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Sex and Pain-Related Psychological Variables Are Associated With Thermal Pain Sensitivity for Patients With Chronic Low Back Pain

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Abstract: Biologic and psychological associations with evoked pain sensitivity have been extensively studied in healthy subjects but not among subjects with clinical pain syndromes. This study involved patients with chronic low back pain and investigated whether: 1) sex differences existed for thermal pain sensitivity; and 2) sex, fear-avoidance beliefs, and/or pain catastrophizing influenced thermal pain sensitivity. Thirty-three consecutive patients enrolled in a pain rehabilitation program completed self-report questionnaires and underwent quantitative sensory testing with an established protocol for thermal stimuli. Women had elevated pain sensitivity for measures of tolerance and temporal summation but not for first pulse response. In the multivariate models predicting thermal pain sensitivity, sex was associated with tolerance, and fear-avoidance beliefs were associated with first pulse response. Sex and pain catastrophizing were associated with temporal summation of thermal pain. Future studies involving clinical samples are necessary to replicate these findings and to explore the involvement of cortical structures.

Perspective: *This study suggests that sex, fear-avoidance beliefs, and pain catastrophizing were associated with thermal pain sensitivity for patients with chronic low back pain. These results corroborated sex differences in tolerance and temporal summation observed in the experimental pain literature for healthy subjects. These results also suggest the potential for these specific pain-related beliefs to be associated with a sensitized state because previous studies have demonstrated their association to clinical pain reports, and this study demonstrated associations with thermal pain sensitivity.*

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Key words: Quantitative sensory testing, experimental pain, gender differences, temporal summation, fear-avoidance beliefs, catastrophizing.

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Pain is a multidimensional experience influenced by complex interactions between biological, psychological, social, and cultural factors.²⁹ One psychological model, the Fear-Avoidance Model of Exaggerated Pain Perception (FAMEPP), proposes that fear-avoidance beliefs and pain catastrophizing are the primary factors involved in the development and maintenance of chronic low back pain.^{20,45} Fear-avoidance beliefs are composed of an individual's pain experiences, present stress level, pain behavior, and spe-

cific personality traits.²⁰ Fear-avoidance beliefs describe an individual's fear of pain and fear of reinjury, as well as beliefs about whether physical activity and work should be maintained while experiencing pain.⁴⁶ Pain catastrophizing is a general negative cognition related to the expectation that the experienced pain will inevitably result in the worst possible outcome.⁴¹ Pain catastrophizing is believed to be a multidimensional construct composed of rumination, helplessness, and magnification.⁴¹

In the FAMEPP, these psychological factors determine an individual's response to an episode of pain along a continuum from confrontation to avoidance.^{20,45} A confrontation strategy (characterized by low levels of fear-avoidance beliefs and pain catastrophizing) is viewed as an adaptive response, enabling the individual to return to normal vocational and social activities. In contrast, an avoidance strategy (high levels of fear-avoidance beliefs and pain catastrophizing) is viewed as a maladaptive response. The theorized consequences of an avoidance strategy are the development of an exaggerated pain perception and chronic disability from reduction in physical activities.^{20,45}

Previous studies supporting the FAMEPP's role in the development and maintenance of chronic pain have primarily emphasized clinical pain reports.^{2,10,19,22} The influence that fear-avoidance beliefs and pain catastrophizing have on evoked pain has not been as widely reported in the literature because previous studies have focused on healthy subjects.^{11,42} Evoked pain paradigms offer several advantages when studying psychological variables and their influence on pain perception. Evoked pain paradigms ensure that each subject receives a standard pain stimulus, thereby reducing variability in pain reports related to clinical factors that can be difficult to quantify (ie, mechanism of the original injury). Also, evoked pain paradigms offer alternate measurement methodology than studies that exclusively use self-reports of clinical pain. This is an important distinction because previous FAMEPP studies relied heavily on self-report measures, and the described relationships between psychological variables and clinical pain could potentially be confounded through measurement bias.¹⁴

Finally, evoked pain paradigms allow for different components of pain perception to be studied, like tolerance or temporal summation of pain.²³ It is not feasible to distinguish among these components in studies that rely solely on clinical pain reports. There is considerable evidence in the clinical literature that fear-avoidance beliefs and pain catastrophizing contribute to the development and maintenance of clinical exaggerated pain perception. In contrast, there is less evidence on how these psychological variables influence different aspects of evoked pain sensitivity. For example, do fear-avoidance beliefs and pain catastrophizing influence all components of pain sensitivity, or do they only influence certain components? Studies that consider this topic could contribute to the literature by providing preliminary data on how the FAMEPP influences pain sensitivity.

We investigated how specific FAMEPP psychological

variables influenced thermal pain sensitivity. Previous studies involving thermal stimuli suggest that biologic (sex) and psychological factors significantly influence thermal pain sensitivity.^{8,11,28,31,42} These studies focused exclusively on healthy subjects, and it is conceivable that different associations exist for subjects with clinical pain conditions. For example, patients with chronic low back pain have reported increased pain sensitivity in response to a variety of stimuli, when compared with healthy subjects.^{1,5,9,12,15,18} Also, a wider range of psychological scores would be expected for patients with low back pain, potentially making for a more robust relationship with thermal pain sensitivity. Whether the previously described associations between sex, psychological variables, and pain sensitivity from healthy subjects are applicable to clinical populations has not been widely reported.

Purpose and Hypotheses

Therefore, the purpose of this study was to determine whether sex and specific psychological variables from FAMEPP influence thermal pain sensitivity in patients with chronic low back pain. Our hypotheses were the following:

- (1) Women with chronic low back pain would exhibit elevated pain sensitivity in response to evoked thermal pain stimuli. Our rationale for this hypothesis was that women have consistently reported higher thermal pain sensitivity in healthy subjects,^{8,31} and we expected to replicate these findings in a clinical sample of patients with low back pain.
- (2) Fear-avoidance beliefs and pain catastrophizing would significantly influence pain sensitivity (tolerance, first pulse response, and temporal summation) to evoked thermal pain stimuli for patients with chronic low back pain. Our rationale for this hypothesis was that state anxiety, pain catastrophizing, and pain-related fear influenced pain sensitivity in healthy subjects,^{11,31,42} and we expected to observe similar influences in this clinical sample of patients with low back pain.

Materials and Methods

Subjects

Consecutive subjects were recruited from an interdisciplinary pain rehabilitation program in Jacksonville, Florida. Inclusion criteria for this study were: 1) between 18 to 70 years of age; 2) ability to read the questionnaires that are part of the protocol (approximately 8th grade reading level); and 3) meet criteria for at least one of the following Quebec Task Force on Spinal Disorders³³ diagnostic classifications: 1c (chronic low back pain without radiation below the gluteal fold), 2c (chronic low back pain with proximal radiation to the knee), 3c (chronic low back pain with distal radiation below the knee), 9.2 (postsurgical status, more than 6 months after surgical intervention, symptomatic), or 10 (chronic pain syndrome).

Exclusion criteria for this study were: 1) concurrent musculoskeletal pain in jaw, neck, or shoulder; 2) concurrent diagnosis of fibromyalgia; and 3) meeting any one of the following Quebec Task Force on Spinal Disorders³³ diagnostic classifications: 1a or 1b (acute or subacute low back pain without radiation below the gluteal fold), 2a or 2b (acute or subacute low back pain with proximal radiation to the knee), 3a or 3b (acute or subacute low back pain with distal radiation below the knee), 4a or 4b or 4c (acute or subacute or chronic low back pain with distal radiation below the knee and neurologic signs), 5 (presumptive lumbar nerve root compression), 6 (confirmed lumbar nerve root compression), 7 (confirmed lumbar spinal stenosis), 8 (postsurgical status, less than 6 months after surgical intervention), 9.1 (postsurgical status, more than 6 months after surgical intervention, asymptomatic), or 11 (other spinal disorders including metastatic disease, visceral disease, or fracture). There were no restrictions of study participation on the basis of sex, race, or gender.

General Procedures

Subjects were referred to research staff after being evaluated by clinical staff for appropriateness of eligibility. At the time of the research assessment, subjects rated their low back pain intensity on a numeric rating scale (NRS) that ranged from 0 (no pain) to 100 (worst pain imaginable). Subjects then completed previously validated self-report questionnaires to assess specific pain-related psychological factors (fear-avoidance beliefs and pain catastrophizing). Subjects completed these questionnaires in reference to their low back pain. Therefore, their responses reflect beliefs about their low back pain, not about the evoked thermal pain they were about to experience. These questionnaires were completed with the research staff in attendance. Research staff was available to answer basic questions related to the questionnaires, but they were specifically instructed not to assist the subjects in completing the questionnaires.

Fear-Avoidance Beliefs

The Fear-Avoidance Beliefs Questionnaire (FABQ) was used to quantify fear-avoidance beliefs in this study.⁴⁶ The FABQ is an 11-item, 7-point rating scale (0, "strongly disagree" to 6, "agree") with physical activity and work subscales. Only the 4-item physical activity scale (FABQ-PA) was used for this study because not all patients were expected to report work-related injury. The FABQ-PA has a potential range of 0 to 24. The test-retest stability of the FABQ-PA has been reported in the literature for patients with chronic low back pain, with reliability coefficients ranging from 0.64 to 0.88.^{21,46} The FABQ-PA has been validated in a study demonstrating that it explained unique amounts of variance in disability after controlling for other relevant factors.⁴⁶

Pain Catastrophizing

The Coping Strategies Questionnaire-Revised (CSQ-R) is a 27-item, 7-point rating scale that measures the fre-

quency of use for common pain coping strategies.³² The CSQ-R contains a 6-item catastrophizing subscale that measures helpless and pessimistic cognitions related to pain perception. Only the catastrophizing subscale was included in the current study, and its items measure the frequency of cognitions related to coping with pain on a 7-point scale (0, "never" to 6, "always"). This subscale is a commonly used and well-validated instrument,^{16,30,32,39} and we used a revised scoring system.³⁰ The pain catastrophizing subscale of the CSQ-R has a potential range of 0 to 36.

Thermal Pain Sensitivity

Subjects underwent quantitative sensory testing to assess pain sensitivity, as per previously established protocols involving thermal stimuli.^{27,31,37,38} Numerous basic studies have suggested that central sensitization of pain is a specific neurophysiologic mechanism resulting from tonic, peripheral input from C and A-delta fibers.^{6,7,24,25,44,47} Collectively the basic literature suggests that input from these fibers enters the central nervous system through spinal cord dorsal horn segments, activating N-methyl-D-aspartate and substance P receptors in wide dynamic range and nociceptive specific cells. The tonic activation of these nerve cells then induces a central hyperalgesia that is mediated at the spinal cord level. A measurable result of this hyperalgesia is that subsequent evoked pain stimuli are relayed from the dorsal horn as increasing in intensity, despite their being of standard amplitude. In basic models, temporal parameters (increasing frequency of nociceptive input) are one of the determining factors in whether central sensitization is experienced.²⁴

Direct measurement of central sensitization is not feasible in human beings, but proxy measures of C and A-delta fiber mediated central sensitization have been developed by using thermal stimuli.^{27,31,37,38} Human studies consistently support the validity of these proxy measures of sensory central sensitization because increasing the temporal parameters of thermal stimuli resulted in increased pain perception, corresponding with basic studies.^{26,36,38} Specific to this study, peripheral thermal input occurring at 0.33 Hz or less induced temporal summation in human beings, whereas input at .20 Hz or greater did not.²³

Thermal stimuli were delivered via contact thermode and a computer-controlled Medoc Neurosensory Analyzer (TSA-2001; Ramat Yishai, Israel) with a peltier-element-based stimulator. Stimuli were applied to the volar surface of the forearm, and exact stimulation sites were varied to prevent carryover effects as a result of spatial summation, local sensitization, or suppression of nociceptors. In addition, the interval between stimuli was at least 60 seconds to avoid carryover effects. A trained research assistant applied the stimuli and recorded subject response to the thermal stimuli by using an NRS to rate evoked pain intensity. The NRS for evoked pain intensity ranged from 0 (no pain) to 100 (worst pain intensity imaginable). The first 5 subjects were tested with a male and female research assistant, whereas the

Table 1. Demographic, Clinical, and Psychological Summary of Sample (n = 33)

VARIABLE	VALUE
Sex (no. male, %)	16, 48.5%
Age (y)	45.8 (10.3)
Race (no. white, %)	25, 75.8%
(No. African American, %)	5, 15.2%
(No. Hispanic, %)	1, 3.0%
(No. not responding, %)	2, 6.1%
Education (y)	12.9 (2.2)
Smoking status (no. smokers, %)	16, 48.5%
Type of LBP (no. work-related, %)	24, 72.7%
Opioid use (no. taking opioid medication, %)	20, 60.6%
Antidepressant use (no. taking antidepressant medication, %)	17, 51.5%
Days LBP interferes with daily activities (no. of days/wk)	6.5 (1.2)
LBP intensity at time of testing (NRS, 0–100)	62.7 (21.4)
Fear-avoidance beliefs–physical activity (FABQ, 0–24)	16.9 (5.6)
Pain catastrophizing (CSQ-R, 0–36)	19.9 (8.9)
Pain threshold (°C)	42.7 (4.3)
Pain tolerance (°C)	47.5 (3.4)
First pulse response (NRS, 0–100)	62.5 (24.3)
Temporal summation	9.0 (18.6)

Abbreviation: LBP, low back pain.

NOTE: All values are reported as mean (standard deviation) or frequency, %. All categorical variables are dichotomous, unless otherwise indicated.

remaining 28 were tested with a female research assistant.

Subjects were familiarized to the thermal stimuli with a practice session before formal pain sensitivity testing. In this practice session, a continuous heat stimulus was delivered to the subject's arm. The stimulus started at 35°C, and the stimulus was increased at a rate of 0.5°C/second, with subjects terminating the stimulus when the temperature reached pain threshold. This was repeated three times, and the average threshold is reported in Table 1. We then assessed the specific components of pain sensitivity related to this study: 1) tolerance; 2) first pulse response; and 3) temporal summation by using the following protocol adapted from previous protocols.^{27,31,36,38}

Tolerance

A continuous heat stimulus was delivered to the subject's arm. This stimulus started at 35°C and increased at a rate of 0.5°C/second. Subjects were asked to terminate the stimulus with the following instructional set, "Please press this button when the heat becomes so painful or uncomfortable that you wish it to stop." Three separate trials were performed, and the average of these trials is reported in this article.

First Pulse Response

One 47°C heat stimulus of 1-second duration was delivered to subject's arm. The research assistant recorded NRS ratings of pain intensity. Subjects were asked to rate their "first" pain intensity felt. These ratings are believed

to be primarily mediated by input from A-delta fibers.^{23,27}

Temporal Summation

A train of 10 consecutive heat pulses of <1-second duration at an interstimulus interval of 0.33 Hz was delivered to the subjects. A frequency of 0.33 Hz was selected to ensure the development of temporal summation.²³ The temperature of the heat pulses rapidly fluctuated (10°C/sec) from a low of 35°C to a peak of 47°C. Temperature levels were monitored by a contactor-contained thermistor and returned to a preset baseline of 35°C by active cooling. The research assistant recorded NRS ratings of pain intensity. Subjects were asked to rate their delayed (second) pain intensity associated with the first, third, and fifth heat pulses. These ratings are believed to be primarily mediated by C-fiber input.^{23,27}

Procedures

The University of Florida's Institutional Review Board approved the protocol for this study. Subjects were screened for eligibility by one of the authors (V.T.W.), with assistance from his clinical staff. Eligible subjects read and signed a consent form that had also been approved by the University's Institutional Review Board before participating in any study-related procedures. After providing informed consent, subjects completed self-report questionnaires capturing demographic, clinical, and psychological information. Then a research assistant completed the quantitative sensory testing protocol.

Data Analysis

All data analyses were performed on SPSS for Windows, Version 13.0 (SPSS Inc, Chicago, IL) at an alpha level of .05. Descriptive statistics were generated for the demographic, clinical, psychological, and pain sensitivity measures. Several preliminary analyses were performed to ensure that potentially confounding factors were not affecting our hypothesis testing, and that regression assumptions were not violated. Pearson correlations determined the influence of low back pain intensity on thermal pain sensitivity, and independent *t* tests determined whether there were differences in thermal pain sensitivity on the basis of opioid or antidepressant medication status. These analyses were performed to determine whether low back pain intensity and/or medication status should be considered as covariates in the subsequent regression models. Pearson correlations were calculated between pain-related psychological variables, and independent *t* tests determined whether there were sex differences in pain-related psychological variables. These analyses investigated the potential of colinearity before entering these variables in regression models and determined whether the psychological variables were confounded by sex differences. Last, Pearson correlations were calculated between the thermal pain sensitivity measures, and the pain sensitivity measures were also assessed by one sample Kolmogorov-Smirnov tests. These analyses investigated how much variance the de-

Table 2. Sex Differences in Pain Sensitivity for Patients With Chronic Low Back Pain

PAIN MEASURE	FEMALE	MALE	EFFECT SIZE	P VALUE
Tolerance*	45.7 (3.5)	49.4 (1.9)	1.37	.001
First pulse response†	65.4 (22.6)	60.0 (26.2)	.22	.568

*Measured in °C.

†Measured in pain rating by NRS (0–100).

pendence variables shared and determined whether they approximated a normal distribution before being used in the regression models.

Sex differences in pain sensitivity were investigated by independent *t* tests (tolerance and first pulse response) and repeated-measures analysis of variance (ANOVA) (temporal summation). Then three separate simultaneous regression models were created to address our second hypothesis. Each regression model included sex, fear-avoidance beliefs, and pain catastrophizing to determine their influence on separate measures of thermal pain sensitivity. The regression models did not include any interaction terms. Tolerance, first pulse response, and temporal summation were separate dependent variables for each regression model. For the regression models, any missing data were replaced by the mean value, and data points with standardized residuals greater than 3.0 were removed.

Results

A total of 82 patients entered the pain program during the study period. Patients were excluded for having medical diagnoses or symptom distribution inconsistent with the inclusion criteria ($n = 29$) or for being unable to independently read the questionnaires ($n = 3$). Of the 50 patients who were study eligible, 33 provided informed consent and participated in this study. Descriptive information for the demographic, clinical, and psychological measures from the sample is provided in Table 1.

The preliminary analyses indicated that low back pain intensity was not strongly or consistently associated with thermal pain sensitivity, with correlation coefficients ranging from -0.25 to 0.20 . In addition, there were no significant differences in evoked pain responses on the basis of medication status ($P > .50$ for comparisons). Therefore, these factors were not entered into the regression models as covariates. As expected, pain catastrophizing and fear-avoidance beliefs had a positive association ($r = .27$, $P = .23$), but this association was not so strong that excessive colinearity was anticipated. There were no sex differences in fear-avoidance beliefs or pain catastrophizing ($P > .50$ for comparisons). Tolerance was negatively associated with first pulse response ($r = -.41$, $P = .03$) and temporal summation ($r = -.48$, $P = .01$), and first pulse response and temporal summation were also negatively associated with each other ($r = -.38$, $P = .05$). Each of the thermal pain sensitivity measures approxi-

mated a normal distribution by 1 sample Kolmogorov-Smirnov tests ($P > .25$ for comparisons).

Sex Differences in Thermal Pain Sensitivity (Hypothesis 1)

Women had lower pain sensitivity for tolerance, but no sex differences were observed for first pulse response (Table 2). The repeated-measures ANOVA indicated a significant interaction between sex and number of pain pulses ($F_{2,52} = 4.8$, $P < .013$) for patients with chronic low back pain. Women had a greater rate of increase in temporal summation when compared with men (Fig 1).

Influences on Thermal Pain Sensitivity (Hypothesis 2)

The regression model for tolerance is summarized in Table 3. This multivariate model was statistically significant ($P = .003$) and explained 38% (31% adjusted) of the total variance in tolerance, with sex being the only statistically significant individual factor. The regression model for first pulse response is summarized in Table 4. This multivariate model was statistically significant ($P = .049$) and explained 23% (15% adjusted) of the total variance, with fear-avoidance beliefs being the only statistically significant individual factor. The regression model for temporal summation is summarized in Table 5. This multivariate model was statistically significant ($P < .001$) and explained 63% (59% adjusted) of the total variance, with sex and pain catastrophizing being the statistically significant individual factors.

Discussion

This study investigated the association of sex and psychological variables with thermal pain sensitivity in subjects with chronic low back pain. Although these issues have been widely investigated in health subjects, studies involving clinical samples are less common. These results speak to the complexity of the pain experience in human beings, because sex and psychological factors significantly influenced different components of pain sensitiv-

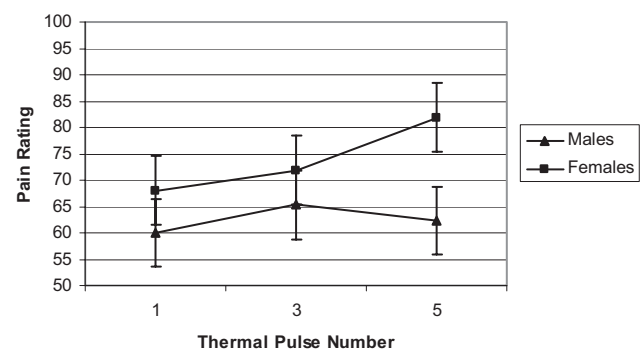


Figure 1. Sex differences in temporal summation of evoked thermal pain for patients with chronic low back pain. A significant interaction ($P < .013$) indicated that women with chronic low back pain experienced significantly greater temporal summation in response to thermal stimuli (bars represent estimate of standard error).

Table 3. Sex Significantly Associated With Thermal Pain Tolerance

Overall model			
$R^2 = .376$			
Adjusted $R^2 = .312$			
$F_{3,29} = 5.83$			
$P = .003$			
VARIABLES	B	STANDARD BETA	P VALUE
Fear-avoidance beliefs	-.2	-.26	.090
Pain catastrophizing	-.1	-.03	.866
Sex	-3.4	.53	.001
Thermal pain tolerance = $52.2 - .2(\text{FABQ}) - 3.4(\text{Sex}) - .1(\text{CSQ-R})$			

NOTE: Fear-avoidance beliefs measured by FABQ. Pain catastrophizing measured by CSQ-R. Sex was coded so that 1 = female.

ity. We first considered the influence of sex, to replicate the literature reporting sex differences in thermal pain sensitivity for healthy subjects.^{8,28,31} Our findings suggest that sex differences persisted in this clinical sample, because women had lower pain tolerance and higher rates of temporal summation. In the multivariate models that considered pain-related psychological factors, sex was the only unique influence on pain tolerance, and it also remained a unique influence on temporal summation. These findings are a preliminary indication that sex differences affecting thermal pain sensitivity are active in healthy subjects and in those with clinical pain conditions.

Sex was not a significant influence on all aspects of thermal pain sensitivity, because no sex differences were observed in first pulse response. We were unable to directly corroborate this finding with healthy subjects because first pulse response is not widely reported in the pain literature. Comparisons could be made to pain threshold, which is a measure primarily mediated by A-

Table 4. Fear-Avoidance Beliefs Significantly Associated With First Pulse Response to Thermal Pain

Overall model			
$R^2 = .234$			
Adjusted $R^2 = .155$			
$F_{3,29} = 2.96$			
$P = .049$			
VARIABLES	B	STANDARD BETA	P VALUE
Fear-avoidance beliefs	2.0	.48	.008
Pain catastrophizing	-.5	-.19	.266
Sex	3.6	.08	.622
First pulse response = $34.7 + 2.0(\text{FABQ}) + 3.6(\text{Sex}) - .5(\text{CSQ-R})$			

NOTE: Fear-avoidance beliefs measured by FABQ. Pain catastrophizing measured by CSQ-R. Sex was coded so that 1 = female.

Table 5. Sex and Pain Catastrophizing Associated With Temporal Summation of Thermal Pain

Overall model*			
$R^2 = .627$			
Adjusted $R^2 = .586$			
$F_{3,28} = 15.15$			
$P < .001$			
VARIABLES	B	STANDARD BETA	P VALUE
Fear-avoidance beliefs	-.7	-.24	.054
Pain catastrophizing	1.3	.64	<.001
Sex	16.6	.53	<.001
Temporal summation = $-13.8 - .7(\text{FABQ}) + 16.6(\text{Sex}) + 1.3(\text{CSQ-R})$			

NOTE: Fear-avoidance beliefs measured by FABQ. Pain catastrophizing measured by CSQ-R. Sex was coded so that 1 = female.

*1 data point was removed from this analysis (standardized residual > 3.0).

delta fiber input. The effect size from the present study ($d = .22$) was smaller than the pooled effect size for thermal pain threshold from the meta-analysis by Riley et al²⁸ ($d = .46$), suggesting sex differences for first pulse response might not be robust. Instead of sex, our results indicated that fear-avoidance beliefs were the only unique influence on first pulse response, suggesting an association with immediate (ie, A-delta fiber mediated) thermal pain sensitivity. Pain catastrophizing was positively associated with temporal summation, suggesting an association with delayed (C-fiber mediated) thermal pain sensitivity.

These findings further support the validity of the FAMEPP by demonstrating that the same pain-related constructs that are associated with clinical pain perception^{10,11,16,19,22,34,35,40,42,46} are also associated with certain aspects of evoked, thermal pain perception. Collectively, these findings suggest fear-avoidance beliefs and pain catastrophizing might be associated with a "sensitized state" in which responses to pain are elevated, regardless of the anatomic location of the stimulus. There was an exception to this trend, because FAMEPP factors were not associated with thermal pain tolerance. The lack of association with tolerance is contrary to another report that found fear of pain to be predictive of lifting tolerance in patients with chronic low back pain.⁴ We believe methodologic differences in the stimuli explain the lack of corroboration among these studies, and future study will clarify the FAMEPP association with different aspects of pain tolerance. When considering the likelihood of a sensitized state, it should be noted that we only measured the subjects' beliefs (fear-avoidance and pain catastrophizing) about back pain. Specific beliefs about the evoked stimuli they were about to experience were not measured, and it is a viable alternate hypothesis that these beliefs might also be associated with thermal pain sensitivity for patients with low back pain.

These data also allow for the development of interesting hypotheses regarding the specific relationship these psychological factors have with thermal pain sensitivity. Specifically, these data indicated that fearful beliefs had a stronger association with first pulse pain perception. As an explanation for this finding, we speculate that fearful cognitions might result in a priming, predisposed state that heightens sensitivity to pain stimuli. Our data also indicated that pain catastrophizing had a stronger association with temporal summation. As an explanation for this finding, we speculate that catastrophic cognitions (ie, rumination, helplessness, and magnification), which take time to develop, as a result might have a stronger association with pain stimuli that builds over time. These are intriguing findings that suggest fear-avoidance beliefs and pain catastrophizing are potentially involved in elevated pain sensitivity through peripheral A-delta and C-fiber input, respectively. However, these findings must also be viewed with caution, because this was only a preliminary study, and these findings need to be replicated in large samples. It is also important to note that the current study might not have had adequate statistical power to detect when both variables were associated with pain sensitivity. This seems to be especially relevant in the model for temporal summation, because fear-avoidance beliefs trended toward having a significant, negative association. Additional research will confirm our speculation regarding fear-avoidance beliefs and pain catastrophizing having specific effects on thermal pain sensitivity.

For temporal summation, a direct comparison between the present study and one involving healthy subjects can be made because both used similar protocols. In a multivariate model for healthy subjects, the strongest individual predictors of temporal summation were gender role expectations of pain (stereotypical willingness to report pain) and negative affect (state anxiety), whereas sex was no longer a significant influence when these psychological factors were considered.³¹ In the present study involving patients with chronic low back pain, sex was a significant influence on temporal summation, but it was not as strong as pain catastrophizing in the multivariate model. It appears a common theme among these studies is that sex and pain-related psychological factors significantly influenced temporal summation, but psychological influence was stronger when considered in a multivariate model. It is also important to note the present study only considered the influence of sex and did not consider the influence of gender role expectations of pain, as in the previous work with healthy subjects.³¹ Thus in the present study, the sex variable is likely to be a multidimensional construct made up of both sex and gender components. The influence of gender role on clinical pain conditions is unknown and should be considered in future studies.

Future Study

Because it is likely that there is a psychological influence on pain sensitivity, functional imaging studies provide insight on the involvement of specific cortical struc-

tures. In a study³ that used standard thermal stimuli to induce pain, the healthy subjects' responses were dichotomized (by median split of pain ratings to the standard stimuli) into those with high pain sensitivity and those with low pain sensitivity, without concurrent psychological assessment. Subjects with high pain sensitivity had higher activation in the primary somatosensory cortex, the anterior cingulate cortex, and the prefrontal cortex.³ Another imaging study in healthy subjects investigated the influence of pain catastrophizing on the cortical responses to pressure pain.¹³ In this study, subjects were dichotomized (by median split of Coping Strategies Questionnaire scores) into high and low pain catastrophizing groups, and the influence of depression was accounted for statistically. In general, pain catastrophizing was associated with widespread cortical activation in areas related to pain anticipation, attention, and emotion, as well as motor control. The high pain catastrophizing group showed unique activation in the anterior cingulate cortex and the lentiform nucleus, when compared with the low group.¹³

Findings from a recent study¹² that involved functional imaging of pain in clinical populations are relevant to the current study. Cortical activation in response to pressure pain was compared between healthy subjects, those with fibromyalgia, and those with chronic low back pain. Subjects with chronic low back pain and fibromyalgia exhibited similar activation patterns in response to the pressure pain, with increased activity in the primary and secondary somatosensory cortices, inferior parietal lobe, and cerebellum.¹² These studies suggest specific cortical areas are involved with pain perception and perhaps give an indication of potential anatomic location of the "sensitized state." Future studies involving psychological questionnaires, administration of standard pain stimuli, and functional imaging of the cortex will help determine how psychological factors influence pain perception.

Limitations of the Present Study

One of the primary limitations to the present study is its correlational design. As a result, we cannot directly speak to the temporal relationship between psychological factors and thermal pain sensitivity. Although we hypothesized that psychological factors influenced pain sensitivity, an equally viable competing hypothesis is that being sensitized influenced the psychological factors. This temporal relationship will be delineated in future studies through longitudinal designs involving the appropriate manipulation of psychological factors. Another limitation of this study is its relatively small sample size, which increased the probability of type II error. Although this did not appear to directly affect our primary hypotheses (all regression models were statistically significant), type II error is a concern for the individual contributions of fear-avoidance beliefs to temporal summation of pain. The small sample size also limited the complexity of our regression models by not allowing investigation of interaction terms. For example, there is evidence in the clinical pain literature^{17,43} that sex moderates the effect of pain catastrophizing on pain, but we

were unable to explore this relationship within the present design. For ethical reasons, patients' medications were not discontinued before testing of thermal pain sensitivity. Although we did not find any obvious differences in response to evoked pain on the basis of opioid or antidepressant use, it is conceivable these results might have been influenced by medication use. Other limitations of this study were that female testers performed a majority of the pain testing, and we were unable to collect information on menstrual cycle, body mass index, duration of pain, or tender point count for these subjects.

Conclusion

This study investigated influences of sex and psychology on thermal pain sensitivity in patients with chronic

low back pain. Sex differences were observed for pain tolerance and temporal summation. Sex differences were observed for measures of tolerance and temporal summation, but not for first pulse response. In the multivariate models predicting thermal pain sensitivity, sex was the only unique influence of tolerance, and fear-avoidance beliefs were the only unique influence on first pulse response. Sex and pain catastrophizing uniquely influenced temporal summation of thermal pain.

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