Sensory, Affective, and Catastrophizing Reactions to Multiple Stimulus Modalities: Results from the Oklahoma Study of Native American Pain Risk

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Abstract: Native Americans (NAs) have a higher prevalence of chronic pain than any other U.S. racial/ethnic group; however, little is known about the mechanisms for this pain disparity. This study used quantitative sensory testing to assess pain experience in healthy, pain-free adults (n = 137 NAs (87 female), n = 145 non-Hispanic whites (NHW; 68 female)) after painful electric, heat, cold, ischemic, and pressure stimuli. After each stimulus, ratings of pain intensity, sensory pain, affective pain, pain-related anxiety, and situation-specific pain catastrophizing were assessed. The results suggested that NAs reported greater sensory pain in response to suprathreshold electric and heat stimuli, greater pain-related anxiety to heat and ischemic stimuli, and more catastrophic thoughts in response to electric and heat stimuli. Sex differences were also noted; however, with the exception of catastrophic thoughts to cold, these findings were not moderated by race/ethnicity. Together, findings suggest NAs experience heightened sensory, anxiety, and catastrophizing reactions to painful stimuli. This could place NAs at risk for future chronic pain and could ultimately lead to a vicious cycle that maintains pain (eg, pain → anxiety/catastrophizing → pain).

Perspective: NAs experienced heightened sensory, anxiety, and catastrophizing reactions in response to multiple pain stimuli. Given the potential for anxiety and catastrophic thoughts to amplify pain, this characteristic may place them at risk for pain disorders and could lead to a vicious cycle that maintains pain.

Native Americans (NAs) have a higher prevalence of chronic pain than any other U.S. racial/ethnic group, yet little has been done to understand what contributes to this pain disparity. Access to health care, difficulties assessing/treating pain cross-culturally, and/or provider biases may contribute to this disparity; however, it could also stem from differences in the way that pain is perceived and managed.
Sensory, Affective, and Catastrophizing Reactions

Methods

Participants

These data were collected as part of the Oklahoma Study of Native American Pain Risk (OK-SNAP). Healthy, pain-free participants were recruited from newspaper advertisements, tribal newspapers, fliers, personal communications with NA groups, email announcements, and online platforms (eg, Facebook). Exclusion criteria included: 1) <18 years old, 2) history of cardiovascular, neuroendocrine, musculoskeletal, or neurologic disorders, 3) chronic pain or current acute pain, 4) body mass index (BMI) ≥ 35 (owing to difficulties recording electromyogram for other tasks), 5) use of antidepressant, anxiolytic, analgesic, stimulant, or antihypertensive medication(s), 6) current psychotic symptoms (assessed by Psychosis Screening Questionnaire)

Table 1. Study Completion Rate by Race and Sex

<table>
<thead>
<tr>
<th></th>
<th>NHW MALE</th>
<th>NHW FEMALE</th>
<th>NA MALE</th>
<th>NA FEMALE</th>
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<tr>
<td>N</td>
<td>77</td>
<td>68</td>
<td>50</td>
<td>87</td>
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<td>%</td>
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<td>Completed 1 day (or quit during day 2)</td>
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<td>3</td>
<td>15</td>
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<td>84.0</td>
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</tr>
</tbody>
</table>

Note: All participants provided verbal and written informed consent before enrollment and received a $100 honorarium for the completion of each testing day (or $10/ hour of noncompleted days). Table 1 presents the response completion rates by race/ethnicity and sex, and Table 2 presents characteristics of the final sample by race/ethnicity and sex. NA participants in the current study represent tribal nations predominately from the southern plains and eastern Oklahoma tribes. NA status was verified from Certificate of Degree of Indian Blood or tribal membership cards.
Sample Size Determination

The parent study was powered to detect racial/ethnic differences in pain tolerance, temporal summation of the nociceptive flexion reflex (NFR), and conditioned pain modulation. That power analyses suggested 120 per group would provide a power of .80 at an alpha of .05, so that was the targeted sample. Based on this sample size, a sensitivity analysis was conducted in G*Power (Franz Faul, Universitat Kiel, Germany) (version 3.1.9.2) to determine what size group difference (ie, effect size) could be detected (by rejecting the null hypothesis) in the present study. That analysis indicated that, with the alpha level set to .05, group differences with \( d \geq .36 \) would be detected 80% of the time (ie, power = .80), whereas with an alpha level set to .01, group differences with \( d \geq .44 \) would be detected 80% of the time (ie, power = .80). Thus, our targeted sample size provided adequate power to detect a small to medium effect size.

General Overview of Procedures/Testing

Testing was conducted over a 2-day period, each lasting 4 to 6 hours. Informed consent and inclusion/exclusion screening were conducted on the first day. If found to be eligible, participants filled out several questionnaires to assess background characteristics to ensure that the groups did not differ on important variables (eg, dispositional pain catastrophizing, state affect, general health perceptions, psychological functioning). On one of the testing days, electric tolerance, heat tolerance, mechanical pain threshold, and the Pain45 heat series were administered in a testing block (with a minimum of a 2-minute break between tasks). There was a 10-minute break after the first testing block and then cold tolerance and ischemia tolerance were administered in a second testing block (with a 20-minute break between tasks). The mandatory breaks were used between tasks to minimize carryover effects. On the other day, suprathreshold electric pain, suprathreshold electric pain series, and the 52\(^\circ\)C heat series were administered in a block of tests (with a minimum of a 2-minute break between tasks). On both testing days, pain tasks were randomized within each block.

Immediately after each pain task, the MPQ-SF, pain-related anxiety questionnaire, and the PCS (using SS instructions) were administered with instructions to rate their experience of the preceding pain task. The order of the 2 testing days was counterbalanced across participants, blocking for sex and race.

Apparatus

Questionnaire presentation was controlled by a computer with dual monitor capacity. Custom built LabVIEW software (National Instruments, Austin, Texas) was used to control the timing and order of
the experimental protocol. One computer monitor was used by the experimenter to monitor experimental timing, and the second monitor was used by the participant to complete electronic questionnaires and to make ratings of stimuli. To decrease experimenter influences on testing, all reported experimental outcomes (except pressure pain) were conducted with participants in a sound-attenuated and electrically shielded testing room and experimenters monitored the testing from an adjacent control room via a video camera (with a microphone) connected to a flat panel monitor. Participants wore a pair of sound-attenuating headphones that allowed them to hear the experimenter and the computer-recorded instructions for each task.

**Background Questionnaires**
These questionnaires were administered to assess eligibility (eg, demographic variables and health status) and to examine whether groups differed on important background characteristics (eg, mood, anxiety, psychological functioning, health, and pain catastrophizing).

**Demographics and Health Exclusion**
A custom-built demographic and health status questionnaire was used to obtain standard background information, as well as information regarding health problems. It was administered immediately after obtaining informed consent. The questionnaire asked about demographic information, such as age, sex, marital status, education level, employment, and income level, as well as potential exclusionary criteria such as cardiovascular problems, neurologic problems, chronic pain, and medication use. Weight and height were assessed from a medical scale to calculate BMI.

**Current Affect**
Positive and negative affect before testing were assessed from the Positive and Negative Affect Schedule. Each positive and negative affect subscale consists of 10 items that measure positive and negative emotions, with subscales ranging from 10 to 50. Higher scores on each scale indicate greater positive or negative affect. In the current study, Cronbach’s alpha (reliability) for the negative affect scale was .76 for NHWs and .73 for NAs, and for the positive affect scale it was .88 for NHWs and .88 for NAs.

**State Anxiety**
State anxiety before testing was assessed by the 20-item state anxiety subscale of the State Trait Anxiety Inventory. The subscale ranges from 20 to 80, with higher scores indicating greater current anxiety. In the current study, Cronbach’s alpha (reliability) was .89 for NHWs and .88 for NAs.

**Psychological Functioning**
The Symptom Checklist-90-Revised was used to assess general psychological functioning. The scale consists of 90 items that assess various psychological symptoms (eg, somatization, obsessive-compulsive, depression, phobic anxiety, paranoia). The Global Severity Index of the Symptom Checklist-90-Revised was used to assess overall psychological distress. Total Global Severity Index scores range from 0 to 4 with higher scores indicating greater distress. In the current study, Cronbach’s alpha (reliability) was .97 for NHWs and .97 for NAs.

**Health Perceptions**
The 5-item general health subscale of the Medical Outcomes Study 36-item Short Form Health Survey was used to determine whether groups differed in their perceptions of their health. Example items from this subscale are: “I seem to get sick a little easier than other people,” “I expect my health to get worse,” and “My health is excellent.” Scores are standardized to range from 0 to 100, with higher scores indicating better health. In the current study, Cronbach’s alpha (reliability) of the general health subscale was .57 for NHWs and .56 for NAs.

**Traditional (Dispositional) Pain Catastrophizing**
The 13-item PCS was used to assess dispositional catastrophizing at the beginning of the testing session to assess how each participant generally reacts to painful events. This step was done to establish whether groups generally differed in pain catastrophizing. Scores ranged from 0 to 52, with higher scores indicating greater catastrophic thoughts. In the current study, Cronbach’s alpha (reliability) was .93 for NHWs and .93 for NAs.

**Sensory, Affective, and Catastrophizing Reactions**
The current study administered questionnaires to determine group differences in sensory (MPQ − Sensory), affective (MPQ − Affective, and Pain-Related Anxiety), and cognitive-emotional (Situation Specific Catastrophizing) responses to pain tasks.

**MPQ-SF**
Immediately after each painful task, the MPQ-SF was administered to assess sensory and affective reactions. The MPQ-SF consists of 15 descriptors (11 sensory, 4 affective) that describe the quality of pain. The sensory subscale includes throbbing, shooting, stabbing, sharp, cramping, gnawing, hot-burning, aching, heavy, tender, and splitting. The affective subscale includes ting-exhausting, sickening, fearful, and punishing-cruel. Subscales are summed creating total scores that range from 0 to 33 (sensory) and 0 to 12 (affective). The MPQ VAS was also used to assess pain intensity (a sensory
reaction). In the current study, Cronbach’s alpha (reliability) for the MPQ-SF sensory subscale was .76 for NHWs and .84 for NAs and for the MPQ-SF affective subscale it was .73 for NHWs and .81 for NAs.

Pain-Related Anxiety

Immediately after each painful task, a computer-presented VAS was administered to assess pain-related anxiety. Instructions asked the participant to rate the level of anxiety they experienced as a result of the task. Anchors of the VAS ranged from not at all anxious to extremely anxious. The computer converted the scores so that they ranged from 0 to 100, with higher scores indicating greater pain-related anxiety. These scores were used as a measure of pain-related affect.

Situation-Specific (SS) Pain Catastrophizing

The PCS was also used to assess SS pain catastrophizing. To assess SS pain catastrophizing, the SS-PCS was administered immediately after each painful task with altered instructions asking the participant to report the degree of catastrophizing they engaged in during the task. Scores ranged from 0 to 52, with higher scores indicating greater catastrophic thoughts. SS pain catastrophizing was used as a cognitive-emotional reaction to pain. In the current study, Cronbach’s alpha (reliability) was .95 for NHWs and .96 for NAs.

Exposure to Noxious Stimuli

To assess reactions to pain, participants underwent several suprathreshold pain tasks that involved electric, heat, cold, ischemic, and mechanical pressure stimuli. After each pain task, participants were administered the MPQ-SF, PCS (SS instructions), and the pain-related anxiety VAS (order randomized).

Electric Pain Tasks

Three tasks were used to assess responses to suprathreshold electric pain. To test these responses, a bipolar electrode (Nicolet Madison, WI; 30-mm interelectrode distance) filled with a conductive gel (EC60, Grass Technologies, West Warwick, Rhode Island) was placed over the retromalleolar surface of the left ankle after the skin had been cleaned with alcohol and abraded with an exfoliating cream (NuPrep, Weaver and Company, Aurora, Colorado). Stimulations were delivered by an isolated, constant current stimulator (Digitimer D57A; Hertfordshire, UK). Each stimulus consisted of a train of five 1-ms rectangular wave pulses with a 3-ms interpulse interval (250 Hz); however, the train was always experienced as a single stimulation. The maximum stimulation intensity was set at 50 mA to ensure safety.

Electric Pain Tolerance

Similar to previous studies, electric pain tolerance was assessed using a single ascending staircase of stimulations that started at 0 mA and increased in 2-mA steps. After each stimulus, the participant rated their pain intensity on a VAS that ranged from no pain to maximum tolerable pain. The stimulation intensity was increased until the participant rated the stimulus as the maximum tolerable pain. Afterward, participants rated their reactions using the MPQ-SF, pain-related anxiety VAS, and SS-PCS.

Suprathreshold Electric Stimuli

In the parent study, single suprathreshold electric stimuli were delivered to assess the size of individual NFRs, but the current analyses focus only on subjective reactions to these stimuli. First, validated procedures were used to determine the stimulus intensity that reliably elicits NFRs (for detailed procedures, see). In brief, stimulation intensity was set at 1.2× the highest of stimulation intensity resulting from 1) the NFR threshold or 2) the 3-stimulation threshold. The NFR threshold assessment involved the delivery of stimulations starting at 0 mA and increased in 2-mA steps (8- to 12-second interstimulus interval (ISI)) until an NFR was evoked. The intensity was decreased in 1-mA steps until an NFR was no longer present. This ascending–descending staircase procedure was repeated 2 more times in 1-mA steps until the NFR appeared and disappeared 2 more times. The 3-stimulation threshold involved the delivery of a train of 3 electric stimulations (5-second ISIs). The intensity of the train was increased in 2-mA steps (8- to 12-second ISIs between trains) until the third stimulus in the train elicited an NFR.

Once the suprathreshold stimulus intensity was determined by the procedures above, participants received 5 individual suprathreshold electric stimuli (8- to 12-second ISIs) and then rated their reactions using the MPQ-SF, pain-related anxiety VAS, and SS-PCS.

Heat Tasks

Heat stimuli were generated using a Medoc (Haifa, Israel) Pathway device with a Contact Heat Evoked Potential Stimulator thermode. The maximum intensity of any heat stimulus was set to 52°C (51°C for heat tolerance). Three different tasks were used to assess responsivity to painful heat. For all 3 tasks, the thermode was
attached to the participants’ left volar forearm using a Velcro strap.

Heat Pain Tolerance

Similar to prior studies,9 heat pain tolerance was assessed 4 times after an initial practice trial. Each trial started from a baseline of 32°C and heated at a rate of .5°C/s. Participants were told to terminate the stimulus by pushing a button as soon as the heat became intolerable. In between trials, the thermode was moved slightly to avoid sensitization and then there was a 25- to 35-second randomly determined intertrial interval. Heat pain tolerance was defined as the average of the 4 trials. Immediately after the fourth trial, participants rated their reactions using the MPQ-SF, pain-related anxiety VAS, and SS-PCS.

The Pain45 Heat Series

In the parent study, 5 series of suprathreshold heat stimuli were delivered to assess temporal summation of heat, but the current analyses focus only on the global sensory, affective, and catastrophizing reactions to this task. This task involved 5 series of 10 heat stimuli delivered with a 2.5-second ISI.70 Each pulse peaked at an individually calibrated temperature corresponding to a rating of 45 on a numerical rating scale with the following labels70: 10 = warm; 20 = a barely painful sensation; 30 = very weak pain; 40 = weak pain; 50 = moderate pain; 60 = slightly strong pain; 70 = strong pain; 80 = very strong pain; 90 = nearly intolerable pain; 100 = intolerable pain. The interval between each 10-pulse series was always 2 minutes. After the delivery of the fifth series, participants rated their reactions using the MPQ-SF, pain-related anxiety VAS, and SS-PCS.

The 52°C Heat Series

In the parent study, 6 blocks of 5 heat pulses (8- to 12-second ISI) were delivered to assess contact heat-evoked potentials from an electroencephalogram.26 However, the current analyses focused only on the subjective reactions to this task. Each pulse started at a baseline of 32°C and increased to 52°C at a rate of 70°C/s and then returned to baseline at a rate of 40°C/s.88 Each 65-second block of 5 pulses was separated by a short (~1-minute) break. After the sixth block of pulses, participants rated their reactions using the MPQ-SF, pain-related anxiety VAS, and SS-PCS.

Cold Pressor Tolerance

A cold pressor procedure9,40,54 was used to assess responses to cold pain. Participants were asked to submerge their hand and forearm into a circulating water bath (Thermo Fisher Scientific, Pittsburgh, Pennsylvania) held at 6 ± .1°C. Participants were instructed to keep their fingers spread apart and to place their hand on the bottom of the water tank and keep it there for as long as they could tolerate it. The water level was kept constant (6 inches deep) across all participants to keep procedures standardized and maintain similar cold exposure to participants’ hands/forearms. During the task, a computer timed the length of the hand/arm immersion. The maximum cold water exposure was set to 5 minutes, but the participant was not informed of the limit. Immediately after tolerance was reached, participants rated their reactions using the MPQ-SF, pain-related anxiety VAS, and SS-PCS.

Ischemia Pain Tolerance

To measure responses to ischemia pain, a standard forearm tourniquet test was used.24 First, participants used their nondominant hand to conduct hand exercises with a dynamometer (Lafayette Hand Dynamometer, Lafayette Instrument Company, Lafayette, Indiana) at 50% grip strength for 2 minutes (1 x/sec). Immediately after the last exercise, the nondominant arm was raised for 15 seconds to allow the blood to drain from the forearm, then a blood pressure cuff was inflated to 220 mm Hg around the nondominant biceps to occlude blood flow to the forearm. Participants were instructed to keep the nondominant arm still during the task and indicate by computer when they could no longer tolerate the ischemic pain. During the task, the computer timed the duration of the arm occlusion until tolerance was reached. The maximum exposure to ischemic pain was set to 25 minutes, but the participant was not made aware of this limit. Immediately after tolerance was reached, participants rated their reactions using the MPQ-SF, pain-related anxiety VAS, and SS-PCS.

Pressure Pain Threshold

To measure responses to mechanical pressure, a Medoc-Wagner computerized algometer was used. Similar to previous studies,53 the pressure pain threshold was assessed at 3 body sites (masseter muscle, trapezius muscle, thumbnail) in random order. Pressure was applied at a rate of 98 kPa/s until the participant reached pain threshold by pressing a button. Pressure pain threshold was defined as the average of the 3 trials. For parsimony, only responses to the masseter muscle were used because this site elicited greater pain (and lower thresholds) than the other 2 sites. Immediately after the last pressure pain trial, participants rated their reactions using the MPQ-SF, pain-related anxiety VAS, and SS-PCS.

Data Analysis

Before analyses, variable distributions were screened using boxplots, histograms, and normality statistics. Those values that were skewed were log or square transformed to reduce positive and negative skew, respectively. If a variable was transformed, this is noted in the units next to the variable name in the tables. Reverse transformed variables are presented and labeled when appropriate. Next, outliers were identified using Wilcox’s MAD-median procedure (using the recommended 2.24 cutoff) and then winsorized by replacing
Rhudy et al

the outlier value with the next nearest nonoutlier value. The following variables were windorsized as a result of outliers: 1) heat tolerance (17 cases) and pressure threshold (20 cases); 2) MPQ-SF sensory ratings for electric tolerance (13 cases), suprathreshold electric stimuli (19 cases), suprathreshold electric series (9 cases), heat tolerance (17 cases), Pain45 heat series (14 cases), 52°C series (5 cases), cold tolerance (14 cases), ischemia tolerance (22 cases), pressure threshold (22 cases), and electric tolerance (13 cases); 3) MPQ-SF VAS for 52°C heat series (6 cases), pressure threshold (19 cases), suprathreshold electric stimuli (4 cases), heat tolerance (12 cases), and ischemia tolerance (6 cases); 4) pain-related anxiety for heat tolerance (20 cases), Pain45 heat series (21 cases), and ischemia tolerance (6 cases); and 5) SS pain catastrophizing for suprathreshold electric series (7 cases), heat tolerance (9 cases), and cold tolerance (26 cases).

Background Characteristics

Preliminary analyses determined that there were significant group differences in sex (ie, there were more women in the NA group); therefore, to examine group differences on background characteristics a new independent variable was created that coded for race and sex in the same variable (ie, a grouping variable that coded for NHW men, NHW women, NA men, and NA women). This independent variable was then used in 1-way analyses of variance (for continuous dependent variables) and $\chi^2$ analyses (for categorical dependent variables) to explore group differences. Significance level for group differences in background characteristics were set to $\alpha < .05$ (2 tailed).

Primary Analyses

Analyses for stimulus intensity (eg, pain tolerance) outcomes were conducted using 2-way factorial analyses of variance with race (NHW vs NA) and sex (men vs women) as the independent variables. The significance level for group differences in stimulus intensity were set to $\alpha < .05$ (2 tailed). For analyses of sensory, affective, and SS catastrophizing outcomes, analyses of covariates were used to control for the fact that stimulus intensity was individually calibrated to the participant (except for the 52°C heat series, where the stimulus was constant and analyses of variance were used). Significance levels for group differences for primary analyses used a Bonferroni adjusted alpha of .01 that accounted for the 5 outcomes (intensity, sensory, affect, anxiety, SS catastrophizing) measured in response to each stimulus (.05/5 = .01). However, because this was the first study of its kind, we also note when results would have been significant at an alpha level of .05.

Results

Final Sample

There were 338 persons who consented to participate, but 56 did not meet inclusion criteria; thus, 282 persons were enrolled (Table 1). Of those, 75% (n = 211) completed both days of testing. Fifteen percent (n = 42) completed only 1 day and 10% (n = 29) quit during the first testing day. Given this, numbers of participants across analyses differed and are reported. Noncompleters were more likely to be NA women (P = .045) and have a lower education level (P = .015); however, there were no differences on age, BMI, marital status, positive affect, negative affect, state anxiety, psychological functioning, or pain catastrophizing (all P > .18).

Background Characteristics

The $\chi^2$ analysis indicated that groups differed by sex, $\chi^2$(df = 1) = 7.85, P = .005. Sixty-four percent of the NA group were women, whereas only 47% of the NHW group were women. Thus, all background characteristic analyses used a 4-level independent variable that coded for race/ethnicity and sex. Inferential statistics, as well as means and standard deviations (SDs) (or number and percent), for these analyses are reported in Table 2. As shown, groups were similar on most variables except for BMI. NHW women had a significantly lower BMI than NA men and NA women (P < .005).

Ethnic/Racial Differences in Stimulus Intensity/Stimulus Exposure

Before examining group differences in sensory, affective, and catastrophizing reactions, stimulus intensity/duration was analyzed. As shown in Table 3, there were significant group differences in suprathreshold electric stimulus intensity (P = .010) and cold pressor pain tolerance (P = .015). The average intensity of the electric stimuli was higher for the NA group than the NHW group. Cold pressor tolerances were lower in the NA group than the NHW group (P = .015), but this was qualified by a Group × Sex interaction (P = .032) that indicated NA women had lower pain tolerances than NHW women (mean, 38.84 seconds, SD, 1.74 seconds vs mean, 62.29 seconds, SD, 2.76 seconds; P = .001; means/SD reversed transformed), whereas NA men and NHW men did not differ (mean, 63.73 seconds, SD, 2.46 seconds vs mean, 65.98 seconds, SD, 2.56 seconds; P = .834; means/SD reversed transformed).

Sex Differences in Stimulus Intensity/ Stimulus Exposure

Sex differences were also found for heat, ischemia, and cold pain tolerance. Compared with men, women had lower heat tolerances (mean, 45.05°C, SD, 1.62°C vs mean, 46.36°C, SD, 1.95°C; P < .001; d = .77), lower ischemia tolerances (mean, 125.20 seconds, SD, 2.77 seconds vs mean, 170.15 seconds, SD, 2.63 seconds; P = .019; d = .33; means/SD reversed transformed), and lower cold pressor tolerances (mean, 47.90 seconds, SD, 2.33 seconds vs mean, 64.84 seconds, SD, 2.51 seconds; P = .008; d = .36; means/SD reversed transformed). This last effect was moderated by race/ethnicity as described in Ethnic/
Racial Differences in Stimulus Intensity/Stimulus Exposure. There were no group or sex differences in electric pain tolerance, heat Pain45 intensity, or pressure pain threshold.

Ethnic/Racial Differences in Subjective Reactions to Painful Stimuli

Table 4 reports the means, SDs, Cohen’s d, and inferential statistics for pain intensity ratings, sensory ratings, affective ratings, pain-related anxiety, and SS catastrophizing in response to the various painful stimulus modalities. Fig 1 depicts these group differences after using reverse operations (eg, $10^x$, square root) to put transformed variables back into their original units. Results indicated that, compared with NHW participants, NAs reported 1) higher pain intensity in response to Pain45 stimuli ($P = .041$); 2) higher MPQ-SF sensory ratings in response to suprathreshold electric stimulations ($P = .008$), suprathreshold electric series ($P = .004$), and Pain45 stimuli ($P = .009$); 3) higher MPQ-SF affective ratings to the Pain45 heat series ($P = .017$); 4) higher pain-related anxiety in response to suprathreshold electric stimuli ($P = .025$), suprathreshold electric series ($P = .047$), heat pain tolerance stimuli ($P = .003$), Pain45 heat series ($P = .004$), cold pressor tolerance stimuli ($P = .030$), and ischemia tolerance stimuli ($P = .002$); and 5) greater SS catastrophizing in response to suprathreshold electric stimuli ($P = .033$), suprathreshold electric series ($P = .008$), and heat tolerance stimuli ($P = .004$).

Sex Differences in Subjective Reactions to Painful Stimuli

As noted in Table 4, sex differences were also found. Fig 2 depicts these results after using reverse operations (eg, $10^x$, square root) to put transformed variables back into their original units. Results indicated that, compared with women, men reported 1) more pain intensity in response to heat tolerance stimuli ($P = .004, \ d = .41$), Pain45 series ($P = .044, \ d = .26$), cold tolerance stimuli ($P = .009, \ d = .32$), and ischemia tolerance stimuli ($P = .0003, \ d = .47$); 2) higher MPQ-SF sensory ratings in response to heat tolerance stimuli ($P = .028; \ d = .31$) and ischemia tolerance stimuli ($P = .015; \ d = .32$); 3) higher MPQ-SF affective ratings in response to heat tolerance stimuli ($P = .033; \ d = .30$) and ischemia tolerance stimuli ($P = .007; \ d = .36$); 4) higher pain-related anxiety in response to heat tolerance stimuli ($P = .011; \ d = .39$) and ischemia tolerance stimuli ($P = .013; \ d = .30$); and 5) higher SS catastrophizing in response to heat tolerance stimuli ($P = .002; \ d = .43$), cold tolerance stimuli ($P = .010, \ d = .23$), and ischemia tolerance stimuli ($P = .044; \ d = .26$). The only significant Group × Sex interaction was noted for log SS catastrophizing during cold pressor ($P = .045$). NA women reported greater SS catastrophizing than NHW women (mean, 12.02, SD, 2.34 vs mean, 7.40, SD, 3.21; $P = .005; \ d = .63$; means were reverse transformed to ease interpretation), whereas there was no difference in SS catastrophizing between NA men and NHW men (mean, 12.94, SD, 2.79 vs mean, 13.06, SD, 2.45; $P = .956; \ d = .01$; means were reverse transformed to ease interpretation).

Discussion

This study used QST to examine racial/ethnic group differences in reactions to painful stimuli that might contribute to chronic pain risk in NAs.5,35,83 To achieve this goal, we measured pain intensity ratings, sensory ratings, affective ratings, pain-related anxiety, and SS catastrophizing after suprathreshold exposure to electric, heat, cold, ischemic, and pressure stimuli.

Race/Ethnic Differences in Pain Reactions

Sensory differences were noted between NAs and NHWs, but were restricted to the electric stimuli and Pain45 (heat) series. In all cases, NAs reported greater pain intensity (although nonsignificant at the $P < .01$ level) and higher MPQ-SF sensory ratings than NHWs. Thus, these electric and heat stimuli evoked a stronger sensory experience in NAs. Interestingly, all of these stimuli were delivered in a series. Two of the 3 stimuli

Table 3. Group Differences in Painful Stimulus Intensity/Duration

<table>
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<th>Stimulus variable</th>
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<td>Cold pressor pain tolerance</td>
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<td>.32</td>
<td>6.04*</td>
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NOTE: G × S = Group × Sex interaction. Cohen’s d is reported for the effect size for the group mean comparisons.

* $P < .05$.  

Fig 2depicts these results after using reverse operations (eg, $10^X$, square root) to put transformed variables back into their original units.
<table>
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<tr>
<th>Stimulus Type</th>
<th>Reactivity Variable</th>
<th>Group</th>
<th>Sex</th>
<th>G x S</th>
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<th>SD</th>
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Abbreviation: ANCOVA, analysis of covariance.
NOTE. Cohen’s d is reported for the effect size for the group mean comparisons.
# P < .05.
* P < .01.
† Analysis of this variable did not include stimulus intensity as a covariate because the intensity was the same for all participants.
(electric series, Pain45 series) were designed to evoke temporal summation of pain (ie, had ISIs of ≤ 3 seconds), a phenomenon associated with temporary sensitization of spinal neurons. Therefore, these racial/ethnic differences could reflect a heightened sensory experience in NAs resulting from the amplification of spinal nociception. However, this finding cannot fully explain the group differences because NAs also had higher sensory responses in response to the 5 suprathreshold electric stimuli whose ISIs were too long to evoke temporal summation. Moreover, we have not observed racial/ethnic differences in temporal summation of pain itself (data to be reported elsewhere). Because sensitized spinal pathways assessed by temporal summation are not likely to explain the results, it would be interesting to determine whether these heightened sensory experiences correspond with pain signaling differences within the primary or secondary somatosensory cortices, or whether they reflect differences in the interpretation of the pain signal. Whatever the mechanism, these data suggest differences in the sensory experience of NAs that occurs during suprathreshold electric and heat stimuli.

There was only 1 group difference in the MPQ-SF affective ratings, and it occurred in response to the Pain45 heat series; however, it did not survive after adjusting for familywise type I error. Some of the most consistent differences were noted for pain-related anxiety. A close examination of Fig 1 finds that NAs reported more anxiety to all stimuli, but only heat tolerance, Pain45, and cold tolerance survived familywise type I error adjustment. Some of the nonsignificant group differences may be due to ceiling and floor effects because stimuli evoking moderate anxiety showed the strongest group differences. Given that anxiety is known to enhance pain, this risk factor could be significant for NAs.

NAs also reported greater SS catastrophizing in response to suprathreshold electric stimuli, electric series, and heat tolerance stimuli (although suprathreshold electric stimuli did not survive familywise type I error adjustment). This finding is interesting, given that there were no group differences in traditionally measured (dispositional) pain catastrophizing (Table 2) and suggests that NAs experienced greater catastrophic thoughts during specific pain tasks. This implies that SS...
catastrophizing may be more sensitive in detecting racial/ethnic differences. Given that prior research has found SS catastrophizing to be a stronger predictor of pain outcomes than dispositional catastrophizing,10,12,18,58 greater SS catastrophizing could put NAs at greater risk of pain.

Implications for Racial/Ethnic Group Differences in Pain Reactions

These differences in pain experience have several implications. First, compared with NHWs, NAs reported heightened sensory, anxiety, and catastrophizing reactions to multiple pain stimuli, suggesting an amplification of the pain experience across different stimulus modalities. Notably, these experiential differences were more consistent than differences in pain thresholds/tolerances (Table 3). NAs had lower cold pain tolerances, but there were no group differences for electric/heat tolerance or pressure thresholds. Thus, pain risk in NAs may not stem from a general decrease in pain tolerance, but rather from the resulting psychological impact of the noxious event (eg, anxiety, catastrophizing). These observations are in contrast with prior studies (with a small number of participants) of NAs that reported dampened pain sensitivity or reduced pain facilitation.47,48,65 So, the present study underscores the importance of replicating findings from small studies using larger, more diverse samples and indicates that pain risk in NAs may be similar to other minorities. Specifically, others have noted that ethnic/racial differences are often attributed to psychosocial variables like hypervigilance, anxiety, and/or depression.9,19,20,29,36,52,63,91 It is noteworthy, however, that we did not find group differences in general psychological status (Table 2; eg, state anxiety, distress). Thus, future research is needed to explore cultural factors (eg, historical trauma) that could contribute to heightened pain reactivity in NAs.

Second, the heightened pain reactivity in NAs cannot be attributed to differences in nociceptive input. Even though most stimuli (except 52°C heat series) were individually calibrated to participants, individual differences in stimulus intensity/exposure were controlled for in the analyses. Moreover, group differences cannot be explained by the unequal number of men/women across racial/ethnic groups, because sex was also controlled for.
Third, the most consistent group differences across stimuli were noted for pain-related anxiety, sensory ratings, and to a lesser extent SS catastrophizing. Both anxiety1,13,44,45,49,59,68,85 and catastrophizing10,12,50,57,73 are strong pain enhancers. Anxiety can activate descending, brain-to-spinal cord facilitation circuits,33,81 and catastrophizing can facilitate pain via supraspinal circuits.17,26,27,57,80,81 Given this finding, these factors may play a significant role in pain risk for NAs owing to their sensitizing effects, perhaps actually promoting the eventual onset of chronic pain. Moreover, anxiety and catastrophizing are related to greater pain-related disability and suffering in those with pain9,50,75; thus, they may also help to maintain pain in NAs. This characteristic could ultimately form a vicious cycle, in which pain leads to anxiety/catastrophizing, which then enhances pain.8,12,39,51,84 Hence, treatments that target pain-related anxiety and catastrophizing may be particularly helpful for NA patients.15,34,67,82

**Sex Differences in Pain Reactions**

Sex differences in pain are often observed, with women showing greater experimental pain sensitivity and a greater likelihood of developing chronic pain7,23,60,62,77,89 (although effect sizes can be quite variable65). Consistent with this, we found that women had lower heat pain tolerances, ischemia pain tolerances, and cold pain tolerances, but cold tolerance was moderated by race/ethnicity such that NA women were less tolerant than NA men (P = .001). Interestingly, sex differences in pain experience did not mirror these differences. Rather, men reported greater pain intensity (heat, cold, and ischemia tolerance), MPQ-SF affective pain (ischemia tolerance), and SS catastrophizing (heat and cold tolerance). Although SS catastrophizing during cold pain was moderated by race/ethnicity, men in both racial/ethnic groups reported greater SS catastrophizing than women (all P < .05).

It is unclear why men reported greater pain reactivity in our study, but it is interesting to note that higher reactivity was only found in response to stimuli that men tolerated longer. By contrast, NAs reported greater pain reactivity in response to stimuli in which their pain tolerances were lower or similar to NHWs. Together, these findings suggest that increased pain reactivity in men may reflect a different mechanism than those observed in NAs. Indeed, the racial/ethnic differences are more likely to reflect pain amplification processes that could promote pain in NAs (ie, a risk factor), whereas the sex differences seem to reflect that men were able to tolerate pain longer despite experiencing greater pain. Taken together, one could argue that this latter observation reflects a resiliency factor for men. However, this hypothesis requires further testing.

**Strengths and Limitations**

This study had a number of strengths. It is currently the largest study of experimental pain in a NA sample. It also used numerous pain stimulus modalities that were pseudorandomly ordered to minimize order effects. We also assessed several measures of pain experience. Analyses also controlled for stimulus intensity and sex. Despite these strengths, a few limitations should be noted.

First, this study was conducted in healthy, pain-free individuals to determine whether group differences in pain processing exist that could contribute to chronic pain risk. This methodology helps to ensure that observed group differences are not due to differences in disease status or access to health care. As a result, we cannot know whether these findings will generalize to NAs experiencing chronic pain. Moreover, it meant that many of our participants were young adults; thus, these results may not generalize to older individuals. Second, NA women were more likely to quit before completing all tasks. Thus, it is possible that our results will not generalize to all NA women. That said, noncompleters were not systematically different than completers on other background variables. Related, our NA sample was recruited mostly from northeastern Oklahoma where NAs are not reservation dwelling. Future studies should determine if our results generalize to NAs from other geographical regions. Third, although we varied the order of pain tasks and scheduled mandatory breaks in between most tasks, several tasks occurred each day. Therefore, it is possible that some carryover occurred, perhaps masking other racial/ethnic differences. And finally, although we adjusted our alpha level, it is possible that the numerous hypothesis tests resulted in inflation of type I error rate.

**Summary**

NAs experienced greater sensory, pain-related anxiety, and catastrophizing reactions to laboratory pain. Given the potential for anxiety and catastrophic thoughts to amplify pain, these enhanced reactions in NAs may, at least partly, explain the greater prevalence of pain in this population.

**Supplementary data**

Supplementary data related to this article can be found at https://doi.org/10.1016/j.jpain.2019.02.009.


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