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Acute effects of dermal suctioning on back pain in racehorses: a pilot study

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RESEARCH ARTICLE

Abstract

Back pain is a common clinical condition that leads to poor performance in racehorses. Therefore, horse owners would benefit from a suitable and effective treatment that results in the early recovery of their horses. Dermal suctioning significantly improves chronic lower back pain in humans. Thus, if a similar effect were to be found in racehorses, it could become a new treatment for back pain in horses. In this study, we examined the acute effects of dermal suctioning on back pain in racehorses. Twelve Thoroughbred racehorses with back pain underwent 10 min of dermal suctioning in the thoracolumbar region. The pain score, mechanical nociceptive threshold (MNT), heart rate variability (HRV), and plasma cortisol concentrations were measured. Results showed that pain scores were significantly improved immediately after dermal suctioning (P=0.028), while MNT, HRV, and plasma cortisol concentrations did not show significant changes (P>0.05). These results indicate that dermal suctioning immediately relieves pain but has a limited effect on the other three parameters.

Keywords: cupping, thoracolumbar pain, Thoroughbreds

1. Introduction

Back pain is a common clinical condition that leads to poor performance in racehorses (Jeffcott, 1980; Mayaki *et al.*, 2020). A previous study showed that the prevalence of back pain is 2% in Thoroughbred racehorses and 94% in equine chiropractic clinics (Haussler, 1999). Back pain causes a variety of musculoskeletal dysfunctions, including hypertonicity of the thoracolumbar muscles, axial skeleton stiffness, and gait abnormalities (Mayaki *et al.*, 2019, 2020). Landman *et al.* (2004) compared horses diagnosed with back pain with healthy horses. They found that the proportion of horses with lameness was approximately 3.8 times higher in the group diagnosed with back pain. As back pain is believed to cause poor performance in racehorses, a suitable treatment for early recovery is of major significance to horse owners.

In humans, dermal suctioning, a traditional Chinese medical treatment also known as 'cupping,' has been widely used as a treatment to alleviate back pain for more than 2,000 years. This treatment involves the application of negative pressure to a target area using a specialised cup. Dermal suctioning is reported to have various effects, including pain reduction, increased blood circulation, and hematological adjustment (Aboushanab and AlSanad, 2018; Al-Bedah *et al.* 2019; Kim *et al.*, 2018). Furthermore, studies in humans show that cupping therapy significantly improves chronic lower back pain (Moura *et al.*, 2018; Rozenfeld and Kalichman, 2016). In recent years, there has been one report of the use of cupping therapy in horses, which determined the effects of wet cupping therapy on hematological and biochemical parameters in healthy horses (Shawaf *et al.*, 2018). To the best of our knowledge, there have been no previous studies that examined the effectiveness of dermal suctioning in alleviating back pain in horses.

To test the hypothesis that dermal suctioning improves back pain, we examined the acute effects of dermal suctioning on back pain in racehorses.

2. Materials and methods

Horses

The study was approved by the Northernfarm Ethics Committee (No. 202201). We selected twelve Thoroughbred racehorses kept at the same training stable which showed escape behavior and suspected back pain on palpation during routine medical examination. Diagnosis of back pain was made by palpation before the measurement on the day of the experiment, as in previous studies (Ericson *et al.,* 2020; Varcoe-Cocks *et al.*, 2006). Horses determined to have back pain by this diagnosis were subjected to the experiment. The severity of back pain was classified into four levels, specifically, the horse's response when moderate pressure was applied to the measurement site with a thumb was scored on a scale from 0 to 3 (score 0, no reaction; score 1, nose wrinkling, ear flattening, and slight spasm on palpation without associated movements; score 2, head jerk, teeth-baring, tail lashing, foreleg stamping, aggressive tail flattening, hind leg rising, and spasms on palpation with associated local movement; score 3, kicking, biting, rearing, sour attitude, restlessness, and shrinking away from the hand) (Ericson *et al.,* 2020; Varcoe-Cocks *et al.*, 2006). Score 0 was judged to be no back pain; 1-3 indicated the degree of back pain; score 1 was considered mild pain and score 3 was considered severe pain. The measurement site was approximately 3 cm to the left of the spinous process of the last thoracic vertebra (Figure 1A). Previous studies used an algometer to assess back pain in horses, and the measurement site was 2-5 cm lateral to the last thoracic vertebra (De Heus *et al.*, 2010; Pongratz and Licka, 2017). In our study, we selected a measurement site that falls within this range. In addition, Pongratz and Licka (2017) suggested that the mechanical nociceptive threshold (MNT) is influenced by muscle thickness, and therefore, a lower MNT may be detected in the chest area, which has a thinner muscle layer than the lumbar area, even in horses without clinical signs of back pain. To prevent this from influencing the results, L18, which has a relatively thick muscle layer, was selected as the measurement site. The examinations were performed three times on each horse, and the average score was calculated. All horses had back pain scores of 2, which indicated moderate back pain, hence the diagnosis of back pain; therefore, all of them were subjected to the experiment.

Horses also underwent lameness evaluation before the tests using the American Association of Equine Practitioners lameness scale, with grades ranging from 0 to 5 (score 0, sound; score 1, mild lameness observed while the horse is trotted in a straight line; score 2, obvious lameness observed; score 3, pronounced head nod and pelvic hike of several centimeters noted; score 4, severe lameness with an extreme head nod and a pelvic hike present; score 5, the horse does not bear weight on the limb) (American Association of Equine Practitioners, 1999). All horses exhibited lameness grade 0 in the lameness evaluation. All the twelve horses were mares, with a mean (± standard deviation) age of 3.7 (±1.0) years and an average weight of 460 (±20) kg. All racehorses actively trained in the morning before the

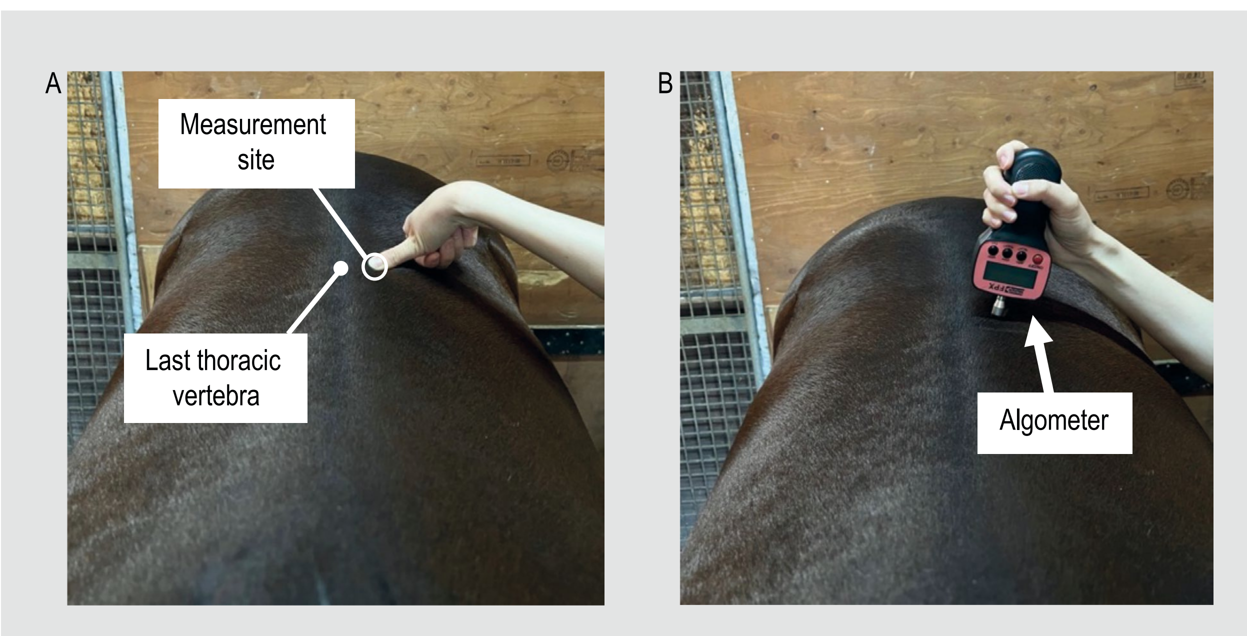

Figure 1. Measurement site. (A) The diagnosis of back pain and the determination of the pain score were made by palpation approximately 3 cm to the left of the spinous process of the last thoracic vertebra. (B) The mechanical nociceptive threshold was measured at the same site using an algometer.

measurement, but they did not train over the maximum speed of 48 km/h on the experiment day.

Measurement schedule

Figure 2 shows the measurement schedule. The pain score, mechanical nociceptive threshold, and plasma cortisol concentrations were measured at three time points: immediately before dermal suctioning (M0), immediately after the treatment (M1), and 10 min after the treatment (M2). Heart rate variability (HRV) was recorded twice for 10 min each: 10 min before dermal suctioning (pre-treatment) and 10 min after (post-treatment). Horses were trained in the morning and then underwent measurement during the afternoon and evening when it was quiet and no workers were present in the stables. A handler restrained the horse while it was standing square in a stall and performed the measurements. All procedures and measurements were performed by an experienced veterinarian (RN) who routinely examines racehorses.

Dermal suctioning

Medicell equipment (MJ Company Co., Ltd., Okayama, Japan) was used for dermal suctioning. The Medicell consists of a main device that generates negative pressure and a probe that suctions the skin. A monitor on the main device shows the amount of negative pressure generated in real time (Figure 3). This device has been used in human research on dermal suctioning (Enomoto *et al.*, 2021). During the experiment, dermal suctioning was applied by moving the 4.5-cm-diameter probe around the target area while maintaining a constant negative pressure at 50 kPa. The target area was the thoracolumbar region, from the caudal side of the withers to the buttocks. The probe was moved along the spine, from the cranial to the caudal side, for 10 min in total, with 5 min each on the left and right sides (Figure 4).

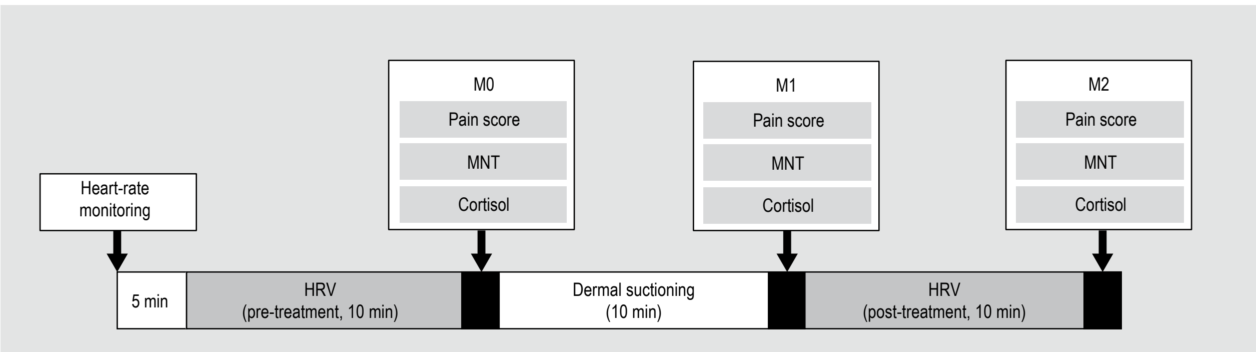

Figure 2. Measurement schedule.

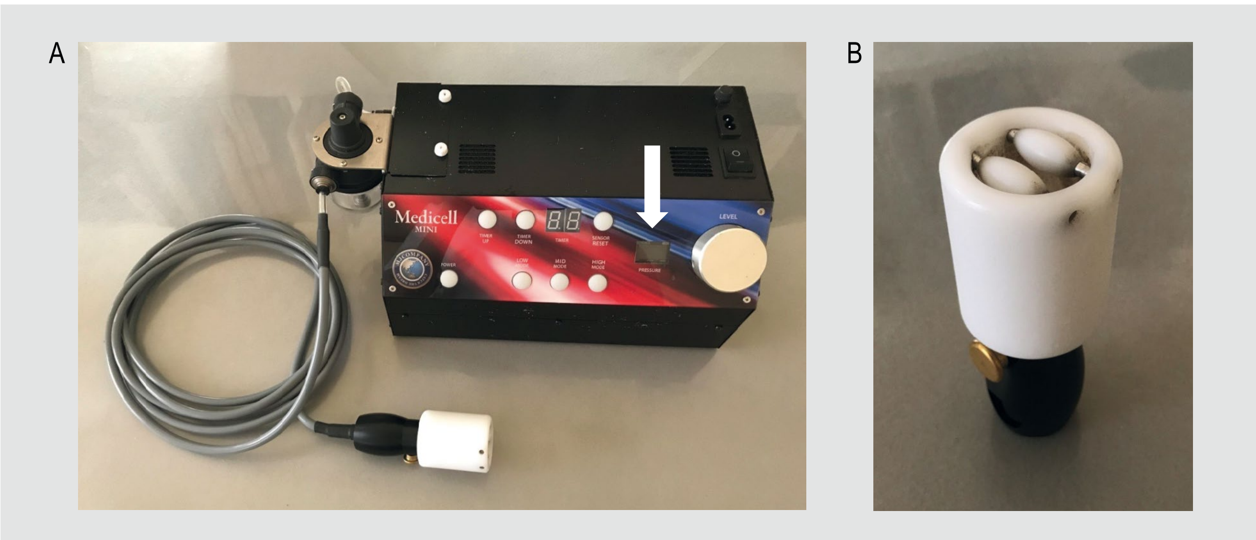

Figure 3. Equipment used for dermal suctioning. (A) Medicell equipment was used for dermal suctioning. The Medicell consists of a main device that generates negative pressure, a probe that suctions the skin, and a monitor on the main device that shows, in real time, how much negative pressure is being generated (arrow). (B) The probe (4.5 cm diameter) that suctions the skin.

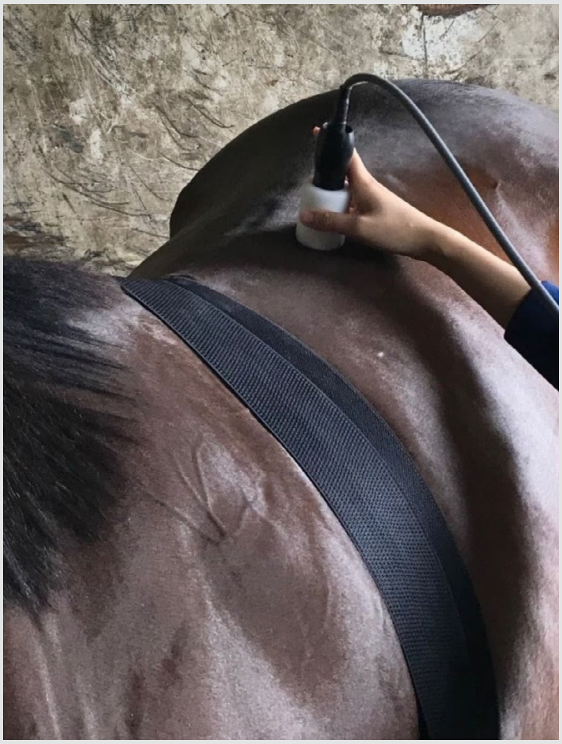

Figure 4. Dermal suctioning.

Pain score and mechanical nociceptive threshold

Pain score was determined based on the four-level classification used to diagnose back pain described in the 'Horses' sub-section in the 'Materials and methods' section (Ericson *et al.*, 2020; Varcoe-Cocks *et al.*, 2006). Briefly, the horse's response when moderate pressure was applied to the measurement site using a thumb was scored on a scale from 0 to 3. The measurement site was the same as the one assessed in the diagnosis of back pain (Figure 1A).

An algometer (Pain test algometer FPX100, Wagner Instruments, Greenwich, CT, USA) was used to measure the MNT required to elicit a pain response, with low MNT values indicating more severe pain (Fischer, 1986; Trager *et al.*, 2020). The algometer was slowly applied to the same sites where the pain score was determined (Figure 1B). The pressure (N) threshold at which the horse first exhibited an avoidance response (skin twitching, local muscle contractions, induced lordosis, and stepping away) was measured. Measurements were performed three times for each horse and the mean value was calculated. In addition, the MNT percentage change (%) from baseline (M0) was calculated at M1 and M2.

Heart rate variability analysis

The present study used Polar heart rate monitors (Polar RS800CX Science Equine, Polar Electro Canada, Lachine, QC, Canada) to measure heart rate. Heart rate monitor electrodes were moistened before being attached to the left side of the chest. After a 5-min habituation period, the RR interval (interval between two successive heartbeats) was recorded. Recorded RR intervals were transferred to the Polar Pro Trainer 5 (Polar Electro Europe BV, Fleurier Branch, Switzerland) program to calculate the standard deviation of all normal-to-normal RR intervals (SDNN) and the root mean square of successive RR differences (RMSSD). RR intervals that deviated by ±25% or more from the mean of five consecutive RR intervals were eliminated manually as noise (Ohmura and Jones, 2017).

Plasma cortisol concentrations

In the present study, plasma cortisol concentrations were measured to evaluate the response of the endocrine system to stress. Blood collected from the jugular vein was placed in a test tube containing heparin (Venoject, TERUMO Corp., Shibuya City, Japan) and was then refrigerated. Plasma cortisol concentration was measured using a chemiluminescent enzyme immunoassay (Immulite 1000 cortisol, SIEMENS, Munich, Germany) at a commercial veterinary laboratory (Fujifilm Vet Systems Co., Ltd., Tokyo, Japan).

Statistical analysis

Statistical analyses were performed using SPSS software (Version 26, IBM Corporation, Armonk, NY, USA). For the pain score, the Friedman test was used to verify whether there was a change due to dermal suctioning. If the results of the Friedman test was significant, differences between pre-treatment and other conditions were tested with the Wilcoxon signed-rank test, applying the Bonferroni correction for multiple comparisons. To verify whether there was a change in the MNT, MNT%Δ, and cortisol concentrations due to dermal suctioning, a one-way repeated-measures analysis of variance (ANOVA) was performed. When appropriate, multiple comparisons with Bonferroni-corrected paired t-tests were used to evaluate differences between pre-treatment and each post-treatment condition. For the comparison between pre-treatment and post-treatment, the SDNN and RMSSD were analysed using a paired t-test. The level of significance was set at $P<0.05$.

3. Results

The pain scores for each measurement are shown in Figure 5. The Friedman test revealed a significant overall effect of the treatment on the pain score ($\chi^2=8.273$, $P=0.016$). Multiple comparisons indicated that the pain score in M1 was significantly lower than that in M0 (P=0.028). However, no significant difference was found between pain score values at M0 and M2 (P=0.068).

The MNT and cortisol concentrations for each measurement are shown in Figure 6. One-way repeated-measures ANOVA revealed no significant main effect of time on the MNT (F=1.133, P=0.340), MNT%Δ (F=1.602, P=0.224), and cortisol concentrations (F=0.569, P=0.498). No significant difference was found in the SDNN (P=0.218) or RMSSD (P=0.288) values between pre-treatment and post-treatment (Figure 7).

4. Discussion

In the present study, we evaluated the pain scores, MNT, HRV, and plasma cortisol concentrations before and after 10 min of dermal suctioning to investigate the acute effects of this treatment on back pain in racehorses. We found that the pain score was decreased significantly after dermal suctioning, and that HRV and plasma cortisol concentrations did not change significantly after the treatment. To the best of our knowledge, the present study is the first to examine the effects of dermal suctioning on back pain in horses.

In our study, pain scores decreased significantly after a 10-min dermal suctioning session (Figure 5). This indicated that dermal suctioning immediately improved back pain in racehorses. This is consistent with the findings of Kim *et al.* (2018) who reported that cupping therapy had pain-relieving properties in humans. Previous studies have explained the pain-alleviating effects of cupping therapy based on mechanisms such as the pain-gate theory, diffuse noxious inhibitory controls theory, and reflex zone theory (Al-Bedah *et al.*, 2019). The pain-gate theory hypothesises that skin stimulation from cupping affects chronic pain by altering the pain signals at the level of nociceptors in the spinal cord and the brain (Moayedi and Davis, 2013). Diffuse noxious inhibitory control is a phenomenon in which a nociceptive stimulus at a distant site suppresses the wide dynamic range of neurons in the dorsal horn, which suppresses the transmission of the original pain signal (Le Bars *et al.*, 1992). Since the external symptoms of visceral disease often appear far from the organs, the reflex zone theory proposes that a link exists between one organ and another in the body through the interaction of nerves, muscles, and chemicals. For example, as a reflexive sign of illness, the skin becomes pale and cold due to vasoconstriction, and warm and red due to vasodilation. Suction stimulation of the skin by cupping may ultimately relieve pain by stimulating skin receptors and improving blood circulation through neural connections to the affected organs (Al-Shidhani and Al-Mahrezi, 2020). The pain-relieving effect of cupping therapy in humans is explained by the aforementioned mechanism. However, there is no single

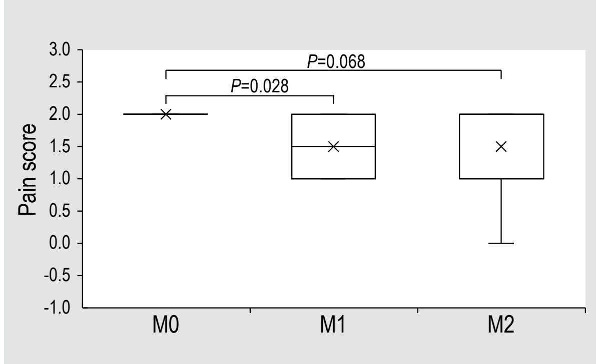

Figure 5. Pain score at M0, M1, and M2. The box plot shows the median (line) and mean (×), with the box showing the interquartile range (IQR) and the whiskers showing the maximum and minimum values.

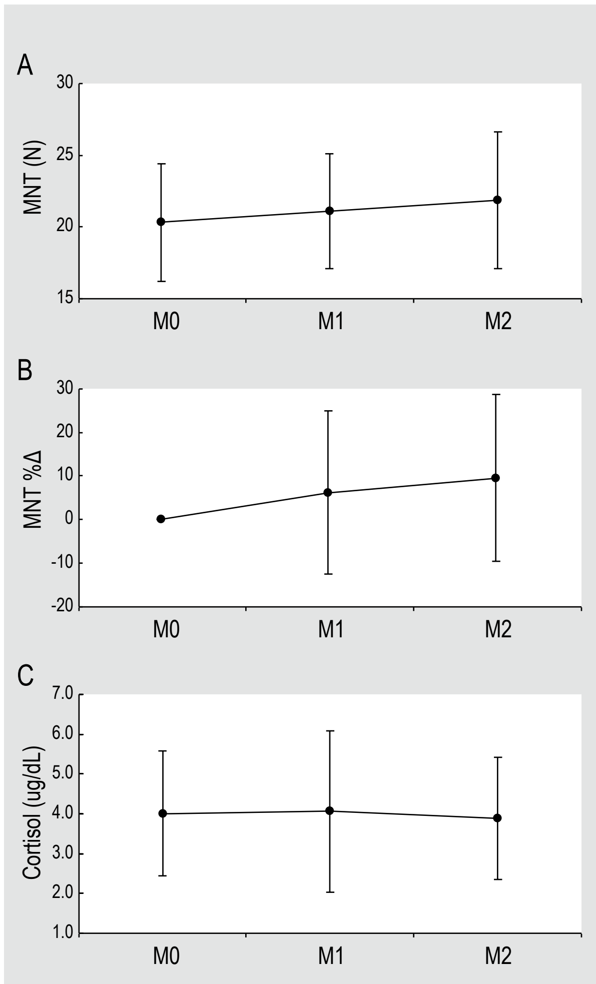

Figure 6. Mean values and standard deviations of the (A) mechanical nociceptive threshold (MNT), (B) MNT average percent change from M0 (MNT%Δ), and (C) cortisol concentrations at M0, M1, and M2.

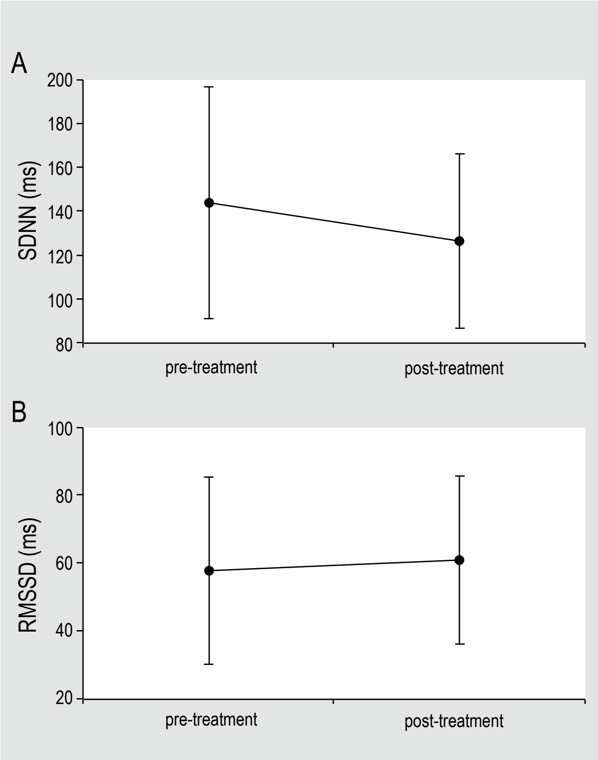

Figure 7. Mean values and standard deviations of (A) the standard deviation of all normal-to-normal RR intervals (SDNN) and (B) the root mean square of successive RR differences (RMSSD) during pre-treatment and post-treatment.

theory that can explain the entire scope of its effect, and elucidation of its mechanism of action remains a challenge (Enomoto *et al.* 2021). The pain-alleviating effect in horses may occur through the same mechanism as in humans.

In this study, although the pain score decreased significantly immediately after dermal suctioning, no significant difference was found 10 min after the procedure (Figure 5). This indicates that the pain-relieving effect of a 10-min dermal suctioning session is limited to immediately after the treatment and does not persist for up to 10 min. Unfortunately, the mechanism of effect waning is currently unknown. In the future, the mechanism may be clarified by measuring additional indicators such as physiological or biochemical data.

Similar to the pain score, we used the algometer to measure the MNT as an indicator of back pain. The results showed that the MNT did not change significantly after dermal suctioning. It was inconsistent with the results of the pain score. This discrepancy may be to the methods used to measure back pain. According to Takahashi *et al.* (2005), an algometer detects pain with small tips in the epidermis and with large tips in the muscle layer. Another study performed in humans examined the shapes of algometer tips and the depth of tissue distortion they generated. A larger algometer contact area and more spherical tip shapes were found to generate greater distortion in the muscle layer (Finocchietti *et al.*, 2011). In this study, the contact area of the thumb during measurement of the pain score was about 3.1 cm^2, according to a measurement tool kit (Leafareacounter Plus, https://www.vector.co.jp/download/file/win95/business/fh625135.html). This is approximately three times the contact area of the algometer tip (1.0 cm^2) used to measure the MNT (Figure 8A). Furthermore, the thumb was hemispherical, but the tip of the algometer was cylindrical (Figure 8B). Based on the above, the pain scores measured in this study may have detected pain deeper in the muscle layer than did the MNT. This, combined with the fact that a significant change was observed only in the pain score, may indicate that dermal suctioning relieved deep tissue pain. However, the detailed mechanism of action remains unclear and should be investigated in future studies.

HRV has been widely used not only in humans but also in horses and other animals as a non-invasive and quantitative index of autonomic nervous system activity. In horses, it is used to evaluate various stresses, including pain (Ohmura and Jones, 2017; Reid *et al.*, 2017; Rietmann *et al.*, 2004). In

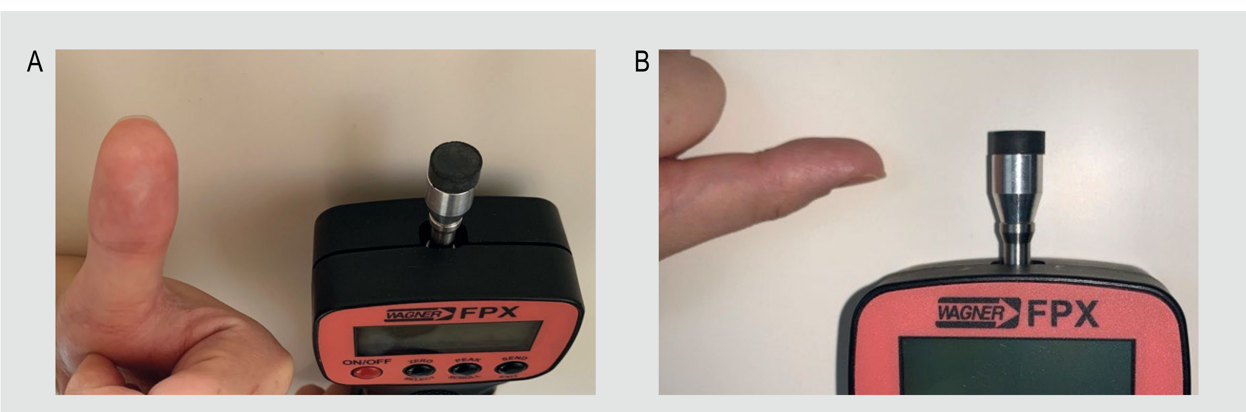

Figure 8. Comparison of the size and shape of the examiner's thumb and the algometer.

the present study, we measured two parameters, SDNN and RMSSD. SDNN measures the balance between sympathetic and parasympathetic activity. RMSSD is commonly used to estimate vagal regulatory activity. Lower SDNN and RMSSD values indicate a shift to sympathetic dominance, while higher values indicate a shift to parasympathetic dominance (Lee *et al.*, 2021; Von Borell *et al.*, 2007). In the present study's measurement of HRV as a physiological parameter of autonomic stress levels including pain, significant changes were not observed in the SDNN or RMSSD after the dermal suctioning session (Figure 7). In humans, cupping therapy has been found to increase parasympathetic nervous system activity by inducing peripheral nerve stimulation (Arslan *et al.*, 2014). We hypothesised that dermal suctioning would improve back pain and thereby lower stress levels by creating a state of parasympathetic dominance, but the experiment yielded different results. In the present study, the mean (± standard deviation) SDNN was 143 (±52) ms, and the RMSSD was 58 (±27) ms in pre-treatment. Both of these are close to the resting values of healthy Thoroughbreds reported by McDuffee *et al.* (2019) (SDNN: 143 [±64] ms, RMSSD: 56 [±18] ms). This indicated that back pain with a pain score of approximately 2 does not cause a decline in the SDNN or RMSSD in resting horses. Since both the SDNN and RMSSD were within the normal range before the intervention, administering dermal suctioning likely did not change their values.

Cortisol is a hormone secreted via the hypothalamus−pituitary gland−adrenal cortex as a biological response to stress and is often used in horses to evaluate stress levels, including pain (Bohák *et al.*, 2017; Bussières *et al.*, 2008; Pritchett *et al.*, 2003; Sellon *et al.*, 2004). In the present study, cortisol concentrations did not change significantly after dermal suctioning (Figure 6). Plasma cortisol concentrations at M0 were 4.0 (1.6) μg/dl (112 [53] nmol/L), which, according to a report by Nogueira *et al.* (2002) is close to the resting mean values (nmol/l) observed in healthy Thoroughbreds (age 1-2 years: 158 [±30]; 2-3 years: 152 [±11]; 3-4 years: 98 [±17]) (Nogueira *et al.* 2002). This indicated that, similar to HRV, back pain with a pain score of approximately 2 does not cause an increase in resting plasma cortisol concentrations. As plasma cortisol concentrations were normal before the intervention, they were unlikely to decline further after dermal suctioning.

This study had several limitations. First, measurements were taken immediately after and 10 min after dermal suctioning. Therefore, these findings only apply to the acute effects of the intervention. Future long-term intervention studies will provide important insights into the treatment of back pain in horses. Second, we conducted the experiment only in female horses. Verifying the effects of dermal suctioning in both sexes would be useful in order to extrapolate these findings for use in clinical practice. Third, although imaging is important for diagnosing back pain in horses, facility limitations did not allow us to perform thoracolumbar imaging on the experimental animals in this study. The lack of imaging diagnosis is a limitation of this study. Fourth, although we discussed the mechanisms of the effect of dermal suctioning in this study, we could not measure the parameters that support it. Further studies with additional indicators, such as physiological evaluation with thermography and electromyography or more detailed hematological and biochemical analyses, may reveal the mechanism of the pain-relieving effect of dermal suctioning. Fifth, there was no control group in this study. To accurately assess the effect of dermal suctioning on back pain, future studies that conduct an experiment with a control group are warranted. Finally, the intensity of dermal suctioning was limited. We performed dermal suctioning only at 50 kPa. Previous research that examined the effects of cupping using finite element analysis found that the pressure on the skin increased as the suction intensity increased (Tham *et al.*, 2006). Performing experiments at various suction strengths would provide more detailed information on the effects of dermal suctioning.

In conclusion, the present study found that pain scores improved significantly immediately after dermal suctioning, while the MNT, HRV, and plasma cortisol concentrations did not change significantly. These results indicate that dermal suctioning for 10 min relieves back pain for a short period in horses. Our findings have important implications for alleviating back pain in horses.

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Conflicts of interest

Tomonari Shibutani is the president of the MJ Company that provided funding for this study.

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