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Effects of a Force Production Task and a Working Memory Task on Pain Perception

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Abstract: The goal in the current study was to examine the analgesic effects of a pinch grip-force production task and a working memory task when pain-eliciting thermal stimulation was delivered simultaneously to the left or right hand during task performance. Control conditions for visual distraction and thermal stimulation were included, and force performance measures and working memory performance measures were collected and analyzed. Our experiments revealed 3 novel findings. First, we showed that accurate isometric force contractions elicit an analgesic effect when pain-eliciting thermal stimulation was delivered during task performance. Second, the magnitude of the analgesic effect was not different when the pain-eliciting stimulus was delivered to the left or right hand during the force task or the working memory task. Third, we found no correlation between analgesia scores during the force task and the working memory task. Our findings have clinical implications for rehabilitation settings because they suggest that acute force production by one limb influences pain perception that is simultaneously experienced in another limb. From a theoretical perspective, we interpret our findings on force and memory driven analgesia in the context of a centralized pain inhibitory response.

***Perspective:** This article shows that force production and working memory have analgesic effects irrespective of which side of the body pain is experienced on. Analgesia scores were not correlated, however, suggesting that some individuals experience more pain relief from a force task as compared to a working memory task and vice versa.*

Key words: *Force, muscle contraction, working memory, analgesia, pain, cognition.*

Rehabilitation often involves the execution of pain-eliciting movements, with patients required to execute many movements that are 10 to 20 seconds long during a 30- to 60-minute session. For example, one treatment approach for rotator cuff injuries is exercise therapy and this often requires patients to execute shoulder movements that can elicit acute musculoskeletal pain.[59] One possibility for altering the experience of pain is to simultaneously contract muscles in a noninjured limb.[27,29] Although endogenous pain responses associated with movements can help a clinician to gauge the acuteness of the injury or to refine the treatment approach, developing nonpharmacologic treatment approaches that can alter pain perception is also important. Indeed, although pharmacologic treatments to manage pain in these contexts are often effective, their use has also been associated with inadequate pain relief and issues related to dependence and addiction.[21,34,37] The goal in the current study is to use an experimental model to examine the effects of acute nonpharmacologic approaches that alter the perception of exogenous pain.

Previous studies have demonstrated that muscle contractions are associated with a reduction in pain perception, and this effect has been termed exercise-induced hypoalgesia.[15,27,42] Analgesia has been associated with relatively long muscle contractions that are performed between 2 repetitions of a pain-pressure test on the same[19,22,25,31,57] or different limb,[27,29] and with very brief pain-eliciting stimuli that are delivered during longer force contractions of the same or different limb.[29,50,54] Although acute pain typically coincides with movement of the injured limb in the clinical setting, in previous experimental

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paradigms muscle contractions and pain elicitation have not occurred at the same time and for a similar duration. This has prevented firm conclusions from being drawn on the existence of a centralized pain inhibitory response when force production and pain occur simultaneously.

Previous studies have also shown analgesic effects when a working memory task is coupled with pain-eliciting stimulation to the left hand[3] and left forearm.[4,5,53] Other studies show similar effects during a Stroop task[58] and a verbal attention task[16] with stimulation delivered to the right forearm and right foot, respectively. Together, these studies suggest that cognition also influences pain perception via a centralized pain inhibitory response that is independent of the spatial location of the pain, but this suggestion has not been directly tested.

We have developed a novel experimental paradigm that allows us to separately measure pinch grip-force production and working memory performance during the delivery of a constant pain-eliciting thermal stimulus to the left or right hand. This paradigm allows us to control for visual distraction during both tasks[42] and to examine whether a centralized pain inhibitory response during each task is related. We tested 3 hypotheses: 1) pain perception will be reduced when force is produced by the right hand and pain is delivered to the right or left hand, 2) pain perception will be reduced when a working memory task is performed while pain is delivered to the left or right hand, and 3) analgesic scores associated with force production and working memory will be positively related, suggesting that a common centralized pain inhibitory response may be associated with both tasks.

Methods

Subjects

Thirty-eight healthy right-handed adults with normal or corrected-to-normal vision and not taking any pain medications participated (19 female, 19 male; mean = 20.78 y, range: 18–43 y). Each subject provided informed consent to all procedures, which were approved by the local institutional review board and were in accord with the Declaration of Helsinki. Exclusion criteria were any history of neurologic disease, including any history of chronic pain or any current episode of acute pain. Subjects who verbally self-reported any history of these disorders were excluded during prescreening. All subjects completed the state and trait segments of the State-Trait Anxiety Inventory (STAI-S, STAI-T),[52] the Beck Depression Inventory,[2] Pain Anxiety Symptoms Scale,[38] Pain Catastrophizing Scale,[55] and the Tampa Scale of Kinesiophobia.[28] All scores were within the normal range of responses typically given by healthy adult subjects (STAI-S: mean = 28.5, SD = 9.20; STAI-T: mean = 33.30, SD = 8.87; Beck Depression Inventory: mean = 2.0, SD = 2.67; Pain Anxiety Symptoms Scale: mean = 54.83, SD = 17.4; Pain Catastrophizing Scale: mean = 11.5, SD = 8.55, Tampa Scale of Kinesiophobia: mean = 29.78, SD = 4.25).[2,44,52,56]

Pinch Grip-Force Task

Pinch grip-force was always produced by the index finger and thumb of the right hand. During the practice session, each subject's maximum voluntary contraction (MVC) was estimated using a force transducer (Jamar Hydraulic Pinch Gauge; Lafayette Instrument Co, Lafayette, IN). Subjects were asked to sustain a contraction of maximum force for three 5-second trials. Trials were separated by 60-second periods of rest. The MVC was calculated as the average of the 3 peak force levels. Mean MVC across subjects was 64.75 N (SD = 16.4 N). The force transducers used were ELFF-B4 model load cells constructed from piezoresistive strain gauges measuring force up to 100 N (Measurement Specialties, Hampton, VA). Force data were collected by Coulbourn Instruments Type B V72-25 amplifiers (Coulbourn Instruments, Allentown, PA) at an excitation voltage of 5 V. The force signal was transmitted via a 16-bit analog-digital converter and digitized at 125 Hz. The summed output from the 2 force transducers (index finger and thumb) was presented to the subject using a visual display on the computer screen. The force output was displayed on a 40-inch liquid crystal display screen at a resolution of 1,600 $\times$ 1,024 pixels and a refresh rate of 59 Hz. The subject sat 50 inches from the screen. Force production was guided by real-time visual information consistent with the paradigm shown in Fig 1A, and with previous force control studies.[11,41] During the rest period and during the task, 2 bars were visible to the subject. A white bar represented the target force level that was set at 25% of each subject's MVC. A red/green force bar was controlled by the subject and provided real-time visual information of force production. When the force bar turned green, the subject's goal was to match the green bar with the white bar. The subject produced force until the green bar turned red. Each task was 15 seconds long and included 5 force pulses. Each pulse was 1.8 seconds long (bar turns green) and pulses were separated by a 1.2-second rest period (bar turns red). Each trial was followed by a 7.5-second rating period in which subjects rated the level of pain they experienced during the previous 15-second trial. Subjects were instructed to make a rating after every trial. This was especially important for the trials where no stimulation was delivered because we wanted to determine whether any pain was experienced as a function of the grip-force task alone. Ratings were always made with the left hand using a keyboard to control a cursor on a visual analog scale (VAS) presented on the screen. As shown in Fig 1A, during experimental trials, 2 verbal descriptors were visible to the subject: "no sensation" on the left side of the scale and "intolerable pain" on the right side of the scale. The range of the rating bar was 0 to 10, with a resolution of .1. As shown in Fig 1A, subjects did not see numbers on the scale. Subjects were familiarized with the rating scale during a practice session. Fig 1B shows an example time series