ARTICLE

Neurological Evidence of a Mind-Body Connection: Mindfulness and Pain Control

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Chronic pain is commonly defined as an unpleasant experience felt in any part of the body that persists longer than 3 months and that may or may not be associated with a well-defined illness process (1). Chronic pain affects up to 28%–65% of the U.S. population and often leads to reduced occupational activity and subsequent economic loss (2). In 2008, the costs of chronic pain in the United States ranged from $560 to $635 billion (3). In addition to health care costs, chronic pain results in lost economic productivity, as well as exorbitant financial compensation for persons unable to work (3). Providing pain relief that is clinically significant and sustained and that has few adverse effects is the goal of chronic pain management (4). Here, we assess the role of the mind-body connection (i.e., social, emotional, and behavioral factors influencing physical health) and how it relates to mindfulness techniques that can alleviate chronic pain (5).

Currently, the most commonly used and most widely available treatment modality for chronic pain is medication, with the goal of maximizing efficacy with the fewest toxic side effects (6, 7). The most commonly prescribed agents are opioid-based medications, nonopioid agents (nonsteroidal anti-inflammatory drugs and acetaminophen), and adjuvant medications (anticonvulsants, muscle relaxants, corticosteroids, topical-numbing agents, and antidepressants) (8). However, there are nonpharmacologic treatment modalities, including mindfulness techniques, exercise programs, brain and spinal cord stimulation, and virtual-reality hypnosis (9). The most effective results are typically seen in multidisciplinary pain clinics, but these clinic services are not widely available to all patients (10).

Numerous studies have demonstrated the inadequacy of current pain management modalities and the need for newer, more widely available interventions (6, 11). Physicians should consider supplementing or replacing medications with nonpharmacologic modalities such as mindfulness (12, 13). Dr. Jon Kabat-Zinn, founder of the Center for Mindfulness in Medicine, defines mindfulness as "paying attention to something, in a particular way, on purpose, in the present moment, non-judgmentally" (14). The goal of mindfulness in the treatment of chronic pain is to cultivate a quality of openness and experiential acceptance of pain, rather than rejecting or avoiding the pain (14). In this way, mindfulness can be beneficial in treating chronic pain through a noninvasive approach via the mind-body connection (11).

THE ROLE OF MINDFULNESS

Mindfulness has been used as a supplement to medication for various conditions, including cancer, diabetes, and eating disorders (15–17). Dr. Kabat-Zinn describes mindfulness as being "more in touch with the fullness of [one's] being through a systematic process of self-observation, self-inquiry, and mindful action" (18). For many patients who experience chronic pain, these concepts of inward reflection may not appear to be possible, helpful, or preferable to medication. Furthermore, such patients may not associate the pervasive, intense nature of their condition with a psychological or spiritual idea (18). However, there is a growing body of evidence suggesting that mindfulness can be effective in the treatment of chronic pain (19).

Many studies have independently examined the effectiveness of mindfulness in pain reduction, the neurological effects of mindfulness, and the neurophysiology of pain (20–22). However, few studies have examined these aspects simultaneously while also investigating the relevant neurophysiological processes in relation to pain reduction (23).

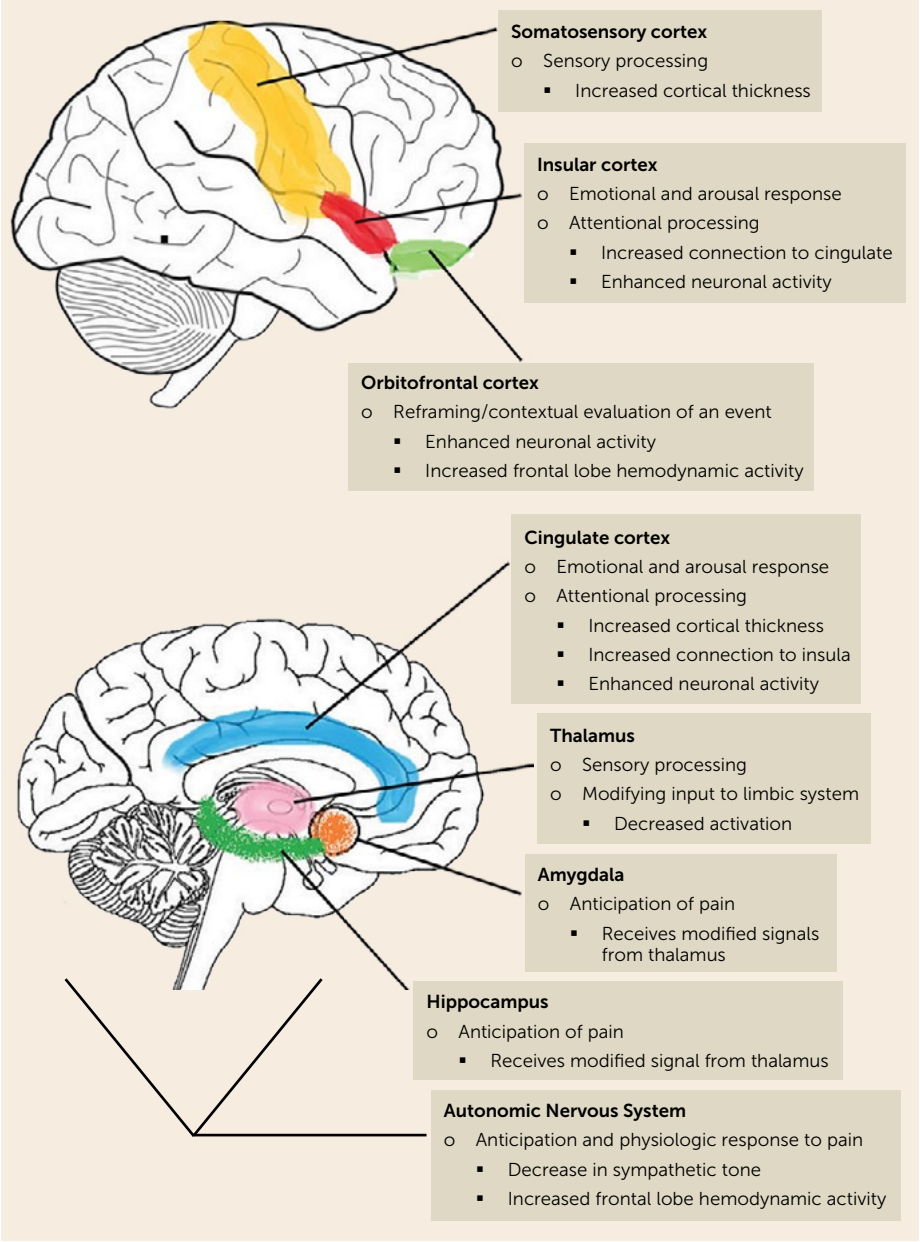
BRAIN REGIONS INVOLVED IN PAIN PROCESSING

The various brain regions involved in central pain processing have specific, understood roles in the anticipation, evaluation, and response to pain. The lateral thalamus and primary somatosensory cortex are associated with the sensory processing and discriminative aspects of painful stimuli (24). The anterior cingulate and insular cortices have been shown to play a role in the emotional and arousal responses to pain, as well as in attentional processing, which is the way a person's brain filters relevant information from distractions in order to appropriately respond to a stimulus (24–26). The hippocampus and amygdala, alternatively, are involved in the anticipation of pain, while the thalamus modifies afferent input to these limbic structures (25, 27) (Figure 1).

STRUCTURAL BRAIN CHANGES

Neuroplasticity can occur within the nociceptive pathways involving the aforementioned brain regions in people who practice mindfulness-based stress reduction (24). Mindfulness-based stress reduction is a structured, weekly meditation program that has standardized guidelines and involves a combination of mindfulness meditation, body awareness, and yoga (19). Su et al. (28) examined functional MRI (fMRI) scans of

FIGURE 1. Brain Regions Involved in Pain Processing[a]



[a] The open circles represent the specific role of a brain region in pain processing, and the small black squares represent neurological changes associated with mindfulness in conjunction with decreasing pain.

the brains of persons who completed a 6-week mindfulness-based-stress-reduction course. fMRI was conducted at baseline and 6 weeks after completion of the course. Participants who completed the course experienced significantly less subjective pain elicited by a thermal stimulus compared with control subjects who did not complete the course. Attenuation of pain was associated with increased neuronal connectivity from the anterior insular cortex and dorsal anterior mid-cingulate cortex. These results suggest that mindfulness plays a role in the modulation of brain connections and networks that underlie the subjective experience of pain (28).

Grant et al. (20) used structural MRI scans to examine a group of individuals who were experts (defined as >10,000 hours of practice) in meditation techniques. Compared with control subjects, the expert meditators had a decreased sensitivity to pain, which was associated with significantly thicker dorsal anterior cingulate cortex and significantly thicker secondary somatosensory cortex. These results suggest that long-term mindfulness practice may affect cortical thickness in pain-related brain areas, thus causing changes in pain sensitivity (20).

SIGNAL-PROCESSING CHANGES

Changes in the processing of pain signals, specifically in areas involved in pain anticipation and attentional processing, have been reported (25). Lutz et al. (25) used fMRI in a study demonstrating that mindfulness techniques can modulate neural brain processes before (anticipation) and during (attentional) painful stimuli. In this study, expert meditators (compared with control subjects) reported significantly less unpleasantness from a painful stimulus elicited during meditation, which was associated with enhanced activity in the dorsal anterior insula and the anterior mid-cingulate, two areas of the brain associated with attentional processing. Meditators also had significantly less activity in the amygdala, an area associated with pain anticipation. These findings support the mindfulness principle, which suggests that openness of oneself to an experience of pain (attentional processing) rather than avoidance (anticipation) may reduce the mind's tendency toward anxiety, which can further exacerbate pain (25).

In another fMRI study, Zeidan et al. (29) reported that subjective decreases in pain sensation were associated with increased activity in the anterior cingulate cortex and anterior insula, two areas involved in the emotional regulation of pain processing as well as attentional processing. Increased activation in the orbitofrontal cortex, an area known to reframe contextual evaluation of sensory events similar to attentional processing, was also observed. Additionally, reductions in pain unpleasantness were associated with thalamic deactivation (29).

The aforementioned studies demonstrated that there are neurological changes involved in differentiating between the sensory experience of pain (subjective intolerance to pain) and the emotional response to pain (hopelessness and fear) (20, 24, 25, 29). Identifying

KEY POINTS/CLINICAL PEARLS

- Chronic pain affects up to 65% of the U.S. population and often leads to reduced occupational activity and subsequent economic loss.
- Current pain management modalities are inadequate, leaving opportunity for nonpharmacological modalities such as mindfulness.
- Mindfulness involves nonjudgmental observation of and present-moment engagement with one's physical, emotional, and mental states.
- There are proven neuroanatomical and neurophysiological changes associated with mindfulness in reducing the subjective experience of pain.

these experiences as separate, or "uncoupling" them from the emotional response via mindfulness techniques, allows one to distinguish between unpleasant sensations and secondary emotions in the context of pain, thus reducing the body's sensitivity to the unpleasant experience (18).

AUTONOMIC NERVOUS SYSTEM PROCESS CHANGES

The autonomic nervous system plays a role in the anticipation of and response to pain (30). Through its integration with structures in the upper brainstem, hypothalamus, anterior cingulate cortex, insula, and amygdala, the autonomic nervous system integrates bodily sensation with emotion and generates homeostatic autonomic responses (30). Lush et al. (31) reported that women with fibromyalgia who completed a mindfulness-based stress-reduction program had decreases in basal sympathetic tone. Sympathetic nervous system responses typically exacerbate the physical symptoms of illness (30). Therefore, mindfulness-based stress reduction appears to play a role in attenuating autonomic nervous system responses, which can reduce chronic pain (31).

Braden et al. (32) reported that mindfulness-based stress-reduction practices were linked to alterations in the autonomic nervous system, specifically an increase in regional frontal-lobe blood flow, which was associated with the attenuation of chronic back pain and affective depression symptoms (32). The frontal lobe plays a role in reframing the contextual evaluation of an event (25). Therefore, this increase in hemodynamic activity is presumably associated with the reevaluation and awareness of changes in emotional state, a key concept of mindfulness (32). Being consciously aware of pain and uncoupling it from negative emotion are keys to decreasing the subjective experience of pain (18, 32).

CONCLUSIONS

Although mindfulness has been well studied as an effective supplement or augmentation for pain management, few studies have simultaneously examined the neuroanatomical and neurophysiological alterations that can occur as a result of mindfulness to actively reduce pain. There are some contradictory studies that have demonstrated the potential ineffectiveness of mindfulness; however, it is important to consider that mindfulness is a modality that has minimal risks and can be beneficial. Further studies are needed to expand our understanding of the neurophysiological and psychological mechanisms underlying the effects of mindfulness on pain processing and perception.

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