymethyl methac-

FIGURE 1: **Horseshoes with differing ground surfaces (left to right): flat, toe-wide, medial-wide, lateral-wide, egg bar and three-degree egg bar shoe.**

FIGURE 2 **Attachment of the accelerometer to the dorsal hoof wall of the left forelimb and illustration of the axial orientation of the sensor.**

FIGURE 3: **Top: Seven walking strides recording the dorsal/palmar hoof angle in red and the medial/lateral hoof angle in green. Bottom: Stride enlarged identifying mid-stance (highlighted in yellow). Right: Dorsal hoof wall angle changes were described as positive if the angle increased and negative if the heels sink into the footing. In the medial–lateral plane, the value was considered positive as the hoof sinks laterally into the footing and negative if sinking medially.**

rylate of adhesive (Lord Adhesives) (Figures 2 and 3). The triaxial accelerometer data were collected in 10 s samples, recording at 1024 Hz with the sensor settings mea- suring two channels of tilt based on low pass filtered data (104 Hz cut-off frequency, manufacturer specifications for tilt: ±10 accuracy, <0.10 precision).

Horseshoes were applied to both front hooves in a predeter- mined randomised order. Stance trials were recorded from standing trials on hard substrates immediately after each pair of horseshoes was applied. The horse was then walked in hand over an outlined path over each footing with alternating trials in oppos- ing directions. A sample recording was triggered once a consistent gait was observed in a straight line. Following data collection on each surface, the horse was returned to the original hard substrate and an additional 10 s stance trial was recorded. The pair of horseshoes was then changed, and the process repeated. The time of each accelerometer trigger was recorded for each stance and walking trial. No changes were made to the hind hooves or to the hind shoes.

Data was logged with time stamps and was analysed using Lord MicroStrain's Sensor Connect software. Stance recordings were noted, and the mean hoof angles were recorded for each of the 10-s recording (see Figure 1). Calculations of pitch (sagittal angle) and roll (transverse angle) were automatically performed using Lord Microstrain's Sensor Connect software.

For walking samples, each stride was identified by the time stamp and individually examined: a signal portion of approximately 0.75 s containing constant acceleration data was selected manually (see Figure 1). The mean value of sagittal and transverse angle was recorded for each selected signal portion (i.e., each stance phase). A mean value was then calculated from the 8 to 10 selected stance phases to create a mean value for each combination of surface and horseshoe types.

Therapeutic farriery has been defined as the treatment of diseases of the equine distal limb through trimming or the application of various appliances.

STATIC AND DYNAMIC HOOF ORIENTATION

Dorsal hoof wall angles computed from the mid-stance portion for each walking stride on hard footing were compared from the same number of calculated dorsal angles derived from 1 s intervals from stance trials (in the standing horse) to obtain equal numbers of values in each data set.

DATA ANALYSIS

First, to evaluate the capability of the hoof sensor to calculate sagittal and transverse plane angles at the walk (during locomotion), the difference between values calculated for standing (pre-stance) and walking trials on the hard substrate was analysed following the method first outlined by Bland and Altman[13] and calculating limits of agreement in SPSS (version 26, IBM). Due to a lack of a priory data, the 50 limits of sagittal positioning established in a study comparing hoof angles obtained from digital photographs to digital radiographs were used to assess the limits of agreement between pre-stance and walk angles.[14] In addition, Lin's concordance correlation coefficient was calculated in Stata (StataCorp) using the same pre-stance and walking observations to determine the similarity of the two data sets. The following categories were used to assess the degree of equivalence: >0.99 almost perfect; >0.95 to ≤0.99 substantial; >0.90 to ≤0.95 moderate; <0.90 poor.[15] Differences between horseshoes and substrates were assessed using a mixed-effects linear regression model with the horse as a random factor and fixed factors of a horseshoe and surface type and their interaction. Bonferroni adjustment was used to correct for multiple comparisons. Histograms of model residuals were created and compared visually to a normal distribution; all residuals were considered normally distributed. Tests were conducted in SPSS (version 26), with a statistical significance level set at $p < 0.05$.

RESULTS

Figure 4 illustrates the limits of agreements between the dorsal hoof wall angles during stance and at mid-stance of walking trials10 show- ing both the mean difference between the data sets as well as the upper and lower limits of agreement [mean difference ± 2 standard deviation (SD) of differences]. The bias (average difference between dorsal hoof wall angle at walking mid-stance-dorsal hoof wall angle at stance) was 0.1190 (SD 1.3360) with the limits of agreement spanning a range from -2.550 to +2.790. The correlation between the difference and the mean was 0.0240.13 Lin's concordance correlation coefficient for the dorsal hoof wall angle at stance against the mid-stance walking values (see Figure 5) resulted in a substantial concordance correlation or very strong,[16] with a Pearson's rho of 0.967. The slope was 1.006.

DYNAMIC MID-STANCE DORSAL HOOF ORIENTATION

Mixed model analysis found significant differences between hoof wall orientation values at mid-stance between different substrates ($p < 0.001$), different horseshoes ($p < 0.001$) and for different substrate-horseshoe combinations ($p < 0.001$) (Table 1). There was an increase in dorsal hoof wall angle (forward rotation in the sagittal plane) observed with all shoes on both turf (mean increase of 2.620, SD 3.760) and in a sand arena (mean increase of 2.64, SD 4.090) with all horseshoes. The increase in observed dorsal hoof wall angle was observed in all horseshoes, with egg bar shoes creating the largest increase, followed by (in order of change): three-degree egg bar shoes, medial-wide shoes, lateral-wide shoes, flat shoes and toe-wide horse- shoes (Figure 6; Table 2; Item S1).

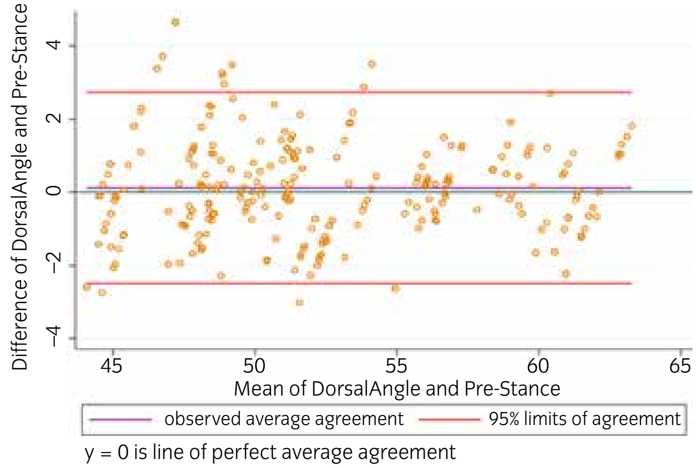

FIGURE 4 **Bland and Altman plot the dorsal hoof wall angle of stance and walking trials, with the limits of agreement (-2.4990 to 2.7370). The correlation between the difference and mean = 0.0240.**

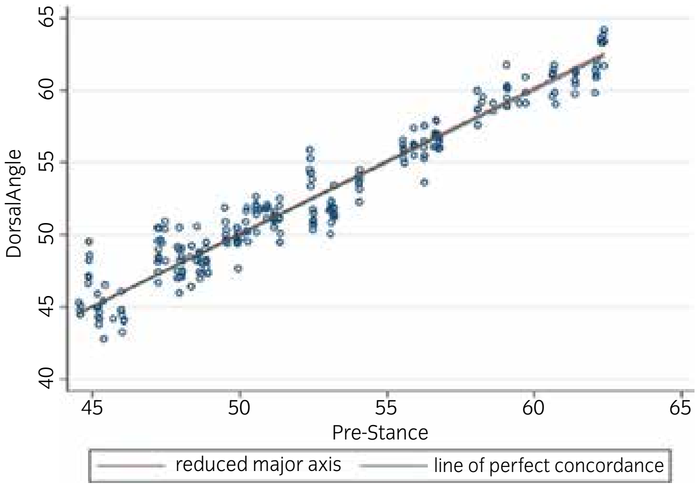

FIGURE 5 **Regression line between dorsal hoof wall angle measurements at stance and mid-stance walking trials, with a slope of 1.006 and an intercept of -0.201. The correlation coefficient between the two methods is r = 0.967, 95% confidence interval = 0.958 0.975, p < 0.001.**

TABLE 1 **Type III test of fixed effects with regard to dorsal hoof wall angle.**

Source	Numerator df	Denominator df	F	Sig.
Shoe Type	5	742.012	13.785	<0.0001
Substrate	2	742.008	93.398	<0.0001
Substrate X Shoe Type	10	742.009	3.857	<0.0001

Note: Numerator and denominator degrees of freedom (df), F statistic (F) used to determine the achieved level of significance (Sig.).

DYNAMIC MID-STANCE MEDIAL–LATERAL HOOF ORIENTATION

Mixed model regression analysis found footing, horseshoes and the combination of horseshoes and substrate to all be statistically significant with regard to changes in medial–lateral hoof orienta- tion (Figure 7; Table 3). There was a lateral shift in hoof orientation at mid-stance observed across all horseshoes in both turf and sand trials (mean lateral shift of 1.110, SD 1.490 on turf and 0.930, SD 1.490 in the sand). The greatest increase in observed lateral shift occurred with a wide medial shoe, followed by (in order of magnitude): egg bar shoes, three-degree egg bar shoes, toe-wide shoes, and flat shoes (Figure 5; Table 4; Item S1). The lateral-wide shoe resulted in the lowest measured lateral shift of hoof orientation in turf (0.620, SD 1.260). In the sand, the lateral-wide horseshoe resulted in the only marginal medial shift of the horseshoes consid- ered (0.070, SD 2.030).

STATISTICAL IMPORTANCE OF SURFACES

There was an observed difference in the mixed model analysis between both the aisle and the turf (p < 0.001) and between the aisle and the sand (p < 0.001) (Item S1). There was no significant difference observed between the turf and sand substrates (p > 0.9) (Item S1).

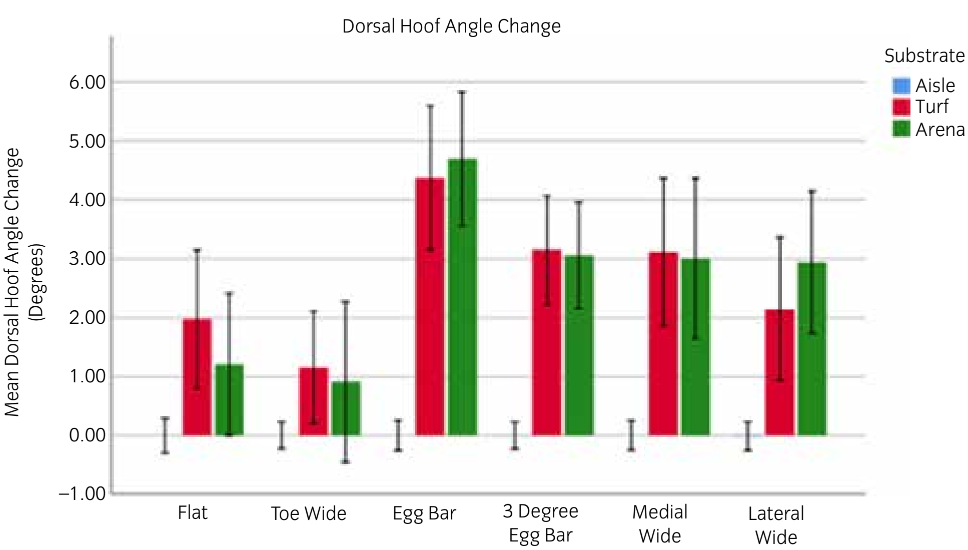

FIGURE 6 **Clustered bar chart showing the change in dorsal hoof wall angle from a walk on hard substrate (aisle). Error bars show the 95% confidence interval. Increasing the dorsal hoof wall angle is measured as a positive value, a reduction would be reflected as a negative value.**

DISCUSSION

Hoof angles in the dorsal–palmar and medial–lateral planes were mea- sured at mid-stance in the left front hoof of walking horses. Standing and walking trials on a hard aisle substrate were compared to determine the limits of agreement between differing methods of data collection. Horseshoes with modified ground contact surfaces and substrates of differing deformability were examined to determine the influence of each on hoof orientation. Changing both the substrate and the horseshoes resulted in changes to the orientation of the hoof capsule in both the dorsal–palmar and medial–lateral planes.

Regarding the first hypothesis, the limits of agreement between the stance and walking data sets revealed relatively small differences. While there is no singular value considered to be acceptable for Lin's concordance correlation coefficient, the similarity of stance and walking mid-stance trials ($r = 0.967$) was considered a 'substantial' correlation, well higher than the accepted value of >0.800 established by McBride15 as a positive result. The correlation would be categorised by Akoglu[16] as being 'very strong'. By any determination, the r value shows a strong relationship between the two variables.

The Bland Altman test showed a 0.1190 mean difference with a SD of 1.3360 with a mean difference regression of 0.024, well within the 95% confidence interval (limits of agreement), -2.499 to 2.737 indicating no proportional bias between the data sets. These limits were well within the ranges established by White et al.[14]

The comparison between dorsal hoof wall hoof angles obtained at the stance and dorsal hoof wall angles measured during walking mid-stance has several potential sources of variation. Hoof capsule deformation might account for a discrepancy in values, as well as the subtle movement of the hoof contributing to accelerations inadvertently being incorporated into the hoof angle calculations, thus contributing to inaccurate dorsal hoof wall measurements. Heel movement

TABLE 2 **Combinations of horseshoes and footings and the changes in dorsal hoof wall angles from walking on hard substrate (aisle).**

Substrate	Horseshoe type	Mean	NStd.	Deviation	Minimum	Maximum	Range
Turf	Flat	1.97	44	3.85	-4.59	11.91	16.5
	Toe-wide	1.15	44	3.13	-5.12	7.71	12.83
	Egg bar	4.37	40	3.82	-1.31	14.32	15.63
	Three-degree egg bar	3.15	41	2.91	-4.25	8.78	13.03
	Medial-wide	3.11	43	4.06	-2.53	14.03	16.56
	Lateral-wide	2.15	44	4.00	-7.08	9.71	16.79
	Total	2.62	256	3.76	-7.08	14.32	21.4
Arena	Flat	1.20	44	3.96	-4.56	10.22	14.78
	Toe-wide	0.91	44	4.48	-7.03	11.4	18.43
	Egg bar	4.69	46	3.83	-1.1	13.11	14.21
	Three-degree egg bar	3.05	42	2.88	-2.64	8.78	11.42
	Medial-wide	3.00	40	4.25	-6.26	13.43	19.69
	Lateral-wide	2.94	44	3.96	-7.64	10.92	18.56
	Total	2.64	260	4.10	-7.64	13.43	21.07
Total	Flat	1.07	130	3.33	-4.59	11.91	16.5
	Toe-wide	0.70	130	3.22	-7.03	11.4	18.43
	Egg bar	3.13	125	3.82	-2.12	14.32	16.44
	Three-degree egg bar	2.06	125	2.80	-4.25	8.78	13.03
	Medial-wide	2.02	126	3.68	-6.26	14.03	20.29
	Lateral-wide	1.73	129	3.52	-7.64	10.92	18.56
	Total	1.77	765	3.49	-7.64	14.32	21.96

Note: Mean values, number of mid-stance angles, standard deviations, minimum and maximum values and range of samples.

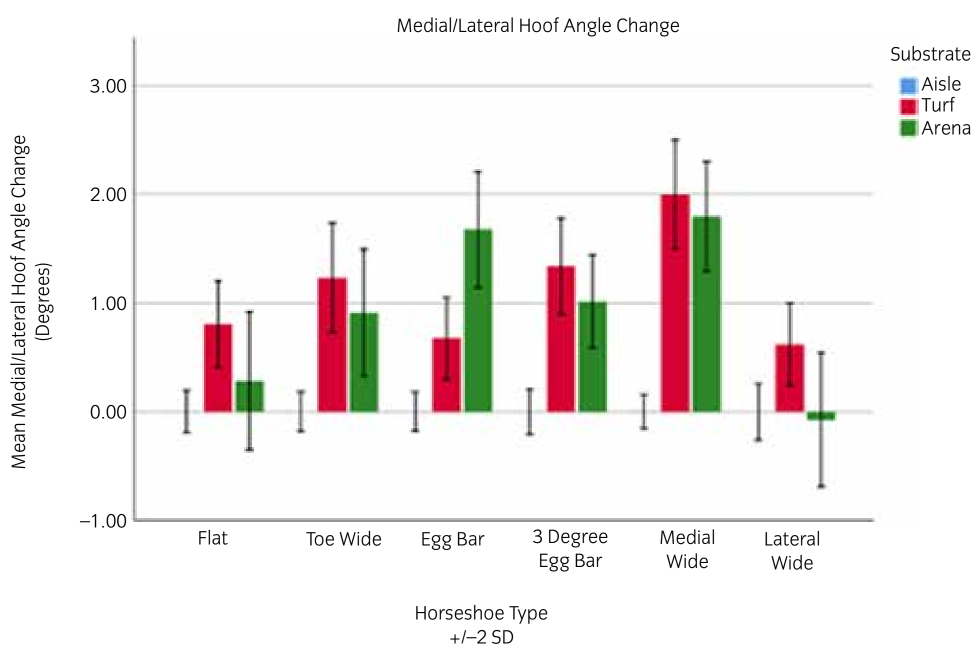

FIGURE 7 **Clustered bar chart showing the change in medial– lateral hoof wall angle from a walk on hard substrate (aisle). Error bars show the 95% confidence interval. The hoof sinking into the substrate in a lateral direction is represented as a positive value and sinking into the substrate in a medial direction is reflected as a negative value.**

has been observed as 4.07 mm in the walking forelimb,17 although the triaxial accelerometer was attached to the dorsal hoof wall which experiences less hoof deformation.18 The combination of these two tests suggests a similarity between the data collected at stance and walking mid-stance, providing support for the first hypothesis that dorsal hoof wall angles are similar between standing and walking trials on the same hard substrate.

TABLE3 **Type III test of fixed effects on medial/lateral hoof angle.**

Source	Numerator df	Denominator df	F	Sig.
Shoe Type	5	742.012	13.785	<0.0001
Substrate	2	742.008	93.398	<0.0001
Substrate x shoe type	10	742.009	3.857	<0.0001

Note: Numerator and denominator degrees of freedom (df), F statistic (F) used to determine the achieved level of significance (Sig.).

Trials from every horseshoe in deformable substrates resulted in an increased measurement in dorsal hoof wall angle, suggesting the hoof pitches forward in kinematic trials in deformable substrates com- pared with static measurements. This was consistent with the findings of other kinematic studies,7,8 with small differences likely accounted by differences in both shoe modifications, substrate variations and the choice of measurement technology. Here, a flat horseshoe

increased the measured dorsal hoof angle by 1.200 in a sand arena and by 1.970 on a turf track. The additional ground contact surface area by the addition of an egg bar shoe further increased the dorsal hoof wall angle, resulting in a 4.370 increase in turf and 4.690 in the sand compared with the angles observed walking on the hard aisle. The toe-wide shoe, on the other hand, was theorised to cause the heels to sink into the deformable substrate,3 but this was not the case. The toe-wide shoe still resulted in an increased dorsal hoof wall angle (1.150 on turf and 0.910 in the sand) compared with the angle observed in the standing horse. Medial (3.110 turf, 3.000

TABLE 4 **Combinations of horseshoes and substrates and the changes in medial-lateral hoof angles from walking on hard footing (aisle).**

Substrate	Horseshoe type	Mean	NStd.	deviation	Minimum	Maximum	Range
Turf	Flat	0.81	44	1.31	-1.31	5.02	6.33
	Toe-wide	1.23	44	1.65	-2.38	6.16	8.54
	Egg bar	0.67	40	1.18	-2.27	3.35	5.62
	Three-degree egg bar	1.34	41	1.41	-1.96	3.55	5.51
	Medial-wide	2.00	43	1.63	-1.37	6.17	7.54
	Lateral-wide	0.62	44	1.26	-1.73	3.67	5.4
	Total	1.11	256	1.49	-2.38	6.17	8.55
Sand	Flat	0.29	44	2.09	-4.15	5.75	9.9
	Toe-wide	0.91	44	1.92	-4.9	4.54	9.44
	Egg bar	1.68	46	1.79	-2	5.56	7.56
	Three-degree egg bar	1.02	42	1.37	-1.71	3.78	5.49
	Medial-wide	1.79	40	1.58	-2.1	5.47	7.57
	Lateral-wide	-0.07	44	2.03	-4.85	4.96	9.81
	Total	0.93	260	1.93	-4.9	5.75	10.65
Total	Flat	0.37	130	1.50	-4.15	5.75	9.9
	Toe-wide	0.73	130	1.59	-4.9	6.16	11.06
	Egg bar	0.83	125	1.48	-2.27	5.56	7.83
	Three-degree egg bar	0.78	125	1.32	-1.96	3.78	5.74
	Medial-wide	1.25	126	1.60	-2.1	6.17	8.27
	Lateral-wide	0.19	129	1.49	-4.85	4.96	9.81
	Total	0.69	765	1.53	-4.9	6.17	11.07

Note: Mean values (in 0), number of mid-stance angles, standard deviations (in 0), minimum and maximum values (in 0) and range of samples (in 0).

arena) and lateral-wide shoes (2.150 turf, 2.940 sand) were both observed to have a similar increase in the dorsal hoof wall angle. The three-degree egg bar shoe was not as effective in increasing the dorsal hoof wall angle in deformable substrates (3.150 in turf, 3.050 increase in sand arena) compared with the flat egg bar shoe, potentially as the frog and sole were more distant from the ground contact surface, thus contributing less to the entire ground contact surface. There was a tendency for the hoof to sink laterally at mid-stance into deformable substrate during walking trials. A flat shoe resulted in a 0.810 lateral change in hoof orientation at mid-stance in turf and a 0.290 lateral change in the sand. While there are many possible explanations for this, it has been observed that 68% of horses land laterally based on force plate measurements19 lending to the possibility of the hoof sinking into the substrate upon hoof impact. Egg bar shoes increased the lateral sink- ing of the hoof into sand (1.680), a finding also noted by Chateau,8 who noted that the egg bar shoes prevented medial sinking of the hoof in a sand track. As theorised by Denoix,3 medial-wide horse- shoes increased the lateral sinking of the hoof into deformable footings, 2.000 in turf and 1.790 in the sand arena. Lateral-wide horseshoes, thought to cause the medial side of the hoof to sink into deformable substrates, were still observed to result in a lateral shift in the turf (0.620). In the sand, the lateral-wide horseshoes did result in a 0.070 medial shift in hoof orientation.

Modifying the ground contact surface of horseshoes changed the hoof orientation at mid-stance during kinematic trials in deformable substrates. In an absolute sense, one might conclude that kine- siotherapic shoes were not always effective (toe-wide shoes did not cause the heels to sink into the ground and the hoof angle was not decreased). In a relative sense one could observe that, in all cases, modifications to the ground contact surface of horseshoes created the theorised change when compared with the hoof orientation observed with flat shoes (toe-wide shoes decreased the dorsal hoof wall angle compared with flat shoes by 0.810 in turf and 0.210 in a sand). There would seem to be no contraindications to the use of ground contact-modified horseshoes, however, the clinical importance of the changes in hoof orientation upon pathologies of the distal limb is unknown.

The difference in hoof orientation between kinematic sampling on deformable substrates and hoof orientation on a hard substrate in a static assessment helps to underscore the lack of accepted parameters for the definition of a ‘balanced hoof’. The lack of a statistical relationship between the turf and sand can likely be explained by the high level of rainfall both preceding and during the data collection period for this study. This represents both a limitation of this study and an area for future consideration, as it does potentially illustrate how environmental changes might affect hoof orientation. Substrates will vary, often due to seasonal changes20 and the interaction between horseshoes and substrates will likely be different. The changes observed between horseshoes

and substrates all represent an immediate response to change, and it is possible that the effect of horseshoes and substrates would change given more time for the horse to adapt. As noted by Wilson et al., horses will redistribute loading based on pathologies, and care should be exercised when studying therapeutic horseshoes when applied to sound horses.21 The clinical importance of the changes in hoof orientation is beyond the scope of this project and requires future investigation.

AUTHOR CONTRIBUTIONS

The concept for the study and its implementation was the work of Patrick T. Reilly under the supervision of Thilo Pfau; data analysis and interpretation were performed by Darko Stefanovski, Thilo Pfau and Patrick T. Reilly; preparation of the manuscript was performed by Patrick T. Reilly with review by Thilo Pfau, Andrew van Eps and Darko Stefanovski.

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FUNDING INFORMATION

None.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

PEER REVIEW

The peer review history for this article is available at https://www.webofscience.com/api/gateway/wos/peer-review/10.1111/evj.13990.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

ETHICAL ANIMAL RESEARCH

Project approval was granted by the Royal Veterinary College's Ethics and Welfare Committee (URN 2020 1976-2).

INFORMED CONSENT

Owners gave informed consent for the inclusion of animals in this study.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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Veterinarian and Farrier Partnerships: **Proactive Equine Hoof Care**

By Sasha Hill, DVM, Associate Veterinarian, Cleveland Equine Clinic and President NAEP
Sponsored by Zoetis Equine.

ONE ASPECT OF EQUINE VETERINARY MEDICINE I especially appreciate is the team-oriented nature of the work. Hoof care professionals (farriers and barefoot trimmers) have become daily collaborators in our team's practice, which sees a lot of sports medicine and lameness.

Early in my career, equine veterinary mentors modeled to me just how impactful sustaining proactive veterinarian-farrier relationships can be. Each member of a horse's team adds a valuable perspective to the animal's well-being and performance, and the farriers I work with often have hoof health information that affirms and guides the next steps in my diagnostic and treatment processes. This article unpacks what I've learned when it comes to building successful connections with hoof care professionals and how to help our mutual clients prepare horses for safe, successful hoof care visits with their farrier.

LET'S DIVE IN: INVEST IN STRONG VETERINARIAN-FARRIER PARTNERSHIPS

Veterinarians are busy. Farriers are busy. However, we each share a common goal of supporting horses' well-being (including foot health and functionality). I've found that when farriers provide additional context based on what they're noticing at the farm, it helps me build a clearer picture of what might be causing a horse's pain or discomfort. A farrier's insights and observations of the horse's hoof health — especially any changes they're seeing in the hoof capsule — are pivotal in the vet-farrier relationship.

Farriers see their clients' horses every so many weeks in perpetuity, while veterinarians typically only see their clients' horses when something happens. Hence, quite often the keen observations of the farrier are what can dictate the prevention of eventual lameness by recommending that the horse be seen sooner rather than later. These insights can provide a leg-up on a potentially nagging or brewing pathology and may even prevent an injury from occurring. The workup that I provide and the findings that result should also be proactively shared with hoof care professionals because these findings can help inform their shoeing and trimming choices.

A strong working partnership with open lines of communication plays a pivotal role in the treatment, management, prognosis and shoeing of horses. Here are just a few important scenarios where veterinarians and farriers need to relay hoof care insights to each other:

- Endocrinopathy or metabolic disorders
- Acute or chronic laminitis

Often the keen observations of the farrier are what can dictate the prevention of eventual lameness by recommending that the horse be seen sooner rather than later.

- Heat in the feet and/or bounding digital pulses
- Neurologic disease (a safety issue)
- Lameness (where diagnosis helps guide shoeing for pathology or shoeing for long-term support and prevention)
- Rehabilitation plans
- Reactive, unruly behavior that may require sedation for the farrier's safety

ARE YOU SURE IT'S A FOOT ISSUE?

Lameness often involves looking at shades of gray, contextualizing the information and analyzing multiple variables at play. In this age of instant fixes, clients can be eager to try new horseshoes or switch farriers on a whim if a horse isn't healing quickly enough or isn't performing well. However, each equine patient's situation is unique and requires thorough analysis. I've unfortunately seen farriers' work be criticized by caretakers before I've even had the chance to fully investigate the true source of the horse's discomfort.

As veterinarians and farriers both know, it could be the foot, but there could be much more to the story too. This is where collaborative veterinarian and farrier appointments truly come into play. Following are a few next steps I like to take:

- Perform a lameness evaluation, watching the horse's gait on multiple surfaces if possible
- Localize the source of unsoundness with analgesia.
- Pursue diagnostics such as radiographs or ultrasounds based on the analgesia.
- Diagnose the horse as thoroughly as possible given the diagnostics performed and share the findings with the farrier (e.g., radiographs, writeups, exercise plans)
- Discuss with the farrier the type of footing the horse typically lives/performs in and how it might influence the optimal shoeing approach.
- Be present with the farrier for shoeing, which is optimal but not always possible.

The client's patience and trust in the process are also key while we investigate issues and recommend thorough treatment plans. Explaining why these steps are necessary helps get everyone on the same page. It's also important that the vet and farrier communicate directly with one another. The owner/trainer/manager shouldn't be a go-between.

PREPARE HORSES FOR SAFE FARRIER VISITS

At the end of the day, my goal is for veterinarians, technicians, assistants, farriers, trainers, horse owners and, of course, our horses to have an uneventful, safe day without injury. Safety is a necessary expectation for hoof care and veterinary visits. Each horse has idiosyncrasies, but they all need a solid foundation of trust built on good horsemanship skills from their owners, trainers and handlers.

To help horse owners prepare their horses for shoeing appointments, I recommend reviewing these tips outlined by farrier, Diego Almeida, in the following blog: "Tips to prepare for successful hoof care visits opens in a new window."

CARING FOR THE HORSES THAT GIVE US SO MUCH IN RETURN

Strong partnerships between veterinarians and farriers result in working dynamics that allow each of us to perform at our best. I'm excited to see equine practitioners continue to invest in partnerships that help us thrive both personally and professionally. From increased efficiency in our day-to-day lives to providing the most accurate diagnoses and treatment plans, working together for the horse results in the success we strive to achieve. We work with these incredible animals to see them improve and thrive, and in so doing we gain so much more from them in return.

About the author: Dr. Sasha Hill grew up in central Ohio riding hunters and jumpers. She graduated with honors from Otterbein University in 2008, having conducted research on anterior segment dysgenesis, now classified as equine multiple congenital ocular anomalies, in various breeds. In 2012, she graduated from The Ohio State University College of Veterinary Medicine. During her clinical year, she won awards for Excellence in Ophthalmology and Excellence in Equine Emergency and Critical Care.

Dr. Hill has been an associate veterinarian at Cleveland Equine Clinic (CEC) since 2012. She was mentored by Dr. Ron Genovese and Dr. Brett Berthold at CEC, focusing on ultrasound diagnostics, the Equinosis Q with lameness locator and regenerative medicine devices including VetGraft LLC. She works alongside farriers and other veterinarians as an integral part of her daily care, which concentrates on sports medicine and lameness. Since 2014, she has been a certified user of the Hallmarq Standing Equine MRI.

Dr. Hill currently serves on the board of the National Alliance of Equine Practitioners and is a member of the American Veterinary Medical Association, Ohio Veterinary Medical Association, American Association of Equine Practitioners and International Equine Ophthalmology Consortium.

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NAEP Student Scholarship Program

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The NAEP is proud to once again be offering the **NAEP Student Scholarship Program* for 2024**

THIS PROGRAM IS DESIGNED TO SUPPORT veterinary and farrier students and offer an opportunity to join the NAEP association, continuing education offerings and annual Saratoga Equine Practitioners Conference

**The scholarship will be awarded to one veterinarian student and one farrier student.*

The recipients will receive the following:

- Paid travel to and from the conference from within North America.
- Paid accommodations at our conference host hotel.
- Paid registration for the annual conference.
- Paid registration for the conference wet lab day.
- Special interaction with the board of directors and members of the program.

WHY YOU SHOULD APPLY

"Attending the NAEP's Saratoga Springs Equine Practitioners Conference was undoubtedly one of the most impactful experiences I could have had at this point in my career development. The Conference gave me the opportunity to not only gain new knowledge pertaining to my career, but it gave me the opportunity to witness firsthand how important making connections and relationships with others in our industry truly is. The NAEP brings together both Veterinarians and Farriers, which is rare to find such healthy relationships between the two careers. Planting the seed that these careers can work together and lead the way in bettering horses' lives when nourishing this relationship will be invaluable to my career. Having discussions and talking with the professionals making such a huge difference in our industry was inspiring. I've made so many connections that I now have so early on in my career. I am deeply appreciative to have had the opportunity to be the 2023 NAEP Farrier Student recipient and highly recommend students to apply"

– Gillian DeLure, Farrier Student
Recipient of the 2023 NAEP Student Scholarship

HOW TO APPLY

Potential students must apply to the NAEP office in writing by June 1st of 2024 to be considered for this award. A successful applicant must submit a 300–400 word essay in which they respond to one of the following questions. The NAEP requests that the essay is also accompanied by a minimum of one reference (from an advisor, professor, mentor, etc.)

1) How would you describe a successful relationship with your peers, be it veterinarians or farriers, and how do you think fostering respect among professionals can benefit the horse industry?

2) How does a sense of community and teamwork direct you in the future as well as assist you in the participation of an overall horse health team?

3) How do you value the role of professional associations such as the NAEP, AAEP, AFA, AAPF and what are your future interests in continuing education?

4) With respect to your chosen profession please share a personal or professional story in which an interaction with a veterinarian or farrier benefited you; or a case study that describes a successful relationship among professionals.

It is the mandate of the NAEP to foster respectful and successful relationships among professionals, as such your response may include positive and/or negative interactions and how these could be improved upon in future cases.

Qualifications for Veterinary Students

- Students should be in their second and third year of veterinary school in North America.
- Students should be considered to have a focus in the equine field and an interest in podiatry.

Qualifications for Farrier Students

- Students must be a graduate from a minimum 12 week program.
- Students should be actively working with another farrier as an apprentice.

Completed applications should be sent via email to info@thenaep.com no later than June 1st, 2024

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