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Pain Catastrophizing Mediates the Relation Between Self-Reported Strenuous Exercise Involvement and Pain Ratings: The Moderating Role of Anxiety Sensitivity

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Abstract

Objective—Exercise involvement has been shown to have hypoalgesic effects and cognitive factors may partially explain this effect. Particularly, alterations in pain catastrophizing have been found to mediate the positive pain outcomes of multidisciplinary treatments incorporating exercise. Further, recent evidence suggests that exercise involvement and anxiety sensitivity may act together, as interacting factors, to exert an effect on catastrophizing and pain outcomes; however, further research is needed to clarify the nature of this interaction. In this study we developed a model to investigate the cross-sectional associations among self-reported weekly strenuous exercise bouts, anxiety sensitivity, and their interaction with pain catastrophizing and pain responses to the cold pressor task (CPT) in healthy, ethnically diverse young adults (N = 79).

Methods—Prior to the CPT, participants were asked to complete the Godin Leisure-Time Exercise Questionnaire, the Beck Depression Inventory, and the Anxiety Sensitivity Index. Following the CPT participants completed a modified version of the Pain Catastrophizing Scale and the Short Form-McGill Pain Questionnaire.

Results—At a high level of anxiety sensitivity, controlling for depressive symptoms, CPT immersion time, and sex differences, a bias-corrected (BC), bootstrapped confidence interval revealed that pain catastrophizing significantly mediated the relation between self-reported weekly strenuous exercise bouts and pain response (95% BC Confidence Interval: (−9.558, −0.800) with 1000 resamples). At intermediate and low levels of anxiety sensitivity, no significant mediation effects were found.

Conclusions—These findings support that for pain catastrophizing to mediate the strenuous exercise-pain response relation, individuals must possess a high level of anxiety sensitivity.

Keywords

strenuous exercise; pain catastrophizing; anxiety sensitivity; moderated mediation; bootstrap

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Introduction

A broad literature suggests that engaging in physical exercise can produce alterations in pain processing and perception (1–3). Studies have demonstrated diminished pain sensitivity and report during and following exposure to a variety of experimental exercise regimens (3,4). Exercise-induced hypoalgesia has been found most consistently when the exercise is performed at a strenuous-intensity (i.e., >70% of maximal aerobic capacity (5). To date, the vast majority of such exercise studies have been conducted experimentally with standardized exercise regimens. However, it is important to study associations between self-reported naturalistic exercise involvement and pain responses because it remains unclear whether naturalistic exercise differs from experimentally-based exercise in relation to pain outcomes.

The mechanisms underlying how strenuous exercise alters pain perception are not entirely understood; however, there are several plausible explanations. Strenuous exercise may affect pain perception via stimulation of the endogenous opioid system and by increasing blood pressure and stimulation of arterial baroreceptors (2,6–8). It is also likely that psychological variables are involved in associations between exercise and pain though such processes have received very little attention. Psychological factors are powerful determinants of pain experiences (9,10) and many of the multidisciplinary interventions developed for the treatment of chronic pain target the modification of patients' pain catastrophizing, fear-avoidance beliefs, and appraisals of control to improve pain-related outcomes (11,12). Although preliminary data attest to the ability of multidisciplinary interventions that typically involve exercise to alter pain-related cognitions, disability and pain intensity, it remains unclear whether self-reported exercise involvement uniquely affects pain cognitions and individuals' experience of pain.

Of all the cognitive factors affecting the experience of pain, pain catastrophizing has emerged as one of the most robust predictors of pain outcomes (13,14). Catastrophizing has been defined as an exaggerated negative mental set brought to bear during actual or anticipated painful experience (15). Catastrophizing seems to be an important factor in the development of chronic pain and disability (16) and has now been shown to mediate the outcome of multidisciplinary pain treatment (17). Recently, associations among strenuous exercise, pain catastrophizing, and pain outcomes have been reported in the context of multidisciplinary treatments for chronic pain. Smeets and colleagues (18) found that pain catastrophizing mediated the effect of active physical treatment on pain and depression such that strenuous exercise decreased pain catastrophizing, which subsequently decreased pain intensity and depressive symptoms. These results are similar to other studies which have shown that reductions in pain catastrophizing mediate the positive effects of strenuous exercise on pain outcomes (19,20). Currently, it is not known whether these associations can be replicated in a laboratory setting with pain-free individuals.

Previous research has shown that anxiety sensitivity and pain catastrophizing are related constructs; however, each provides unique predictive ability for pain ratings (21,22). Turk (23) addressed the possibility that anxiety sensitivity might function as a precursor to the development or expression of catastrophic thinking. People with high levels of anxiety sensitivity may be especially hypervigilant to pain and other noxious sensations and thus possess a greater tendency to catastrophize when presented with a painful experience. In examining the indirect effect of strenuous exercise on pain outcomes through catastrophizing, anxiety sensitivity must be taken into account. Similar to studies that have reported a trait anxiety-aerobic exercise interaction and the ability of aerobic exercise to decrease state anxiety (24,25), catastrophizing may be significantly reduced by strenuous exercise to indirectly affect the experience of pain when anxiety sensitivity is high. This is because catastrophizing in response to painful stimulation is likely to be exaggerated for those with high anxiety sensitivity. Alternatively, when anxiety sensitivity is intermediate or low, catastrophizing may be only minimally expressed (24) and thus, is not likely to be meaningfully affected by strenuous exercise involvement. Figure 1 illustrates the putative mechanism.

Our study examined whether anxiety sensitivity moderates the mediating effect that pain catastrophizing has on the strenuous exercise-pain response relationship, using self-reported weekly strenuous exercise bouts as the target predictor. This was done in 2 steps, examining 1) whether strenuous exercise affects pain response through pain catastrophizing (i.e., whether a mediation exists), and 2) whether the strength of the mediated effect through pain catastrophizing is influenced by the level of anxiety sensitivity (whether the mediation is moderated by anxiety sensitivity). It was also determined whether the moderated mediation in step 2 holds true after accounting for several control variables (depressive symptoms, CPT immersion time, and sex differences). Given the overlap between measures of catastrophizing and negative affect, it is now customary (if not required) that any analysis of pain catastrophizing adjust for depressive symptoms or some general negative affective factor, in order to establish the unique effect of catastrophizing (14). Further, variability in CPT immersion time and sex is often predictive of pain outcomes and must be controlled to demonstrate the unique relations of strenuous exercise. To our knowledge, ours is the first study to test moderated mediation for this research question.

Methods

Participants

Eligible participants met the following criteria: (a) 18 to 45 years old; (b) no ongoing chronic pain; (c) no hypertension or blood pressure medication; (d) no circulatory disorders; (e) no history of cardiac events; (f) not pregnant; (g) no history of metabolic disease or neuropathy; (h) not currently using prescription medications including analgesics, tranquilizers, antidepressants, or other centrally acting agents; and (i) no mental health disorders (e.g., depression). Participants were instructed to refrain from using alcohol, nicotine, and non-prescription medications on the day of the study. Participants were asked to abstain from caffeinated beverages and vigorous exercise for at least two hours prior to study participation. Seventy-nine healthy young adults participated in the current study (52% female). Participants mean age was 20.1 years (SD = 2.8), and the mean BMI was 22.6 (SD = 3.3). The participant sample was ethnically diverse; Caucasian (52%), African American (28%), Asian/Pacific Islander (15%), Hispanic (4%), and 1% of the sample reported some other ethnic background. Chi-square tests showed that ethnic groups did not differ significantly by sex ($p > 0.05$).

Procedure

Data were collected from 09/2006 to 05/2007. Participants completed a single 90 minute laboratory session. Health and pain-related questionnaires were completed before and following pain testing procedures. Participants were paired with experimenters of the same sex to minimize the effects of experimenter sex on participants' report of pain (26). All study procedures were approved by the Institutional Review Board, and informed consent was obtained prior to the initiation of study procedures. Participants were compensated for their participation.

As part of a larger study examining the psychophysiological correlates of diffuse noxious inhibitory controls (Goodin, unpublished data) participants were instructed to immerse their dominant hand into a circulating cold water bath maintained at 4° Celsius. Participants were encouraged to keep their hand immersed for at least 2 minutes, but were told they could remove their hand at any time they chose. Unknown to participants, the maximum permitted immersion time was 5 minutes.

Questionnaires

Godin Leisure-Time Exercise Questionnaire (GLTEQ)—The GLTEQ (27) is a self-report measure originally created for epidemiological studies of exercise behavior in the community. Three questions assess the average frequency of the subject's involvement in light, moderate, and strenuous-intensity exercise over seven days. In addition, participants report how frequently they are involved in an exercise activity long enough to work up a sweat. The investigators modified the GLTEQ so that average duration (in minutes) per bout of exercise and most preferred type of exercise were also assessed. In the current study, the question specifically assessing participants' average weekly bouts of strenuous-intensity exercise involvement was used to predict pain-related outcomes because research has suggested that the beneficial effects of exercise involvement on pain outcomes is most often observed during strenuous exercise (5). The GLTEQ defines a single bout of strenuous exercise as at least 15 consecutive minutes of sustained activity performed vigorously enough so that the heart beats rapidly. Examples of such activities include running, vigorous swimming, vigorous bicycling, basketball, and soccer. The question assessing strenuous exercise involvement has also been shown to be most strongly related to objective assessments of physical activity and physical fitness (27). An independent evaluation of the GLTEQ found that its reliability and validity compares favorably to nine other self-report measures of exercise based on various criteria, including test-retest scores, objective activity monitors, and fitness indices (28).

Anxiety Sensitivity Index (ASI)—The ASI total score (29), calculated by summing the 16 item responses, provides an index of individuals' fears of anxiety-related sensations. Higher scores on the ASI indicate greater sensitivity to anxiety-related sensations. The ASI assesses three lower-order factors: 1) fear of physical symptoms and anxiety, 2) fear of cognitions associated with anxiety attacks, and 3) fear of publicly observable symptoms of anxiety (30). These lower-order factors are hierarchically arranged beneath a single higher-order factor (i.e., general anxiety sensitivity). The ASI was administered prior to the completion of the laboratory pain task. The internal consistency of the ASI in the current study was adequate ($\alpha = 0.75$).

Beck Depression Inventory (BDI)—The BDI is a 21-item self-report measure designed to assess DSM-IV depressive symptomatology in adolescents and adults (31). Respondents are asked to rate each of the depressive symptoms, ranging from 0 (not present) to 3 (severe), in terms of how they have been feeling during the past two weeks. The BDI is designed to provide a single overall score that can range from 0 to 63. The BDI has well-established psychometric properties (32) and the internal consistency of the BDI in the current study was good ($\alpha = 0.81$). The BDI was administered prior to the completion of the laboratory pain task.

Standard Pain Catastrophizing Scale (PCS)—The standard PCS (15) is a 13-item scale that assesses catastrophic thinking in response to pain. The standard PCS assesses catastrophic pain-related cognitive-emotional processes by asking participants to recall their experiences during a past occurrence of pain. In the current study, as is typically done in experimental pain studies, the standard PCS was administered prior to the initiation of the laboratory pain task and was considered an assessment of individuals' general self-reported tendency to engage in pain-related catastrophizing. The PCS total score is calculated by summing the 13 item responses. Higher scores are indicative of greater pain-related catastrophizing. The internal consistency of the standard PCS in the current study was very good ($\alpha = 0.90$).

Situation-specific Pain Catastrophizing Scale (PCS)—The situation-specific PCS uses the same 13 items as the standard PCS (15), but with modified instructions and item wording. The situation-specific PCS was administered immediately following the completion of the laboratory pain task and the instructions asked participants to refer to the pain experienced during the cold water task. The situation-specific PCS total score is calculated by summing the 13 item responses. Higher scores are indicative of greater pain-related catastrophizing. The internal consistency of the situation-specific PCS in the current study was excellent (α = 0.95).

Short Form-McGill Pain Questionnaire (SF-MPQ)—The SF-MPQ allows quantitative, multidimensional pain ratings to be obtained in a brief period of time (33). In the current study, respondents rated 15 pain descriptors on a scale from 0 (none) to 3 (severe) and a sum of all rankings was used to compute a total pain rating score. The SF-MPQ is a reliable and valid instrument commonly used in clinical and research applications (35). The SF-MPQ was administered immediately following the completion of the laboratory pain task and the instructions used in the current study asked participants about “the painful procedure you just experienced.” The internal consistency of the SF-MPQ in the current study was good (α = 0.80).

Data Analysis

Prior to testing hypotheses, the distribution of each variable was inspected to identify outliers, assess for skewness or other abnormalities, and determine the need for transformation. Strenuous-intensity exercise involvement was log transformed to reduce skew. The sampling distributions for all other variables did not require transformation.

The descriptive statistics for strenuous exercise involvement (non-transformed), anxiety sensitivity, depressive symptoms, CPT immersion time, standard pain catastrophizing, situation-specific pain catastrophizing, and SF-MPQ pain ratings are provided in Table 1. Other factors that could confound any observed relations were examined in ancillary analyses. Specifically, independent sample t-tests were completed to examine sex differences among key variables. The Pearson correlation coefficients for zero-order relations among continuous variables are displayed in Table 2.

Recommended multiple regression procedures (34) were the basis of the analyses. In the first step, a simple mediation model was tested by Sobel Z, using a SPSS macro (syntax; 35). In the second step, anxiety sensitivity was added as a moderator of the strenuous exercise-pain response relation, and depressive symptoms, CPT immersion time, and sex differences were added as covariates. This analysis was completed using the MODMED macro (Model 2) provided by Preacher, Rucker, and Hayes (34) to obtain confidence intervals (CIs) for moderated indirect effects. We used centered variables to test the interaction (36). For simple slope analyses, high, intermediate, and low values of the moderator (anxiety sensitivity) corresponded to 1 standard deviation (SD) above the mean, the mean, and 1 SD below the mean, respectively. Moderated mediation is expressed by an interaction between anxiety sensitivity and self-reported weekly strenuous exercise bouts (moderator*independent) on situation-specific catastrophizing, which affects the mediation process (37). In addition, we applied an extension of the Johnson-Neyman technique to moderated mediation (for review see 34,38). This technique tests the significance of the indirect effect within the observed range of values of the moderator until the value of the moderator is identified, for which the conditional indirect effect is just statistically significant at a set level (α = .05). Values of the moderator for which the mediation effect is significant constitute the region of significance.

In the current study, five participants had missing data on a single item from the SF-MPQ. Within person imputation that incorporated the mean of non-missing items was used to generate scores for these missing values rather than omitting these cases from analyses.

Results

Frequency of Self-Reported Weekly Strenuous Exercise Bouts

Among the 79 participants, 68 (86%) indicated that they were involved in at least one bout of strenuous-intensity exercise within the last seven days. The average number of weekly bouts of strenuous exercise was 3.28 (SD = 3.07; Median = 3.00) and the average reported duration for each bout was 43 minutes (SD = 32.33; Median = 35.00). Each participant reported the strenuous exercises in which they engaged. The Compendium of Physical Activities (39) and the Centers for Disease Control and Prevention (40) criteria for what constitutes strenuous-intensity exercise were used to verify whether each participant's reported exercise met criteria for classification as a strenuous activity.

Of the 68 individuals who reported engaging in strenuous-intensity exercise, 65 individuals (82% of the total sample) reported an activity that did indeed meet the criteria for classification as a strenuous-intensity activity. Two individuals (3% of the total sample) mistakenly reported engaging in strenuous activities that met criteria for moderate intensity exercise. One participant failed to report the type of strenuous activity. These three individuals were given a score of zero for strenuous-intensity exercise and were included in all analyses. Running was the most frequently endorsed strenuous activity (56% of participants).

Sex Differences, Standard and Situation-Specific Catastrophizing

Men and women did not significantly differ in weekly strenuous exercise bouts, nor were they significantly different in anxiety sensitivity or depressive symptoms (p's > 0.05). However, men reported significantly lower SF-MPQ pain ratings (M = 13.58 versus M = 18.82; $p < 0.01$) than did women. Consistent with previous reports, Table 2 shows that there was a moderate correlation between standard reports of catastrophizing and situation-specific catastrophizing, $r = 0.29$, $p < 0.01$. Men and women did not significantly differ in their standard PCS report ($t = 1.94$, $p > 0.05$), and, since standard catastrophizing was not significantly related to SF-MPQ pain ratings ($r = 0.15$, $p > 0.05$), standard catastrophizing was excluded from further analyses. Sex differences in the situation-specific assessment of catastrophizing were significant ($t = 2.01$, $p < 0.05$); women reported higher situation-specific catastrophizing than men. The zero-order correlation showed that situation-specific catastrophizing was significantly related to SF-MPQ pain ratings ($r = 0.65$; $p < 0.001$). Thus, situation-specific catastrophizing was retained for the moderated mediation analysis.

Zero-Order Relations

Weekly strenuous-intensity exercise bouts were significantly related to SF-MPQ pain ratings ($r = -0.24$, $p < 0.05$) such that those respondents with greater weekly strenuous exercise bouts had less severe pain ratings. In addition, respondents with greater weekly strenuous exercise bouts had less situation-specific catastrophizing ($r = -0.24$, $p < 0.05$). Greater situation-specific catastrophizing was significantly related to higher SF-MPQ pain ratings ($r = 0.65$, $p < 0.01$). Greater anxiety sensitivity was significantly correlated with less weekly strenuous exercise bouts ($r = -0.26$, $p < 0.05$). Additionally, greater anxiety sensitivity was related to greater situation-specific catastrophizing ($r = 0.33$, $p < 0.01$). However, anxiety sensitivity was not significantly correlated with SF-MPQ pain ratings ($r = 0.21$, $p = 0.06$).

Simple Mediation

Results yielded a significant indirect effect of weekly strenuous exercise bouts on pain response through situation-specific catastrophizing, $R^2 = .44$, Sobel $Z = -2.05$ ($p = .04$). Situation-specific catastrophizing fully mediated the strenuous exercise-pain response relation because the effect of weekly strenuous exercise bouts on pain response (β = −.28, p = .01) was no longer significant when controlling for situation-specific catastrophizing (β = −.13, p = .13).

Moderated Mediation

A bias-corrected (BC) bootstrapped moderated mediation analysis was performed to investigate the overall predictive utility of the explanatory model and the unique contribution of the proposed mediator to the prediction of SF-MPQ pain ratings. The total model (including the moderator and covariates) accounted for approximately 49% of the variance in SF-MPQ pain ratings ($R^2 = 0.49$, $p < 0.001$). This model was examined to determine whether anxiety sensitivity significantly interacted with strenuous-intensity exercise to produce differential effects of the predictor (i.e., strenuous exercise) on the mediator (i.e., situation-specific catastrophizing) controlling for CPT immersion time, depressive symptoms, and sex differences. Specifically, we wanted to test the hypothesis that situation-specific catastrophizing mediates the relation between weekly strenuous exercise bouts and pain response when anxiety sensitivity is high (Figure 2).

Two regression analyses with centered variables tested the moderated mediation hypothesis. Anxiety sensitivity (β = .23, p = .02) uniquely predicted situation-specific catastrophizing; however, weekly strenuous exercise bouts (β = −.16, p = .16) did not. The statistical trend for the interaction between strenuous-intensity exercise and anxiety sensitivity (β = −.20, p = .07) suggests that the indirect effect of weekly strenuous exercise bouts on pain response through situation-specific catastrophizing is moderated by anxiety sensitivity (Table 3). The sign of the interaction is consistent with the interpretation that the indirect effect is larger for individuals with greater anxiety sensitivity. Additionally, SF-MPQ pain response was significantly predicted by situation-specific catastrophizing (β = .56, p < .001). The simple slope analyses provided further evidence of a moderated indirect effect. Self-reported weekly strenuous exercise bouts significantly predicted situation-specific catastrophizing for individuals with high anxiety sensitivity (β = −.34, p = .03), but not intermediate (β = −.16, p = .16) or low (β = .03, p = .85; Figure 2). The indirect effect of weekly strenuous exercise bouts on SF-MPQ pain ratings through pain catastrophizing was significant when individuals' anxiety sensitivity was high, but not when anxiety sensitivity was intermediate or low. In Table 3, normal theory tests (i.e., *p* values) are provided; however, these tests should be interpreted with caution, if at all. It has been suggested that there is reason to be suspicious of the use of the normal distribution for computing the *p* value for the test of mediation because the sampling distribution of *ab* (the cross-product) is often not normal, but rather positively skewed (35)., Therefore, the significance of each indirect effect across levels of the moderator was subsequently verified with bootstrapped standard errors and CIs.

Table 3 shows that at a high level of anxiety sensitivity, the 95% BC bootstrapped CI for the indirect effect of weekly strenuous exercise bouts on pain ratings through situation-specific catastrophizing was significantly different from zero (95% BC CI: (−9.558, −0.800) with 1000 resamples). However, the bootstrapped CI for the indirect effect was not significantly different from zero (i.e., nonsignificant) at an intermediate level (95% BC CI: (−5.674, 0.973) with 1000 resamples) or low level (95% BC CI: (−3.169, 4.165) with 1000 resamples) of anxiety sensitivity. For the significant indirect effect at a high level of anxiety sensitivity, the mediated effect through pain catastrophizing demonstrated a moderate effect size ($f^2 = 0.20$). The indirect effect sizes were small for intermediate ($f^2 = 0.09$) and low ($f^2 = 0.02$) levels of anxiety sensitivity.

The results of the J–N technique (Table 4) show that as the level of individuals' anxiety sensitivity increases, the indirect effect becomes stronger. According to the BC CIs and probability values, the critical value of the moderator whereby the indirect effect becomes significant is 25.60. This value closely corresponds to the simple slope analysis examining the indirect effect at one standard deviation above the mean (25.218; high anxiety sensitivity). Within this study model, results of the moderated mediation analysis and the J–N technique support the hypothesis that at high anxiety sensitivity, situation-specific catastrophizing is a significant mediator of the relation between weekly strenuous exercise bouts and SF-MPQ pain ratings.

Discussion

Several recent clinical trials have suggested that physical exercise may alter catastrophic cognitions related to pain (12,19). The aim of this study was to test whether situation-specific pain catastrophizing mediated the relation between self-reported strenuous-intensity exercise and ratings of pain produced by experimental noxious stimulation. Consistent with recent clinical trials (18–20), we found that catastrophizing significantly mediated the strenuous exercise—pain rating relation for a specific subgroup of our sample. To our knowledge, our data are the first to suggest that self-reported weekly strenuous exercise bouts and anxiety sensitivity may interact and exert a combined effect on pain catastrophizing as it relates to individuals' experience of pain. In a sample of healthy young adults, using bias-corrected bootstrapped confidence intervals, our data preliminarily suggest a moderated mediation effect. The results of the bootstrapped simple slope analyses and J–N technique provide support for the statistical significance of our model such that the mediated effect though situation-specific pain catastrophizing was significant at a high level of anxiety sensitivity but not at an intermediate or low level. This suggests that anxiety sensitivity significantly interacted with strenuous exercise to affect pain catastrophizing (i.e., moderation). Given the preliminary nature of these self-report data, our findings must be considered tentatively, and further research is needed to clarify the nature of this interaction. Ideally, future laboratory-based studies will incorporate exercise interventions, and longitudinally assess changes in pain catastrophizing and response in relation to exercise involvement.

Our results suggest that the decreased pain reported by those who engage in greater amounts of weekly strenuous exercise may be related to lower pain catastrophizing. These findings are comparable to those of Smeets and colleagues (18) who conducted the first prospective clinical trial demonstrating that the pain- and disability-reducing effects of a physical exercise treatment, without any cognitive-behavioral components, seemed to be mediated by the decrease of pain catastrophizing. One potential explanation for these results is that individuals who actively engage in strenuous exercise may, at times, experience acute exercise-induced pains and post-exercise muscle soreness. Effectively coping with exercise-induced pain and muscle soreness contests the idea that pain is a sign of impending threat and may thereby render it a perceived challenge to be overcome (20,41). Perhaps involvement in strenuous exercise results in increased confidence in one's own physical capabilities and consequently produces stronger beliefs for effective management of painful sensations during the noxious stimulation procedure. Alternatively, it is possible that increased physical capacity (muscle strength, muscle endurance, and aerobic capacity) positively influenced individuals' perceived ability to control their responses to an acute bout of pain, which resulted in a reduced level of pain catastrophizing during the experimental pain task

As described by Sullivan et al. (21), greater anxiety sensitivity may relate to the expression of greater pain catastrophizing. Turk (23) has argued that pain catastrophizing is a manifestation of anxiety sensitivity. One potential explanation for why mediation was seen only at a high level of anxiety sensitivity is because those individuals with intermediate and low anxiety sensitivity may not demonstrate high pain catastrophizing. Therefore, when the anxiety sensitivity level is high there may be greater opportunity for strenuous-intensity exercise to exert positive influences on pain catastrophizing, which subsequently produces less severe pain reports. This is consistent with previous literature that has suggested more beneficial and consistent psychological changes result from exercise involvement when individuals have been characterized by moderate to severe cognitive/affective disturbances from the outset (25,42, 43).

Future research should address some important limitations within the current study. First, despite acceptable to good reliability and validity, self-report exercise questionnaires may be vulnerable to the misrepresentations of participants who intentionally or unintentionally errantly recall their past exercise involvement. Second, it remains unclear whether meaningful exercise-induced changes in cognition can occur after several acute bouts of strenuous exercise or if more chronic strenuous exercise is required. Third, although our data are consistent with prospective findings among low back pain patients in which changes in catastrophizing mediated the reduction in pain behavior following an exercise-based treatment (11), the current study does not rule out the possibility that the associations among strenuous exercise, diminished catastrophizing, and pain responsiveness may be bidirectional or co-occurring. However, one recent study showed that patients with chronic low back pain who reported low physical activity had significantly higher fear-avoidance beliefs and catastrophizing than patients who reported high physical activity (44). These results lend support to the pathways specified in our predictive model. Finally, the probability value for the interaction between weekly strenuous exercise bouts and anxiety sensitivity demonstrated a trend for statistical significance. Our small sample size may have lacked sufficient power for detecting moderation by conventional standards (e.g., multiple regression). However, a strength of the current study is the use of bias-corrected 95% bootstrapped confidence intervals for examination of unconditional indirect effects; it has been shown that bootstrapping is more appropriate for studies with smaller sample sizes and non-normally distributed variables, resulting in improved type I error rates and statistical power (45,46).

The current study extends prior research suggesting the important role of exercise and cognitive factors in shaping individuals' pain responses. Whether the ability of strenuous exercise to produce decrements in catastrophizing is long-lasting or short-lived remains unclear. Additionally, whether decreased catastrophizing is associated with exercise performed at moderate and low intensity is not yet known. The possible protective role of exercise involvement in the development of chronic pain has been postulated but not longitudinally examined. Emerging evidence suggests that regular exercisers may have some adaptation in pain perception, but whether such adaptations occur during chronic pain has yet to be explored. Understanding the mechanisms by which exercise may reduce pain and modify pain cognitions has important implications for exercise interventions. It may be particularly beneficial to supplement exercise programs with activities like cognition tracking during exercise to better elucidate the process by which exercise affects pain cognitions. Further, studies that examine the effects of acute and chronic strenuous exercise on cognitive processes and pain outcomes are needed.

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Abbreviations

BC, bias-corrected
CI, Confidence Interval
CPT, cold pressor task
GLTEQ, Godin Leisure-Time Exercise Questionnaire
PCS, Pain Catastrophizing Scale

ASI, Anxiety Sensitivity Index
BDI, Beck Depression Inventory
SF-MPQ, Short Form-McGill Pain Questionnaire
MET, Metabolic Equivalent
BMI, Body Mass Index
J–N technique, Johnson-Neyman technique

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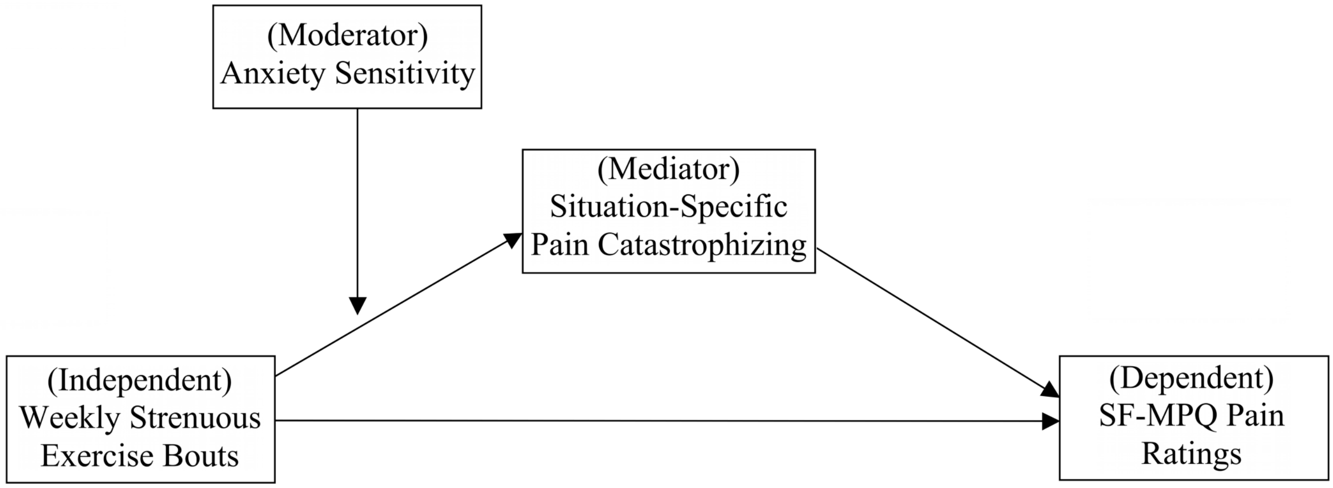
(Moderator)
Anxiety Sensitivity
(Mediator)
Situation-Specific
Pain Catastrophizing
(Independent)
Weekly Strenuous
Exercise Bouts
(Dependent)
SF-MPQ Pain
Ratings

Figure 1.

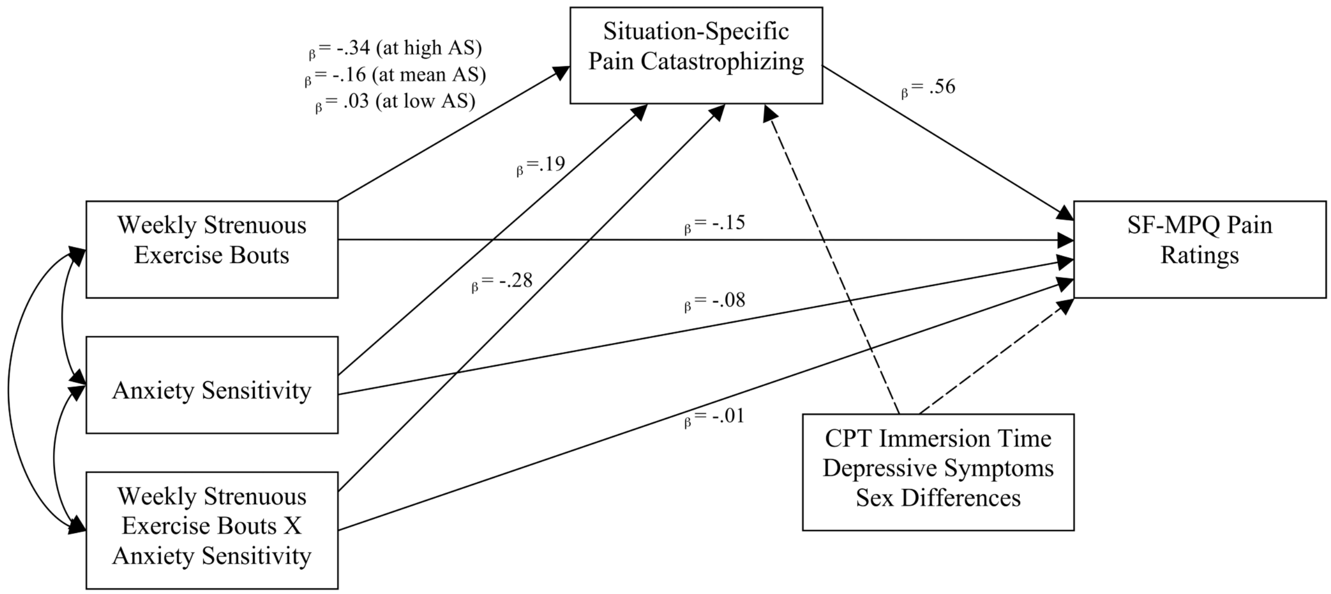
Situation-Specific Pain Catastrophizing
β = -.34 (at high AS)
β = -.16 (at mean AS)
β = .03 (at low AS)
β = .56
β =.19
β = -.15
β = -.28
β = -.08
β = -.01
Weekly Strenuous Exercise Bouts
Anxiety Sensitivity
Weekly Strenuous Exercise Bouts X Anxiety Sensitivity
SF-MPQ Pain Ratings
CPT Immersion Time
Depressive Symptoms
Sex Differences

Figure 2.

Table 1

Descriptive statistics for pain ratings and psychosocial variables

Variable	Mean	SD	Range
Weekly strenuous exercise bouts	3.28	3.07	0 – 21
Depressive symptoms	6.20	5.03	0 – 20
Anxiety sensitivity	18.33	6.89	7 – 38
Standard pain catastrophizing	13.66	8.64	0 – 41
Situation-specific pain catastrophizing	18.37	11.99	0 – 48
CPT immersion time[b]	198.84	80.30	49 – 300
SF-MPQ	16.30	7.02	4 – 31

[b]Note: Time of hand immersion measured in seconds.

Table 2

Pearson correlation coefficients for pain ratings and psychosocial variables

Variable	1	2	3	4	5	6	7
1) Weekly strenuous exercise bouts[b]	—						
2) Anxiety sensitivity	−0.26*	—					
3) Depressive symptoms	−0.28*	0.37**	—				
4) Standard pain catastrophizing	−0.32**	0.41**	0.37**	—			
5) Situation-specific pain catastrophizing	−0.24*	0.33**	0.17	0.29**	—		
6) CPT immersion time	0.07	−0.26*	0.17	−0.10	−0.26*	—	
7) SF-MPQ	−0.24*	0.21	0.09	0.15	0.65**	−0.30**	—

[b] Log transformed.

* $p < .05$ (2-tailed).

** $p < .01$ (2-tailed).

Table 3

Indirect effect of strenuous exercise in pain response through situation-specific pain catastrophizing at varying levels of anxiety sensitivity

	Mediator	**Variable**	**Model**		
Predictor	**B**	**SE**	***t***	***p***	**95% BCa CI's**
Constant	11.568	8.268	1.400	.166	—
Strenuous exercise[b]	−13.574	11.619	−1.168	.246	—
Anxiety sensitivity	.914	.395	2.316	.023	—
Strenuous exercise X Anxiety Sensitivity	−1.089	.605	−1.801	.072	—
	Dependent	Variable	Model		
Predictor	B	SE	*t*	*p*	95% BCa CI's
Constant	16.363	4.070	4.021	<.001	—
Pain catastrophizing	.335	.057	5.844	<.001	—
	Conditional effects at anxiety sensitivity = mean and +/− 1 SD				
Anxiety sensitivity	ab	SE	Z	*p*	95% BCa CI's
(−1 SD) 11.440	.490	1.942	.252	.801	(LL = −3.169, UL = 4.165)
(Mean) 18.329	−2.106	1.658	−1.270	.204	(LL = −5.674, UL = 0.973)
(+1 SD) 25.218	−4.648	2.400	−2.004	.048	(LL = −9.558, UL = −0.800)

[b]Log transformed

LL = Lower Limit, UL = Upper Limit

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Table 4

The Johnson-Neyman technique: Conditional indirect effects at a range of values of anxiety sensitivity

	Conditional effects at range of values of anxiety sensitivity				
Anxiety sensitivity	**ab**	**SE**	**Z**	***p***	**95% BCa CI's**
7.00	2.155	2.442	.883	.378	(LL = −2.636, UL = 7.767)
8.55	1.576	2.237	.705	.481	(LL = −2.993, UL = 5.996)
10.10	.998	2.055	.486	.627	(LL = −2.857, UL = 5.065)
11.65	.419	1.902	.220	.825	(LL = −3.533, UL = 4.348)
13.20	−.160	1.784	−.090	.928	(LL = −4.201, UL = 3.067)
14.75	−.738	1.711	−.432	.666	(LL = −4.272, UL = 2.475)
16.30	−1.318	1.687	−.781	.435	(LL = −5.317, UL = 1.754)
17.85	−1.896	1.714	−1.106	.269	(LL = −5.797, UL = 0.867)
19.40	−2.475	1.791	−1.382	.167	(LL = −6.780, UL = 0.537)
20.95	−3.054	1.911	−1.598	.110	(LL = −7.523, UL = 0.216)
22.50	−3.633	2.067	−1.758	.079	(LL = −8.174, UL = 0.004)
24.05	−4.211	2.251	−1.871	.058	(LL = −8.767, UL = −0.229)
25.60	−4.790	2.357	−2.010	.047	(LL = −9.747, UL = −0.347)
27.15	−5.369	2.680	−2.021	.045	(LL = −11.151, UL = −0.484)
28.70	−5.948	2.916	−2.040	.041	(LL = −12.378, UL = −0.560)
30.25	−6.527	3.162	−2.064	.039	(LL = −13.465, UL = −0.770)
31.80	−7.105	3.415	−2.080	.038	(LL = −15.033, UL = −1.173)
33.35	−7.684	3.676	−2.090	.037	(LL = −16.352, UL = −1.406)
34.90	−8.263	3.942	−2.096	.036	(LL = −16.543, UL = −1.284)
36.45	−8.841	4.211	−2.100	.036	(LL = −19.584, UL = −1.505)
38.00	−9.421	4.484	−2.101	.035	(LL = −20.385, UL = −1.563)

LL = Lower Limit, UL = Upper Limit