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Mindful Yoga pilot study shows modulation of abnormal pain processing in fibromyalgia patients

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Abstract

Published findings from a randomized controlled trial have shown that Mindful Yoga training improves symptoms, functional deficits and coping abilities in fibromyalgia and that these benefits are replicable and can be maintained 3 months post-treatment. The aim of this study was to collect pilot data in fibromyalgia patients (N = 7) to determine if initial evidence indicates that Mindful Yoga also modulates the abnormal pain processing that characterizes fibromyalgia. Pre- and post-treatment data were obtained on quantitative sensory tests and measures of symptoms, functional deficits and coping abilities. Separation test analyses indicated significant improvements in heat pain tolerance, pressure pain threshold, and heat pain after-sensations at post-treatment. Fibromyalgia symptoms and functional deficits, including physical tests of strength and balance, and pain coping strategies also improved significantly. These findings indicate that further investigation is warranted into Mindful Yoga's effects on neurobiological pain processing.

Fibromyalgia afflicts up to 15 million persons, primarily women, in the U.S. and carries an annual U.S. direct care cost of greater than $20 billion (Spaeth, 2009). Fibromyalgia results in profound suffering, including widespread musculoskeletal pain and stiffness, fatigue, disturbed sleep, dyscognition, affective distress, and very poor quality of life (Jones & Hoffman, 2009). Diminished aerobic fitness has been documented for decades, but recent studies report that the average 40 year-old with fibromyalgia has fitness findings expected for a healthy 80 year-old (Jones, Rutledge, Jones, Matallana, & Rooks, 2008; Jones, King, Mist, Bennett, & Horak, 2011). Fibromyalgia has also been associated with increased mortality (McBeth et al., 2009). Fibromyalgia is likely due in part to altered pain processing in the central and peripheral nervous system (Jensen et al., 2009; Staud, Bovee, Robinson, & Price, 2008). Additional pathophysiologic factors include genetic predispositions, autonomic dysfunction, and emotional, physical or environmental stressors (Clauw, Arnold, McCarberg, & FibroCollaborative, 2011).

The successful management of fibromyalgia patients is still a work in progress. FDA-indicated drug therapies are generally only 30% effective in relieving symptoms and 20% effective in improving function (Russell et al., 2008). Most clinicians and researchers recommend non-pharmacological modalities such as exercise and cognitive-behavioral therapy in addition to pharmacotherapy (Hauser, Thieme, & Turk, 2010). However recently there has been a growing interest in incorporating age-old Asian mind/body practices such as yoga, tai chi, and qigong (da Silva, Lorenzi-Filho, & Lage, 2007; Haak & Scott, 2008; Mist, Firestone, & Jones, 2013; Wang et al., 2010).

In a recently published study, we randomized 53 fibromyalgia patients to an 8-week Mindful Yoga intervention (previously published as ‘Yoga of Awareness’) or to wait-listed usual care (Carson et al., 2010). Mindful Yoga as we teach it is distinct from many current hatha yoga styles in that 1) it intensively emphasizes moment-to-moment mind/body awareness during asana practice, rather than the precise execution of postural alignments; and 2) substantial practice of meditation, breathing exercises, study of yoga philosophy, practitioner meetings and informal application of mindful awareness in daily life are highlighted along with gentle asana practice.

At post-treatment, women assigned to the Mindful Yoga program showed significantly greater improvements on standardized measures of fibromyalgia symptoms and functioning, including pain, fatigue, stiffness, poor sleep, depression, and anxiety, and also on measures of relaxation, acceptance, and vigor. Physical tests showed improvements in strength and balance. A majority of these improvements qualified as “clinically significant changes” (Dworkin et al., 2008). Adverse effects were limited to anticipated experiences such as transitory increases in mild muscle soreness, and minor non-intervention related events such as developing the common cold. Subsequent analyses showed sustained significant improvements on most measures at 3 months follow-up. When the wait-list group was crossed over into the Mindful Yoga intervention, results largely replicated the post-treatment improvements seen in the original Mindful Yoga group (Carson, Carson, Jones, Mist, & Bennett, 2012).

Given these replicated findings, we were interested in the possibility that such improvements might be accompanied by changes in the abnormal pain processing found in fibromyalgia. Research in the past decade has significantly increased our understanding of the pathophysiological mechanisms of fibromyalgia, due in large part to the expanding use of quantitative sensory testing (QST) to characterize the pain processing abnormalities of this disorder. QST modalities assess and quantify the detection threshold of accurately calibrated sensory stimuli, such as thermal, pressure, or other stimuli (Kindler et al., 2011). Varying QST modalities capture unique aspects of the pain processing continuum including mechanisms of peripheral and central sensitization, and central integration of pain (Arendt-Nielsen & Yarnitsky, 2009). Most relevant to the present study are QST studies demonstrating that fibromyalgia is characterized by: 1) generalized neurobiological amplification of sensory stimuli, as evidenced by hyperalgesia in terms of lower sensory thresholds and tolerance (e.g., decreased heat pain threshold and tolerance, Geisser et al., 2003); 2) sensitization of ascending pathways as a component of central sensitization, as measured by temporal summation, or hyperexcitability of dorsal horn neurons in response to repetitive C fiber input (e.g., increased ratings of prolonged heat pain, Gracely, Grant, & Giesecke, 2003; and more intense and prolonged after-sensations of painful stimuli, Price & Staud, 2005); and 3) mechanical hyperalgesia and allodynia, as assessed using pressure algometry (e.g., decreased pressure pain threshold, Petzke, Gracely, Park, Ambrose, & Clauw, 2003).

The majority of QST studies have characterized baseline pain processing in fibromyalgia. Few have investigated changes in pain processing following an intervention. A handful of intervention studies have focused on the effects of yoga. One study used QST to investigate the effects of 8 weeks of “relaxing yoga” on pain processing in individuals with fibromyalgia, finding a small but non-significant reduction in pressure pain thresholds (da Silva et al., 2007). Another study tested the effect of slow yogic breathing among women with fibromyalgia and reported reduced ratings of pain intensity and unpleasantness compared to matched healthy controls (Zautra, Fasman, Davis, & Craig, 2010).

Several other studies have used QST to quantify the effects of yoga and/or mindfulness on pain in other populations. Improvement in pressure pain thresholds was reported among patients with chronic nonspecific neck pain after a 9-week Iyengar yoga intervention compared with standard exercise (Cramer et al., 2013). A brief 3-day mindfulness meditation intervention demonstrated a decrease in pain sensitivity in healthy normals (Zeidan, Gordon, Merchant, & Goolkasian, 2010). In another study Villemure and team found that yoga practitioners tolerated cold pain more than twice as long as matched controls (Villemure, Ceko, Cotton, & Bushnell, 2014). In addition to QST, a series of recent experimental studies have focused on brain imaging techniques such as functional magnetic resonance imaging (fMRI) to elucidate the impact of meditation techniques on pain (see Grant, 2014 for a review). These studies reveal findings demonstrating that mindfulness reliably decreases pain scores. Moreover, mindfulness-related improvements in pain are consistently accompanied by a neural pattern characterized by reduced affective and cognitive processing of pain, but increased sensory processing of pain. This pattern suggests that meditators may learn to view painful stimuli more neutrally (Grant, 2014).

While prior QST studies have provided important objective data regarding yoga and mindfulness effects on pain, most have assessed only single measures of pain sensitivity (threshold or tolerance). Multi-modal QST assessment is advantageous because of the ability of each QST modality to assess a different aspect of the pain pathway (Arendt-Nielsen & Yarnitsky, 2009) and hence provides the opportunity to elucidate a variety of the exact mechanisms by which yoga exerts pain reducing effects. Our intention with the current study was to conduct an uncontrolled pilot study of Mindful Yoga using a multi-modal QST protocol in a small sample of fibromyalgia patients, to determine if initial evidence indicates that further investigation is merited. If the Mindful Yoga pilot data demonstrate that significant improvements in fibromyalgia symptoms indeed appear to be accompanied by significant changes in QST measures of pain processing, this would provide a strong rationale for pursuing a more thorough, controlled study of such effects.

Method

Participants

Seven women participated in this single arm, pre-post trial. All were women ≥21 years of age. To be eligible, patients had to meet the following criteria: be diagnosed with fibromyalgia by 1990 American College of Rheumatology criteria (Wolfe et al., 1990) for at least 1 year, and be on a stable regimen of pharmacologic and/or non-pharmacologic treatment for fibromyalgia ≥3 months. Patients who met any of the following conditions were excluded from the study: (a) currently engaged in intensive yoga practice (practice >3 days/week), (b) residing >70 miles from the research site or unavailable to attend the intervention at one of the scheduled times, (c) actively contemplating suicide (none were excluded on this basis), (d) currently undergoing disability application, determination or litigation, (e) scheduled for elective surgery during the study period, (f) physically disabled in a manner that precluded meaningful participation in the intervention (e.g., quadriplegic paralysis), (g) unwilling to forgo changing their voluntary pharmacologic and/or non-pharmacologic treatments for the length of their participation in the study, or (h) do not speak English. The rationale for excluding women who were currently engaged in practicing yoga more than 3 days per week was based on our research indicating that the majority of women with fibromyalgia have tried yoga at some point (Firestone, Carson, Mist, Carson, & Jones, 2014), thus excluding women with yoga experience would have resulted in an unrepresentative sample. Given that the yoga intervention under investigation was relatively intensive (5-7 days/week, see Treatment section below) and that we wanted to test its effects as complementary to patients' current treatment modalities, we decided to exclude individuals who were already practicing yoga at least 4 times per week.

Overall Design and General Procedures

The protocol for this study was approved by the Oregon Health & Science University Institutional Review Board. Potential participants were identified between July – September 2010 from a database of fibromyalgia patients referred to our university tertiary care center who had indicated their interest in participating in research studies. A research assistant initially contacted potential participants by telephone or email and subsequently provided a description of the study, including inclusion and exclusion criteria. After signing informed consent forms, patients completed the baseline assessment, and within 2 weeks they began the yoga intervention. Patients completed the post-treatment assessment immediately after the 8-week yoga intervention ended. Patients received $25 for completing the post-treatment assessment. Throughout their participation in the study, all patients continued to receive the standard care provided by their health care providers.

Treatment

The Mindful Yoga intervention followed the same format as in our prior fibromyalgia trial (Carson et al., 2010; Carson et al., 2012). The yoga teacher followed a manual, including detailed class guidelines, that were developed to standardize delivery of the intervention in research settings (Carson & Carson, 2016). The intervention consisted of 8 once-per-week classes, each lasting 120 minutes (min). Each class included approximately 40 min of gentle stretching poses, 25 min of mindfulness meditation, 10 min of breathing techniques, 20 min of didactic presentations on the application of yogic principles to optimal coping, and 25 min of group discussions. The didactic portions explored traditional topics such as the principles of simple being (*sat*), awareness (*chit*), love (*ananda*), acceptance (*tapas*), and skill in action (*karmasu kaushalam*); and also modern concerns, such as the physiological underpinnings of mind/body stress reactivity, and how yoga may have beneficial effects on stress-related problems.

The yoga poses sequence consisted of low intensity, low impact postures which were modified to avoid movements that are known to aggravate pain in fibromyalgia (Jones & Liptan, 2009). Two versions were offered that could be done either in a chair, or out of a chair. The sequence included self-massage, warm-ups, table, mountain, mountain with sun arms, breath of joy, warrior 1 flow, chair, downward-facing dog on chair, sphinx, modified locust, child’s pose, supine core strengthening, supine pigeon, supine thoracic twist flow, bridge, knees to chest, and corpse. The teacher emphasized the importance of gentle practice when one’s body is challenged by illness. Patients were supplied with yoga mats, blankets, eye pillows, and bolsters for doing the poses. They were encouraged to practice specific yoga techniques at home 20-40 minutes per day, 5-7 days per week, guided by a professionally produced DVD and a CD. Applications of yoga principles to daily life were also assigned each week. For further intervention details see our previous trial reports (Carson et al., 2010; Carson et al., 2012)

Measures

At baseline we collected information about standard demographic and clinical variables (age, years since diagnosis, years symptomatic, race/ethnicity, marital status, education, employment). At both baseline and post-intervention we collected information about any changes in medications or in medical or non-pharmalogical treatments for fibromyalgia.

Outcome assessments were administered twice: two weeks before the intervention, and during the week after the intervention ended. Three types of measurements – QST, standardized questionnaires, and physical tests - were used to gather data about neurobiological pain processing, fibromyalgia symptoms and functional deficits, and pain coping strategies. These instruments are briefly described below; for a fuller description, see our earlier papers (Carson et al., 2010; Kindler et al., 2011).

Quantitative Sensory Tests of Pain Processing

We used a QST protocol which we had previously used to capture post-intervention pain processing changes (Kindler et al., 2011). First, participants engaged in heat pain threshold and tolerance testing. Second, participants engaged in pressure pain threshold testing. Lastly, after-sensations of prolonged heat pain were assessed. The QST procedures lasted approximately 60 minutes.

Heat Pain Threshold and Tolerance. A majority of studies characterizing the neurophysiology of fibromyalgia have demonstrated hyperalgesia and decreased thresholds in response to stimuli applied to the skin, such as heat, cold, or electrical modalities (Williams & Clauw, 2009). We chose to utilize a heat stimulus with a slow rate of rise in order to capture response of C fiber afferents in these individuals. Sensitivity to input from C fibers, which transmit 'second pain' - the duller, longer-lasting component of pain sensations, a key characteristic of many chronic pain states - seems to underlie the mechanism behind central sensitization whereby nociceptors within the dorsal horn display an augmented response to painful stimuli (hyperalgesia) or even non-painful stimuli (allodynia) (Price & Staud, 2005).

Thermal stimuli were delivered to the right volar forearm using a contact thermode and a computer controlled Medoc Neurosensory Analyser (TSA-2001; Ramat Yishai, Israel) with a peltier element stimulator (note that handedness has not been shown to affect pain processing). From a baseline of 32° C, temperature of the thermode was increased at a rate of 0.5 °C/s. As noted, this slow rate of rise preferentially activates C fibers and diminishes artifact associated with reaction time (Yeomans & Proudfit, 1996). For heat pain thresholds, participants reported the point at which they first experienced pain from the heat. For heat pain tolerance, participants reported the point at which they no longer felt able to tolerate the pain. Three trials of heat pain threshold and three trials of heat pain tolerance were delivered with the position of the thermode being altered slightly between trials to avoid sensitization or habituation of cutaneous receptors. The average of the three trials for each procedure was computed for a final score of heat pain threshold and heat pain tolerance.

After-Sensations of Prolonged Heat Pain. We chose to quantify A delta and C nociceptor augmentation, temporal summation, and adaptation to nociceptive input in this study given that key studies investigating the neurobiology of fibromyalgia have documented abnormal temporal summation, which provokes an augmented sensory response along with a slower resolution of the nociceptive input (termed ‘after sensations’). Leaders in the field of fibromyalgia neurobiology have documented these findings by demonstrating that patients with fibromyalgia, as compared to health controls, report significantly increased pain sensations following repeated nociceptive input along with after-sensations that were more intense and took more than twice as long to resolve (Price & Staud, 2005). These after sensations of prolonged and enhanced intensity have been demonstrated to arise as a direct result of temporal summation in patients with fibromyalgia (Gracely et al., 2003).

Thermal stimuli were delivered using the thermode described above to the right volar forearm at 44°C for 30 seconds, and pain ratings (0-100) were obtained 15 and 30 seconds after the stimuli were removed. We utilized prolonged suprathreshold heat stimulation, which activates both A delta and C nociceptors and captures pain fluctuations due to temporal summation and adaptation in healthy individuals (Koyama, Koyama, Kroncke, & Coghill, 2004) and those with chronic pain (King et al., 2009). After-sensations were calculated as the average of 15 and 30 seconds pain ratings.

Pressure Pain Threshold. We chose to investigate pressure pain thresholds in this study given that this QST modality is the most consistently demonstrated finding among neurophysiological abnormalities in fibromyalgia (Williams & Clauw, 2009). It has been clearly demonstrated over numerous studies that mechanical hyperalgesia and allodynia exists not only at tender points, but in a widespread manner throughout the body (Price & Staud, 2005).

Mechanical pressure was applied using a handheld algometer (Pain Diagnostics and Thermography Inc., Great Neck, NY) at a rate of 1 kg/s until the participant reported the first sensation of pain from the pressure at which point the amount of pressure being applied was recorded. Pressure was applied to three sites on the right side of the body (masseter, trapezius, quadricep) and three trials were recorded for each site. These sites were chosen due to their wide use in experimental pain studies, good inter-examiner reliability, and availability of normative values (Antonaci, Sand, & Lucas, 1998). The average of the recordings across the three sites was used for analysis.

Questionnaire Assessing Fibromyalgia Symptoms and Functional Deficits

Revised Fibromyalgia Impact Questionnaire (FIQR). The FIQR is a widely used 21-item instrument assessing fibromyalgia-related pain, fatigue, stiffness, poor sleep, depression, poor memory, anxiety, tenderness, poor balance, and environment sensitivity (Bennett et al., 2009). Scores range from 0-100 with higher scores indicating more symptom burden and functional limitations.

Physical Tests of Fibromyalgia Functional Deficits

Timed Chair Rise. In this test of functional strength deficits, seated subjects are asked to rise to full height with arms crossed over their chest as many times as possible within 30 seconds (Rikli & Jones, 2001).

Sensory Integration for Balance Test (SCBT). Functional balance deficits were measured by the SCBT during which subjects stand on a NASA-grade 60 cm x 60 cm block of 4-inch, medium-density Tempur foam with eyes open, then closed (Horak, Wrisley, & Frank, 2009). The scores for Balance-Eyes Open and Balance-Eyes Closed are the number of seconds the position is held, up to 30 seconds maximum.

Questionnaires Assessing Pain Coping Strategies

Chronic Pain Acceptance Questionnaire (CPAQ). Pain acceptance was measured by the 20-item CPAQ (McCracken, Vowles, & Eccleston, 2004). The Acceptance Total Score ranges from 0-120 with higher scores indicating greater pain acceptance.

Pain Catastrophizing Scale from the Coping Strategies Questionnaire. The 6-item catastrophizing scale of the Coping Strategies Questionnaire was used to capture the frequency of patients' responses to pain that characterize it as being awful, horrible and unbearable (Rosenstiel & Keefe, 1983). Scores range from 0-36 with higher scores indicating greater pain catastrophizing.

Statistical Analyses

The outcome data in this study was subjected to the separation test (Aickin, 2004), a modified form of the null hypothesis test designed to determine whether preliminary data from small pilot trials indicate sufficient change to warrant further study (type 1 error = .05).

The separation test addresses a difficulty often faced in early-phase research with relatively small samples, when a standard null-hypothesis test leads to a negative result because the study is statistically underpowered. Typically this would be interpreted as evidence against further research on the tested intervention, but because the trial is underpowered, such a conclusion may be unwarranted.

The separation test, which is derived from the fundamental theory of hypothesis testing as developed in the early 20^{th} Century by Neyman and Pearson (1933), offers an alternative for small pilot trials. This test calculates an interval around a null-hypothesis value (i.e., no treatment difference) to determine whether a certain degree of separation exists between two assessments. When the specified separation is confirmed, this is an indication derived from the data that can provide a firm inferential basis for deciding if an intervention is 'promising' enough to merit further research. The formula for determining the separation interval criteria is as follows: Value of criteria equals the observed difference multiplied by 0.5, minus the product of the standard deviation of the sampling distribution of the estimate multiplied by 1.645 (Aickin, 2004).

Considering the preliminary nature of the study and the need to balance committing type 1 error against the possibility of dismissing potentially important findings, an alpha level of .05 was used for all outcomes. In addition to the separation test, percent of change was calculated for each outcome as a more intuitively interpretable indication of effect size (Durlak, 2009).

Results

Sample Characteristics and Treatment Adherence

A total of 12 women were contacted about potentially participating in the study, and 7 of these were enrolled. The characteristics of the sample are summarized in Table 1. The mean age of the 7 patients in the study was 49.7 years (SD = 17.0), and average time since diagnosis was

8.4 years (SD = 7.6). Participants were primarily Caucasian (85.7%), well educated (100% ≥ college degree) and currently married/partnered (57.1%). Attendance at treatment sessions among the 7 women was good (mean = 7 of 8 classes, range 6-8) as was home practice (daily total practice mean = 48 minutes, range 21-67).

Insert Table 1 about here

Post-treatment Outcomes

Quantitative sensory tests. Table 2 summarizes all post-treatment outcome results. Notably, several QST variables improved significantly, including heat pain tolerance (+2.30, criteria = ±0.80), pressure pain threshold (+0.79, criteria = ±0.02), and after-sensations following prolonged heat pain (-16.71, criteria = ±3.21). Heat pain threshold shifted in the expected direction (higher score) but did not reach the separation test significance criteria.

Insert Table 2 about here

Fibromyalgia symptoms and functional deficits, and pain coping strategies. Of 16 variables in these categories, 11 significantly improved, including the FIQR Total Score (-15.67, criteria = ±0.41), pain (-3.14, criteria = ±0.36), fatigue (-2.00, criteria = ±0.51), stiffness (-2.57, criteria = ±0.08), poor sleep (-1.29, criteria = ±0.72), poor memory (-2.57, criteria = ±0.15), tenderness (-2.29, criteria = ±0.03), physical strength (+2.43, criteria = ±1.55), physical balance with eyes closed (+3.91, criteria = ±1.36), pain acceptance (+4.86, criteria = ±3.43), and pain catastrophizing (-0.95, criteria = ±0.07). Three variables - depression, poor balance, and environment sensitivity – shifted in the expected direction (lower scores) but did not meet significance criteria. Two variables – anxiety, and physical balance with eyes open – showed no pre-post change.

Discussion

While a series of studies have documented the benefit of yoga and mindfulness for chronic pain management, few of these studies have investigated the mechanisms by which positive outcomes are achieved. The present pilot study utilized a multi-modal QST protocol to demonstrate several specific improvements in neurobiological pain processing in fibromyalgia patients following a Mindful Yoga intervention. Significant changes were recorded in heat pain tolerance, heat pain after-sensations, and pressure pain thresholds. These improvements imply mitigation of several abnormalities associated with fibromyalgia, including thermal hyperalgesia related to lower pain tolerance; abnormal temporal summation leading to more intense pain sensations that are slower to resolve; and mechanical hyperalgesia (Price & Staud, 2005).

One of the strengths of this small study was the application of a variety of QST modalities, including a temporal summation paradigm, to assess different aspects of the pain pathway. The fact that both heat-related and pressure-related pain processing were modified after the intervention suggests a possible effect on the underlying central processing mechanism of fibromyalgia pain. Overall, our findings are consistent with results from prior yoga and mindfulness QST studies, which have reported reduced pain intensity following slow yogic breathing among women with fibromyalgia (Zautra et al., 2010), improved pressure pain thresholds among patients with chronic nonspecific neck pain after an Iyengar yoga intervention (Cramer et al., 2013), increased cold pain tolerance among healthy yoga practitioners (Villemure et al., 2014), and decreased pain sensitivity in healthy normals following a mindfulness meditation intervention (Zeidan et al., 2010). Our findings also fit with a wider body of literature using QST to assess analgesia following exercise interventions (Koltyn, 2000). Results from a variety of QST modalities indicate that exercise produces analgesia through activation of descending inhibitory pathways and reduced activation of ascending pathways.

Importantly, changes in sensory pain processing in this pilot study were accompanied by improvements in fibromyalgia symptoms and functional deficits, including physical tests of strength and balance, and in pain coping strategies. These additional improvements replicate changes we have reported in our prior fibromyalgia samples (Carson et al., 2010; Carson et al., 2012). Several outcomes qualified as clinically meaningful improvements (e.g., fibromyalgia severity -30.7%, pain -51.2%, stiffness -40.0%, pain catastrophizing -47.1%). The association of this range of symptomatic improvements with changes in pathophysiological pain processes suggests that these mechanisms may account at least partially for the overall positive impact of the yoga intervention.

More broadly, we believe that the effectiveness that Mindful Yoga has demonstrated - not only with fibromyalgia but also with cancer-related pain, fatigue, and emotional distress (Carson, Carson, Porter, Keefe, & Seewaldt, 2009; Carson et al., 2007) - is based on this approach’s focus on shifting how participants relate to challenging experiences such as persistent pain, troubling thoughts, and disturbing emotions. To this end, cues to remain mindful (e.g., “What do you notice right now? What waves of sensation, emotions of the heart, stories in the mind?”) and the application of deeper yogic teachings (e.g., noticing the steady presence of “simple being”) are woven into Mindful Yoga posture instructions, such that yoga poses can become a forum for developing nonreactive awareness of bodily sensations, including pain (Grant, 2014). Posture practice is complemented in Mindful Yoga by substantive meditation practice, and other yogic strategies tailored to enhance awareness of what choices contribute to more well-being versus suffering (McCracken et al., 2004).

More work with a larger, randomized controlled sample is needed to better determine what neurobiological and psychological processes account for the improvements in pain and other outcomes induced by Mindful Yoga. Future research could include not only QST but also more proximal measures of neural pain processes, such as fMRI, and also a measure of mindfulness (Baer et al., 2008). A dismantling study might also be useful to determine the relative contribution of the yoga posture versus meditative components of Mindful Yoga to improvements in outcomes.

Conclusions from this pilot study are quite restricted. Limitations come from the very small rather homogeneous sample, the lack of a control condition, and potential selection bias given that all subjects expressed interest in participating in a yoga study. In addition, this study cannot fully rule out various nonspecific effects such as expectancy for improvement, attention from an intervention provider, intent to please, placebo effect, or a combination of such effects. Future more rigorous studies will be needed to address these limitations, including determining whether these findings can be generalized to a diverse population, and how durable the intervention effects are.

Nonetheless, this study has documented initial evidence that indicates the ability of the Mindful Yoga intervention to modulate abnormal pain processing in fibromyalgia. This evidence is sufficiently substantive to conclude that more research is warranted into the intervention’s effects on neurobiological pain processing.

Table 1

Table title

Table 1

Characteristics of the sample (N = 7)

	N(%)/*M*(SD)
Age, years	49.7 (17.0)
Years since diagnosis	8.4 (7.6)
Race/ethnicity	
Caucasian	6 (85.7%)
Native American	1 (14.3%)
Education	
College degree	6 (85.7%)
Graduate studies	1 (14.3%)
Marital status	
Married/partnered	4 (57.1%)
Divorced/separated	2 (28.6%)
Never married	1 (14.3%)

Table 2

Baseline outcome means, post-treatment change (Δ) means, post-treatment change criteria*, indications of significant outcomes from separation tests ($p < .05$), and post-treatment change percentages.

Variable	Baseline Mean	Post Δ Mean	Post Δ Criteria	Outcome Indication	Percent Change
Heat Pain Threshold	40.57	1.60	±3.90	--	+3.94%
Heat Pain Tolerance	44.13	2.30	±0.80	Higher	+5.20%
Pressure Pain Threshold	8.50	0.79	±0.02	Higher	+9.26%
Heat Pain After-sensations	19.79	-16.71	±3.21	Lower	-84.48%
FIQR Total Score	51.10	-15.67	±0.41	Lower	-30.66%
Pain (FIQR)	6.14	-3.14	±0.36	Lower	-51.16%
Fatigue (FIQR)	7.14	-2.00	±0.51	Lower	-26.92%
Stiffness (FIQR)	6.43	-2.57	±0.08	Lower	-40.00%
Poor Sleep (FIQR)	8.14	-1.29	±0.72	Lower	-15.79%
Depression (FIQR)	3.43	-0.86	±1.71	--	-25.00%
Poor Memory (FIQR)	6.86	-2.57	±0.15	Lower	-37.50%
Anxiety (FIQR)	2.71	0.00	--	--	0.00%
Tenderness (FIQR)	6.71	-2.29	±0.03	Lower	-34.04%
Poor Balance (FIQR)	3.71	-0.71	±1.05	--	-19.23%
Environment Sensitivity (FIQR)	4.71	-0.86	±1.36	--	-18.18%
Strength (Timed Chair Rise)	11.43	2.43	±1.55	Higher	+21.25%

Balance-Eyes Closed (SCBT)	23.55	3.91	±1.36	Higher	+16.61%
Balance-Eyes Open (SCBT)	30.00	0.00	--	--	0.00%
Pain Acceptance	59.71	4.86	±3.43	Higher	+8.13%
Pain Catastrophizing	2.02	-0.95	±0.07	Lower	-47.06%

*post-treatment change criteria were calculated as the post-treatment change mean multiplied by 0.5, minus the product of the standard deviation of the sampling distribution multiplied by 1.645.

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Author Note

This work was supported by a grant from the Oregon Health & Science University Medical Research Foundation and resources supplied by the Fibromyalgia Information Foundation.