Published in final edited form as:

J Pain. 2012 April ; 13(4): 370–378. doi:10.1016/j.jpain.2011.12.011.

Pain Related Fear and Catastrophizing Predict Pain Intensity and Disability Independently Using an Induced Muscle Injury Model

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Abstract

Timing of assessment of psychological construct is controversial and results differ based on the model of pain induction. Previous studies have not used an exercise induced injury model to investigate timing of psychological assessment. Exercise induced injury models may be appropriate for these investigations because they approximate clinical pain conditions better than other experimental stimuli. In this study we examined the changes of psychological constructs over time and determined whether timing of assessment affected the construct's association with reports of pain intensity and disability. One-hundred twenty-six healthy volunteers completed the Fear of Pain Questionnaire (FPQ-III), Pain Catastrophizing Scale (PCS), and Tampa Scale of Kinesiophobia (TSK) prior to inducing muscle injury to the shoulder. The PCS and TSK were measured again 48 and 96 hours post-injury induction. Pain intensity and disability were collected at 48 and 96 hours and served as dependent variables in separate regression models. Results indicated that the FPQ-III had the strongest prediction of pain intensity from baseline to 96 hours. After baseline the PCS and TSK were stronger predictors of pain intensity and disability, respectively. These data provide support for the use of psychological constructs in predicting outcomes from shoulder pain. However, they deviate from the current theoretical model indicating that fear of pain is a consequence of injury and instead suggests that fear of pain before injury may influence reports of pain intensity.

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Disclosures

Some authors (SZG, RBF, JJP, PAB) received support from the National Institutes of Health to complete the submitted work (NIAMS/NIH grant AR055899). The primary author (JJP) is also supported by NINDS training grant NS045551. All authors have no financial relationships with any organizations that might have an interest in the submitted work in the previous 3 years; and all authors have no other relationships or activities that could appear to have influenced the submitted work.

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Perspective—The current study provides evidence that fear of pain can be assessed prior to injury. Furthermore, it supports that after injury pain catastrophizing and kinesiophobia are independently associated with pain and disability. Overall these data suggest that timing of psychological assessment may be an important consideration in clinical environments.

Keywords

Fear; catastrophizing; assessment; pain; disability

The impact of musculoskeletal disorders in the United States continues to rise.²⁵ A cross sectional survey found that 35% of individuals reported persistent musculoskeletal pain that had lasted at least three months.² The shoulder in particular is vulnerable to traumatic injury as well as injury from repetitive loading.³³ Prognosis for shoulder pain is not encouraging. For example, a prospective cohort found that only 20% of individuals reporting new shoulder episodes completely resolved their symptoms following six months, and 50% had still not resolved after 18 months.⁷

Several factors, such as gender,^{4,11,12,14,35} age,^{6,14} and psychological influences^{18–20,23,37} are known to contribute to an individual's symptomatic response and disability following musculoskeletal injury. Several studies have suggested that catastrophizing increases pain-related fear, which in turn increases the attention and focus to the injury stimulus.^{19,20,23} The inclination of an individual to catastrophize about pain can lead to a prolonged and sometimes incomplete recovery following musculoskeletal injury and has been associated with an increased rate of chronic pain and muscle dysfunction.^{19,20,37} Sullivan et al. found that pain catastrophizing was linked to activity intolerance following a repeated bout exercise.³⁷ However, other studies have deemed fear of pain as a potentially better indicator of dysfunction following injury.^{17,18,23} Kinesiophobia is much like fear of pain, but is specifically related to the fear of movement or fear of re-injury. Studies have found that kinesiophobia is a reliable predictor of chronic pain in patients with low back pain^{8,39} and in exercise induced pain models.⁴¹ However, fewer studies have examined these psychological factors simultaneously.

Research has reported that state or “in-vivo” catastrophizing (assessed after application of experimental pain with modified instructions) has a stronger correlation with pain responses in comparison to trait catastrophizing assessed before pain induction.^{13,16,23} A potential methodological issue with many of these studies is that assessing catastrophizing immediately after induction of an experimental pain stimulus of short duration (i.e. thermal pulses, cold water bath) does not mimic musculoskeletal pain. Individuals with musculoskeletal pain have typically been experiencing pain and dysfunction for several days, weeks, or months before psychological assessment is performed. Previous studies have been able to identify a positive correlation for timing of psychological assessment using immediate pain models.^{13,16,23} However, it is not yet known how pain catastrophizing, fear of pain and kinesiophobia are affected when longer painful states are induced.

Exercise induced muscle pain approximates injury through causing micro-trauma, muscular pain, inflammation and loss of physical function.^{4,10,11,31} While it is not an exact replica for clinical pain due to its shorter duration, it does cause tissue damage and is believed to involve both A-delta nerve fibers and C-fiber mediated pain pathways. The presence of inflammatory mediators, activation of A-delta and C fiber pathways, and resulting longer duration of pain then thermal stimuli or cold pressor test allows for an approximation of clinical pain conditions in the laboratory setting.

In the current study we used a model of exercise induced muscle pain to advance our prior work investigating the influence of pain related fear and catastrophizing on pain perception and disability.^{18,21,23} Our objectives were to determine if psychological factors change following exercise-induced shoulder pain and dysfunction and determine how timing of psychological assessment affected associations with pain and disability in an experimentally induced muscle pain model. In this study we hypothesized that 1) baseline levels of fear of pain and catastrophizing would predict peak pain and disability (first 48 hours) 2) kinesiophobia and pain catastrophizing would increase over the time course of peak pain and disability (first 48 hours) and return to baseline following recovery from an exercise induced muscle injury (at 96 hours) and 3) pain catastrophizing and kinesiophobia would be predictive of pain intensity and disability at 48 hours following muscle injury induction. A portion of this work was presented at the 2011 Annual Scientific Meeting of the American Pain Society.³⁰

METHODS

All subjects underwent three testing sessions over a five day period. During the baseline session, subjects (1) read and signed the informed consent, (2) completed a series of brief questionnaires asking for demographic data including age, height, and weight, (3) filled out three validated questionnaires examining psychosocial risk factors, (4) had pre-injury (baseline) impairment measurements taken, and (5) performed an eccentric exercise protocol on their dominant shoulder to induce pain and dysfunction. Subjects were asked to return to the lab post-injury at follow up 1 (48 hours) and follow up 2 (96 hours). All follow-up visits were scheduled within a plus or minus three-hour window of their recorded time of fatigue to prevent any confounding effects from diurnal rhythms. Follow-up measurements were identical to baseline measurements.

Subjects

Subjects for this study were otherwise healthy men and women of any racial/ethnic background (n = 126). Subjects were recruited from undergraduate and graduate courses at the University of Florida and from the surrounding community. To meet the inclusion criteria, subjects had to be between 18–85 years old and not currently performing strength training exercises (no resistance exercise of the upper extremity during the previous six weeks). Subjects were also excluded if they 1) were currently experiencing neck or shoulder pain, 2) had any neurological impairments of the upper extremity, such as loss of sensation, muscle weakness or reflex changes, 3) were currently taking pain medication or 4) had previous history of shoulder surgery. These eligibility criteria are the same as used in our previous studies.^{18,19} All study subjects read and signed a written informed consent approved by the University Institutional Review Board. All self report measures were completed on the computer as part of a battery of electronic questionnaires including demographic information, psychological assessment, pain intensity, and disability.

Predictive Measures

Fear of Pain Questionnaire—In this study we used a shortened 9 –item version of the Fear of Pain Questionnaire (FPQ-III). The original 30 item FPQ-III is a well-validated instrument that is appropriate for use in non-clinical and clinical populations.²⁸ Psychometric data for the 9-item FPQ used in this study has not been published but we have supporting data from our pilot studies in healthy volunteers, as well as subjects with low back or shoulder pain. In these studies the 9-item FPQ has acceptable internal consistency (ICC = 0.83–0.87 compared to 0.94–0.95 for the 30 item version, all p's < 0.001) and is very highly correlated with the 30-item FPQ (r = 0.94 – 0.97). The 9 items selected for this study were #3, 9, 10, 14, 17, 19, 21, 23, and 24 from the original 30 item FPQ-III. These items

assessed total fear of pain from different specific situations (e.g. How fearful are you of experiencing the pain of “Breaking your arm?”) that would normally be expected to produce pain. Each item was rated on a 5-point rating scale, with a score of 5 meaning extremely painful and a score of 1 meaning not at all painful. Subjects were asked to complete this questionnaire only on the first visit because in our other pilot studies we have found that the FPQ-III and 9 item FPQ do not change statistically over one week in healthy subjects, from pre-operative to 3 months post-operative for those with shoulder pain, and 6 months after receiving physical therapy for low back pain. The total of the 9 items was used in the current study to reflect the FPQ score. We did not investigate subscales of the FPQ because our hypotheses were related only to total fear of pain.

Pain Catastrophizing Scale—The Pain Catastrophizing Scale (PCS) consists of 13 items and assesses different thoughts that may be associated with experiencing pain (e.g. “I worry all the time about whether the pain will end”).³⁸ Each item is rated on a 5-point scale, where a 4 means there is worry all the time about the pain and a 0 means no worry at all. Subjects were instructed to rate the degree to which they have specified feelings when experiencing pain. Three dimensions of pain catastrophizing have been identified, but only the total score was used for the current study. Subjects were asked to fill out the PCS on each visit to the lab. The PCS has been validated for clinical and nonclinical populations.^{9,29,34}

Tampa Scale of Kinesiophobia—We used the previously validated 11 item version of the Tampa Scale of Kinesiophobia (TSK-11) to measure the fear of movement or re-injury (e.g. “I’m afraid that I might injure myself if I exercise”).⁴⁴ Each item is rated on a 4-point scale, where a 4 represents there is strong agreement with the statement and a 1 represents strong disagreement. Subjects were asked to fill out the TSK-11 on each visit to the lab. The total score was used in the current study. The TSK-11 has been deemed a valid and reliable method for determining fear of re-injury in both clinical and nonclinical populations.⁴⁴

Outcome Measures

QuickDASH—The QuickDASH (Disability of the Arm, Shoulder, and Hand) was implemented as a measure of the subject’s ability to use the affected arm during activities of daily living. Scores were obtained by summing indicated responses, dividing the total by the number of items answered, subtracting 1, and then multiplying that figure by 25. This calculation provides a score between 0–100. A score of zero represents no dysfunction at all, while higher scores represent more limitations in self reported function, with a score of 100 being the highest possible score. A minimum of ten questions needs to be answered to score the QuickDASH. The QuickDASH is comparable with the full DASH ($r = 0.98$), and its construct validity and responsiveness suggest that the QuickDASH scores should give views of disability that are relatively similar to scores provided by the full DASH.^{1,22,27}

Pain Intensity—The Brief Pain Inventory (BPI) was used to measure pain intensity. The BPI consists of 4 questions with each question rated on an 11-point scale (0–10). The higher the score given on the BPI indicates a greater degree of pain intensity. The BPI asks subjects to rate their pain at worst, best and average over the past 24 hours and includes a rating for current pain. The BPI has been found to have good test-retest reliability, especially over shorter intervals.²⁴ Due to the nature of the current eccentric injury model, only current pain intensity was used in this study. Since induced muscle pain typically peaks within 48 hours and dissipates by 96 hours we decided current pain was the best choice to give us accurate ratings. Using only current pain also allowed us to directly correlate pain ratings to psychological questionnaires at time of assessment.

Shoulder Injury Protocol

Muscle injury was induced using a Kin-Com isokinetic dynamometer (Chattanooga Group., Chattanooga, TN). Subjects were placed in a seated position, with shoulder straps applied to support the torso as per manufacturer's recommendations. The dominant shoulder was placed in the scapular plane because this position has been associated with high test-retest reliability and is believed to have decreased impingement of the greater tuberosity under the acromion.^{32,40} Maximum voluntary isometric contraction (MVIC) was determined by having the participants perform three repetitions of isometric shoulder external rotation. Participants were asked to perform the contraction with maximal effort and were given verbal encouragement during the contractions. The highest torque value was recorded as their MVIC.

After initial MVIC was determined, subjects completed isokinetic concentric/eccentric external rotation repetitions to induce an experimental muscle injury. The first set of repetitions was completed at 100°/s to familiarize the subjects with the testing apparatus and protocol. Then, the speed was lowered to 60°/s for 3 sets of 10 repetitions that constituted the injury protocol. Following the isokinetic repetitions, MVIC was measured and if subjects could still generate greater than 50% of their initial MVIC, they performed an additional 1 to 8 sets of 10 repetitions at 60°/s until their peak force was lower than 50% of the initial MVIC. Previous research has indicated the inability to achieve 50% of initial peak MVIC is a consistent indicator of muscle fatigue.^{4,5,43} Subjects were given 30 seconds rest between sets. Time to fatigue was recorded as total number of repetitions performed at a speed of 60°/s. We have previously used this protocol in our lab for inducing shoulder muscle pain and dysfunction.^{18,19}

Data Analysis

Descriptive Data—All data analyses were performed using PASW® for Windows 18.0 (SPSS, Inc., Chicago, IL). Standard significance for non-regression statistics was set a-priori at an alpha of < 0.05. Summary statistics were calculated for all demographic, psychological, pain sensitivity and impairment measures. Correlation analyses characterized the bivariate relationships among pain, disability and the psychological variables. One-way ANOVA were run to examine the effect of gender on pain intensity, disability, PCS scores and TSK scores.

Psychological Trend Analysis—Since there is some literature available that suggests there are gender differences in psychological distress^{13,15,36} a mixed-model repeated measures ANOVA was run to determine any differences between genders over time for the change in PCS and TSK.

Predictive Assessment Analysis—Regression models were designed to examine influence of sex and psychological variables on outcome measures at 48 and 96 hours. Since previous studies have found gender, fear of pain, pain catastrophizing and kinesiophobia to all be important variables in models predicting pain intensity, all factors were simultaneously entered into each regression model as independent variables to determine how they affected each other. Pain intensity and disability served as our dependent variables for all regression models. Three regression models were analyzed for each dependent variable to determine the importance of our independent variables on the predictive ability of pain intensity and disability. Regression models were developed by entering sex, FPQ, TSK, and PCS baseline values to predict pain intensity and disability at 48 and 96 hours. Then, a separate regression model was designed by entering gender, PCS and TSK values from 48 hours to predict pain intensity and disability at 96 hours. Collectively these models were referred to as predictive models.

Timing Assessment Analysis—Finally, two regression models were analyzed for each dependent variable to determine the importance of timing of assessment of our independent variables. To examine the influence of timing of assessment we entered sex and values for the 48 hour TSK and PCS to predict pain intensity and disability at 48 hours. This was repeated for independent variables and outcome measures at 96 hours. Collectively these models were referred to as timing models.

RESULTS

Descriptive statistics for the demographic data from the sample ($n = 126$) are summarized in Table 1. Females reported significantly higher pain intensity at follow-up 1 post-injury induction (Table 2). They also reported higher levels of disability at both follow-up 1 and 2 post-injury induction (Table 2). Females also tended to report higher scores for both the PCS and TSK; however, these were not statistically significant in this sample. Correlation data for predictor measures and outcome measures are summarized in Table 3. Correlations were highest within psychological questionnaires over time. Significant relationships among predictor variables were found, however the Pearson r values were low to moderate.

Psychological Trends

Descriptive data showed fluctuations but there were no statistical differences between genders across the three assessment times for the psychological variables (Table 4). Even though none of this data is statistically significant we feel it is novel since the lack of change of PCS ($F_{2,248} = 0.26$, $p = 0.76$) and TSK ($F_{2,248} = 1.02$, $p = 0.36$) between gender over time has not been reported and was counter to our hypotheses based on our prior data collection in clinical populations. Effect sizes for the interaction of gender over time were small for both the PCS ($\eta^2 = 0.005$) and TSK ($\eta^2 = 0.008$).

Predictive Assessment

Statistics for the regression models can be found in Tables 5 and 6. Gender was the only variable found to significantly predict pain intensity at follow-up 1 ($\beta = -0.201$, $p = 0.024$). However, when predicting pain at follow-up 2 from baseline values, gender no longer had an effect, and fear of pain was the only significant variable ($\beta = 0.310$, $p = 0.002$). Predicting pain at follow-up 2 using variables from follow-up 1 showed that only pain catastrophizing ($\beta = 0.282$, $p = 0.012$) was significant.

When predicting disability from baseline variables, gender ($\beta = -0.203$, $p = 0.020$) was the only variable found to predict disability at follow-up 1. This was the same for follow-up 2, where gender ($\beta = -0.285$, $p = 0.001$) was still a robust predictor at follow-up 2. Gender ($\beta = -0.219$, $p = 0.007$), kinesiophobia ($\beta = 0.223$, $p = 0.028$) and pain intensity ($\beta = 0.590$, $p < 0.001$) at follow-up 1 were all found to be predictive of disability at follow-up 2.

We also ran an exploratory hypothesis controlling for pain and disability at follow up 1 (48 hours) when predicting pain and disability at follow up 2 (96 hours). As expected the variance shared with these variables was so high that psychological variables no longer contributed to our *a priori* proposed models. Since our hypotheses were focused on psychological contributions to the pain and disability variables at follow up 1 were excluded from the final models predicting outcome at follow up 2.

Timing Assessment

Statistics for timing assessment models can be found in Table 5 and 6. Same day analyses were similar for pain intensity at follow-up 1, where gender ($\beta = -0.196$, $p = 0.027$) was the only significant predictor. For the follow-up 2 pain intensity model, pain catastrophizing (β

= 0.259, $p = 0.027$) was a significant predictor in this same day analysis model. Same day analysis for disability at follow-up 1 showed pain intensity ($\beta = 0.590$, $p < 0.001$) and kinesiophobia ($\beta = 0.250$, $p = 0.002$) to be significant predictors. At follow-up 2 we found gender ($\beta = -0.232$, $p = 0.004$), pain intensity ($\beta = 0.314$, $p < 0.001$) and kinesiophobia ($\beta = 0.273$, $p = 0.010$) were the strongest predictors.

DISCUSSION

Our objectives were to investigate whether psychological factors change following exercise-induced muscle injury and determine whether differences existed for timing of assessment for fear of pain, pain catastrophizing and kinesiophobia. Our results indicated that while catastrophizing and kinesiophobia do not significantly change over a short duration, they are predictive of pain and disability following induction of injury. Contrary to some research, but in agreement with our previous work, we found that fear of pain was the most robust psychological construct to predict pain intensity reports prior to injury induction. A strength of the current study is that while these variables have been examined previously, to our knowledge, this is the first study that has concurrently examined all three variables using an exercise-induced muscle injury model.^{18–20,23,34,35,42} A benefit of using the exercise-induced muscle injury model is that it may approximate clinical pain conditions better than other experimental pain models that have briefer duration of pain and occur without tissue damage. This pain model also allowed us to examine multiple outcomes (i.e. pain and disability) at the same point.

To our knowledge this is the first study that has examined changes over time for pain catastrophizing and kinesiophobia in healthy subjects going through an induced muscle injury protocol. We hypothesized that scores for pain catastrophizing and kinesiophobia would increase through follow-up 1 before returning to normal at follow-up 2, following the expected course of pain intensity. This however was not the case, indicating that, in our opinion, individuals were likely not threatened by the painful experience. This could be due to the information provided during the informed consent process indicating that exercise induced muscle injury is only short-term. In addition, it is likely that a young healthy population, like the one studied here, has experienced muscle soreness in some circumstance and did not perceive it as threatening. Future studies should examine whether manipulating the instruction set for the exercise induced muscle injury would influence the way subjects answer the psychological questionnaires.

We confirmed our previous reports that baseline measures of fear of pain may be a stronger predictor of subsequent pain intensity from induced pain paradigms when compared to catastrophizing. This finding has been reported for pain intensity following induced muscle pain in healthy subjects¹⁸ and cold pressor immersion for subjects with clinical shoulder pain.²¹ Interestingly, these collective data are in conflict with how current fear-avoidance models have been conceptualized, with fear of pain as a consequence of pain catastrophizing.²⁶ The current study provides further evidence that baseline fear of pain may be a more robust predictor of pain intensity when measured prior to injury. Our data do support other theoretical aspects of the current fear-avoidance model,²⁶ specifically that pain catastrophizing is associated with pain²³ and disability³⁷ following and during the painful experience. Regression analyses in this study were consistent with previous studies that reported in-vivo assessment of pain catastrophizing resulted in a positive association with pain intensity ratings at follow-up 1.^{17,23} We also found that pain intensity and kinesiophobia were stronger predictors of disability at follow-up 1 than fear of pain, which was different than our previous report that involved a smaller sample size.¹⁸ While the scores for pain catastrophizing and kinesiophobia did not significantly change over the time-course of this study, we did find that psychological construct were independently associated

with different pain and disability outcomes following exercise induced muscle pain. Of interest, while pain intensity and kinesiophobia may be more robust predictors of disability following injury, it appears gender is more consistent as a predictor both prior to and following induction of muscle injury.

In determining the importance of psychological assessment in using a fear avoidance model, there is little research confirming if timing of these psychological assessments is important. Previous studies used psychological constructs and examined an “in-vivo” method of assessment following a cold pressor test.^{13,16} Subjects would fill out a questionnaire, receive a painful stimulus and then fill out the same questionnaire again with specific instructions to complete the instrument based on one’s preceding experience. While our study did not alter the instruction set for the questionnaires following injury induction, we believe this method matches clinical application, where questionnaires are not tailored to clinical conditions. We found “in-vivo” catastrophizing was a better predictor of pain intensity than baseline catastrophizing, but it was still not as strong as baseline fear for predicting pain intensity at 96 hours. So the current study using a novel pain induction method both confirms studies which found in-vivo measurements for pain intensity were a better predictor of experimental pain,^{13,16} but is in conflict with work from Hirsh et al,²³ which found no appreciable differences between standard and in-vivo measurements for pain catastrophizing. The difference between our study and those that found “in-vivo” to be a better predictor could be due to differences in pain models or our study not using explicit instruction sets for the “in-vivo” catastrophizing measure.

While we cannot make direct clinical recommendations from this study, there are some potential suggestions for psychological assessment in clinical populations. While fear of pain was a strong predictor of pain intensity, our data suggest individuals would need to have fear of pain assessed prior to their injury. This is not practical in most clinical settings. One exception would be for individuals competing in sports, as these questionnaires could easily be completed during pre-season screening. However, these data suggest that in most clinical settings psychological assessment should include early assessment of pain catastrophizing and kinesiophobia as they were consistently associated with shoulder pain and disability outcomes following exercise induced injury.

Despite the fact that models of exercise-induced pain do not exactly replicate chronic musculoskeletal conditions, they do provide a better pattern of pain and disability than models using discrete methods of pain induction that only last several minutes. Bishop et al. found a considerable overlap between individuals seeking intervention for low back pain and their model of exercise-induced muscle pain.³ Similarly, we found that in this shoulder pain model an age and sex matched cohort that the top 39th percentile of pain in our healthy population and top 41st percentile of disability overlap with the lower 80th percentile of pain and lower 90% percentile of disability in an available sample of patients awaiting surgery for shoulder pain.³

This study has several limitations that should be considered when interpreting the results. While the exercise-induced muscle injury model does have some clinical validity, results must be translated with caution to clinical populations. Also, this study only assessed outcomes for individuals experiencing shoulder pain and disability, so generalizations to other injury locations should be done with prudence. While most individuals had recovered by follow-up 2, this does not hold true for everyone following an exercise-induced muscle injury so assumptions made past this time point need to be done with care. In addition, this study was completed in a group of young healthy individuals with generally low levels of psychological distress which may limit application to populations with higher levels of psychological distress. Also, in our primary analyses we did not control for levels of pain or

disability at follow-up 1 in our final model predicting outcomes at follow-up 2. When these data were included in the regression models, pain and disability were the strongest predictors of the respective outcomes. These were expected findings and not consistent with our original hypotheses which were to identify other potential prognostic factors. Finally, our study only examined an exercise induced model of pain induction, so comparisons to studies using other methods of pain induction should be done with caution.

In summary, this is a novel study because of its combination of multiple psychological constructs assessed and use of an exercise-induced injury model. Furthermore, we have found that timing of assessment of psychological factors is important, but it may not be as essential as the specific construct assessed. While fear of pain was a better predictor of pain intensity prior to injury, pain catastrophizing was associated with pain intensity following injury. In addition, after injury kinesiophobia was associated with disability. This study suggests that while there is validity of a fear-avoidance model for patients with shoulder pain, changes may need to be made based on the order and timing for relationship of fear of pain, pain catastrophizing, and pain intensity. Furthermore, these data suggest that multiple psychological constructs should be assessed when dealing with clinical populations as their associations with pain and disability might be construct specific.

References

1. Beaton DE, Wright JG, Katz JN. Development of the QuickDASH: comparison of three item-reduction approaches. *J Bone Joint Surg Am.* 2005; 87:1038–1046. [PubMed: 15866967]
2. Bergman S, Herrstrom P, Hogstrom K, Petersson IF, Svensson B, Jacobsson LT. Chronic musculoskeletal pain, prevalence rates, and sociodemographic associations in a Swedish population study. *J Rheumatol.* 2001; 28:1369–1377. [PubMed: 11409133]
3. Bishop MD, Horn ME, George SZ, Robinson ME. Self-reported pain and disability outcomes from an endogenous model of muscular back pain. *BMC Musculoskelet Disord.* 2011; 12:35. [PubMed: 21288349]
4. Borsa PA, Sauters EL. The importance of gender on myokinetic deficits before and after microinjury. *Med Sci Sports Exerc.* 2000; 32:891–896. [PubMed: 10795777]
5. Carpenter JE, Blasier RB, Pellizzon GG. The effects of muscle fatigue on shoulder joint position sense. *Am J Sports Med.* 1998; 26:262–265. [PubMed: 9548121]
6. Cole LJ, Farrell MJ, Gibson SJ, Egan GF. Age-related differences in pain sensitivity and regional brain activity evoked by noxious pressure. *Neurobiol Aging.* 2009; 31:494–503. [PubMed: 18513833]
7. Croft P, Pope D, Silman A. The clinical course of shoulder pain: prospective cohort study in primary care. Primary Care Rheumatology Society Shoulder Study Group. *BMJ.* 1996; 313:601–602. [PubMed: 8806252]
8. Crombez G, Vlaeyen JW, Heuts PH, Lysens R. Pain-related fear is more disabling than pain itself: evidence on the role of pain-related fear in chronic back pain disability. *Pain.* 1999; 80:329–339. [PubMed: 10204746]
9. D'Eon JL, Harris CA, Ellis JA. Testing factorial validity and gender invariance of the pain catastrophizing scale. *J Behav Med.* 2004; 27:361–372. [PubMed: 15559733]
10. Dannecker EA, Gagnon CM, Jump RL, Brown JL, Robinson ME. Self-care behaviors for muscle pain. *J Pain.* 2004; 5:521–527. [PubMed: 15556831]
11. Dannecker EA, Hausenblas HA, Kaminski TW, Robinson ME. Sex differences in delayed onset muscle pain. *Clin J Pain.* 2005; 21:120–126. [PubMed: 15722804]
12. Dannecker EA, Knoll V, Robinson ME. Sex differences in muscle pain: self-care behaviors and effects on daily activities. *J Pain.* 2008; 9:200–209. [PubMed: 18088556]
13. Dixon KE, Thorn BE, Ward LC. An evaluation of sex differences in psychological and physiological responses to experimentally-induced pain: a path analytic description. *Pain.* 2004; 112:188–196. [PubMed: 15494200]

14. Doherty TJ. The influence of aging and sex on skeletal muscle mass and strength. *Curr Opin Clin Nutr Metab Care*. 2001; 4:503–508. [PubMed: 11706284]
15. Edwards RR, Haythornthwaite JA, Sullivan MJ, Fillingim RB. Catastrophizing as a mediator of sex differences in pain: differential effects for daily pain versus laboratory-induced pain. *Pain*. 2004; 111:335–341. [PubMed: 15363877]
16. Edwards RR, Campbell CM, Fillingim RB. Catastrophizing and experimental pain sensitivity: only in vivo reports of catastrophic cognitions correlate with pain responses. *J Pain*. 2005; 6:338–339. [PubMed: 15890636]
17. George SZ, Danneker EA, Robinson ME. Fear of pain, not pain catastrophizing, predicts acute pain intensity, but neither factor predicts tolerance or blood pressure reactivity: an experimental investigation in pain-free individuals. *Eur J Pain*. 2006; 10:457–465. [PubMed: 16095935]
18. George SZ, Dover GC, Fillingim RB. Fear of pain influences outcomes after exercise-induced delayed onset muscle soreness at the shoulder. *Clin J Pain*. 2007; 23:76–84. [PubMed: 17277648]
19. George SZ, Dover GC, Wallace MR, Sack BK, Herbstman DM, Aydog E, Fillingim RB. Biopsychosocial influence on exercise-induced delayed onset muscle soreness at the shoulder: pain catastrophizing and catechol-o-methyltransferase (COMT) diplotype predict pain ratings. *Clin J Pain*. 2008; 24:793–801. [PubMed: 18936597]
20. George SZ, Wallace MR, Wright TW, Moser MW, Greenfield WH 3rd, Sack BK, Herbstman DM, Fillingim RB. Evidence for a biopsychosocial influence on shoulder pain: pain catastrophizing and catechol-O-methyltransferase (COMT) diplotype predict clinical pain ratings. *Pain*. 2008; 136:53–61. [PubMed: 17686583]
21. George SZ, Hirsh AT. Psychologic influence on experimental pain sensitivity and clinical pain intensity for patients with shoulder pain. *J Pain*. 2009; 10:293–299. [PubMed: 19070551]
22. Gummeson C, Ward MM, Atroshi I. The shortened disabilities of the arm, shoulder and hand questionnaire (QuickDASH): validity and reliability based on responses within the full-length DASH. *BMC Musculoskelet Disord*. 2006; 7:44. [PubMed: 16709254]
23. Hirsh AT, George SZ, Bialosky JE, Robinson ME. Fear of pain, pain catastrophizing, and acute pain perception: relative prediction and timing of assessment. *J Pain*. 2008; 9:806–812. [PubMed: 18486557]
24. Keller S, Bann CM, Dodd SL, Schein J, Mendoza TR, Cleeland CS. Validity of the brief pain inventory for use in documenting the outcomes of patients with noncancer pain. *Clin J Pain*. 2004; 20:309–318. [PubMed: 15322437]
25. Lee P. The economic impact of musculoskeletal disorders. *Qual Life Res*. 1994; 3 (Suppl 1):S85–91. [PubMed: 7866377]
26. Leeuw M, Goossens ME, Linton SJ, Crombez G, Boersma K, Vlaeyen JW. The fear-avoidance model of musculoskeletal pain: current state of scientific evidence. *J Behav Med*. 2007; 30:77–94. [PubMed: 17180640]
27. Matheson LN, Melhorn JM, Mayer TG, Theodore BR, Gatchel RJ. Reliability of a visual analog version of the QuickDASH. *J Bone Joint Surg Am*. 2006; 88:1782–1787. [PubMed: 16882902]
28. McNeil DW, Rainwater AJ 3rd. Development of the Fear of Pain Questionnaire--III. *J Behav Med*. 1998; 21:389–410. [PubMed: 9789168]
29. Osman A, Barrios FX, Gutierrez PM, Kopper BA, Merrifield T, Grittmann L. The Pain Catastrophizing Scale: further psychometric evaluation with adult samples. *J Behav Med*. 2000; 23:351–365. [PubMed: 10984864]
30. Parr J, Borsa P, Fillingim R, Tillman M, Manini T, Gregory C, George S. Fear of pain and pain catastrophizing predict pain intensity using an induced muscle injury model regardless of timing of assessment. *J Pain*. 2011; 12:12.
31. Parr JJ, Yarrow JF, Garbo CM, Borsa PA. Symptomatic and functional responses to concentric-eccentric isokinetic versus eccentric-only isotonic exercise. *J Athl Train*. 2009; 44:462–468. [PubMed: 19771283]
32. Plotnikoff NA, MacIntyre DL. Test-retest reliability of glenohumeral internal and external rotator strength. *Clin J Sport Med*. 2002; 12:367–372. [PubMed: 12466692]
33. Quillen DM, Wuchner M, Hatch RL. Acute shoulder injuries. *Am Fam Physician*. 2004; 70:1947–1954. [PubMed: 15571061]

34. Rainville P, Feine JS, Bushnell MC, Duncan GH. A psychophysical comparison of sensory and affective responses to four modalities of experimental pain. *Somatosens Mot Res.* 1992; 9:265–277. [PubMed: 1492527]
35. Riley JL 3rd, Robinson ME, Wise EA, Myers CD, Fillingim RB. Sex differences in the perception of noxious experimental stimuli: a meta-analysis. *Pain.* 1998; 74:181–187. [PubMed: 9520232]
36. Robinson ME, Dannecker EA, George SZ, Otis J, Atchison JW, Fillingim RB. Sex differences in the associations among psychological factors and pain report: a novel psychophysical study of patients with chronic low back pain. *J Pain.* 2005; 6:463–470. [PubMed: 15993825]
37. Sullivan MJ, Rodgers WM, Wilson PM, Bell GJ, Murray TC, Fraser SN. An experimental investigation of the relation between catastrophizing and activity intolerance. *Pain.* 2002; 100:47–53. [PubMed: 12435458]
38. Sullivan MJL, Bishop SR, Pivik J. The Pain Catastrophizing Scale: Development and validation. *Psychological Assessment.* 1995; 7:524–532.
39. Swinkels-Meewisse EJ, Swinkels RA, Verbeek AL, Vlaeyen JW, Oostendorp RA. Psychometric properties of the Tampa Scale for kinesiophobia and the fear-avoidance beliefs questionnaire in acute low back pain. *Man Ther.* 2003; 8:29–36. [PubMed: 12586559]
40. Tis LL, Maxwell T. The effect of positioning on shoulder isokinetic measures in females. *Med Sci Sports Exerc.* 1996; 28:1188–1192. [PubMed: 8883008]
41. Trost Z, France CR, Thomas JS. Pain-related fear and avoidance of physical exertion following delayed-onset muscle soreness. *Pain.* 152:1540–1547. [PubMed: 21419575]
42. Vlaeyen JW, Linton SJ. Fear-avoidance and its consequences in chronic musculoskeletal pain: a state of the art. *Pain.* 2000; 85:317–332. [PubMed: 10781906]
43. Voight ML, Hardin JA, Blackburn TA, Tippet S, Canner GC. The effects of muscle fatigue on and the relationship of arm dominance to shoulder proprioception. *J Orthop Sports Phys Ther.* 1996; 23:348–352. [PubMed: 8727014]
44. Woby SR, Roach NK, Urmston M, Watson PJ. Psychometric properties of the TSK-11: a shortened version of the Tampa Scale for Kinesiophobia. *Pain.* 2005; 117:137–144. [PubMed: 16055269]

Table 1

Descriptive Statistics

Variable	Values	% or SD
Sex (no. females, %)	75	59.5
Age	23.6	9.8
Height (cm)	170.5	9.9
Weight (kg)	68.3	14.6
Hand dominance (no. right handed, %)	113	89.7
Race		
No. White, %	101	80.8
No. African American, %	7	5.6
Other, %	18	13.6

All values are means and SDs, unless otherwise indicated

Table 2

Pain and Disability Outcomes

Variable	Baseline	Follow-up 1	Follow-up 2
Current Pain Level (BPI)			
Female	0.17(0.58)	2.55 (2.14) ^{*†}	0.76(0.96)
Male	0.20(0.45)	1.63(1.81) [*]	0.53(0.90)
QuickDASH Score			
Female	3.52(5.80)	21.13(14.98) ^{*†}	14.31(11.93) ^{*†}
Male	1.65(3.15)	14.57(13.96) [*]	7.53(9.27) [*]

All scores are mean (SD).

BPI indicates brief pain inventory scale from 0–10

^{*} Significantly different than baseline

[†] Significantly different between gender

Table 3

Intercorrelations Between Predictor and Outcome Measures

Variable	2	3	4	5	6	7	8	9	10	11	12
1. Sex	-0.220 *	-0.121	-0.217 *	-0.294 **	-0.088	-0.087	-0.123	0.002	-0.058	-0.089	-0.008
2. Pain Intensity (F/U 1)		0.420 **	0.650 **	0.339 **	0.094	0.225 *	0.113	-0.018	0.119	0.055	0.164
3. Pain Intensity (F/U 2)			0.239 **	0.388 **	0.128	0.242 **	0.280 **	0.052	0.099	0.175	0.290 **
4. Disability (F/U 1)				0.641 **	0.283 **	0.362 **	0.176 *	0.241 **	0.366 **	0.202 **	0.164 *
5. Disability (F/U 2)					0.250 **	0.339 **	0.289 **	0.228 **	0.331 **	0.314 **	0.164 *
6. Pain Catastrophizing (Baseline)						0.764 **	0.714 **	0.625 **	0.625 **	0.633 **	0.393 **
7. Pain Catastrophizing (F/U 1)							0.879 **	0.415 **	0.616 **	0.602 **	0.299 **
8. Pain Catastrophizing (F/U 2)								0.426 **	0.522 **	0.666 **	0.351 **
9. Kinesiophobia (Baseline)									0.816 **	0.739 **	0.286 **
10. Kinesiophobia (F/U 1)										0.812 **	0.340 **
11. Kinesiophobia (F/U 2)											0.377 **
12. Fear of Pain (Baseline)											

*
p < 0.05**
p < 0.01

Table 4

Psychological Constructs

Variable	Baseline	Follow-up 1	Follow-up 2
Fear of Pain Questionnaire*			
Female	23.08(5.30)		
Male	22.98(6.63)		
Pain Catastrophizing Scale			
Female	10.48(7.83)	8.60(8.06)	7.47(8.22)
Male	9.10(7.64)	7.16(8.26)	5.47(7.64)
Tampa Scale of Kinesiophobia [#]			
Female	17.99(3.96)	19.19(4.96)	17.31(4.94)
Male	18.00(4.98)	18.59(5.38)	16.39(5.29)

All scores are mean and SD.

Effect sizes for the interaction of gender over time PCS ($\eta^2 = 0.005$) and TSK ($\eta^2 = 0.008$).

* FPQ had 9 items and was only measured at baseline

[#] TSK had 11 items

Table 5

Results of Regression Analyses for Predicting and Timing of Pain

		Predictive		Timing	
		Baseline-F/U 1	Baseline-F/U 2	F/U 1-F/U 1	F/U 2-F/U 2
		R²=0.086, p=0.029			
Gender	β	-0.201	-0.101	-0.101	-0.083
	p-value	0.024*	0.246	0.250	0.351
		R²=0.072, p=0.027			
FPQ	β	0.171	0.310		
	p-value	0.080	0.002*		
		R²=0.083, p=0.014			
PCS	β	0.070	0.022	0.216	0.259
	p-value	0.540	0.844	0.012*	0.027*
		R²=0.065, p=0.042			
TSK	β	-0.146	-0.101	-0.033	-0.043
	p-value	0.173	0.341	0.762	0.708

* Denotes significant values, F/U = Follow up, FPQ had 9 items, and TSK had 11 items.

Table 6

Results of Regression Analyses for Predicting and Timing of Disability

	Predictive			Timing		
	Baseline-F/U 1	Baseline-F/U 2	F/U 1-F/U 2	F/U 1-F/U 1	F/U 2-F/U 2	
	R ² =0.124, p=0.007 R ² =0.124, p=0.001 R ² =0.263, p<0.001 R ² =0.515, p<0.001 R ² =0.279, p<0.001					
Gender	β	-0.203	-0.285	-0.219	-0.067	-0.232
	p-value	0.020*	0.001*	0.007*	0.305	0.004*
FPQ	β	0.078	0.094			
	p-value	0.409	0.311			
PCS	β	0.185	0.164	0.127	0.069	-0.013
	p-value	0.107	0.147	0.218	0.400	0.904
TSK	β	-0.033	0.017	0.223	0.250	0.273
	p-value	0.756	0.867	0.028*	0.002*	0.010*
Pain intensity	β	0.136	0.097	0.232	0.590	0.314
	p-value	0.126	0.269	0.006*	0.000*	0.000*

* Denotes significant values, F/U = Follow up, FPQ had 9 items, and TSK had 11 items.