

Clinical Studies

Correlation Between Acupuncture Point Sensitivity and Front Hoof Thermography in Horses: A Preliminary Investigation

Shu Dai, Deng-Shan Shiau, Jose Zilberschtein, Huisheng Xie

ABSTRACT

The objective of this pilot study was to determine whether acupuncture point sensitivity to palpation at LI-18 and/or PC-1 in horses was associated with changes in hoof surface temperature as measured by high-resolution infrared camera. Client-owned horses (n=18) presented for traditional Chinese veterinary medicine (TCVM) exam for poor performance were recruited. After 20 minutes of stall rest and permission for study participation, bilateral front hoof thermography was performed in a designated stall. This was followed by bilateral acupoint scan, with a positive scan identified when acupoint palpation elicited a flinch response. Study findings suggest acupoint scan results (positive versus negative) were associated with thermographic imaging temperature differences between the right and left front feet. Further investigation and confirmation of these findings is needed along with further studies associating this temperature difference with hoof disorders for diagnostic investigations.

Keywords: acupoint scan, acupuncture, acupuncture point scan, hoof temperature, infrared camera, thermography

Lameness is one of the most common health problems in horses and locating the source can be a diagnostic challenge for equine practitioners. Based on a national study, it is estimated that 50% of horse operations with 3 or more horses have 1 or more lame horses annually, and on a given day as many as 5% of the horses could be expected to be lame.¹ Limb or joint problems account for half of all lameness cases in the spring/winter and foot problems account for half of all cases that occur in the summer.¹ In many cases, lameness diagnosis may require advanced or comprehensive procedures such as local nerve blocks, arthroscopy, ultrasound, radiographs or magnetic resonance imaging (MRI). Some of these diagnostic tools, however, may not be readily available at many equine clinics, which could result in delayed diagnosis and treatment.

Meridian theory is one of the core components of traditional Chinese medicine (TCM)/traditional Chinese veterinary medicine (TCVM). In Meridian theory, each of the 12 regular Meridians consists of a network that connects specific *Zang-fu* organs internally with the associated joints, limbs and body surfaces externally through a group of acupoints.^{2,3} Sensitivity at specific groups of acupoints is considered highly correlated with disorders originating at various local and referred body sites associated with the Meridians/Channels.⁴ Based on this theory, the acupuncture point scan (APS) is a method of palpating specific acupuncture points to detect pain/sensitivity. The pattern of sensitivity has been used to diagnose and localize lameness and other disorders in horses.⁵ The APS

diagnostic method is not only safe and non-invasive but also without the additional cost of special equipment, and its outcomes have correlated with those of conventional clinical diagnosis.⁶⁻¹¹ Despite these findings, to date, this correlation has not been established using location-specific, objective and quantitative measurements. Once APS sensitivity can be correlated with a well-accepted physiologic measurement of lameness or hoof disorders, APS can be considered an evidence-based diagnostic and monitoring tool for equine lameness management.

Thermography is an imaging technique that uses an infrared camera to map and measure body surface temperature of specific anatomic sites. Skin temperature is largely under the control of the autonomic nervous system and inflammatory processes. Sagittal symmetry of thermal distribution is expected throughout the body. Asymmetric infrared emission of 1 °C or greater can be indicative of sympathetic nervous system dysfunction or other pathology.¹² The use of thermography, as a noninvasive method to detect and assess equine lameness, continues to increase along with protocols to minimize artifacts that have been associated

Author Professional Degrees and Certifications: DVM, MS-TCVM (Dai), PhD (Shiau), DVM, MS, PhD (Zilberschtein), DVM, MS, PhD (Xie); **From:** Equine Acupuncture Center (University of Florida), Reddick, FL (Dai, Shiau, Xie) and College of Veterinary Medicine, Murcia University, Spain (Zilberschtein); ***Address correspondence to** Dr. Shu Dai (daishu@chiu.edu).

with past use of the procedure.¹²⁻¹⁴ Additionally, clinical investigations have demonstrated its reliability when used for diagnosing tendon-ligament injury, joint disease, stress fractures, navicular disease and back pain.¹⁵⁻²¹ Higher therapeutic success rates have been obtained when the physiological diagnostic imaging of thermography is paired with the anatomical imaging of ultrasound and radiographs for equine limb pathology and its superiority for diagnosing caudal back pain.¹³ With consideration of its use in lameness diagnosis, thermography could serve as a quantitative physiologic measurement for validation of acupuncture point sensitivity as a diagnostic tool.

The purpose of this study was to determine whether there exists a relationship between acupoint sensitivity and hoof temperature on thermographic images. The acupoints Large Intestine 18 (LI-18) and Pericardium 1 (PC-1) have been used as key diagnostic points for front hoof pain/disorders.⁹ Both acupoints are on Meridians that flow through the front hooves with the LI Meridian starting at the craniomedial coronary band while the PC Meridian ends on the palmar side of the foot between the bulbs of the heel.²¹ APS sensitivity at these acupoints is considered, in TCVM, to indicate pain in the front foot on the ipsilateral side of the horse and has been validated in current studies.^{9,10} Hoof pain/inflammation often is associated with regional blood circulation changes that could lead to surface thermal changes. Based on this, it was hypothesized that horses with unilateral positive LI-18/PC-1 APS scan would have greater thermal measurement differences between thoracic hooves than horses with bilateral negative APS scans.

MATERIALS AND METHODS

Animals

Adult performance horses, regardless of age, sex or breed, admitted to the Equine Acupuncture Center (University of Florida), Reddick, Florida, USA between September 15th and December 15th, 2019 for TCVM exam and acupuncture/Chinese herbal medicine therapy were eligible for the study. Horses were only excluded from recruitment if owner informed consent was not obtained. Rectal temperatures of all study candidates were measured after 20 minutes of stall rest and any horse recording over 101 °F or having medications or wraps on the hoof that could not be removed were excluded, as these conditions were likely to affect the thermography measurements.

Experimental Procedure

This study was designed as a pilot phase to evaluate the feasibility of a research project to investigate thermography and acupuncture point sensitivity. After



Figure 1: All thermal images were taken in a designated infrared thermography (IRT) imaging stall (pictures) with an ambient temperature ranging between 20 °C to 30 °C.

permission for study participation, each recruited horse was individually brought to the designated imaging stall (Figure 1). The front hooves were then visually inspected for problems (e.g. wraps, topical hoof medications) and a potential study horse was eliminated from sampling if the problem was determined to interfere with accurate hoof imaging. The horse was then allowed to rest for at least 20 minutes to acclimatize to the thermographic imaging environment.²² This was followed by checking the rectal temperature of a horse to verify a body temperature less than 101 °F (normal equine range 36.0 °C-38.0 °C/ 96.8 °F-100.4 °F).²³ Hoof imaging for all study horses was then performed with a portable high-resolution infrared camera^a (Table 1). The experimental protocol for all procedures in the study (equipment, environment, imaging technique, image analysis) were performed in a standardized manner as described in this section. The camera was calibrated prior to use by a company representative^a with expertise in the equipment to be used in the study investigation.

Table 1: Summary of specifications for the thermal camera^a used to produce hoof images of study horses; the unit measured 327,680 points of temperature (highest resolution available)

Thermal Camera Specifications	
Detector Array	FPA (VOx)
Pixel Resolution	640 x 512
Frame Rate	30 Hz
Pixel Pitch	17 µm
Thermal Sensitivity	<0.02 °C at 30 °C
Accuracy	+/- 1 °C
Spectral Response	7 µm-14 µm.75G Shock/4G vibration

Thermal images were taken in the designated infrared thermography (IRT) imaging stall the horse had acclimatized to, with an ambient temperature ranging between 20 °C to 30 °C, according to Veterinary Guidelines for Infrared Thermography.¹² The stall had the lights and fan turned off and was free from drafts. The position of the stall in the barn (facing indoor arena) prevented exposure to infrared rays such as incandescent lights or direct sunlight that might result in heating or reflective artifacts.

The IRT imaging techniques were directed at defining the region of interest (ROI) which was a dorsopalmar view of the front hooves. This imaging area technique was selected due to less interference from the haircoat (only minimal coronary band hair in image), and covered almost 80% of the hoof. The distance between the camera and the targeted hoof was 45 cm, based on previous investigations of thermal imaging techniques demonstrating that 45 to 100 cm distance has no significant effect on measurement.²⁴ As the IRT imaging method specified, any other object having contact with the hooves to be examined would be removed for a minimum of 20 minutes prior to commencement of the thermal imaging.

Before the hoof images were taken, the foot was placed on a wood board (Figure 2). To ensure that nothing was in the frame that could increase camera temperature range (e.g. lights, sun through a window or on barn metal siding, requirement for homogeneous background), a cardboard screen was used to block the rear legs of the horse and other objects in the stall. To capture images, the IRT imaging camera lens was perpendicular to the ROI of the targeted hoof and was focused on the hair around the coronary band. The images were first captured with grey scale to allow accurate focusing and then changed to the rainbow palette for analysis.

Freehand drawing on the recorded images was used to select the targeted area of the hoof for data collection. The hand drawn region included the hoof above the shoe nails (i.e. horses could be shod/unshod as thermal calculated zone did not include shoes/nails) and below the upper coronary band hair margin (Figure 3). The thermal readings of this hoof region were collected for analysis.

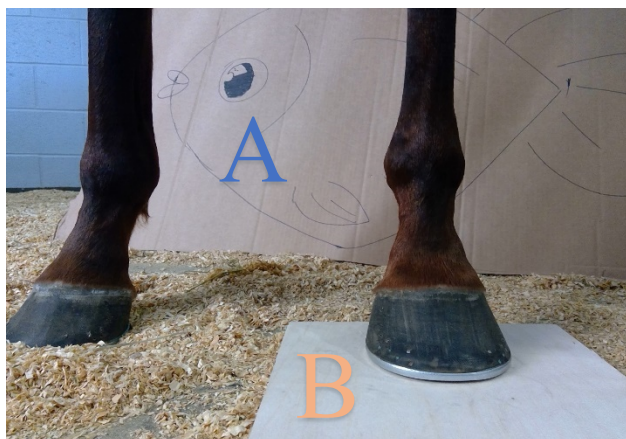


Figure 2: Before hoof images were taken, the foot was placed on a wood board (B). To ensure that nothing was in the frame that would increase camera temperature range, a cardboard screen (A) was used to block the rear legs of the horse and other objects in the stall

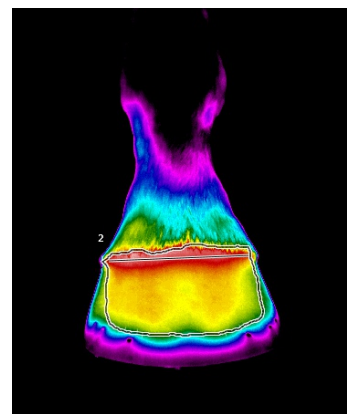


Figure 3: Region of Interest (ROI) selected for analysis; freehand drawing on the recorded images was used to select the targeted area of the hoof for data collection. The hand drawn region included the hoof above the shoe nails and below the upper coronary band hair margin (hand drawn grey line in this image).

Immediately after the thermo-imaging, APS was performed on LI-18 and PC-1 bilaterally to determine sensitivity/pain at each acupoint (Figure 4). This procedure was performed using an acupuncture needle guide tube (28 gauge, 2 inch) which was stroked firmly across the skin on a neutral area of the neck (base of mane) that does not have diagnostic acupoints. This preliminary step both familiarized the horse with contact by the tool and allowed the clinician to gauge the amount of pressure to exert on the skin of that individual. The pressure was sufficient to be easily felt by the horse on the skin and underlying musculature but be well-tolerated by that individual. At LI-18, the strokes of APS were in a cranial-to-caudal direction, but at PC-1, the APS strokes were in a dorsal-to-ventral direction. The scanning stroke was repeated 5 times. To be assigned a sensitivity grade, at least 4 of 5 strokes had to have a positive response. Based on a horse's response (behavior change) to palpation at each acupoint, the sensitivity was graded on a scale from 1 to 5 (Table 2).⁵ The veterinarian (CVA qualified) who performed the APS was blinded to each horse's physical condition/clinical diagnosis and thermal imaging results. The same person performed all APS evaluations on study horses to reduce between-subject variability. The APS and horse's response were recorded during examinations for later evaluation.

Table 2: The acupuncture point sensitivity scoring system

Grade	Criteria*
0	No response
1	Minimal local reaction; an inconsistent localized flinch
2	A mild consistent localized flinch
3	A moderate regional consistent twitch or mild whole body reaction
4	A severe regional flinch or moderate whole body reaction to scanning of the acupoint
5	Dramatic response with severe flinching, evasion/attempt to run away and may kick, bite or paw at evaluator when the acupoint is scanned

* Scanning of an acupoint was repeated 5 times, and at least 4 of 5 strokes had to have a positive response to be assigned a grade.



Data Analysis

The thermal data was collected from the camera after each horse completed the study and mean temperature (maximum) of the dorsal surface of the front hooves were then calculated. A positive APS outcome (APS+) was defined using both acupoints or only one acupoint. Horses enrolled in the study that had a positive acupuncture point scan for LI-18/PC-1 on only 1 side of the body were compared to horses with negative acupoint reactivity on both sides of the body. Horses that had positive acupoints on both sides of the body were not assessed in this preliminary study. As a pilot investigation on the association of acupoint sensitivity and thermography (hoof temperature change) between the positive and negative acupoint sensitivity sides of the body, for each APS group (Group 1: positive on one side only; Group 2: negative on both sides), pairwise-temperature comparison between the two hooves was performed (Wilcoxon sign rank test). Summary statistics of the temperature data were presented as mean±standard deviation. Significance level was set at 0.05 for all tests. All data graphic presentations and statistical analysis were performed using a commercial statistical software^b.

Figure 4: Locations of LI-18 and PC-1; the acupoint LI-18 is located at the depression just above the jugular groove, along the line of the ventral mandible with the head extended; PC-1 is located at the depression, medial to the point of the elbow and in the fifth intercostal space. The long red arrow at the bottom of the picture indicates the ROI for thermal imaging (dorsal surface of the hoof).

Table 3: Pilot study findings for the 5 study horses with unilateral positive acupoint sensitivity listing hoof temperatures for the right and left hoof, along with acupoint sensitivity score results as measured by digital infrared thermography.

Horse	AP Scan-L Foot (LI-18)	AP Scan-L Foot (PC-1)	AP Scan-R Foot (LI-18)	AP Scan-R Foot (PC-1)	L Foot Max T °F	R Foot Max T °F
Group 1						
H-04	0	0	4	4	92.2	94.1
H-08	4	0	0	0	91.2	90.6
H-09	0	0	3	3	94.9	96.4
H-10	4	2	0	0	90.4	89.9
H-11	0	0	4	4	91.5	93.7
Group 2						
H-02	0	0	0	0	96.8	96.9
H-03	0	0	0	0	92.7	93.1
H-05	0	0	0	0	93.5	94.0
H-06	0	0	0	0	92.3	93.5
H-07	0	0	0	0	95.3	95.9
H-13	0	0	0	0	96.0	94.4
H-15	0	0	0	0	97.8	98.8
H-18	0	0	0	0	97.0	97.4

L=left, R=right, T=temperature

RESULTS

A total of 18 horses were enrolled in this small pilot study. Out of these horses, there were 5 horses that had a positive scan for LI-18 and/or PC-1 on only 1 side of their body (Group 1), and there were 8 horses with bilateral negative acupoint sensitivity (Group 2) [Table 3]. This simple grouping allowed hoof temperature comparison of the hoof associated with a positive acupoint scan with the opposite front hoof that had a negative scan. Five other horses had positive APS outcomes on both hooves and were excluded from the data analysis.

All 5 horses in Group 1 had a higher temperature (maximum) on the hoof that had a positive scan outcome than the hoof with the negative outcome ($p = 0.0625$ against the chance level). The group mean $\pm$ SD temperature (maximum) on the APS+ hooves was 93.2 ± 2.4 °F and was 91.8 ± 1.9 °F over the negative hooves (Figure 5). The mean difference was 1.34 ± 0.76 °F ($p = 0.0625$ against the H_0 : both sides are equal). Horses with bilateral negative acupoint sensitivity (Group 2) had a mean temperature difference between the 2 sides of the body of 0.33 ± 0.85 °F; $p = 0.1953$ (Figure 6).

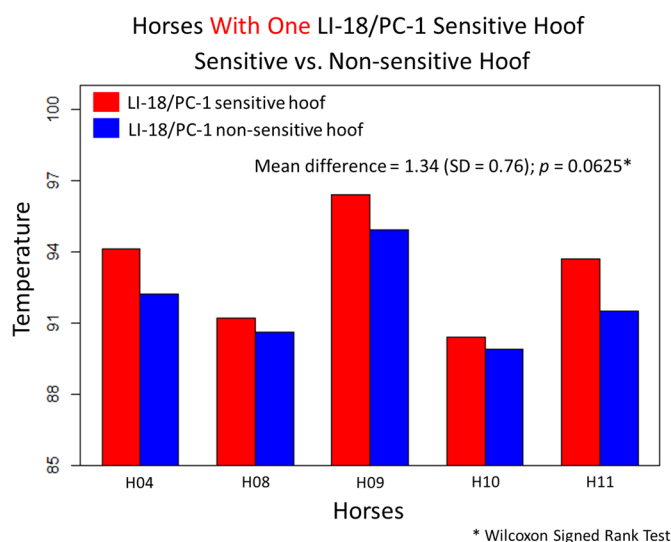


Figure 5: Horses with one side LI-18/PC-1 Sensitive

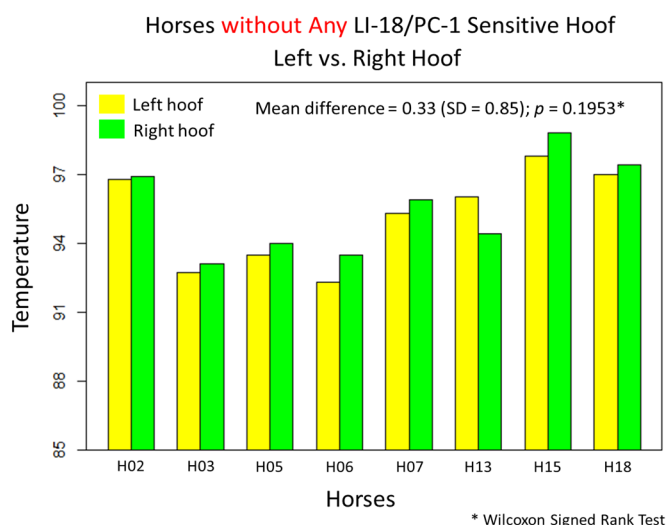


Figure 6: Horses with no acupoint sensitivity (bilateral negative scans)

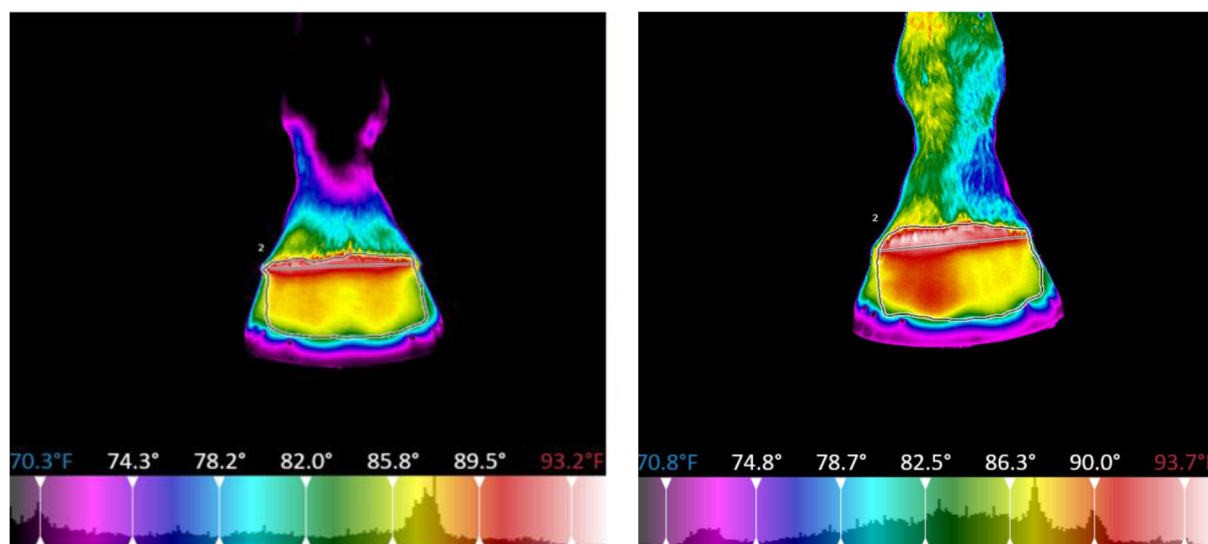


Figure 7 (case example): 3-year-old TB gelding (H-04) with pain in the left stifle which resolved but developed a recent lameness in right front limb. Thermographic image on left is left front foot (max temp:92.2) and image on right is right front foot (max temp: 94.1); left acupoint scan=negative and right acupoint scan = +4 positive for both LI-18 and PC-1.

DISCUSSION

Thermal imaging provides a remote quantitative measurement of changes in body temperature at anatomic areas of interest through a non-invasive process. It is a rapidly evolving technology with multiple studies investigating standardization and recommendations for clinical usefulness.¹²⁻¹⁴ The objective of this small pilot study was to use thermal medical imaging to determine whether acupuncture point sensitivity to palpation at LI-18 and/or PC-1 in horses was associated with forelimb hoof surface temperature change as measured by a high-resolution infrared camera. It was hypothesized that study horses with unilateral acupoint sensitivity would have significant thermal measurement differences between their front hooves, whereas horses with a negative acupoint scan would have little hoof temperature difference, as demonstrated by thermographic imaging of the front hooves.

Study findings had an increased mean ($1.34^{\circ}\text{F} \pm 0.76^{\circ}\text{F}$, $p = 0.0625$) hoof temperature difference between front hooves in horses associated with a unilateral acupoint positive test versus the more symmetrical temperature in negative acupoint sensitive scan hooves ($0.33^{\circ}\text{F} \pm 0.85^{\circ}\text{F}$). Even though the mean temperature difference did not reach 0.05 statistical significance level in this small number of horses ($n=5$), the magnitude of the change was greater than 1°F . Evaluation of standard images, by investigators in a recent study, demonstrated mean contralateral forelimb temperature variation between corresponding areas was $0.32^{\circ}\text{C} \pm 0.27^{\circ}\text{C}$ ($0.58^{\circ}\text{F} \pm 0.49^{\circ}\text{F}$) between corresponding areas, despite technique differences. The authors concluded temperature variation greater than this with additional consideration of specifications of the infrared camera used, may be clinically relevant and indicate a pathological process. The authors also emphasized evaluating thermographically determined temperature differences in concert with medical history and clinical examination.²⁴ With these considerations, the temperature difference findings in the present study suggest that unilateral acupoint sensitivity at LI-18 and/or PC-1 in horses is associated with a biologically meaningful front hoof surface temperature difference as measured by thermography (Figure 7 case example).

By design, the protocol allowed flexibility to identify and address problems that might jeopardize the success of the main project. It allowed study investigators to optimize infrared camera operation, gain experience recruiting study subjects, and standardize research environment/procedures (e.g. barn temperature, sunlight, angle of camera, preparation of hooves). This work additionally allowed testing of methods and procedures suggested by other groups for use of the infrared camera within the facility environment where the main investigation would be conducted.¹²

Problems noted and addressed during this preliminary investigation included 1) optimizing the ROI (dorsopalmar view) to avoid hair and provide consistent thermal image

repetition and 2) freehand drawing on the thermal image of the ROI avoided temperature artifacts from hoof nails/shoes. These 2 learnings are critical for conduct of the main study. The trend noted in this study (increase mean hoof temperature difference), although not statistically significant in this small group of horses, suggest that thermography could be successfully used to investigate the validity of acupoint sensitivity. Findings from this study (association of hoof surface temperature and acupoint sensitivity), were used to determine the likely success of the main trial and the appropriateness to proceed.

There have been several thermography studies on horses reported, and the thermal imaging procedures/protocols have predominately focused on larger ROIs (e.g. whole extremities, the foot including the fetlock).^{14,17,19,24} Based on the authors' knowledge, there has not been a standardized thermography protocol specifically for hooves in horses. Important aspects considered when developing a hoof thermography protocol included artifacts from hair, metal shoes and nails. As the hair coat on horses can significantly affect thermal imaging, the readings from images captured on the hoof surface employed in this study focused on the craniodorsal aspect of the front hooves.²⁵ This imaging area, which has less interference from the haircoat (only minimal coronary band hair in image), covers almost 80% of the hoof and maximizes hoof temperature determination with little hair artifact. An additional imaging requirement to decrease variability was selecting an ROI which would not include hoof nails/shoes in a thermal reading. This would allow horses to be shod or unshod without restrictions when having hoof thermography performed. Shapes provided by computer software (i.e. various geometric outlines) did not optimally delineate the ROI area. A freehand technique to outline the ROI was developed in the pilot study to maximize accurate thermal measurement (Figure 3). The imaging protocol developed for this study provides additional data to help standardize equine hoof thermography. Further study (large main clinical trial) is recommended based on the findings of this study. An enrollment goal of 100 horses made up of 75 subjects (unilateral positive acupoint scan), 20 subjects (bilateral acupoint negative) and 5 (bilateral acupoint sensitivity) is suggested. This sample size will have an approximate 77% power to reject the null hypothesis with a 0.05 significance level.

In summary, this pilot study procedure included bilateral front foot thermography followed by acupuncture point scan at LI-18 and PC-1. Comparisons were made of hoof temperature and acupoint sensitivity. The acupoint scan results were associated with thermographic imaging temperature differences between the right and left front feet in this study in horses with a unilateral positive acupoint scan. Future investigation is recommended to study correlations between hoof pathology and APS outcomes.

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Declaration of Interest and Funding

The authors declare that there is no conflict of interest that could be perceived as prejudicing the impartiality of this paper and the authors did not receive any specific grant of funding from any organization in the public, commercial or non-profit sectors.

FOOTNOTES

^a IR Tablet 640 thermal camera, Digatherm LLC, Ocala, FL, USA

^b R version 3.5.2. The R Foundation for Statistical Computing, Vienna Austria; <http://www.R-project.org>

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