Short-term habituation of equine limb kinematics to tactile stimulation of the coronet

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Summary

A lightweight bracelet that provides tactile stimulation to the horse's pastern and coronet induces a higher flight arc of the hoof. This study addresses the pattern of habituation to these devices. **Objective:** To evaluate short-term habituation to tactile stimulation of the pastern and coronet in trotting horses. **Methods:** Tactile stimulation was provided by a lightweight (55 g) device consisting of a strap with seven chains that was attached loosely around the pastern. Reflective markers were fixed to the dorsal hoof wall, the forehead and over the tenth thoracic vertebra of eight sound horses. The horses trotted in hand 10 times at a consistent velocity along a 30 m runway under three conditions applied in random order at two-hour intervals: no stimulators, stimulators on both front hooves or stimulators on both hind hooves. One stride per trial was analyzed to determine peak hoof heights in the swing phase. Sequential trials with stimulators were compared with unstimulated trials using a nested ANCOVA and Bonferronni's post hoc test (P < 0.005). **Results:** Peak hind hoof height increased significantly for all 10 trials when wearing hind stimulators, whereas peak fore hoof height increased during the first six trials only when wearing fore stimulators. The first trial with stimulators showed the greatest elevation, followed by a rapid decrease over the next three trials and then a more gradual decrease. **Conclusions:** If the goal is to facilitate a generalized muscular response, a short burst of tactile stimulation is likely to be most effective, whereas longer periods of stimulation will be more effective for strength training.

Introduction

Following recovery from orthopaedic injury, gait deficits may persist due to muscle atrophy, altered muscle coordination patterns or inhibition of the activity of specific muscles. During rehabilitation, physical therapy is used in order to restore normal musculoskeletal function in terms of range of motion, muscle activation and muscular coordination. There is a lack of evidence-based research on the value of techniques used in physical therapy and rehabilitation in animals. This manuscript describes the first of a series of experiments designed to evaluate the effects of a proprioceptive facilitation technique used to increase joint flexions during the swing phase of the stride.

Proprioception is defined as the awareness of posture, movement and changes in equilibrium, together with the knowledge of position, weight and resistance of objects in relation to the body (1). Kinesthesia is a sense of body posture and motion that arises from the interactions of input provided by a rich set of biological proprioceptors within the musculoskeletal system, which has a rich set of biological proprioceptors providing information to the sensorimotor nervous system (2). Knowledge of position, both static and dynamic, depends on information describing the joint angulations in all planes and their rates of change, which is provided by peripheral receptors. These peripheral receptors include cutaneous mechanoreceptors and nociceptors; receptors located within the joint capsule, Golgi tendon organs and muscle spindles. The information is transmitted to the nervous system via group Ia and group II afferent fibres, and the ensuing muscular response is controlled by the central nervous system via efferent fibres. Physical therapy techniques may restore or change muscular function by stimulation of the peripheral receptors and the response may be modified over time by inhibitory mechanisms.

The authors observed that lightweight tactile stimulation devices attached to the fore or hind pasterns appeared to increase the height of the flight arc of the instrumented hooves. The tactile device is thought to have an effect through stimulation of cutaneous mechanoreceptors. It is uncertain whether there may be an accommodation effect over time. Information regarding habituation to this type of proprioceptive stimulation is a prerequisite for its incorporation in rehabilitation programs. This type of response may be useful for mobilizing the joints, facilitating muscle contractions, and for strength training of atrophied muscles.

The present study was designed in order to address short-term habituation to tactile stimulation of the pastern and coronet by measuring peak height of the hoof during the swing phase over the course of 10 consecutive trotting trials covering a distance of approximately 300 m. The experimental hypothesis was that elevation of the flight arc of the hoof in response to tactile stimulation of the pastern and coronet persists through 10 trotting trials or a distance of 300 m.

Materials and methods

The study was performed with approval of the Michigan State University animal care and use committee.

Horses

The subjects were eight horses (four mares and four geldings; height: 149.7 ± 7.93 cm;

mass: 450.0 ± 56.12 kg) that were assessed by an experienced observer to be sound at the trot. The horses were accustomed to the data collection runway and the surrounding equipment before the start of the study. They were trained to trot in a straight line at a consistent velocity and to adjust their velocity to that of the handler, based on the handler's shoulder and body movements rather than tension in the lead rope. Before the study started, a preferred trotting velocity was established for each horse. During data collection, velocity was available immediately after each trial and this information was provided to the handler in order to assist in maintaining a consistent velocity across trials.

Tactile stimulation

Custom fabricated lightweight (55 g) bracelets consisted of a braided strap with seven brass chains, each 6 cm in length. The strap was loosely attached around the distal part of the pastern so that the chains moved against the pastern, coronet, and hoof wall during locomotion (Fig. 1). The horses were accustomed to the sound and feel of the stimulators the day before the start of the study.

The patients were prepared for data collection by applying six reflective markers (6 mm cubes) to the head, trunk and limbs. Midline markers were attached to the forehead and the skin overlying the spine of the tenth thoracic vertebra (T10). One marker was attached to each hoof on the dorsal midline, 4 cm proximal to the tip of the toe.

Data collection

Kinematic data were collected using an automated motion analysis system (Motion Analysis Corporation, Santa Rosa, CA, USA) with eight infra-red cameras arranged at various heights and angulations in two arcs on the left and right sides of the runway. The data collection volume (5 x 3 x 2 m) was calibrated using a wand technique. The error in a linear measurement of 500 mm within the calibrated volume was < 0.8 mm. Recordings were made under three conditions:

Fig. 1   Tactile stimulator attached to the pastern.

no stimulators, stimulators attached to both forelimbs and stimulators attached to both hind limbs. Ten consecutive trials were collected for each condition, with the data collection being randomized as three blocks of 10 trials.

A stationary file was recorded prior to data collection in order to define the kinematic model. The horse was then positioned on the runway ready for the first trial and, if required, the stimulators were applied. Horses were trotted back and forth through the data collection volume until 10 consecutive trials had been recorded. Each trial covered a distance of approximately 30 m for a total of 300 m during the evaluation of each condition. The stimulators were removed after the tenth trial had been completed.

Data analysis

The data were analyzed using proprietary (Realtime 5.0.4 software, Motion Analysis Corporation, Santa Rosa, CA, USA) and custom software in order to determine the average velocity of the T10 marker during each trial and the maximal height of the toe markers during the swing phase for one stride within each of the 10 trials for the three conditions.

Statistical analysis

Data for the left and right limbs were entered separately giving 16 data points for hoof

height of the eight horses in each trial. The decline in hoof heights was not linear so the data were log transformed in order to use a linear regression. The data were tested for differences between the stimulated and unstimulated conditions using an ANCOVA, with right/left nested within horse, horse as a random factor, condition as a fixed effect and trial number as a covariate. The forelimbs and hind limbs were tested separately. Post hoc (Bonferroni) tests were used to make pairwise comparisons between successive fore or hind limb trials with and without stimulators. The habituation effect of the stimulators on hoof height was quantified by regression analyses of hoof height against trial number. Due to the large number of comparisons that were performed, a probability of $P < 0.005$ was chosen in order to reduce the likelihood of Type II errors. All of the statistical tests were performed using a statistical package (SPSS v16 for Windows, SPSS Inc., Chicago, IL, USA).

Results

Velocity did not vary significantly between trials without stimulators (2.88 ± 0.12 m/s), with forelimb stimulators (2.93 ± 0.12 m/s) and with hind limb stimulators (2.94 ± 0.18 m/s). All of the trials were maintained within ± 0.4 m/s of the preferred trotting velocity for each horse. Regression analysis of the data recorded from both the forelimbs and the hind limbs without stimulators indicated that hoof height in the unstimulated condition did not differ significantly over the 10 trials. When stimulators were applied to either fore or hind hooves, the slopes of the regression lines (Fig. 2) indicated that the effect on peak hoof height was largest immediately after application and decreased over time. Peak height of the fore hooves with forelimb stimulators was significantly greater than unstimulated fore hooves for the first 6 trials ($P<0.005$), but hoof elevation during trials 7–10 did not differ from control values (Fig. 2). Peak height of the hind hooves with hind limb stimulators was significantly greater than unstimulated hind hooves for all 10 trials and extrapolation of the regression line indicated that hoof

height would return to the control value after 14 trials.

Discussion

The flight arc of the hoof, which represents the summation of the swing phase flexions of all of the joints in a limb, is easily measured in kinematic analysis and is one of the aspects of gait that is assessed qualitatively by an observer. It was suggested in a pilot study that it is possible to increase swing phase joint flexions by tactile stimulation of the pastern and coronet (Clayton, unpublished data), and we were interested to investigate the duration of this effect in relation to its application as a tool in rehabilitation from musculoskeletal injuries. Although the trot was used in this study, it would be interesting to compare the effects on hoof flight at the walk, which is less reliant on elastic recoil than the trot.

The results reported here indicated an immediate, exaggerated response to the application of tactile stimulators but the response diminished over time.

The tactile device is thought to have an effect through stimulation of cutaneous mechanoreceptors; the sensory input must then either be synergistically combined with the motor commands and thus alter gait, or be suppressed in order to minimize interference with the sensory information and normalise gait (3). In voluntary motion, the flow of cutaneous input to the spinal neuron can be suppressed by presynaptic inhibition via gamma aminobutyric acid (GABA)-ergic interneurons (3), which provides a mechanism for influencing motor behaviour and the perception of somatosensory stimuli (4). Thus, the use of a tactile device may dramatically increase sensory synaptic transmissions and affect motor control by overriding presynaptic GABAergic interneurons. The most rapid adaptation occurred during the first four trials, after which a more gradual adaptation continued. Repeated cutaneous stimulation during gait may cause an increase in the perceptual thresholds to cutaneous input, which has been shown to occur in other species during self-induced movements (3, 4).
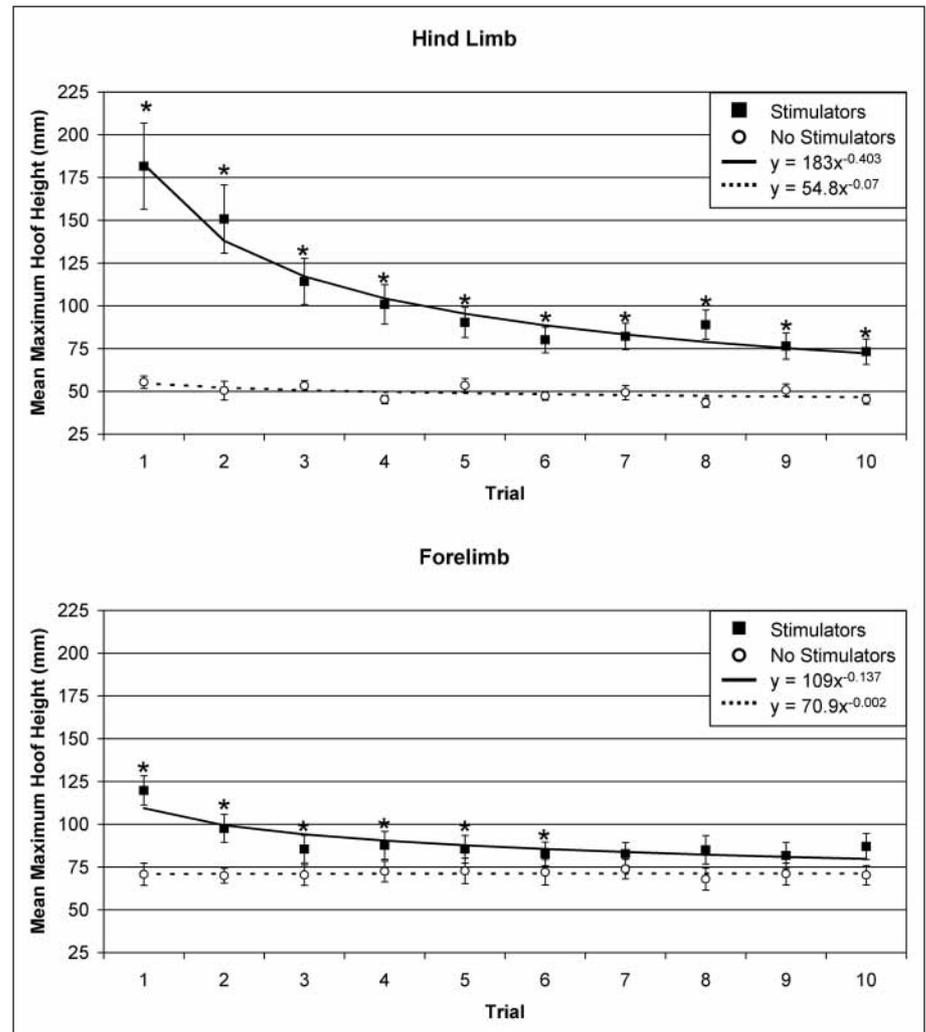

Fig. 2 Mean values ±1 SD and regression equations for log normalized data for peak hoof heights of the hind limbs (above) and forelimbs (below) without stimulators and with stimulators on both pasterns. Asterisks indicate pairs of values that differ significantly ($P < 0.005$).

The pyramidal and extrapyramidal systems of the central nervous system may also influence the accommodative effect. These systems are responsible for initiation and maintenance of voluntary movement, tone and posture, anti-gravitational support and regulation of posture in order to provide a stable background upon which to initiate voluntary activity (5). Although the two systems overlap, their separation is more significant in primates in which the pyramidal system is more highly developed than in domestic animals (5). The pyramidal system that controls fine motor tasks in primates is poorly developed in the horse, and is confined to the cervical spinal cord (6), thus limiting its influence on tasks related to gait.

This explains why the gait of a domestic animal can be preserved in the face of a lesion of the pyramidal system that would otherwise cause contralateral paralysis of voluntary muscle activity in a person. It is hypothesized that the overriding extrapyramidal system may cause a habituative effect on gait over time in the normal horse.

Interestingly the initial effect of the tactile device and effect of habituation over time differed in the fore and hind limbs. In the hind limbs, the initial response was much larger and peak height of the hoof was still higher than control values in the tenth trial by which time the horses had trotted a distance of approximately 300 m wearing the stimulators. In the forelimbs, the initial

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response to wearing stimulators was less exaggerated than in the hind limbs and, by the seventh trial, peak hoof height was no longer different from control values. The experimental hypothesis was supported for the hind limbs but not for the forelimbs due to the shorter duration of the forelimb effect. The discrepancy between the fore and hind limbs in their initial responses and in the effect of habituation might be explained by two inter-related mechanisms. Firstly, the inherent increase in extensor tonicity in the forelimbs of the horse may affect (diminish) the magnitude of the flexor response. Secondly, the effect of the stimulus may be influenced by the ascending inhibition system from the pelvic limbs to the forelimbs. This system originates from neurons located in the lumbar spinal cord that are responsible for tonic inhibition of a motor neurons of the extensor muscle in the cervical intumescence (5).

In relation to the design of rehabilitation schedules, it would be useful to determine whether the hind limbs ultimately habituate to coronary tactile stimulation beyond 10 trials or if the hind limbs continue to be affected by the tactile device over an even longer period of time. The effect may differ under a state of continuous exercise versus disrupted exercise and may vary between gaits. It is also uncertain whether there is a training effect over time due to an alteration of motor control, a muscle-strengthening effect, or an alteration of the horse's natural gait (central pattern generators of the extrapyramidal system). The results of this study indicate that the stimulators should be applied in short bursts (for example, trotting 50 to 100 m), if the goal is to facilitate as many muscles as possible. If the goal of rehabilitation is to strengthen or improve endurance of the flexor muscles, which might be necessary after a period of immobilization of the limb, then stimulators will be effective over a longer duration or distance, for example, trotting 200 to 300 m.

Conclusions

Lightweight devices that provided tactile stimulation to the pastern and coronet increased the peak height of the flight arc of the stimulated limbs. Elevation was greatest in the initial trials and was maintained through six trotting trials and a distance of 180 m in the forelimbs, and was maintained over at least 10 trotting trials and a distance of 300 m in the hind limbs. Application of the stimulators for short periods (e.g. trotting 50–100 m) is recommended when the goal of rehabilitation is to maximize muscle facilitation. If rehabilitation is being used to mobilize the joints or to improve strength or endurance of atrophied flexor muscles, longer periods of treatment (e.g. trotting 200–300 m) are more appropriate. It is unknown how rapidly horses rehabituate to the effect of tactile stimulation of the pastern, which would be useful information with regard to how frequently the techniques should be reapplied.

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