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RESEARCH PAPER

Mechanical nociceptive thresholds using four probe configurations in horses

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Abstract

Objective To examine the relationship between probe tip size and force readings of mechanical nociceptive thresholds (MTs) to identify appropriate probes for horses.

Study design Randomized, crossover study.

Animals Eight adult, mixed-breed horses aged 5–10 years, weighing 268–460 kg.

Methods Four probe configurations (PCs) were used in random sequence: 1.0 mm diameter (SHARP); 3.2 mm (BLUNT); spring-mounted 1.0 mm (SPRING), and 3 × 2.5 mm (3PIN). A remote-controlled unit on the horse increased force (1.2 N second^{-1}) in a pneumatic actuator on the metacarpus. Mean MT for each PC was calculated from 10 readings for each horse. Data were log-transformed for analysis using mixed-effects ANOVA/linear regression ($p < 0.05$). Variability of data for each PC was assessed using the coefficient of variation (CV).

Results Mean ± standard deviation MTs were: SHARP, 5.6 ± 2.3 N; BLUNT, 11.4 ± 3.4 N; 3PIN, 9.6 ± 4.6 N, and SPRING 6.4 ± 1.8 N. Mean MT for SHARP was significantly lower than for BLUNT ($p < 0.001$) and 3PIN ($p < 0.001$), but not different from SPRING ($p > 0.05$). Mean MT was significantly higher for BLUNT than for 3PIN ($p < 0.05$) and SPRING ($p < 0.001$). Mean MT for 3PIN was significantly higher than for SPRING ($p < 0.001$). Larger contact area PCs produced higher MTs than smaller PCs, but the relationship was not linear. BLUNT (area: 10-fold greater) gave a MT two-fold higher than SHARP. 3PIN (area: 20-fold greater) produced more variable MTs, less than two-fold higher than SHARP. SPRING was similar to SHARP. CVs were: SHARP, 22.9%; BLUNT, 72.3%; 3PIN, 44.2%, and SPRING, 28.7%.

Conclusions and clinical relevance The PC has nonlinear effects on MT. Therefore, it is important to define PC when measuring MT. Smaller probe tips may be preferable as MT data are less variable.

Keywords force, nociception, pain, pressure, probe size, stimulus intensity.

Introduction

Mechanical thresholds (MTs) for nociception are widely used in studies investigating pain, analgesia, hyperalgesia and allodynia (Le Bars et al. 2001). Numerous stimuli are used to elicit MTs, but considerable variation in the characteristics of these stimuli hampers comparison between studies, even in the same species. When a noxious mechanical stimulus is applied, pressure distorts the nociceptive nerve endings, activating the nociceptive pathway to the spinal cord. The minimal stimulus intensity to evoke nociception causing an aversive response is regarded as the MT (Le Bars et al. 2001). The stimulus intensity may be reported as either the force or the pressure required to elicit the response. If force is reported without reference to the contact area between the probe and the skin (the area of the probe tip), the intensity of the stimulus is unknown and the data are useful only for comparison within the study itself. If MT is reported in pressure units, it would appear more appropriate for comparison with other studies, although the effect of contact area on threshold pressures is not straightforward (Greenspan & McGillis 1991). As pressure equals force/area (doubling the area halves the pressure exerted by the same force), it might be assumed that the relationship between force and pressure at MT would be linear. However, even a limited review of the literature suggests that this is not the case as larger probes produce lower MT values than a straightforward relationship would suggest (Taylor & Dixon 2012).

Mechanical thresholds have been measured in horses and food animals for the evaluation of lameness and analgesia (Chambers et al. 1993; Whay et al. 2005; Lizarraga et al. 2008). In accordance with the problem outlined above, these investigations used a range of stimuli, which impedes comparison among studies. Numerous additional factors may affect the recorded MT, including the operator, the environment, the anatomical site, the rate of stimulus application and the characteristics of the tissue (Antonaci et al. 1998; Haussler & Erb 2006; Finocchietti et al. 2011a; Love et al. 2011; Grint et al. 2014). Moreover, particularly in animals, the test subject's mental state has considerable impact. Distraction is known to alter human MT (Ruscheweyh et al. 2011) and, particularly in prey animals, which are under evolutionary pressure to mask any signs of infirmity, response to a painful stimulus may be difficult to detect (Flecknell & Waterman-Pearson 2000).

Mechanical stimuli may be applied using either a hand-held algometer or via apparatus fixed to the animal's body, usually a limb, which can be operated remotely. Studies in horses have employed both these methods, but there is considerable discrepancy among the various studies in the data recorded in normal animals. Haussler & Erb (2006) reported use of a hand-held algometer with an 11.3 mm diameter flat rubber tip (area: 1.0 cm^2) to document MT at a number of sites on normal adult horses, and reported a range of 60–180 N (reported as pressure of 6–18 kg cm^{-2}). A separate study used the same algometer to assess MT in several sites around the spine and reported baseline MTs of 80–110 N (8–10 kg cm^{-2}) (van Loon et al. 2012). Another investigation used an alternative algometer with a probe tip of the same size in the sacroiliac region and recorded a mean MT of 51.9 N (reported in pressure as 51.9 N cm^{-2}) (Varcoe-Cocks et al. 2006). A limb-mounted, 2.0 mm diameter, blunt-ended pin driven pneumatically against a thoracic limb resulted in a mean MT of 5.2 N (Chambers et al. 1994), and similar equipment with a 1.5 mm diameter, blunt-ended pin recorded baseline MT of around 4 N (Love et al. (2012). A limb-mounted, 4.0 mm diameter probe resulted in MTs of 2.3–3.6 N (Moens et al. 2003). In donkeys, a 2.0 mm diameter pin mounted on a thoracic limb resulted in mean baseline MTs of 5.9–6.3 N (Lizarraga & Janovyak 2013), whereas using a limb-mounted system with three round-ended, 2.5 mm pins (total tip area: 15.0 mm^2) recorded mean MTs of 9.2–10.6 N (Grint et al. 2014).

Measurements made with hand-held and limb-mounted methods have not been compared directly in horses. However, it has been shown in pigs that a hand-held algometer resulted in lower MT than a limb-mounted actuator with an identical probe tip in both normal and lame adult sows (Nalon et al. 2013). Presumably, the presence of the operator alerts the animal to an impending stimulus, whereas there is no visual or auditory cue associated with the use of a limb-mounted actuator. Use of limb-mounted remotely controlled equipment avoids many of the problems related to distraction and anxiety and thus represents the most widely used system for pharmacodynamic investigation of analgesic agents. However, a hand-held method is more convenient for the clinical evaluation of pain during treatment on the farm or in the clinic (Nalon et al. 2013; Raundal et al. 2014).

Currently, there is no clear guidance as to the best mechanical stimulus for measuring MT in any species. Although numerous external factors affect the recorded MT, it is clear that the nature of the probe tip has considerable impact. We aimed to elucidate the relationship between probe tip size and force readings for MTs using different probe tips. A secondary aim was to identify the probe tips that provided the most consistent results in order to facilitate valid comparisons among studies. This study sought to confirm the hypothesis that, under otherwise controlled conditions, probe size will affect