American Pain Society
RESEARCH
EDUCATION
TREATMENT
ADVOCACY
PUBLISHED BY ELSEVIER

The Journal of Pain, Vol 17, No 7 (July), 2016: pp 815-823
Available online at www.jpain.org and www.sciencedirect.com

Position Sense in Chronic Pain: Separating Peripheral and Central Mechanisms in Proprioception in Unilateral Limb Pain

Anthony J. Tsay[*,†] and Melita J. Giummarra[*,†,‡]

*School of Psychological Sciences and Monash Institute of Cognitive and Clinical Neurosciences, Monash University, Clayton, Victoria, Australia.
[†]Caulfield Pain Management and Research Centre, Caulfield Hospital, Caulfield, Victoria, Australia.
[‡]School of Public Health and Preventive Medicine, Monash University, Melbourne, Victoria, Australia.

Abstract: Awareness of limb position is derived primarily from muscle spindles and higher-order body representations. Although chronic pain appears to be associated with motor and proprioceptive disturbances, it is not clear if this is due to disturbances in position sense, muscle spindle function, or central representations of the body. This study examined position sense errors, as an indicator of spindle function, in participants with unilateral chronic limb pain. The sample included 15 individuals with upper limb pain, 15 with lower limb pain, and 15 sex- and age-matched pain-free control participants. A 2-limb forearm matching task in blindfolded participants, and a single-limb pointer task, with the reference limb hidden from view, was used to assess forearm position sense. Position sense was determined after muscle contraction or stretch, intended to induce a high or low spindle activity in the painful and nonpainful limbs, respectively. Unilateral upper and lower limb chronic pain groups produced position errors comparable with healthy control participants for position matching and pointer tasks. The results indicate that the painful and nonpainful limb are involved in limb-matching. Lateralized pain, whether in the arm or leg, does not influence forearm position sense.

***Perspective:** Painful and nonpainful limbs are involved in bilateral limb-matching. Muscle spindle function appears to be preserved in the presence of chronic pain.*

***Key words:** Position sense, chronic pain, muscle spindles, proprioception, thixotropy.*

The sense of limb position allows us to determine where our limbs are in space when we are not looking at them. This information is primarily derived from muscle spindles, which are stretch receptors that signal length changes imposed on the muscle. Spindles also play a role in motor control, reflexively regulating muscle tension and providing input to body representations in the brain, especially body schemata.[52] These factors, collectively, appear to be disturbed in patients with chronic pain (for a review, see Tsay et al[59]).[2,21,34] However, the role of muscle spindles in proprioceptive disturbances associated with chronic pain remains unclear.

Although there is evidence of reduced position sense acuity in persons with chronic pain,[4,7,13,18,26,31,45,46,49,50,56] others have reported no such differences between persons with chronic pain and pain-free control participants.[1,8,9,28,29,39,44] The aforementioned studies used a repositioning task, in which participants reproduce a previously remembered postural position. In contrast, the present study examined the role of simultaneous afferent information to make positional judgements by manipulating the thixotropic properties of the muscle.[53,54,59]

The background firing rate in spindles is dependent on the preceding contraction and length changes of the muscle fiber.[53] Thixotropic behavior occurs with the formation of stable cross-bridges between actin and myosin when the muscle relaxes after a contraction. Shortening the muscle introduces slack into the sensory ending of spindles, decreasing the spindle discharge. Because the

Received November 22, 2015; Revised February 19, 2016; Accepted March 9, 2016.
Melita J. Giummarra was supported by a National Health and Medical Research Council (Australia) early career fellowship (APP1036124).
The authors have no conflicts of interest to declare.
Address reprint requests to Mr. Anthony J. Tsay, BBiomed (Hons), School of Psychological Sciences and Monash Institute of Cognitive and Clinical Neurosciences, Building 17, Monash University, Clayton, Victoria 3800, Australia. E-mail: anthony.tsay@monash.edu
1526-5900/$36.00

http://dx.doi.org/10.1016/j.jpain.2016.03.005

length of the muscle is signaled by muscle spindle activity, manipulating its sensitivity to stretch can lead to reproducible errors in perceived limb position.[54] Previous studies investigating proprioception in chronic pain have not controlled for the thixotropic properties of muscles. Therefore, it is unclear whether disturbances to position sense in persons with chronic pain occur at the level of the muscle spindles,[2,25] or in higher-order brain regions involved in motor control or body representation.[19,40]

Our group has developed a simple, noninvasive method of conditioning a muscle, on the basis of recordings of spindle discharges[15] and on measurements of position sense.[52-54,61] In the present study, we assessed position sense after thixotropic muscle conditioning, to determine whether this led to position errors consistent with an alteration in spindle function in the presence of chronic unilateral limb pain. If proprioceptive disturbance in chronic pain is due to altered activity in, or processing of, spindle discharge, participants with unilateral upper limb pain would be expected to show forearm matching errors that could not be explained by spindle discharge. Because spindles seem to play less of a role in pointing tasks,[60] differences in pointing errors between pain and control groups would suggest altered reference maps from body schemata or exteroceptive cues in position sense.[51] Finally, disruptions to body schemata seem to generalize to the affected side of the body,[57] reflecting higher-order neuroplastic changes across the body midline.[41-43] Therefore, we expected participants with lower limb pain would show deficits in pointing to the forearm on the affected side of the body, however, the role of spindle signals would remain unaffected. These findings may shed light on the source of motor dysfunctions observed in chronic pain disorders.

Methods

Participants

Forty-five volunteers participated in the study, including 15 with unilateral upper limb pain, 15 with unilateral lower limb pain, and 15 pain-free control participants. Participants were recruited from Caulfield Pain Management and Research Centre, and the general community. Inclusion criteria for the patient groups included: 18 to 65 years of age, having experienced pain more days than not for at least 3 months, experiencing pain that was localized to 1 arm or leg, and having no history of diabetes. Although a wide range of chronic pain etiologies were accepted, we excluded those with pain caused by inflammation, such as arthritis, or fibromyalgia, which is generally experienced as a diffuse pain affecting multiple body regions. Table 1 lists the demographic and clinical characteristics for each group. The pain groups were matched for sex, age, duration of pain, average pain intensity, pain interference, and kinesiophobia (Tampa Scale of Kinesiophobia) scores. However, the upper limb pain group reported higher pain severity (on the Brief Pain Inventory) on average than the lower-limb pain group. All Depression, Anxiety, and Stress Scale (DASS) subscale scores were significantly higher in the pain groups compared with healthy control participants, confirmed using the Bonferroni post hoc test ($P < .01$). The study was approved by the Alfred Health and Monash University Human Research Ethics Committees. All participants gave written informed consent and were financially reimbursed for their time.

Materials and Procedure

Forearm position sense was assessed in the vertical plane using 2 tasks, which have been described in detail elsewhere.[60] For the matching task, the blindfolded participant sat at a table with the upper arms on horizontal supports (allowing shoulder muscles to be relaxed), and both forearms placed on lightweight paddles in a custom-built apparatus. Velcro straps (5 cm in width) were wrapped just below the crease of the wrist with the palms supinated. Participants were asked if the tension in the 2 wrist straps felt the same, and adjusted as instructed by the participant to minimize potential differences in skin sensations between the 2 arms. One arm was designated the reference arm (the arm placed at the test angle by the experimenter) and the other was the indicator arm (the arm moved by the participant to match the position of the reference arm). The reference arm was passively moved by the experimenter to the test angle, which ranged from 40° to 50° to the horizon. In all conditions, unless stated otherwise, the painful limb or side was assigned as the reference. For the control group, the reference arm was randomly assigned to minimize biases arising from arm dominance.[14]

For the pointer task, only the reference arm remained strapped to the paddle, which was hidden from view by a screen. Unlike the matching task, participants had full view of the contralateral paddle, designated the indicator. Participants could maneuver the indicator paddle to the perceived angle of the reference arm by pushing a lever downward, which was attached to the indicator paddle. They were given the instruction to "show me where your arm is with the paddle."

Potentiometers (25 kΩ; Spectra Symbol Corp, Salt Lake City, UT) located at the hinges of each paddle were used to measure the angle at the elbow joint. The potentiometers provided a continuous voltage output proportional to the angle of each paddle, a reading of 0° indicated the forearm lay horizontal, and 90° referred to a forearm in the vertical position. Correct calibration of the potentiometers was checked before each experiment.

Position error was calculated between the 2 paddles using the formula:

$$\textit{Position error}\ (^\circ) = \textit{reference angle}\ (^\circ) - \textit{indicator angle}\ (^\circ)$$

Hence, a positive value meant that the indicator was placed in a more extended position than the reference arm. Conversely, where the indicator was placed in a more flexed position, relative to the reference arm, a negative value was assigned.

Muscle Conditioning

Before each trial, the elbow muscles were conditioned to place them into a defined thixotropic state, using