THE IMPACT OF OBSERVATIONAL LEARNING ON PHYSICAL ACTIVITY
APPRaisal AND EXERTION FOLLOWING EXPERIMENTAL BACK
INJURY AND THE ROLE OF PAIN-RELATED FEAR

Adam J. Guck, MA, LPA

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APPROVED:

Kim Kelly, Major Professor
Adriel Boals, Committee Member
Ed Watkins, Committee Member
Zina Trost, Committee Member
Vicki Campbell, Chair of the Department of Psychology
David Holdeman, Dean of the College of Arts and Sciences
Victor Prybutok, Dean of the Toulouse Graduate School

Chronic low back pain (CLBP) is one of the most prevalent and disabling health conditions in the US and worldwide. Biomedical explanations of acute injury fail to account for why some individuals experience remission of pain and restoration of physical function while others do not. Pain-related fear, accompanied by elevated appraisals of physical exertion and avoidance of physical activity, has emerged as a central psychosocial risk factor for transition from acute injury to chronic pain and disability. Research has indicated that these pain-related factors may be maintained through observational learning mechanisms. To date, no studies have experimentally examined the role of observational learning and pain-related fear in the context of actual musculoskeletal injury. Accordingly, the present study examined the impact of observational learning and pain-related fear on activity appraisals and exertion following experimentally-induced acute low back injury. Healthy participants’ appraisal of standardized movement tasks along with measures of physical exertion were collected prior to and following a procedure designed to induce delayed onset muscle soreness (DOMS) to the lower back. Following induction of DOMS, participants observed a video prime depicting CLBP patients exhibiting either high or low pain behavior during similar standardized movements. In line with hypothesized effects, participants assigned to the high pain behavior prime demonstrated greater elevation in pain and harm appraisals as well as greater decrement in physical exertion. Further in line with hypotheses, significant changes in appraisal and physical performance following the high pain behavior prime were only observed among participants endorsing high pain-related
fear during baseline assessment. Discussion of findings addresses potential mechanisms of action as well as study limitations and direction for future research.
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INTRODUCTION

General Background

Chronic low back pain (CLBP) is among the most prevalent and costly health problems facing society (Hoy et al., 2012; Gore et al., 2012). It has been shown to exact an enormous emotional and financial toll on suffering individuals and remains a difficult condition to treat (Weisberg & Clavel, 1999). In a vast majority of cases involving acute back injury, symptoms remit over the course of weeks or months (Waddell, 2004). However, approximately 10% of individuals who incur an acute back injury develop a chronic condition characterized by enduring pain and disability (Pengel et al., 2003). The enormous direct and indirect societal costs associated with low back pain are driven primarily by the minority of patients who develop a chronic pain condition (Brault et al., 2005). It is commonly the case that biomedical explanations do not account for the presence and severity of symptoms in those who suffer from chronic back pain (Morris, 1983). Additionally, a biomedical approach does not adequately predict which individuals go on to recover following acute injury while others do not.

The following sections review the theoretical background related to the role of pain-related fear, avoidance behavior, and appraisals of physical activity that are conceptualized as central variables in the transition from acute to chronic pain. Recent theoretical and empirical work regarding the role of social, or observational learning processes in shaping pain- and disability-relevant responses, as well as limitations to existing evidence and methodology are outlined. Then finally, insight into processes of chronic pain development and maintenance are discussed.
Theoretical Background

The International Association for the Study of Pain defines pain as, “[an] unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage” (IASP, 2012). Contemporary accounts of pain have evolved to appreciate the multidimensional (i.e., cognitive, behavioral, emotional) nature of the pain experience, supported by evidence that biomedical accounts do not sufficiently explain chronic pain or disability. These contemporary accounts were scaffolded by the emergence of Gate-Control theory of pain (Melzack & Wall, 1965) which, for the first time, asserted that chronic pain and pain-related disability are not simply the result of sensory experiences, but rather are complex, multidimensional, subjective, and perceptual phenomena driven both by top-down (i.e., thoughts, emotions) and bottom-up (injury severity) variables (Keefe & France, 1999).

The fear-avoidance model. Building on early behavioral models of pain and disability (see Fordyce, 1976), the fear-avoidance model of low back pain (Vlaeyen et al., 2000) has evolved over the past two decades as the foremost cognitive-behavioral account of mechanisms by which some individuals with an acute musculoskeletal injury go on to develop chronic pain and disability whereas others do not (Figure 1 outlines the processes associated with the original fear-avoidance model). The model proposes that, following acute musculoskeletal injury, individuals are differentially susceptible to pain-related fear (or fear of movement and re/injury) based on their cognitive appraisal of the painful injury. The model posits two opposing appraisal/behavioral response types: avoidance and confrontation. “Avoiders” are high on scales of pain-related fear (Crombez et al., 1998b) and are characterized by highly negative orientations toward pain, including elevated attention to the threatening or harmful aspects of pain and/or
Figure 1. The fear-avoidance model of low back pain (Vlaeyen & Linton, 2000).

Negativistic beliefs about ability to control or cope with pain (i.e., high pain catastrophizing; Sullivan et al., 1995). Subsequently, pain-related fear promotes hypervigilance towards pain sensations and initiates behaviors designed to escape/avoid potentially painful stimuli. In this way, fear leads to avoidance, which results in functional disability -- broadly referring to disturbances or limitations in physical functioning relevant to activities of daily living (Gheldof et al., 2005). Avoidance of physical activity further serves to exacerbate the pain experience through detrimental physical and physiological effects on the musculoskeletal system and adoption of precarious postural strategies – the so-called “disuse syndrome” (Bortz, 1984; Mosely et al., 2004). Pain experience might be further exacerbated by emotional effects such as increased frustration, depression, or irritability accompanying the loss of essential reinforcers as the individual withdraws from daily life (Bair et al., 2003; Yalcin et al., 2014). In contrast, confrontation is posited as an adaptive response. Confronters, low on scales of pain-related fear,
are less likely to engage in catastrophic thought or experience fear of movement and (re)injury. After a period of rest following injury, they are more likely to confront potentially painful situations and return to daily activities. This behavioral alternative is associated with faster rehabilitation and recovery (see Figure 1).

Revisions to the fear-avoidance model. Recent updates to the fear-avoidance model emphasized a greater focus on individual variation in perception and appraisal of painful stimuli by addressing the theoretical distinction between anxiety and fear (see Figure 2). Specifically, Asmundson et al. (1999, 2004a) noted that fear is the emotional reaction to a specific and immediate threat (or perceived threat) that typically instigates defensive escape behavior associated with the fight or flight response (Cannon, 1929). Thus, fear prepares the organism toward action. Anxiety is distinguished as a future-oriented affective state, eliciting less sympathetic arousal, and motivating preventative behaviors, such as avoidance.

Figure 2. Proposed revisions to the fear-avoidance model of low back pain (Asmundson et al. 2004).
Hypervigilance, including environmental scanning for potential sources of threat, is cited as a pre-emptive anxiety response. Moreover, as one cannot avoid a threat that is already present, the updated model distinguishes between an anxiety pathway in the anticipation pain and a fear pathway in the presence of pain. Both fear and anxiety pathways are represented in Figure 2.

Asmundson and colleagues (2003, 2004b) further suggest that pain-related fear and catastrophizing are secondary to fundamental dispositional factors such as anxiety sensitivity (Asmundson et al., 2000; Zvolensky et al., 2001) and negative affectivity (or neuroticism; Goubert et al., 2004; Gheldof et al., 2006). Anxiety sensitivity refers to the tendency to respond with fear to *sensations associated with anxiety* (Reiss, 1991; Reiss & McNally, 1985) and has been linked to fear of pain in chronic back pain and other health conditions (for review, see Asmundson et al., 2000). Both the original (Vlaeyen & Linton, 2000) and revised (Asmundson et al., 2004) fear-avoidance models share the basic argument that *anxiety- and fear-reducing strategies that are effective in the short term may be counterproductive in the long run.*

Moreover, while the distinction between fear and anxiety is theoretically correct, they are harder to differentiate in a clinical context where the threatening stimulus (i.e., chronic pain) may always be present (Leeuw et al., 2007a). While the updated model supplies useful consideration to potentially important underlying variables (e.g., anxiety sensitivity) and to the role of autonomic arousal, its clinical value beyond the original model remains to be empirically validated.

Although the fear-avoidance model presents an enticing explanatory sequence for the evolution of chronic back pain and disability, researchers emphasize its primarily *heuristic* structure, organizing hypothesized relationships that have emerged in existing data, rather than offering a rigidly-defined causal framework. Temporal insinuations (in which constructs are
posited as “predictors” or “precursors”) are tempered with the recognition of the circular and, in a sense, necessarily incomplete nature of the model (Wideman et al., 2012). In addition, the model neither addresses nor discounts the possibility of a sub-group of chronic low back pain sufferers whose condition may be exacerbated by a maladaptive over-exertion, propelled by a denial of functional limitations. These individuals display excessive behavioral endurance in the face of increasing pain sensations, possibly leading to greater physical damage and increased pain. Recent investigations have started to further explore this “avoidance-endurance model” of pain chronicity (Hasenbring, 2000; Verbunt et al., 2003a).

The following sections examine elements of the fear-avoidance model that are particularly relevant to the present study, including pain-related fear, activity appraisal, and activity avoidance. While additional constructs (e.g., hypervigilance, depression) are also key components to the model, they are outside the scope of this study and are therefore not explored further.

Assessment of pain-related fear

Fear is an acute emotional state which occurs in response to a perceived threat or risk (Öhman, 2000). A number of physiological concomitants are also known to occur in tandem with the fear response, including activation of the sympathetic nervous system to manifest behavioral responses resulting in confrontation or escape/avoidance (Cannon, 1932). The concept of “pain-related fear” is an over-arching term, referring not to a single construct, but rather a group of related constructs that have demonstrated association with long-term pain and disability. These include pain catastrophizing, fear-avoidance beliefs, pain-related anxiety, and fear of pain/(re)injury due to movement (kinesiophobia). As it will be discussed below, these measures examine distinct dimensions of fearful responses to pain. The absence of a single,
unified self-report measure of pain-related fear has presented empirical challenges in the comparison and generalizability of findings. Nonetheless, the body of literature utilizing these measures lends support to the fear-avoidance hypothesis (Zale et al., 2013). The following section is intended to provide a brief overview of the constructs associated with fearful and avoidant responses to pain, their conceptual foundations, instruments used to measure them, and current state of supporting evidence. Additional information, including reliability, validity, and psychometric properties of instruments used specifically in this study will be discussed further in the Methods section.

_Pain Catastrophizing._ Prior to its emergence in the pain literature, catastrophizing was primarily referenced as a “cognitive distortion” in the context of theories of depression (Beck, 1967; Ellis, 1962), contributing to the precipitation and maintenance of depressive and anxious symptomatology (Sullivan et al., 2001a; Turner & Aaron, 2001). The role of catastrophic cognition has likewise been recognized in anxiety disorders and hypochondriasis, where a catastrophic “cognitive style” signals the tendency to misinterpret and exaggerate the threat value of specific situations – for example, bodily sensations (Van Damme et al., 2002). In the pain literature, catastrophizing has been broadly conceived as “an exaggerated ‘mental set’ brought to bear during actual or anticipated pain experience” (Sullivan et al., 2001), wherein pain is interpreted as being extremely threatening or unending (Crombez et al., 1998b).

The Pain Catastrophizing Scale (PCS) is a 13-item self-report measure which asks participants (both clinical and nonclinical, chronic, acute, and pain-free populations) to indicate the degree to which a number of thoughts and feelings have contributed to past painful experiences (Sullivan et al., 1995). Subsequent studies of the measure (e.g., Osman et al., 2000) have confirmed the factor structure of the PCS as measuring a single construct. Research has also
found that the association between catastrophizing and pain is independent of other distress-related variables such as anxiety and depression, lending support for its divergent validity (for review, see Sullivan et al., 2001).

**Fear-avoidance beliefs.** The term “fear-avoidance” was first coined by Lethem et al. (1983) in the context of the Fear-Avoidance Model of Exaggerated Pain Perception (Buer & Linton, 2002). The model first posited that two polar responses to pain, avoidance and confrontation, determine an individual’s “prognosis” in the face of acute injury. Where on this continuum a particular person exists during recovery is determined by his or her fear of pain. The Fear-Avoidance Beliefs Questionnaire (FABQ), developed by Waddell et al. (1993) and derived from the early iterations of the fear-avoidance model (Lethem et al., 1983; Fritz et al., 2001) was designed to quantify an individual’s beliefs about how physical activity and work may affect his or her pain and risk of (re)injury. It consists of 16 items and is divided into two subscales; fear-avoidance beliefs for work (FABQ-W) and fear-avoidance beliefs for physical activity (FABQ-PA). Respective items include the statements “I should not do my normal work with my present pain” and “I should not do physical activities that (might) make my pain worse.” Items in both subscales are rated on a 7-point scale, with higher numbers indicating elevated fear-avoidance beliefs (Crombez et al., 1999; Fritz et al., 2001). A number of studies have confirmed the FABQ as a reliable and valid instrument, (e.g., Waddell et al., 1993; Crombez et al., 1999).

**Pain-related Anxiety.** While the FABQ taps beliefs about the necessity of avoidance (e.g., “Physical activity might harm my back”), the Pain Anxiety Symptoms Scale (PASS, McCracken et al., 1992) assesses various dimensions of pain-related fear and anxiety. The PASS (McCracken et al., 1992) is a 40-item self-report measure in which respondents rate anxiety related to pain on a 6-point Likert scale ranging from 0 (never) to 5 (always). Summation of
individual items allows the derivation of a total and four subscale scores. The four subscales describe (a) cognitive anxiety symptoms related to the experience of pain (“I find it hard to concentrate when I hurt”), (b) escape and avoidance responses intended to reduce pain (“I try to avoid activities that cause pain”), (c) fearful appraisals of pain (“Pain sensations are terrifying”), and (d) pain-related physiological anxiety symptoms (“Pain makes me nauseous”; Larsen et al., 1997; Vowles et al; 2004). The measure has demonstrated good validity and reliability across items and administrations (McCracken et al., 1996). Consistent with the fear-avoidance model, research employing the PASS in samples of chronic pain patients has demonstrated a pattern of greater pain anxiety relative to matched comparison groups, poorer coping responses (e.g., avoidance), positive correlation with measures of general anxiety and self-reported disability, and evidence of greater somatic reactivity in anticipation of pain-eliciting physical movement (Crombez et al., 1999; McCracken et al., 1996, 1998). Recently, the PASS has also been linked with physical capacity variables (Burns et al., 2000; Trost et al., 2012a).

Kinesiophobia (Fear of pain/(re)injury due to movement). The Tampa Scale for Kinesiophobia (TSK; Kori et al., 1990) comprises 17 items intended to assess fear of pain and possible (re)injury stemming from movement, and includes such statements as, “It’s really not safe for a person with a condition like mine to be physically active.” The TSK has established reliability and validity with chronic pain patients, and has shown to be strongly associated with measures of functional disability (Swinkels-Meewisse et al, 2003a,b). Studies have supported a two-factor structure for items of the TSK (Clark et al., 1996; Geisser et al., 2000; Roelofs et al., 2004) across both chronic low back pain and fibromyalgia samples (Goubert et al., 2003). These two factors have been labeled somatic focus (reflecting a belief in underlying serious medical
problems) and activity avoidance, which reflects the belief that activity may result in (re)injury or increased pain.

*Relationships among the pain-related fear measures.* The described constructs and their respective instruments of measurement are often used interchangeably in reference to pain-related fear -- an umbrella term spanning very specific (e.g., fear that movement will trigger (re)injury) to general (e.g. “globally dysfunctional”) responses. In spite of their descriptive differences, studies which utilize two or more measures of pain-related fear generally show highly significant (but imperfect) intercorrelation (see Lundberg et al., 2011 for systematic review). The measures described above do not represent an exhaustive list of available instruments that assess pain-related fear (for comprehensive review, see McNeil & Vowles, 2004). However, from this brief review of what are arguably the most widely used existing measures, it is apparent that early efforts to validate pain-related fear relied largely on self-report. Recent efforts have given greater attention to a multidimensional approach to assessing pain-related fear, relying on measures such as nonverbal pain behavior, as well as physiological, physical, and motoric assessment at various points following injury (Norton & Asmundson, 2003; Flor et al., 2001).

The role of pain related fear in pain outcomes

*Pain-related fear and self-reported disability in chronic low back pain.* A substantial body of literature has examined how pain-related fear and associated escape/avoidance relate to self-reported disability in work and daily life (see Table 1 for a representative list of these studies). The following sections provide a review of findings supporting this association, with several representative examples explored in detail below.
Using linear regression analysis Vlaeyen et al. (1995b) found that fear of movement/(re)injury as measured by the TSK was a better predictor of CLBP patient’s self-reported disability than biomedical status and current pain level. Disability was assessed using the Roland and Morris Disability Questionnaire (RMDQ; Roland & Morris, 1983), a 24-item 2-point scale measuring the difficulty of performing daily tasks. Disability correlated significantly with TSK scores \( r = .49, p < .01 \); controlling for pain duration and gender, fear of movement accounted for an additional 17% of the variance in disability. In a sample of 35 chronic back pain patients (mean age 36.1 years, mean pain duration 6.7 years), Crombez et al. (1999) likewise found the TSK and FABQ superior to current pain intensity and duration in predicting self-reported disability. The pain-related fear instruments exhibited a stronger correlation with RMDQ-rated disability \( r = .51 \text{ to } .56, p < .001 \) than did pain intensity and a measure of general negative affect, which showed no significant association. Again, controlling for sociodemographic variables, regression analyses corroborated these relationships.

Applying the multiaxial assessment of pain taxonomy (MAP; Turk & Rudy, 1988), an empirical approach to the identification of chronic pain subgroups, Asmundson et al. (1997) found that chronic pain patients classified as ‘globally dysfunctional’ (and thus most disabled) using the Multidimensional Pain Inventory clustering procedure (MPI; Kerns et al, 1985) reported more escape/avoidance behavior, elevated fearful appraisals of pain, and pain-specific cognitive and physiological anxiety compared to those classified as ‘interpersonally distressed’ or ‘adaptive copers’. The MPI is a 52-item self-report measure that taps a wide range of physical, psychological, and social factors involved in individuals’ pain experience. Of the chronic back
Table 1

Correlations of Pain-Related Fear and Disability Measures in Chronic Low Back Pain Samples

<table>
<thead>
<tr>
<th>Investigators</th>
<th>n</th>
<th>Pain-related fear Measure</th>
<th>Disability measure</th>
<th>Correlation Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waddell et al., 1993</td>
<td>184</td>
<td>FABQ-PA</td>
<td>RMDQ</td>
<td>0.51**</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FABQ-W</td>
<td></td>
<td>0.55**</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FABQ-PA</td>
<td>Work Loss</td>
<td>0.13</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FABQ-W</td>
<td></td>
<td>0.23**</td>
</tr>
<tr>
<td>McCracken et al., 1996</td>
<td>45</td>
<td>PASS Total</td>
<td>PDI</td>
<td>0.61**</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cognitive Escape/Avoidance</td>
<td></td>
<td>0.51</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fear</td>
<td></td>
<td>0.66**</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Physiological FABQ Total</td>
<td></td>
<td>0.38**</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FABQ-PA</td>
<td></td>
<td>0.51**</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FABQ-W</td>
<td></td>
<td>0.52**</td>
</tr>
<tr>
<td>Crombez et al., 1999a</td>
<td>35</td>
<td>FABQ-PA</td>
<td>RMDQ</td>
<td>0.51**</td>
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<tr>
<td></td>
<td></td>
<td>FABQ-W</td>
<td></td>
<td>0.63**</td>
</tr>
<tr>
<td></td>
<td></td>
<td>TSK</td>
<td></td>
<td>0.56**</td>
</tr>
<tr>
<td></td>
<td>31</td>
<td>TSK</td>
<td>RMDQ</td>
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</tr>
<tr>
<td>Severejins et al., 2001</td>
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<td>PCS</td>
<td>MPI subscales</td>
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<td>Interference/Life control</td>
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<tr>
<td>van den Hout et al., 2001</td>
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<td>PCS</td>
<td>QBPDS</td>
<td>0.51**</td>
</tr>
<tr>
<td>Woby &amp; Watson, 2004</td>
<td>54</td>
<td>FABQ-PA</td>
<td>RMDQ</td>
<td>t=3.49**</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FABQ-W</td>
<td>R²=0.71</td>
<td>t=2.37**</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CSQ (Catastrophizing subscale)</td>
<td></td>
<td>t=1.96*</td>
</tr>
<tr>
<td>Grotle et al., 2004</td>
<td>233</td>
<td>FABQ-PA</td>
<td>ODI</td>
<td>0.21**</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FABQ-W</td>
<td></td>
<td>0.30**</td>
</tr>
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<td>Demison et al., 2004</td>
<td>210</td>
<td>TSK</td>
<td>PDI</td>
<td>0.47**</td>
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<tr>
<td></td>
<td>161</td>
<td>CSQ (Catastrophizing subscale)</td>
<td></td>
<td>0.53**</td>
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<tr>
<td>Peters et al., 2005</td>
<td>100</td>
<td>TSK</td>
<td>QBPDS</td>
<td>0.27*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PASS</td>
<td></td>
<td>0.40*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PCS</td>
<td></td>
<td>0.33*</td>
</tr>
<tr>
<td>Vranceanu et al., 2010</td>
<td>120</td>
<td>PASS-20</td>
<td>DASH</td>
<td>0.25*</td>
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<tr>
<td>Vernon et al., 2011</td>
<td>91</td>
<td>TSK</td>
<td>NDI</td>
<td>0.45**</td>
</tr>
<tr>
<td>Grotle et al., 2012</td>
<td>87</td>
<td>FABQ-PA</td>
<td>ODI</td>
<td>0.33*</td>
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<td></td>
<td></td>
<td>DRI</td>
<td></td>
<td>0.32*</td>
</tr>
<tr>
<td>Lewis et al., 2012</td>
<td>47</td>
<td>TSK</td>
<td>RMDQ</td>
<td>0.39**</td>
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<tr>
<td></td>
<td></td>
<td>PASS-20</td>
<td></td>
<td>0.54**</td>
</tr>
</tbody>
</table>

pain patients comprising the $n = 200$ sample (mean age 38.3 years, mean duration of pain 2.3 years), ‘globally dysfunctional’ participants likewise reported higher-than-average pain severity, pain interference and affective distress, and lower levels of self-efficacy and general activity. In a comparison of instruments quantifying anxiety and fear in 45 chronic pain patients, McCracken et al. (1996) showed that pain-specific anxiety measures (i.e., FABQ, PASS) were more predictive of pain, disability, and pain behavior than instruments tapping more general anxiety responses (e.g., the trait form of the State Trait Anxiety Inventory [STAI; Spielberger et al; 1983]). Disability was assessed via the Pain Disability Index (PDI; Pollard et al., 1984), a 7-item self-report measure which describes participants’ perceived disability in seven areas of daily functioning. Consistent with the preceding studies, conclusions were drawn from an unambiguous pattern of zero-order correlations and hierarchical regression analyses.

A study by Denison et al., (2004) surveyed a sample of patients with CLBP of varying duration. Fear-avoidance variables were assessed using the TSK and select items from the Coping Strategies Questionnaire (CSQ; Rosenstiel & Keefe, 1983). The CSQ contains a 6-item catastrophizing subscale (e.g., “When I feel pain I worry all the time when it will end”). Participants rate each of these 6 items on a scale of (0) never to (6) always. Denison et al. found that fear-avoidance variables accounted for more variance in disability scores than pain intensity and pain duration.

Woby and Watson, (2004) surveyed 54 patients for pain-related fear (FABQ and CSQ-Catastrophizing) and disability (RMDQ) before and after completing an 8-week multidisciplinary pain management/rehabilitation program. Reductions in pain-related fear observed from beginning to end of treatment co-occurred with reductions in self-reported disability. The authors also performed a hierarchical regression analysis predicting discharge
disability scores, using relevant demographic (age, gender), medical (pain intensity), and pain-related fear (FABQ, CSQ-Catastrophizing) variables added into three separate steps. Whereas demographic and medical variables accounted for a combined 49% of the variance in discharge disability, the addition of pain-related fear measures accounted for 71% of the variance, with both FABQ and CSQ scores as significant predictors. The authors also noted that there was high statistical overlap between fear avoidance beliefs and catastrophizing, supporting the earlier observation regarding the interrelatedness of pain-related fear measures. A similar study by Mannion, and colleagues (2001) found that changes in fear avoidance beliefs of CLBP patients were associated with reduced disability. Patients were surveyed for pain intensity, pain-related fear (FABQ), and disability (RMDQ) before and after undergoing three months of physical therapy. Patients showed reductions in pain and pain-related fear as well as associated reductions in disability.

Notably, most of the above studies are cross-sectional in nature, therefore any potential inferences with respect to pain-related fear as a predictive factor in or precursor to the establishment of disability are precluded by these methodologies. As it has been observed that patterns of fear-based avoidance and disability become established in the acute phase following injury (Asmundson et al., 2004), more recent efforts have been made to examine the role of pain-related fear as a predictor of future disability in the transition from acute to chronic pain. Historically, the term “acute” has been applied to pain with a duration of less than 3 months (Turk & Okifuji, 2002). However, it has been suggested that the term “subacute” be applied to pain with a duration that spans the gap from an acute, short term event to a chronic condition. Operationally, it is suggested that acute pain now refer to pain up to 2-6 weeks, with subacute spanning from the end of acute to onset of chronic pain (3 months; Kovacs et al., 2005). The
studies reviewed below (see Table 2) broadly demonstrate that pain-related fear exists in the
general population, that it is associated with relevant factors (e.g., disability, return to work)
early in problem onset, and is predictive of poorer outcome trajectories.

**Pain-related fear in acute and subacute pain.** Cross-sectional evidence: Findings from
cross-sectional studies conducted with acute low back pain samples echo those from the chronic
pain population, explicitly linking high pain-related fear with perceived disability and associated
outcomes. Importantly, results point to the widespread presence of fear-avoidance beliefs among
participants without a longstanding history of recalcitrant back pain (see Table 2; Goubert et al.,
2004). In a sample of 44 general practice patients consulting their physician with a new episode
of non-specific back pain, Sieben et al. (2002) found levels of pain-related fear comparable to
mean values found in both subacute and chronic pain populations (Swinkels et al., 1999; van den
Hout et al., 2001). Buer and Linton (2002) confirmed that fear-avoidance beliefs and
catastrophizing occur in a general non-patient population; among 917 individuals suffering no,
mild, or moderate pain, higher catastrophizing (PCS) was associated with greater pain intensity,
and higher fear avoidance beliefs (FABQ) were associated with difficulty performing activities
of daily living. This “dose-response” pattern was observed despite relatively low-to-moderate
levels of pain-related fear identified in the study (Buer & Linton, 2002).

From a cross-sectional survey of 443 patients with subacute low back pain and 286
treating rheumatologists, Poirauden et al. (2006) likewise found FABQ-Physical Activity scores
comparable to a sample of 2,727 acute (mean pain duration 5 days) and 248 chronic pain patients
in a functional restoration program (Chaory et al., 2004). Stepwise regression analyses revealed
significant associations between patients’ FABQ scores (on both subscales) and level of
### Table 2

**Cross-Sectional and Prospective Evidence of Acute and Subacute Pain Populations**

<table>
<thead>
<tr>
<th>Investigators</th>
<th>n</th>
<th>Acute (A) / Subacute (S)</th>
<th>Pain-related fear measure</th>
<th>Follow-up duration</th>
<th>Outcome Measure</th>
<th>Results/Effect Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buer &amp; Linton, 2002</td>
<td>917</td>
<td>A/S</td>
<td>PCS FABQ</td>
<td>---</td>
<td>Activities of Daily Living</td>
<td>2.5 OR (CI: 1.46-4.19)* 1.8 OR (CI: 1.20-2.68)*</td>
</tr>
<tr>
<td>Poiraudieu et al., 2006</td>
<td>443</td>
<td>S</td>
<td>FABQ-PA</td>
<td>---</td>
<td>QBPDS</td>
<td>1.05 OR (CI: 1.03-1.07)*</td>
</tr>
<tr>
<td>Grotle et al., 2004</td>
<td>123</td>
<td>A</td>
<td>FABQ-PA</td>
<td>---</td>
<td>ODI</td>
<td>$\beta =0.60^{**}$ ($f^2=1.18$)</td>
</tr>
<tr>
<td>Swinkels-Meewisse et al., 2003b</td>
<td>615</td>
<td>A</td>
<td>TSK</td>
<td>---</td>
<td>RMDQ</td>
<td>$\beta =0.22^{<strong>}$ ($f^2=0.52$)$\dagger$ $\beta =0.17^{</strong>}$</td>
</tr>
<tr>
<td>Swinkels-Meewisse et al., 2006a</td>
<td>615</td>
<td>A</td>
<td>FABQ-W</td>
<td>---</td>
<td>RMDQ</td>
<td>$\beta =0.21^{*}$ ($f^2=0.10$) $\beta =0.24^{<strong>}$ ($f^2=0.20$) $\beta =0.36^{</strong>}$ ($f^2=0.22$) $\beta =0.33^{**}$ ($f^2=0.28$)</td>
</tr>
<tr>
<td>Swinkels-Meewisse et al., 2006b</td>
<td>96</td>
<td>A</td>
<td>TSK PCS</td>
<td>---</td>
<td>RMDQ</td>
<td>$\beta =0.35^{*}$ ($f^2=0.13$) $\beta =0.40^{**}$ ($f^2=0.17$)</td>
</tr>
<tr>
<td>Kleenerman et al., 1995</td>
<td>123</td>
<td>A</td>
<td>Analog measure</td>
<td>12 mo.</td>
<td>ODI</td>
<td>$R^2 =0.14^{*}$ ($f^2=0.16$)</td>
</tr>
<tr>
<td>Fritz et al., 2001</td>
<td>78</td>
<td>A</td>
<td>FABQ-W</td>
<td>4 wks.</td>
<td>ODI</td>
<td>$\beta =0.36^{*}$ ($f^2=0.10$) $\beta =0.21^{**}$</td>
</tr>
<tr>
<td>Fritz et al., 2002</td>
<td>78</td>
<td>A</td>
<td>FABQ-PA</td>
<td>4 wks.</td>
<td>Work status</td>
<td>1.20 OR (CI: 1.07-1.34)*</td>
</tr>
<tr>
<td>Sieben et al., 2002</td>
<td>44</td>
<td>A</td>
<td>TSK PCS</td>
<td>3-12 mo.</td>
<td>RMDQ</td>
<td>$R^2=.29$ ($p&lt;.05$)</td>
</tr>
<tr>
<td>Soucy et al., 2006</td>
<td>258</td>
<td>S</td>
<td>FABQ</td>
<td>6 mo.</td>
<td>Work status</td>
<td>$r = -0.36^{**}$</td>
</tr>
<tr>
<td>Turner et al., 2006</td>
<td>1.0</td>
<td>A</td>
<td>FABQ-W</td>
<td>6 mo.</td>
<td>Return to work</td>
<td>4.64 OR (CI: 1.57-13.71)*</td>
</tr>
<tr>
<td>Grotle et al., 2006b</td>
<td>123</td>
<td>A</td>
<td>FABQ-PA</td>
<td>12 mo.</td>
<td>ODI</td>
<td>1.3 OR (CI: -1.9-4.6) ns $-4$ OR (CI: -2.3-1.5)*</td>
</tr>
<tr>
<td>Swinkels-Meewisse et al., 2006c</td>
<td>555</td>
<td>A</td>
<td>TSK</td>
<td>6 mo.</td>
<td>RMDQ Participation</td>
<td>$\beta= 0.23^{**}$ $\beta= -0.10^{*}$</td>
</tr>
<tr>
<td>van der Windt et al., 2007</td>
<td>171</td>
<td>A/S</td>
<td>FABQ-PA PCS</td>
<td>3 mo.</td>
<td>RMDQ</td>
<td>1.12 OR (CI: 0.75 – 1.67)* $1.34 OR (CI: 0.90-1.99)*</td>
</tr>
<tr>
<td>Hancock et al., 2009</td>
<td>240</td>
<td>A</td>
<td>FABQ-PA FABQ-W</td>
<td>3 mo.</td>
<td>Recovery duration</td>
<td>1.3 OR (CI: 1.2-3.6)* $2.0$ OR (CI: 0.7-3.2*</td>
</tr>
<tr>
<td>Dubois et al., 2009</td>
<td>346</td>
<td>S</td>
<td>FABQ</td>
<td>3 mo.</td>
<td>Return to work</td>
<td>1.05 OR (CI 1.02-1.09)*</td>
</tr>
<tr>
<td>Truchon et al., 2010</td>
<td>439</td>
<td>A/S</td>
<td>FABQ-W</td>
<td>12 mo.</td>
<td>Return to work</td>
<td>3.13 OR*</td>
</tr>
</tbody>
</table>

*p<.05 **p<.01 ns = non-significant finding. PCS = Pain Catastrophizing Scale (Sullivan et al., 1995). FABQ=Fear Avoidance Beliefs Questionnaire (Waddell et al., 1993). TSK=Tampa Scale of Kinesiophobia (Kori et al., 1990). QBPDS=Quebec Back Pain Disability Scale (Kopec et al., 1995). ODI=Oswestry Disability Index (Baker et al., 1990). RMDQ=Roland Morris Disability Questionnaire (Roland & Morris, 1983).
perceived disability, as measured by the Quebec Back Pain Scale (QBPDS; Kopec et al., 1995). Moreover, patients’ fear-avoidance beliefs about physical activity were significantly associated with perceived disability, as well as level of education and rheumatologists’ scores, but not with pain intensity or physical work demands. This pattern of results led the researchers to suggest that fear-avoidance beliefs are partly independent of the experience of back pain, and may be reinforced by the medical community (Poirauudeau et al., 2006).

In a study comparing early-stage (less than three weeks; \(n = 123\)) and chronic (exceeding one year; \(n = 233\)) low back pain patients, Grotle et al. (2004) found that fear-avoidance beliefs (FABQ-PA) were significantly related to disability in both groups after adjusting for sociodemographic, pain, and clinical variables. Current pain intensity in lower back and limb was scored on a visual analog scale ranging from 0 (no pain) to 100 (worst possible pain). Version 2.0 of the Oswestry Disability Index (ODI, Baker et al., 1990) assessed activity limitations. While patients with chronic low back pain reported significantly more fear-avoidance beliefs, distress, and activity limitation due to pain than the acute sample, regression analyses within each group and in the merged sample revealed that the associations between avoidance beliefs and disability were equally strong in both groups. Importantly, the results suggest that fear-avoidance beliefs are present in patients prior to their first consultation with a doctor.

Swinkels-Meewisse et al. (2003b) found that fear of movement/(re)injury as measured by the TSK, together with pain intensity, significantly predicted disability and daily activity participation in a sample of 615 acute low back pain patients. Acute low back pain was defined as less than 4 weeks duration. Disability was measured using the RMDQ while the five-item participation measure tapped work/housekeeping, sport, leisure, and social or family activities.
Both constructs comprising the TSK were found significantly associated with pain and disability
($r = .18$ to $.38, p < .01$). Swinkels-Meewisse et al. (2006a) have subsequently reported that pain-intensity (VAS) and pain-related fear (FABQ) significantly predicted disability (RMDQ) in this same sample, with separate analyses performed for workers and non-workers. Perceived disability, in turn, significantly predicted participation. No significant correlations were found between pain intensity and fear avoidance beliefs in the nonworking sample; in the working group, the physical activity subscale of the FABQ showed a slight relationship to the visual analog pain scores.

Prospective evidence: Prospective investigations of patients with acute low back pain likewise reveal pain-related fear as a significant predictor of pain, disability, and other indices of functional impairment (e.g., work status), supporting the idea that fear is a precursor to disability, rather than a consequence (see Table 2). Using a large sample of acute low back pain patients in the primary care setting, Klenerman et al. (1995) concluded that pain-related fear variables were the most relevant in predicting chronicity one year later. By assessing participants at the acute (no more than one-week post onset of pain), two, and twelve – month stages following onset of back pain, this study mapped the natural progression of back pain, with emphasis on the contribution of fear-of-pain and avoidance factors to the development of dysfunctional chronicity. Underlying the study was the question of whether psychological variables/comorbidity are a consequence of back pain or potential contributors to it. Of the 300 patients initially recruited for the study, information from a core group of 123 participants was included at each point of data collection. Fear-avoidance contextual measures were based on the four psychosocial factors hypothesized by the fear-avoidance model (Lethem et al., 1983) to determine a confrontational or avoidant coping style. Thus, assessment tapped stressful life
events (Social Readjustment Rating Scale; Holmes & Rahe, 1967), characteristic personality patterns (Modified Somatic Perception Questionnaire MSPQ, Main, 1983 -- a measure in which the participant must qualify the frequency and severity of 13 somatic symptoms), use of active vs. passive coping strategies in the context of internally originating pains, and previous pain history along three categories of pain experience (externally-produced, internally-produced, and accidental pain). At the two month follow-up (n=162), fear-avoidance variables collected at the acute stage accounted for 25% of the variance in outcome; importantly, analyses revealed that those who had not recovered by 2 months (7.3% of the core sample) went on to become chronic low back pain patients, with unremitting and even increasing back pain. Results of multiple discriminant function analyses suggested that the future course of back pain can be correctly classified in 66% of patients from fear-avoidance variables alone and in 88% when all variables are employed – these included various physical measures and psychosocial (demographic and pain history) variables.

Focusing on acute work-related low back pain, Fritz et al., (2001, 2002) found that, in a sample of 78 participants with less than 3 weeks since pain onset (mean age 37.5 years, mean pain duration 5.5 days), higher levels of fear-avoidance beliefs were associated with more persistent occupational disability (i.e., returning to work full status). In the first study (Fritz et al., 2001), the FABQ work and physical activity subscales were significantly correlated with initial pain and disability scores ($r = .40$ to $.53$, $p < .01$, $r = .34$ to $.40$, $p < .05$ for pain and disability, respectively). Disability was assessed by the Modified ODI (Fairbank et al., 1980). Following 4 weeks of standardized rehabilitation treatment, the FABQ work subscale explained the greatest amount of variability in disability scores ($r = .46$), exceeding even the initial disability measures. Fear-avoidance beliefs about work likewise significantly improved regression models accounting
for disability and work status outcome, even after controlling for initial levels of pain, physical impairment, disability, and type of treatment received. Applying receiver operator characteristics and logistic regression analysis to the data collected in the above study, Fritz and George (2002) again identified FABQ-W as the strongest predictor variable of restricted work status after four weeks of physical therapy.

In a prospective inception cohort study, Swinkels-Meewisse et al. (2006c) followed the progress of 555 patients with acute low back pain who had consulted general practitioners and physical therapists in a primary care setting. Acute low back pain was again defined as having less than 4 weeks duration, with a minimum 3 prior months without symptoms. Data was collected at baseline (first visit to healthcare provider), 6 weeks, and 6 months and included biographical and psychosocial variables as well as questions addressing history and quality of back pain. Fear of movement and (re)injury as measured by the TSK emerged as the most powerful predictor of future disability (RMDQ), even above the contribution of baseline pain intensity. Future participation in daily activities was best predicted by a combination of TSK score, pain duration, and pain radiation. The authors note that, in predicting future disability, the TSK “harm” subscale was more powerful than the “activity avoidance subscale”, underscoring the existence of fear of (re)injury early in the pain experience. Likewise, George et al. (2006) found that, among 63 patients with acute low back pain (duration less than 60 days) enrolled in a 4-week physical therapy program, changes in fear-avoidance beliefs explained significant variance in changing pain intensity as well as a significant amount of disability change (as measured by the ODI), after considering changes in pain intensity.

Using a sample of 44 general practice patients consulting their physician with a new episode of benign low back pain, Sieben et al. (2002) explored the natural course of pain and fear
during the first 2 weeks of a back pain episode. Participants completed daily visual analogue “diaries” corresponding to (and derived from) measures of movement-related fear (TSK), catastrophizing (PCS), and pain intensity; follow-up disability assessment (RMDQ) occurred at 3 and 12 months following initial consultation. Time-series analyses for the first 2 weeks revealed three subgroups of patients with descending, stable, and rising levels of pain-related fear – the latter comprising 26.5% of the sample. The authors focus on the progressively more fearful patients who, though starting with relatively low levels of disability, were most disabled at one year follow up. Although the study appears to highlight a subgroup of patients vulnerable to chronicity, the authors caution that the ‘rising’ subgroup likewise reported a longer history of recurrent back pain prior to the current episode ($p = .004$). In contrast to the above findings, comparing patients with acute (less than 3 weeks, n=123) and chronic (more than three months, n=50) low back pain at 3, 4, 9, and 12 months, Grotle et al. (2006b) observed a significant decline in the FABQ physical activity subscale in the acute sample, whereas chronic ratings remained unchanged.

*Pain-related fear in the prediction of future pain in healthy individuals.* A limited number of studies provide evidence that pain-related fear may be an important predictor of future pain episodes and disability in the general population. Houben and colleagues (2005) replicated the commonly identified factor structure and correlational pattern using a modified version of the Tampa Scale of Kinesiophobia, designed specifically for testing in the general population. Items on the TSK-General (TSK-G) have been altered to include the phrase “If I had low back pain.” The large sample included individuals both with and without back pain complaints in the previous year ($n = 1029$ and $n = 1211$, respectively). Higher scores on the TSK-G significantly predicted pain catastrophizing, pain intensity, and pain-related health indices, even when
controlling for the presence of low back pain. In concert with studies reviewed above (e.g., Sieben et al., 2002; Buer & Linton, 2002), these results indicate the existence of elevated fear-avoidance beliefs in the general population, including pain-free individuals, thus providing a plausible foundation for the proposed investigation.

In order to examine the prevalence and prospective effects of fear-avoidance beliefs in a non-clinical population, Linton et al., 2000 recruited 415 people (mean age = 43 years) who reported no spinal symptoms in the previous year to undergo initial assessment and a 12-month follow-up. At the follow-up, 19% (78 of 413) of the sample reported experiencing an episode of back pain. Moreover, while the initial correlation between physical functioning and the psychosocial measures was weak ($r = -.08, p > .05$ and $r = .13, p < .05$, for the FABQ and PCS scales, respectively), logistic regression analyses on the median split of FABQ scores demonstrated a significant two-fold increase in the risk of developing back pain in participants with elevated fear-avoidance scores. In a similar fashion, risk of lowered physical functioning increased 1.7 times above the FABQ median. Importantly, for those who went on to experience back pain, the correlation between the FABQ and catastrophizing measure rose from .26 ($p < .05$) to .42 ($p < .01$) at posttest; these values remained relatively low for those who remained pain-free -- .22 ($p < .01$) at pretest compared to .25 at the posttest ($p < .01$). Because the study could not control for the effects of prior pain experience, the authors suggest that fear-avoidance beliefs may be an important element implicated in the development of a pain problem, rather than a directly “causal” factor.

Using a sample of the general Dutch population, Picavet et al. (2002) found that a high level of catastrophizing or kinesiophobia increased the risk of future chronic low back pain and disability. The examined cohort included 1,571 citizens aged 25 to 65 who did not suffer from
severe forms of illness (e.g., serious heart disease, cancer, rheumatoid arthritis). Questionnaires administered at baseline included the PCS and TSK; several features of low back pain were assessed both at baseline and at a 6-month follow-up. Results followed the striking pattern of associations displayed in the previous study. Among the 1,160 participants without low back pain at baseline, a high level of kinesiophobia (highest TSK tertile; n=361) predicted low back pain and disability at follow-up (OR = 3.4, 95% CI: 1.6, 8.7). Elevated catastrophizing scores (highest PCS tertile; n=345) were predictive of severe low back pain (rated greater than 5 on a scale of 1 to 10; OR = 2.2, 95% CI: 1.0, 5.0), chronic low back pain (exceeding 3 months; OR = 2.1, 95% CI: 1.1, 3.9), and low back pain with disability (OR = 3.1, 95% CI: 1.1, 8.7), as determined by the Quebec Back Pain Disability Scale (Kopec et al., 1995). For the 411 participants experiencing low back pain at baseline, a high level of kinesiophobia (highest tertile TSK score; n=161) predicted existing low back pain at follow up (OR = 1.6, 95% CI: 1.0, 2.7) and chronic low back pain (OR = 1.6, 95% CI: 1.0, 2.7). Elevated TSK scores were especially predictive of low back pain limitation in daily activities (OR = 3.6, 95% CI: 1.9, 6.7), severe low back pain (OR = 3.0, 95% CI: 1.8, 5.1), and low back pain with disability (OR = 4.4, 95% CI: 2.5, 7.9). High catastrophizing showed a similar pattern of associations. Associations remained significant after adjustment for pain duration, pain severity, or for disability at baseline, and were observed to be in the same direction across gender, age, and education-sorted SES subgroups.

Summary. In sum, the associations observed between self-reported pain-related fear and self-reported disability and are generally moderate to strong. In samples of individuals with chronic pain, this association has been observed in cross-sectional studies and in the context of interventions aimed at reducing disability. While the results of these investigations appear persuasive, a number of factors qualify their findings. First, strong correlations or regression
weights cannot be misinterpreted as indicative of causal effects (Waddell et al., 1993; Vlaeyen et al., 1995; Swinkels-Meewisse et al., 2003; Grotle et al., 2004). Conceptually, it is plausible that pain-related fear occurs secondary to the experience of low back pain, or that it is a prime determinant of becoming a chronic back pain patient. Second, and equally likely, is the possibility that pain-related fear is a marker for other latent variables that have not been sufficiently measured or conceptualized, such as history of back pain (or other type of pain) at baseline, which may increase the likelihood of avoidance and disability. Similarly, the supposed predictor and outcome variables may be related to a third overarching factor (e.g., traumatic experience; Slepian et al., 2014). Some researchers (e.g., Roland & Morris, 1983) have maintained that emotional distress in patients with chronic pain is more likely a consequence rather than an antecedent of chronic pain exacerbation. Research suggests that it is premature to draw such firm distinctions. Patterns of correlations tend to support a dynamic evolving relationship between one’s pain and one’s (possibly dispositionally-guided) responses to it, leading some authors to note that “psychological variables can act both as antecedents and consequences, reinforcing the pain problem in a complex chain of events with feedback loops” (Vlaeyen et al., 1995).

Despite these limitations, the results of independent studies support similar conclusions with both univariate (correlations) and multivariate analyses (regression) pointing to the central importance of pain-related fear. Additionally, meta-analytic findings lend support to an effect size of strong magnitude between pain-related fear and disability. Moreover, prospective/longitudinal designs support the idea that pain-related fear is a precursor to and powerful predictor of disability, rather than its consequence (Wideman et al., 2012).
Pain-related fear and behavioral avoidance

The concept of avoidance, long understood to be a spontaneous and adaptive response to acute injury, has emerged at the center of the fear-avoidance model in attempting to account for the development of chronic pain and disability. First described in the area of chronic pain in an article by Lethem et al. (1983), avoidance refers to a pattern of learned behavior that delays or averts an undesirable/aversive situation or experience (Asmundson et al., 1999; Barlow, 2002). Avoidance responses have long been associated with anxiety disorders and phobic states (Philips, 1987; Barlow, 2002). Avoidance-based models of chronic pain rest on the basic premise that avoidance of pain in general and of painful activities in particular actually leads to the perpetuation of pain and pain behaviors. Early instrumental models (Fordyce, 1976) described how initially adaptive responses to acute injury (e.g., medication taking, pain expression, inactivity) may come under the control of external contingencies (e.g., a spouse’s attention, reduced responsibilities) to develop into a chronic condition characterized by a long-term pattern of activity avoidance (i.e., disability). Linton et al. (1984) combined classical and operant conditioning processes wherein a threatening and pain-producing situation elicits a conditioned response of sympathetic activation (the physiological correlate of fear) which leads to avoidance of the situation; the avoidance behavior is negatively reinforced by a reduction in unpleasant stimuli (i.e., pain, fear, anxiety). As avoidance inherently prevents contact with the consequences of the threatening situation (i.e., movement), established avoidant behavior is extremely resistant to extinction. Fear returns whenever the avoidance behavior cannot be carried out (Vlaeyen & Linton, 2000).

Pain-related fear and behavioral avoidance in clinical populations. The fear-avoidance model posits avoidance as a crucial mediating variable between pain and disability, as well as the
progression from acute to chronic pain. Accordingly, research conducted with individuals experiencing chronic low back pain explicitly links pain-related fear with escape and avoidance of physical activity, resulting in impaired behavioral performance (Vlaeyen & Linton, 2000; see Table 4). In the studies detailed below performance deficits are assumed to correspond to behavioral avoidance. In a sample of 104 outpatients at a multidisciplinary pain management center (mean age= 45 years, mean pain duration = 5.2 years), the majority of whom presented with back pain, McCracken et al. (1992) found a significant negative correlation between pain-related fear (as measured by the PASS) and range of motion as measured by a flexometer during a passive straight leg raise test. During this routine physical examination, a physical therapist lifted the supine patient’s leg until the patient indicated that the maximum tolerated raise had been achieved. Three such trials were performed on each leg. These findings support the high correspondence between pain related fear and observable physical limitations, such as range-of-motion.

Vlaeyen et al. (1995a) asked thirty-three chronic low back pain patients (mean age = 42.4 years, mean duration of pain = 10.3 years) to lift and hold a 5.5 kg weight with their dominant arm for as long as possible. They found a substantial negative correlation between fear of movement/(re)injury as measured by the TSK and behavioral performance as measured by lifting time \( (r = -.44, p < .01) \). When the sample was divided into high and low fear responders (according to TSK median), the difference in mean lifting scores between the two groups was likewise significant \( (t = 2.63, p < .05) \), with patients reporting greater kinesiophobic fear engaging in greater avoidance of the motoric loading. A significant moderate correlation was also identified between the TSK and a visual analog scale measuring fear of (re)injury administered immediately after the lifting task \( (r = .52, p < .001) \).
Table 3
Review of Findings: Pain-Related Fear and Behavioral Performance Measures in Clinical Populations

<table>
<thead>
<tr>
<th>Investigators</th>
<th>n</th>
<th>Pain-related fear measure</th>
<th>Behavioral performance measure</th>
<th>Correlations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vlaeyen et al., 1995a</td>
<td>33</td>
<td>TSK</td>
<td>Lifting a 5.5 kg weight</td>
<td>-0.44**</td>
</tr>
<tr>
<td>Crombez et al., 1998a</td>
<td>49</td>
<td>TSK</td>
<td>Peak torque</td>
<td>-0.16</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fear of pain</td>
<td>Performance variability</td>
<td>0.31*</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Work ratio</td>
<td>0.38**</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fear of reinjury</td>
<td>Peak toque</td>
<td>-0.27*</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Performance variability</td>
<td>0.33*</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Work ratio</td>
<td>0.39**</td>
</tr>
<tr>
<td>Crombez et al., 1999a</td>
<td>38</td>
<td>TSK</td>
<td>Trunk-extension-flexion peak torque</td>
<td>-0.40**</td>
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<tr>
<td></td>
<td></td>
<td>FABQ-W</td>
<td></td>
<td>-0.10</td>
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<tr>
<td></td>
<td></td>
<td>FABQ-PA</td>
<td></td>
<td>-0.45**</td>
</tr>
<tr>
<td></td>
<td></td>
<td>TSK</td>
<td></td>
<td>-0.49**</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PASS</td>
<td>Lifting a 5.5 kg weight</td>
<td>-0.33</td>
</tr>
<tr>
<td>Al-Obaidi et al., 2000</td>
<td>63</td>
<td>FABQ-PA</td>
<td>Isometric torque of back muscles</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0°</td>
<td>-0.43**</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>12°</td>
<td>-0.37**</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>24°</td>
<td>-0.33**</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>36°</td>
<td>-0.34**</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>48°</td>
<td>-0.39**</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>60°</td>
<td>-0.24</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>72°</td>
<td>-0.03</td>
</tr>
<tr>
<td>McCracken et al., 1992</td>
<td>43</td>
<td>PASS</td>
<td>Passive straight – leg test</td>
<td>-0.36*</td>
</tr>
<tr>
<td>Geisser et al., 2000</td>
<td>13</td>
<td>TSK-2</td>
<td>Progressive Isoinertial Lifting Evaluation (PILE)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Activity</td>
<td>Floor-to-waist lift</td>
<td>-0.30**</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Waist-to-shoulder lift</td>
<td>-0.31**</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Harm</td>
<td>Floor-to-waist</td>
<td>-0.29**</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FABQ-PA +</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Self-selected walking speed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Al-Obaidi et al., 2003</td>
<td>21</td>
<td>FABQ-PA +</td>
<td>Fast walking speed</td>
<td>(R^2 = 0.87^*)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Anticipated pain</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vowles &amp; Gross, 2003</td>
<td>65</td>
<td>FABQ-W</td>
<td>Change scores</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Floor-to-waist lift</td>
<td>-0.46**</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Waist-to-shoulder lift</td>
<td>-0.36**</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Carrying tasks</td>
<td>-0.31**</td>
</tr>
</tbody>
</table>

*p<.05 **p<.01. TSK=Tampa Scale of Kinesiophobia (Kori et al., 1990). FABQ=Fear-Avoidance Beliefs Questionnaire (Waddell et al., 1993). PASS=Pain Anxiety Symptom Scale (McCracken et al., 1992).
The fear VAS was anchored with the terms ‘I am not afraid to re-injure myself’ and ‘I have never been so afraid to reinjure myself.’ Importantly, pain intensity ratings were not predictive of fear of movement/(re)injury, underscoring that fear occurs independently of current nociception. Besides the small sample size, one essential limitation of the study was the potential confounding of fear scores with pain duration (and, by extension, pain intensity); high TSK responders reported a significantly longer duration of pain complaints than lower responders ($t = 2.51, p = .017$). As a consequence, it cannot be ruled out that the inhibited performance of the highly fearful patients was due to more extensive experience with severe pain rather than to avoidance tendencies beyond back-straining activity.

A similar study by Crombez et al. (1998a) employed a behavioral task (knee-extension-flexion) believed by participants to be minimally back straining. Based on response to a survey designed for the study, forty-nine patients suffering from nonspecific chronic musculoskeletal back pain (mean age = 39.65 years, mean pain duration = 6.2 years) were classified as ‘avoiders’ or ‘confronters.’ From a seated position, participants were required to push a bar attached to the thigh until the knee was extended (extension) and then pull the bar back downward (flexion) until he or she could no longer continue. The protocol – repeated for each leg – consisted of a maximum 20 consecutive extensions and flexions. Using a verbal graphical rating scale (GRS; Jensen & Karoly, 1992) which offers the adjectives not, weak, moderate, strong, and very strong at equal distances along a 100 mm line, participants rated their back pain immediately prior to and following the behavioral test session. GRS ratings of fear of (re)injury were also obtained following the test. Behavioral performance was reflected in peak torque, variability of muscle strength within a series, and a calculated work ratio. A significant association between behavioral performance and pain-related fear but not between performance and pain intensity
corroborated that poor performance was due to escape/avoidance rather than increased back pain. In further support of the fear-avoidance model, avoiders reported higher fear of pain ($t = 5.05, p = .001$) and (re)injury ($t = 4.32, p = .001$), more frequent pain ($t = 1.96, p = .05$), more daily disability ($t = 3.21, p = .05$), fatigue, and longer recovery periods ($t = 2.55, p = .01$) than confronters. However, no significant differences in pain intensity were found between the two groups.

Crombez et al. (1999a) subsequently replicated and extended these findings. An initial study employed an isokinetic trunk-extension-and-flexion test, which required participants to push a bar placed across the chest until the back is maximally flexed and then pull the bar back until maximum extension; this is assumed to assess the functional capacity of the trunk flexors and extensors. Thirty-eight chronic back pain patients (mean age = 40.84 years, mean pain duration = 6.35 years) were requested to consecutively flex and extend three times with maximal speed and force. Measures of pain-related fear – the TSK and the physical subscale of the FABQ – were the most consistent predictors of behavioral performance ($R^2 = .56, p < .05; R^2 = .57, p < .05$, respectively) from among a number of variables, including pain duration and intensity. A second study using 31 chronic back pain patients (mean age = 41.61 years, mean pain duration = 10.1 years) and the lifting paradigm employed by Vlaeyen et al. (1995) similarly demonstrated that pain related fear (TSK) was superior in predicting behavioral performance in comparison with other pain-relevant variables, such as pain intensity and reported increase in pain (VAS; $R^2 = .79, p < .001$).

Using the Progressive Isoinertial Lifting Evaluation (PILE), Geisser et al. (2000) investigated functional avoidance patterns in a sample of 133 persons with chronic low back pain (mean age = 41.7 years, mean pain duration = 65.3 months). Performance on the PILE is
measured in terms of percentage of maximum weight lifted and is used to assess strength, endurance, and psychophysiological effort. Each person is tested on a floor-to-waist (30 in.) lift, and a waist-to-shoulder (30–54 in.) lift. Investigators specifically focused on the relative contribution of two subscales derived from the TSK-2 (a 13-item version of the original scale), namely, activity avoidance and fear of harm/damage to the body. Activity avoidance was inversely associated with both floor-to-waist and waist-to-shoulder PILE lifts \( r = -.30 \) and \( r = -.31, p < .001 \), respectively; the fear subscale was significantly related to the waist lift only \( r = -.29, p < .001 \). In a simultaneous regression analysis controlling for demographic, physiological, and other psychological variables (e.g., depression), only activity avoidance significantly and consistently predicted PILE performance.

Al-Obaidi et al. (2000) found that fear-avoidance beliefs about physical activity, rather than actual experienced pain, significantly accounted for variation in spinal isometric strength deficit observed during a lumbar extension test. Sixty-three patients experiencing a minimum 7 weeks chronic low back pain participated in a behavioral protocol that included measurement of maximal voluntary isometric contraction of the lumbar extensor muscles at 0, 12, 24, 36, 60, and 72 degrees of lumbar flexion. VAS ratings of anticipated and experienced pain were collected prior to and following the test at each angle. Anticipation of pain and fear-avoidance beliefs (assessed by the FABQ-physical activity subscale) showed a significant inverse relation to isometric strength tested at all angles \( r = -.38 \) to -.52; \( p < .05 \) to .01). Following pain-anticipation in a stepwise regression analysis, fear-avoidance beliefs about physical activity explained an additional 12% of the variance at the various tested angles. Using a computerized gait mat to assess spatial and temporal walking parameters, Al-Obaidi et al. (2003) further found that, among 31 individuals with chronic low back pain (mean age = 36.1 years), disability (RMDQ;
Roland & Morris, 1983) and fear-avoidance beliefs (FABQ-PA) were the strongest predictors of velocity deficits at self-selected walking speed, while FABQ-PA plus anticipated pain (measured using a visual analog scale) best predicted deficits at fast walking speed. The Disability Beliefs Questionnaire instructs participants to choose from a wide range of statements that reflect activities affected by disability and therefore avoided by the participant.

Contributing important ecological validity to the fear-avoidance model, Vowles and Gross (2003) investigated the relationship between fear avoidance beliefs and measures of physical work capability in a sample of 65 chronic pain patients (mean age = 39.7 years, average pain duration = 17.3 months), mostly suffering from low back pain, who had completed an interdisciplinary functional restoration program combining intensive physical and cognitive behavioral interventions. A structured Functional Capacity Evaluation consisting of a number of lifting and carrying tasks was performed by a physical therapist in order to determine each patient’s Physical Demand Classification (PDC), thus providing an indication of how physically able he or she is to perform certain types of vocations (Snook, 1978; Hart & Wright, 2002). Significant reductions in pain severity and fear-avoidance beliefs were observed pre- to post-treatment (all p values <.001); significant increases in physical work capacity were likewise observed. Importantly, a significant inverse relationship between (pre-to-post) changes in the FABQ-Work subscale and all physical capacity variables (r = -.31, p < .01 to r = -.46, p < .001) indicated an association between decreased work-related fears and improved physical capability. Separate regression analyses concluded that change in the FABQ-Work subscale accounted for a significant amount of change across all three measures of physical work capacity (β = -.31 to -.46, p < .01 to .001) even when controlling for the contribution of other pertinent variables, such as pain severity.
It is important to observe that the avoidance studies reviewed above most commonly focus on physical parameters that may not be directly relevant to back injury (e.g., leg flexion, weight lifting, gait/walking speed; McCracken et al., 1992; Vlaeyen et al., 1995a; Crombez et al., 1998a; Al-Obaidi et al., 2003). While these studies provide important information regarding the pervasive nature of avoidance in chronic pain, little effort is made to gauge participants’ beliefs about potential harm/injury to the back, thus differentiating the observed avoidance behavior from a possibly larger pattern of physical deterioration and disuse. Arguably, such a distinction would be vital in challenging CLBP patients’ maladaptive (and possibly erroneous) expectancies about engaging in certain movements (see next section on appraisal of physical activity).

Moreover, the above studies are almost entirely cross-sectional and have been conducted exclusively with chronic back pain samples, thereby precluding any causal or directional implications, as would be provided by experimental or prospective designs. As previously noted, the circular nature of the fear-avoidance model presents a challenge to empirical scrutiny, as potentially important variables – e.g., previous pain episodes, duration of pain problem – remain outside of experimental control. However, since fear-avoidance beliefs exist in the general population, studies have identified avoidant behavior in healthy participants threatened with simulated “acute” injury. While these studies do not easily parallel physical capacity data, they provide an important foundation for the present project, which in effect intends to “prime” participants with an analog to acute injury (i.e., muscle soreness).

*Escape/avoidance among healthy participants.* The above studies represent lines of research which attempt to examine and validate pain-related fear with overt, behavioral indices of activity avoidance. Importantly, these studies were conducted using samples of chronic pain patients performing various physical tasks and, while rigorous attempts were made to randomize
assignment of conditions and/or control for pain-relevant variables, it is nonetheless plausible that medical (e.g. pain severity, pain location, pain chronicity) and psychosocial factors outside the scope of these studies were confounding factors during behavioral performance. To address this limitation, and to increase understanding of avoidance patterns in the acute phase following injury (rather than after onset of long-term pain and disability), studies have examined healthy individuals undergoing experimentally induced pain while measuring their behavioral and self-reported tolerance of the task, conceptualized as a proximate measures of escape/avoidance behavior.

Jackson et al. (2005) looked at the impact of threatening information on coping and cold pressor tolerance in a sample of 121 healthy college students. The Cold Pressor Test (CPT) requires immersion of one’s hand in ice water for as long as possible. Students randomly assigned to a threat condition – in which they read about the accompanying sensations and potential consequences of frostbite – were less likely to tolerate or complete the CPT compared with participants assured of its safety or participant controls who read no orienting passage. Importantly, participants did not differ in level of reported pain (VAS) during task performance, but threatened participants reported significantly greater catastrophizing (CSQ) than controls. Perceived threat regarding the CPT challenge was collected on a 3 point scale (‘not at all/somewhat/very threatening’) following task completion. A path analysis indicated that catastrophizing/cognitive coping fully mediated the relationship between threat and pain tolerance. Thus, appraisals of threat, rather than increase in pain, predicted pain tolerance – in this case, conceptualized as pain avoidance. Additionally, threatened participants endorsed less use of cognitive coping strategies, including mental diversion, re-interpretation of sensations, coping self-statements, or ignoring the pain (see Table 4).
In a study utilizing the Cold Pressor Test (CPT) with a sample of 100 healthy undergraduates, Boston and Sharpe (2005) likewise observed that participants provided with threatening information regarding the CPT showed significantly less tolerance for ice-water immersion than participants in the reassurance condition. Prior to the CPT, students were administered the Fear of Pain Questionnaire (FPQ; McNeil & Rainwater, 1998), a 30-item instrument that describes different painful situations, about which individuals rate the amount of fear they anticipate would be associated with the experience. Ratings are made on 5-point scales with the endpoints not at all and extreme. Using this scale, individuals identified as fearful endorsed greater worry and anxiety about harm associated the task (measured on an 11 point numerical scale, 0-10); worry was found to mediate the relationship between fear of pain, threat manipulation, and pain tolerance. Worry had no mediating impact on participants’ pain threshold (the time taken for participants to first register pain after placing their hand in the cold pressor), supporting the secondary importance of actual pain ratings.

In an inventive paradigm highlighting the central role of interpretation in the pain experience, Arntz and Claassens (2004) manipulated the meaning of a stimulus – a cooled metal bar that could be perceived as hot – briefly placed against the participants’ skin. Participants were 31 healthy students who did not see the object being applied. Prior to application, the experimenter noted that the object was “very hot” (heat condition) or “very cold” (cold condition). In line with research hypotheses, participants in the heat condition described the object as hotter, more painful, and potentially more damaging on a visual analog scale. In turn, damage ratings mediated the relationship between experimental manipulation and ratings of pain. Similar to the manipulation used by Jackson et al. (2005), these results suggest that the
### Table 4

**Escape/Avoidance Following Experimentally Induced Pain in Healthy Samples**

<table>
<thead>
<tr>
<th>Investigators</th>
<th>n</th>
<th>Mode of pain Induction</th>
<th>Pain-related fear measure or Experimental manipulation</th>
<th>Tolerance of Task (escape/avoidance)</th>
</tr>
</thead>
</table>
| Arntz & Claassens, 2004 | 31  | Cold metal stick against neck                 | “Very hot” group (high threat)  
“Very cold” group (low threat) | Pain rating (VAS)  
$\chi^2(1)=3.91, p=0.048$  
Damage rating (VAS)  
$\chi^2(1)=3.80, p=0.05$ |
| Jackson et al., 2005   | 121 | CPT                                           | Threat Group  
Non-Threat Group | Tolerance (time)*  
143.8 sec  
179.6 sec |
| Boston & Sharpe, 2005  | 100 | CPT                                           | Threat Group  
Non-Threat Group | Sensory Bias**  
5.30  
Affective Bias*  
10.10  
Threat Group  
Non-Threat Group | Tolerance (time)  
$\chi^2(1)=3.16, p=0.075$ |
| van Damme et al., 2008 | 101 | CPT                                           | Threat Group versus  
Non-Threat Group | FPQ  
Pre-pain PCS  
Pre-pain CSQ- catastrophizing subscale  
Post-pain PCS  
Post-pain CSQ- catastrophizing subscale | $r = -0.38**$  
$r = -0.15$  
$r = -0.12$  
$r = -0.26**$  
$r = -0.31**$ |
| Hirsh et al., 2008     | 100 | CPT                                           | FPQ  
Pre-pain PCS  
Pre-pain CSQ- catastrophizing subscale  
Post-pain PCS  
Post-pain CSQ- catastrophizing subscale | ns  
ns |
| Dannecker & George, 2009 | 61  | Ischemic task (hand grip)                    | FPQ  
PCG  
PASS – Escape/Avoidance subscale | ns  
t = −2.92*  
ns |
| Sharpe et al., 2010    | 104 | CPT                                           | Threat Group  
Non-Threat Group | Mean = 60.60 sec  
Mean = 95.93 sec | $F(1,99)=5.17**$ |

*p < .05  
**p < .01  
ns = non-significant finding.  
CPT = Cold pressor test.  
PCS = Pain Catastrophizing Scale (Sullivan et al., 1995).  
CSQ = Coping Strategies Questionnaire (Rosenstiel & Keefe, 1983).  
PASS = Pain Anxiety Symptom Scale (McCacken et al., 1992).
attribute of pain to underlying damage enhances its subjective intensity and, conceivably, avoidance behavior.

Dannecker and George (2009) recruited 61 participants and compared measures of escape and avoidance behavior during an ischemic pain task. The task consisted of participants gripping a force-measuring device (dynamometer) while applying the maximum force possible. Application of maximum force with the hand resulted in pain/discomfort within a relatively short time. Participants had the capacity to discontinue or relax the grip at any time, which was expressed instantly as reduction in force generated. Participants were randomly assigned to receive one of two instructions prior to the ischemic task: one group was instructed that they could stop the task whenever they wanted (i.e., before the onset of pain; unrestricted group), the other group was instructed to perform the task for as long as they could endure (tolerance group). Task duration in the unrestricted group was not predicted by fear, anxiety, or catastrophizing. However, task duration within the tolerance group was predicted by catastrophizing ($t = -2.92$, $p < .01$). The results thus support the validity of task duration with a tolerance stop rule as a measure of escape from pain or avoidance of pain exacerbation.

In a study examining 100 healthy volunteers, Hirsh et al. (2008) collected ratings of pain-related fear (FPQ) and pain catastrophizing (PCS and CSQ catastrophizing subscale) before performance of the CPT. As in previous studies involving the CPT, participants were able to discontinue hand immersion at any time (3 minute maximum). Duration before withdrawal was recorded as the measure of pain tolerance and immediately upon withdrawal, participants were again administered the PCS and CSQ-Catastrophizing. Pain tolerance, that is, the amount of time before participants withdrew their hand from the ice bath, served as a dependent variable in a regression model. Gender, pain catastrophizing, and pain-related fear were included as predictor
variables. Results of regression analyses indicated that after controlling for gender, pain-related fear was a strong predictor of pain tolerance. It was additionally demonstrated that post-pain induction (in-vivo) scores of catastrophizing were significantly associated with pain tolerance while pre-pain induction catastrophizing scores were not. These latter findings suggest that, while healthy individuals may have pre-injury orientations toward pain and avoidance, a painful stimuli may be necessary to “activate” these orientations or evoke corresponding patterns of avoidance behavior.

Sharpe and colleagues (2010) conducted a study in which 104 healthy students were randomly assigned to one of two conditions prior to performing the CPT. For those in the “threat group,” the cold pressor task was referred to as a ‘vasodilation’ task, and for those in the “no-threat” group, the task was referred to as a ‘cold pressor’ task. Further, although all participants were provided factually accurate information, participants in the threat group received information which emphasized the physical mechanisms of pain through the use of biomedical terminology and an example of an extreme reaction to cold (frostbite) designed to induce fear. Participants in the no threat group received reassuring information in everyday terminology, which stressed the lack of danger associated with the task through the use of benign examples of exposure to the cold (searching for a cold drink in a bucket of ice). The dependent measure used in analyses was tolerance (i.e., duration before participants withdrew from the water bath). Analyses indicated a significant between-group main effect, \( F[1,99] = 5.17, p = 0.025 \) indicating that individuals more attuned to the harmful or threatening aspects of the CPT demonstrated lower tolerance for the task and, in effect, greater avoidance/escape behavior. Recently, this type of laboratory-based research has indicated that healthy individuals who exhibit high fear of pain similarly exhibit greater avoidance and escape during performance of
behavioral tasks following experimentally-induced *muscular pain*, (e.g., George et al., 2008; Trost et al., 2011). Because a similar design was utilized in the present study, a more detailed description of this paradigm and supportive findings is presented in later sections.

**Summary.** While these studies provide a proximate empirical basis for the proposed design (i.e., eliciting avoidance behavior from healthy participants in response to experimentally induced pain) it is useful to note a number of limitations which suggest improvement for the current paradigm. Importantly, the reviewed studies were primarily focused on coping strategies rather than on causal pathways in pain disability; pain-related fear was therefore not a primary construct of the study designs. Moreover, since Jackson et al. (2005) did not measure participants’ fear-avoidance beliefs at the outset of the investigation, it is unclear whether the fear stimulus indeed “primed” fear cognitions; Jackson et al. (2005) acknowledge that collecting catastrophizing ratings only *after* task completion may have confounded participants’ recollection of *initial* task appraisal. Additionally, studies utilizing the CPT and other self-imposed modalities of pain induction provide participants with control over the pain stimulus. As noted above, some would argue that pain-related fear (specifically in the context of CLBP) promotes avoidance/inactivity precisely because pain is perceived to be *uncontrollable* or *without end* (McCracken, 1992). In the above described CPT paradigms, participants were informed prior to the task that they could discontinue the task at any time and, in most cases, made aware that the pain/discomfort experienced would be temporary. As such, the ecological validity of pain induction methods which still allow for participant control over a temporary pain stimulus may be disputed.
Appraisals of physical activity

The concept of appraisal, first proposed in the context of stress and coping literature, comprises two components: (1) The perceived difficulty or danger of the stressful event and (2) one’s perceived resources or ability to cope with the stressful event (Lazarus & Cohen, 1977). On the basis of these two factors, an individual makes an automatic assessment of a stimulus, triggering an emotional response (Lazarus & Folkman, 1984). In this way, appraisal of the harmful or threatening aspects of an event/stimulus, such as pain elicited during physical activity, precipitates the subjective emotional response of fear. Just as appraisal is observed to be an important factor in global conceptions of the fear response, it is also conceptualized as a process central to development/maintenance of chronic pain and disability (Turk & Wilson, 2010).

As a relatively underdeveloped subset of the Fear Avoidance literature, empirical findings regarding the association between appraisal of physical activity and pain-related fear are limited. Much of the research which substantiates the role of activity appraisal in the context of the Fear-Avoidance model emerges from data collected during clinical interventions intended to reduce pain-related fear (Vlaeyen et al., 2012). Specifically, graded exposure in-vivo applies well-validated exposure interventions used in the treatment of phobias (Wolpe, 1958) to pain-related fear, facilitating incremental confrontation of avoided physical activity. Repeated exposure is expected to facilitate disconfirmation of the initially-appraised threat value of specific physical activities/aspects of movement (Vlaeyen et al., 2004; Linton et al., 2008) and thus mitigate fear and fear-based behaviors (i.e. avoidance/escape; Philips, 1987). Appraisal of physical activities serves a central educational and therapeutic role in treatment and provides a measure of outcome assessment and/or case monitoring (Vlaeyen et al., 2012).
As an example, Leeuw et al. (2008) reported outcomes from a cohort of CLBP patients completing an exposure in-vivo intervention. At the onset of the intervention, patients were administered a shortened electronic version of the Photograph Series of Daily Activities (PHODA-SeV; Leeuw et al., 2007). The PHODA consists of photographs of real people performing everyday tasks (e.g., driving, bending and lifting objects). Participants are asked to sort the activities in terms of those which they would most vs. least avoid. Next, participants are asked to appraise the pain and threat value of each physical activity (i.e., “How much pain would you expect while performing this activity?”; “How concerned would you be about harming or injuring your back?”). Participants respond on a 0-100 scale (anchored “no pain” to “worst possible pain” and “not at all concerned” to extremely concerned,” respectively). As a measure of pain and harm appraisal, the PHODA has seen widespread use in clinical and experimental settings (Kugler et al., 1999, Trost et al., 2009). In the context of graded exposure treatment participants utilize these appraisals to establish a hierarchy of feared activities/tasks. Working with a clinician, the patient then formulates a series of individualized “behavioral experiments” to serve as goals for the treatment. As a prototypic example of the exposure in-vivo paradigm, participants may be asked to provide appraisal of a task (e.g., lifting a bag of groceries into a car) and would subsequently be supported through task performance. Following performance of the task, participants are asked to again appraise the activity. On average, appraisal of the physical task decreases over successive trials, indicating a parallel reduction in pain-related fear and a corresponding reduction in avoidance of the task.

Leeuw et al. (2008) reported significant reductions in pain-related fear and disability following treatment completion; these improvements were reflected in reduced appraisals of the pain and harm value of physical activity (as measured by the PHODA-seV before and after
As a well-validated treatment, similar results – reflecting changes in appraisals, pain-related fear, and disability -- have been observed in single-case clinical studies (Boersma et al., 2004; de Jong et al., 2005; Linton et al., 2002; Vlaeyen et al., 2001, 2002) and randomized controlled trials (Linton et al., 2008; Smeets et al., 2006; Woods et al., 2008).

Laboratory-based research likewise supports the association between pain-related fear and appraisals of physical activity. In a study by Goubert et al. (2005), 84 CLBP patients completed measures of pain-related fear (TSK and PCS) and performed a variable number of trials of three different movements (torso rotation, knee extension, and upper body strength) in randomly counterbalanced order. Prior to performing the three movements, participants provided an appraisal of expected pain using a verbal graphic rating scale (GRS; responses ranging from “none” to “very severe”). Last, participants performed a trunk extensor-flexion test to measure force generated by the trunk flexor and extensor muscles. Results indicated that individuals with high pain-related fear reported higher appraisals of expected pain across all tasks as well as lower muscle force production. In a similar study, Crombez, Eccleston, & Vlaeyen et al. (2002), had 37 CLBP patients complete the TSK and PCS prior to two trials of two behavioral physical challenges: bending forward to touch their toes from a standing position and lifting one leg while lying down. The order of these two tasks was counterbalanced and patients’ appraisals of pain during movement were recorded using a NRS. For individuals with high pain-related fear, appraisal of the first movement was higher than that of their low-fear counterparts. No difference in pain appraisal between high and low fear individuals was apparent during second movement.

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1 It is important to note that the above description is a schematic overview of the role of appraisal in the context of a typical exposure paradigm. Appraisal is by no means the sole or “active” component of the treatment, as additional elements such as psychoeducation and coping skills training are also generally employed (Vlaeyen et al., 2012), nor is the PHODA-seV considered the definitive measure of appraisal in exposure interventions (see Roorda et al., 2005).
performance. Goubert et al. (2002) repeated this study with 39 CLBP patients and again found that patients who reported high pain-related fear (as measured by the PCS) reported higher appraisals of pain in comparison to low-pain related fear patients.

Trost, France, & Thomas (2008), investigated 60 CLBP patients who demonstrated either high or low pain-related fear (median split on TSK). Both high and low fear individuals were asked to perform several variations of a standardized reaching task, reaching toward targets at varying heights, such that task difficulty increased over each trial. For each trial, participants provided their expectancies of pain and harm (VAS 0-100). Overall, participants demonstrated an increase in pain and harm appraisal over the course of the reaching task, in keeping with the increasing difficulty of the task. Consistent with findings from above studies (Goubert et al., 2005), individuals exhibiting high pain-related fear demonstrated higher appraisal of pain and harm while performing physical movements.

Expanding on this methodology, Trost, France, & Thomas, (2009), examined the relationship between pain-related fear (TSK), appraisals of imagined/hypothetical tasks, and appraisals of actually performed physical tasks in 33 patients with CLBP. Having been surveyed for pain-related fear (TSK), participants were asked to perform the reaching task described above. In addition, participants completed the PHODA-M, a modified form of the PHODA, providing appraisals of the pain and harm they would expect while performing various daily tasks. For both the reaching task, and PHODA ratings, findings indicated that individuals with high pain-related fear reported higher appraisals of pain and harm in comparison to individuals with low pain-related fear. Additionally, because of the significant relationship observed between appraisal of daily physical activity (PHODA) and the appraised pain while actually
performing physical activity, findings lend support to the relevance of appraisal in general, as well as the ecological validity of in-lab assessment.

**Summary.** The studies above provide evidence of the positive association between pain-related fear and appraisals (expectancies) of pain and harm during physical tasks. From a conceptual perspective, given our understanding of the role of appraisals as precipitants to the fear response, appraisal of movement is understood to result in corresponding emotional (i.e., fear) and behavioral (i.e., avoidance) responses. As the above evidence corroborates, appraisal is an important metric in the assessment of fear-based responses to pain and movement.

Several limitations of existing appraisal studies are of note and will be addressed by the proposed methodology. First, in several of the studies reviewed above, participants were categorized according to “high” vs “low” pain-related fear. This was generally achieved through mean or median split of measure scores (e.g., TSK). Thus, assignment of “high pain-related fear” was done on a statistical, rather than clinically- or ecologically-validated basis. In addition, this simplification precluded examination of pain-related fear on a continuum, as it exists in the general population. Second, in the case of several of the clinical studies cited, patient samples exhibited at least “moderate” pain-related fear, as indicated by self-report measure (Leeuw et al., 2008). Again, this precludes examination of the impact of various levels of pain-related fear. As such, it is not possible to distinguish effects that are uniquely attributable to pain-related fear from those attributed to (for example) a broader constellation of global or latent fear or anxiety-related variables captured by “high pain-related fear.”

In addition, clinical and experimental use of measures such as the PHODA examine appraisal of *imagined* physical activity. Specifically, respondents are asked to estimate the pain and harm level of tasks which they will not actually be performing at that moment (*in-vivo*).
While this mode of examining appraisal provides for a broader range of movements consistent with “daily activity,” the level of ambiguity and speculation required to make these appraisals raises some doubt as to the validity of this means of assessment. By contrast, the laboratory studies which utilized an experiential component in appraisal of physical tasks (i.e., appraisal during actual movement performance), raise some doubt as to the ecological validity and generalizability of highly standardized exercise activity to performance of everyday physical tasks.

Delayed onset muscle soreness

As described in previous sections, the most consistently noted methodological limitations of previous attempts to examine pain-related fear and its impact on behavioral outcomes (i.e., activity avoidance) are the cross-sectional nature of the studies and, consequently, the inability to control for confounding variables (e.g., previous pain history, healthcare interactions). The following section will discuss delayed onset muscle soreness (or, DOMS) as a novel experimental methodology that has been employed to address these limitations. DOMS has been extensively examined in the context of physiological responses to injury (Cleak & Eston, 1992; Gulick et al., 1996), kinesiology/sports medicine (Rowlands et al., 2001; Harris et al., 1990), and pharmacological intervention (Staahl et al., 2004); the sections below provide a brief description of the DOMS paradigm followed by representative studies that have utilized a DOMS paradigm to examine the impact of psychological factors (in particular, pain-related fear) in responses to acute injury.

Delayed onset muscle soreness (DOMS) refers to a condition of painful muscle tenderness that typically appears 12 to 48 hours following eccentric or strenuous exercise to a localized anatomic area (Cheung et al., 2003). The muscle soreness that develops following
strenuous exercise is the result of structural damage to the muscle fibers recruited during the task, triggering a localized inflammatory response which produces pain upon movement or tactile stimulation (Vecchiet et al., 1999). Soreness gradually subsides and disappears by 5-7 days (Cleak & Eston, 1992; Zainuddin et al., 2005). Thus, this phenomenon is a self-limited process that resolves completely in a relatively short amount of time. Eccentric activity is characterized by the simultaneous elongation and contraction of a muscle; if the muscle cannot actively resist an externally applied load, the muscle is forced to lengthen, thus generating active tension (Cheung et al., 2003).

Intensity of DOMS has been found to vary from mild and rapidly dissipating stiffness to more severe irritation that can restrict movement (Bishop et al., 2011). DOMS is usually associated with unfamiliar, high intensity muscle work and frequently strikes athletes upon return to training after a protracted period of inactivity (George et al., 2007; Cheung et al., 2003). In this way, DOMS may be a particularly relevant stimulus in the context of pain-related fear, as individuals who have suffered an acute pain episode may be faced with musculoskeletal discomfort after a period of rest; according to the fear-avoidance cycle, this may represent a “dangerous moment” for highly fearful individuals in terms of perpetuating disuse and disability. In the context of the proposed study, DOMS is intended to serve as an analog for acute musculoskeletal injury. The pathophysiology associated with DOMS shares essential characteristics with traditional acute injury inflammation models, including vascular and cellular responses in and around damaged tissue (for review, see Cheung et al., 2003). DOMS symptoms also mirror those of acute injury, including pain, swelling and edema, as well as impaired force production, mobility, proprioception, and range of motion (George et al., 2007; Udermann et al., 2002). From a behavioral standpoint, DOMS has also been observed to instigate self-care
behaviors such as stretching, over-the-counter medication use, and application of heat/cold to affected muscle groups (Dannecker et al., 2004).

Delayed onset muscle soreness stemming from exercise has been studied extensively across various muscle groups (Newham et al., 1983; Schwane et al., 1987; Howell et al., 1993). Previous investigations have induced DOMS using eccentric protocols such as downhill running and resisted cycling. Of central interest to the proposed study, Udermann and colleagues (2002) developed an eccentric exercise protocol for inducing DOMS in the lower back (i.e., trunk extensor) muscles. In this protocol, participants perform 2 sets of 25 repetitions of seated lumbar flexion at 80% peak extensor load. Using this approach, back pain peaks at 24-30 hours and is nearly resolved by 5 days following exercise (Udermann et al., 2002; Mayer et al., 2006). For the purposes of the current investigation and based on observations from pilot data, the proposed protocol (described in the Methods section) will be modified to ensure both effectiveness and participant safety.

DAMS and pain-related fear. An expanding body of literature has examined the predictive value of pain-related fear in the context of DOMS methodology. The studies reviewed in detail below constitute a representative sample of this literature; additional studies that are not reviewed are displayed in Table 4. Consistent with the advantage conferred by this experimental paradigm, all studies employed prospective designs.

In a sample of fifty healthy but sedentary undergraduate participants (mean age = 21.1 years), Sullivan et al. (2002) induced DOMS via a strenuous exercise protocol of repeated eccentric and concentric contractions. Specifically, each participant completed a multiple repetition maximal strength test that was comprised of five commonly used strength exercises (i.e., chest press, leg press, lateral pulldowns, leg flexion, and shoulder press), each being
performed for three sets of 8–10 repetitions. Thus, the protocol induced soreness and fatigue in a variety of anatomical areas. Prior to engaging in exercise, pain-related fear was assessed using the Pain Catastrophizing scale (PCS) and negative mood was measured using the Profile of Mood States (POMS; McNair et al., 1971), where participants rate the subjective intensity of nine mood adjectives on an 11-point scale ranging from 0 (not at all) to 10 (extremely). Adjectives correspond to the states of sadness, anger, and anxiety; summed rankings represent the total negative mood score. Participants completed the same exercise bout upon their return to the laboratory 48 hours later. As predicted, there was no significant relation between pain-related fear and maximum load or endurance (repetitions) during the first exercise maneuver (prior to DOMS induction). Catastrophizing was significantly correlated with negative mood, pain intensity (assessed on a visual analog scale [VAS]) and reduction in weights lifted during the second exercise bout. Importantly, regression analyses showed that catastrophizing predicted reduction in maximal weight lifted even after controlling for pain and negative mood state. From these results, the authors inferred that, in the absence of pain, catastrophizing is not associated with reduced physical function. Thus, pain may be a significant contextual cue for the manner in which pain-related fear will influence behavioral performance. In other words, pain “primes” fear-avoidant cognitions. A recent study by Niederstrasser and colleagues (2014) replicated and extended these findings. The study involved the gathering of prospective data for 119 individuals, including measures of catastrophizing (PCS), pain-related fear (FPQ) as well as depression (PHQ-9).

Niederstrasser et al. induced DOMS using four different strength exercises (i.e., chest press, lateral pull downs, shoulder flexion, and shoulder abduction) to create a state of diffuse
### Table 5

**Studies of Pain-Related and Pain/Behavioral Outcomes Following DOMS Induction**

<table>
<thead>
<tr>
<th>Investigators</th>
<th>n</th>
<th>Site of DOMS</th>
<th>Pain-related fear measure</th>
<th>Association of Pain-related fear with Post-DOMS effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sullivan et al., 2002</td>
<td>50</td>
<td>Multisite</td>
<td>PCS</td>
<td>↑ Pain intensity (VAS)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>↓ Maximal weight (repetitions)</td>
</tr>
<tr>
<td>George et al., 2007</td>
<td>19</td>
<td>Shoulder</td>
<td>FPQ</td>
<td>↑ Disability (DASH)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>↑ Pain intensity (VAS)</td>
</tr>
<tr>
<td>George et al., 2008</td>
<td>63</td>
<td>Shoulder</td>
<td>FPQ</td>
<td>ns Pain intensity (VAS)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>CSQ</td>
<td>↑ Disability (DASH)</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>↑ Pain intensity (VAS)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PCS</td>
<td>↓ Maximal weight (torque)</td>
</tr>
<tr>
<td>Bishop et al., 2011a</td>
<td>60</td>
<td>Low back</td>
<td>FPQ</td>
<td>↑ Pain intensity (VAS)</td>
</tr>
<tr>
<td>Bishop et al., 2011b</td>
<td>52</td>
<td>Low back</td>
<td>FPQ</td>
<td>↑ Pain intensity (VAS)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>TSK</td>
<td>ns Pain unpleasantness</td>
</tr>
<tr>
<td>Trost et al., 2011</td>
<td>30</td>
<td>Low back</td>
<td>PASS</td>
<td>↑ Pain-related interference</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>↓ Maximal weight (isometric)</td>
</tr>
<tr>
<td>Trost et al., 2012</td>
<td>51</td>
<td>Low back</td>
<td>PASS</td>
<td>↑ Pain-related interference</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>↓ Lumbar hip flexion</td>
</tr>
<tr>
<td>Niederstrasser et al., 2014</td>
<td>119</td>
<td>Multisite</td>
<td>PCS</td>
<td>↑ Pain during movement (NRS)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>FPQ</td>
<td>↑ Multisite pain</td>
</tr>
<tr>
<td>Parr et al., 2014</td>
<td>126</td>
<td>Shoulder</td>
<td>FPQ</td>
<td>ns Pain duration</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>↑ Pain intensity (BPI)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PCS</td>
<td>↑ Pain duration</td>
</tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>↑ Pain intensity (BPI)</td>
</tr>
</tbody>
</table>

soreness across multiple sites of the body. Following successful induction of DOMS, participants returned to complete a schematic body drawing (used as a measure of multisite pain) and to provide ratings of pain intensity while performing a back-stressing activity (lifting a weighted canister). Results indicated that catastrophizing and pain-related fear predicted higher intensity of pain symptoms as well as a greater distribution of pain, with high fear participants reporting more sites across the body affected or experiencing pain symptoms following induction of DOMS.

Focusing on chronic shoulder pain, George et al. (2007) induced DOMS in the shoulder muscles of 19 healthy men and women (mean age = 20.2 years) using eccentric/concentric external rotation repetitions. Resting clinical pain, evoked pressure pain, muscle force production, and disability measures were collected prior to DOMS induction as well as 24 hours following the protocol. Pain-related fear was also measured at baseline using the Fear of Pain Questionnaire (FPQ; McNeil & Rainwater, 1998) and the CSQ catastrophizing subscale. The TSK was administered during the second testing session (following DOMS induction) and was therefore not used as a predictor variable in the analyses. Muscle force production was measured by maximum voluntary isometric contraction, in which participants performed 5 repetitions of isometric shoulder external rotations. The Disability of Arm, Shoulder, and Hand (DASH) Questionnaire (Beaton et al., 2001) assessed perceived upper-extremity disability; the questionnaire contains 30 performance items, rated from 1 (no difficulty) to 5 (unable). Pressure pain was applied to various parts of the shoulder musculature and measured with an algometer. Separate pressure pain ratings for each anatomic region were combined into a single factor for regression analyses. Fear of pain (FPQ) showed the most consistent univariate association with outcome measures 24 hours following the DOMS procedure. Stepwise regression analyses
indicated that, when used as the only predictor variable, the FPQ measure alone explained 16% of the variance in clinical pain intensity (VAS) and 10% of the variance in evoked pressure pain 24 hours after DOMS induction. Similarly, controlling for all other variables, clinical pain VAS ratings (24 hours after DOMS) alone explained 11% of the variance in muscle force production. In subsequent models, clinical pain intensity (VAS) and FPQ scores together explained 50% of the variance in perceived disability outcome whereas FPQ scores together with Sex accounted for 26% of variance in kinesiophobia (TSK) ratings. Importantly, none of the psychological variables were predictive of muscle force production after considering DOMS-induced clinical pain intensity (VAS).

Of particular relevance to the current design, a study by Trost et al. (2011) examined the relationship between pain-related fear, physical performance, and pain-related interference in the context of DOMS, induced specifically to the lower lumbar region of the back. A sample of 30 healthy participants completed a test of maximal trunk strength before and after induction of DOMS to the trunk extensors. Pain-related fear (TSK, PASS) was assessed prior to DOMS induction, and measures of pain intensity and pain-related interference with life activities were obtained 24 hours post-DOMS induction. Following DOMS induction, pain-related fear predicted decrements to maximal strength performance. Of particular note was this study’s incorporation of a pain-related interference measure. While the measure only consisted of two items, it constitutes the first attempt to apply a self-report measure analogous to disability in the context of experimentally induced acute injury. Interestingly, participants with high pain-related fear reported greater post-injury pain-related interference in life activities. Findings support that fearful orientations toward pain in healthy populations is a potential risk factor for avoidant behavior patterns in the acute phase following injury (Trost, 2011).
Another study conducted by Trost and colleagues (2012) examined the prospective relationship between pain-related fear and avoidant physical performance following DOMS induction. In this study, 51 healthy participants were assessed for pain-related fear (as measured by the PASS) and completed variations of a reaching task (reaching for high and low targets at self-selected and fast speeds). While performing the reaches, a three dimensional tracking apparatus was used to measure movements of the spine and hip to examine degree of lumbar and hip flexion. Previous literature has identified restriction in lumbar flexion as a motoric form of postural avoidance among high fear individuals with chronic low back pain (Thomas & France, 2008; McGorry & Lin, 2012). Following baseline motor assessment, participants completed a procedure to induce DOMS in the lower lumbar region of the back. Participants returned to the testing site 24 hours later to perform repeated trials of the reaching task. Findings indicated that pain-related fear was associated with decreased lumbar flexion during low target-reaches for both self-selected speed and fast speed. As observed in the previous study, pain-related fear predicted self-reported interference in life activities after DOMS induction.

Additional studies examining induction of DOMS in the low back (Bishop et al., 2011a, 2011b), have also demonstrated a post-DOMS increase in pain intensity that corresponded with participants’ pain-related fear. This small collective of studies focusing specifically on experimentally induced low back pain has indicated, with relative uniformity, that pre-injury fear of pain has moderate to strong prognostic power in prediction of post-injury pain (Bishop et al., 2011b) and function (Trost et al., 2011, 2012). However, this interpretation must be tempered by the observation that different measures of pain-related fear have been used across these studies, with occasional non-significant results (Bishop et al., 2011b)
The above studies provide an important empirical foundation for the current investigation. However, in contrast to the targeted interests of this study (i.e., low back pain), the diffuse soreness procedures implemented by Sullivan et al. (2002) and Niederstrasser (2014) make it difficult to presume back-specific findings. Likewise, George et al. (2007, 2008) and Parr et al., (2013) did not focus on back pain, although their findings suggest a connection between pain-related and pain intensity/disability measures post-injury. In addition, the above studies did not collect measures of appraisal of the physical tasks performed by participants (i.e., “how much pain do you expect to experience from this?”). As an important indicator and, conceptually, a precipitant to fear-based responses to movement, the inclusion of appraisal data would likely have provided unique information regarding participants’ subjective experiences of performing the tasks, beyond simply rating their pain intensity. Of important note, the majority of DOMS studies to date have used standardized and exercise-based modes of behavioral performance following DOMS induction (e.g., maximal strength capacity, can-lift). While this is a useful measure of exertion/avoidance, there is doubt regarding the ecological validity of these tasks. The current study aimed to advance the ecological validity of measures following DOMS induction by assessing participant appraisals of pain while performing common, daily activities (further explained in Methods).

Summary

In summary, induction of DOMS, as opposed to other experimentally induced pain modalities is primarily endogenous, self-induced, and clearly linked to movement. It is also a relatively common response to physical exertion. In addition, the DOMS paradigm (as a well-validated pain-induction technique) has a clear activating effect in producing differential behavioral outcomes which are moderated by pre-DOMS pain-related fear, with the caveat that
sound prospective investigations entail comprehensive measurement of baseline orientation to pain in addition to assessment of history of pain and disability. Methodologically, DOMS induction provides a useful experimental model of pain that confers important benefits to extend research regarding the relationship between pain-related fear and disability. In contrast to other pain-induction modalities (discussed in previous section) such as the cold presser task, DOMS offers an ecologically valid mode of pain induction. That is, pain is experienced in the musculature and can be localized to a specific region (site), making it an appropriate analog for injury-related musculoskeletal pain in the low back region. Also, whereas previous literature using chronic pain samples has utilized cross-sectional and/or quasi-experimental designs, use of DOMS affords a prospective, repeated measures design which allows for experimental control of otherwise potentially confounding environmental factors (e.g., spousal support, access to healthcare), and medically-relevant factors such as injury severity, time since injury, mode of injury, and location/site of injury.

Interpersonal processes in pain-related fear

While the impact of pain-related fear and associated responses (elevated appraisals, avoidance) has been well documented, significantly less is known about processes by which pain-related fear and fear-based responses are developed and maintained. As noted in the previous sections, one of the most provocative aspects of pain-related fear is that high fear of pain can be observed in non-clinical samples. That is, individuals exhibit fear of pain/movement and associated appraisal and avoidance responses in advance of prior pain experience. In efforts to explicate these processes, recent theoretical and empirical advances have turned to the interpersonal context of pain and pain-related social processes (Jackson et al., 2005; Williams et al., 2002). These theoretical accounts highlight that the experience of pain does not take place in
a vacuum but is rather a confluence of sensory and affective factors being *influenced by and expressed within* a social context (for review see Goubert et al., 2005). In particular, recent reviews have highlight observational learning as a potential interpersonal mechanism by which pain-related beliefs and behaviors are developed and maintained (e.g., Goubert et al., 2011).

Observational or social learning processes comprise the basis of early accounts of behavior change (Bandura, 1986), including acquisition and maintenance of fear responses (Askew & Field, 2008). Observation of others’ behavior in specific contexts or salient stimulus pairings can provide information regarding the consequences of particular actions or the threat value of particular stimuli, subsequently affecting an observer’s own behavior. In terms of pain, observational learning provides a valuable tool in that one can identify (or avoid) circumstances, actions, or stimuli observed to result in hurt/harm to others. Through observation of another’s behavior in a particular situation, an individual acquires information about that situation and about the consequences of specific actions in that situation.

The role of observational learning in pain experience is supported by several lines of research. First, neuroimaging studies provide compelling support that observing another in pain activates similar neural responses in the observer, analogous to personal experience of pain (Botvinick et al., 2005; Singer et al., 2004). In particular, observing pain in others has shown to activate those brain areas associated with affective (emotional distress) in the observer (see Lamm et al., 2011 for meta-analysis). These findings suggest that similar neural processes may underlie both direct and observational learning of fear-based responses to pain (Olsson et al., 2007). Second, a number of studies (particularly of parents and children) provide evidence of social modeling of pain responses (reviewed by Hermann, 2007). Finally, given the relevance of
pain-related fear to pain responses in the intrapersonal context, surprisingly few studies have examined the impact of pain-related fear on observational learning responses.

As an example of social modeling in pain, Goodman & McGrath (2003) examined whether a child’s observation of their mother’s reaction to a CPT would influence the child’s own ratings of pain threshold and pain intensity, as well as their pain-related facial behavior during CPT performance. The study’s participants included 96 mothers and 96 children in good health. The study randomly assigned mothers to either an “exaggerated” group (asked to exaggerate their pain behavior during the CPT), a control group (given no instruction), or a “minimize group” (asked to minimize their pain behavior). Children watched their mother’s reactions and then completed a similar CPT procedure. Children’s facial pain behavior was measured with the Child Facial Coding System (CFCS). Pain intensity was measured using a rating scale of 1-10 (0 = no pain at all and 10 = the worst pain you can imagine). Pain threshold was measured as participants signaled the moment they felt any pain after they submerged their arm. Goodman & McGrath (2003) found that children in the “exaggerate” group displayed lower thresholds than the children in the control group and that children in the “minimize” group had significantly lower CFCS scores than children in the control group. While these findings do not directly address pain-related fear, they support the role of observational learning and modeling in pain behavior.

Olsson, Nearing, & Phelps (2007) examined physiological fear responses in the context of observational learning during a two-part experiment. Participants were measured for skin conductance response (SCR) throughout the study, and had their responses during the test phase measured by fMRI. First, participants (n=11) watched a movie of a person being repeatedly presented with two different colored cues (squares of a specific color). The video subject
received a painful electric shock during presentation of one color cue, but not the other.

Participants were told they would complete the same study and receive shock as signaled by a color cue identical to the film. Although they were told there would be shocks, no shocks were actually administered, ensuring that any learning was indirect. While being presented with the same sequence of color cues, participants were scanned within an fMRI. Participants exhibited a heightened SCR/fear response both while observing the video subject being color cued to receive shock and when they themselves were exposed to the same set of cues. The findings indicated establishment of a fearful response to a previously neutral color cue that had been associated with pain through observational processes. FMRI results likewise indicated that the regions of the brain activated during presentation of the pain-related color cue were those areas associated with both sensory and affective/emotional responses to pain, even in the absence of an actual painful stimulus.

A study by Helsen and colleagues (2011) examined whether observing others exhibiting pain behavior during CPT performance contributes to the development of pain-related fear, assessed by the Pain Catastrophizing Scale (PCS). Healthy participants (n=62) first watched videos of people taking part in a colored cold presser task (i.e., the water in the CPT apparatus was dyed either blue or red). One color was randomly paired with faces demonstrating painful expressions and the other color was paired with neutral facial expressions. Helsen, et al. (2011) found that participants exhibited more pain-related fear when they were subsequently expecting to engage in the cold presser task reflecting the color paired with the painful facial expressions. This study was the first to offer evidence for observational learning of pain-related fear in response to anticipated pain.
Using a similar paradigm, Helsen and colleagues (2013) conducted a study with 60 healthy adults without history of chronic pain. Participants completed measures of pain-related fear (FPQ, PCS), prior to observing a video prime depicting an individual submerging their hand in a colored tank of warm water. As in the previous study, half the participants observed the video subject display a high pain expression when paired with a particular color CPT and half observed a neutral pain expression when paired with that color. Following observation of the video prime, participants proceeded to submerge their own hand in the same colored water tank while providing subjective reports of fear of the task. Results indicated that those observing a high expression of pain reported the greatest increase in fear prior to submerging their hand in a water tank of the same color. This effect was especially pronounced for those with high catastrophizing and high pain-related fear.

Recently, a study by Trost and colleagues (2012) examined the impact of observational learning and pain-related fear on healthy individuals’ appraisals of imagined physical tasks. Participants without a history of pain completed a modified form of the Photograph Series of Daily Activities Scale (PHODA-M; Kugler et al., 1999) prior to and following a video prime, described below. The PHODA-M comprises a series of 20 photographs of daily tasks for which participants provided appraisals of expected pain and harm on a 0-100 scale (0 = no pain to 100 = worst possible pain; 0 = no concern [about harm] to 100 = extreme concern [about harm]). Specifically, participants were asked to indicate the anticipated pain and harm of the depicted activities in the imagined circumstance that they were suffering from back pain. Next, participants viewed a video prime, consisting of individuals incurring sports-related back injury accompanied by high expression of pain behavior. This study found that only participants with high pain-related fear (TSK) reported an elevation in both pain and harm ratings from the first to
second administration of PHODA-M; this change in ratings was not apparent for participants classified as low fear. This was the first study to demonstrate the impact of observational learning and pain-related fear on activities specifically relevant to back pain and injury.

Summary. Relatively few studies to date have examined the impact of observational learning on pain-related responses. Of studies that have addressed this mechanism, findings suggest that observing threatening pain in others has the effect of increasing individual subjective experience of pain, threat, and appraisal of physical activity (Helsen et al. 2011; Trost et al., 2012). Of particular importance, there is evidence that these learning effects may be differentially moderated by individuals' level of pain-related fear, such that individuals with high pain-related fear show a more pronounced change in fear-based responses to pain when observing others in pain, while low fear individuals exhibit lesser effect (Trost et al., 2012). In accounting for these findings, it has been suggested that individuals with high pain-related fear may – to a greater extent than low-fear counterparts – selectively reinforce established schema regarding the meaning and nature of pain experience (Goubert et al., 2005). In this way, high fear individuals selectively attend/respond to information regarding pain, especially cues that emphasize the harmful and threatening nature of pain (van Damme et al., 2010). In this sense, pain-related fear could be conceptualized as a vulnerability factor which, in the context of an environment which reinforces fear-based responses to pain, may promote maladaptive responses when painful stimuli are encountered.

While the above findings support the basic notion that fearful orientations to pain can be established via observation, several limitations prevent extrapolation of these findings to CLBP or other musculoskeletal conditions. The first concerns the mode of pain induction used to initiate learned responses to pain. Thus far, studies have utilized modalities including the CPT
(Goodman & McGrath, 2003), electric shock (Olsson et al., 2007), and warm water bath (Helsen et al., 2011, 2013). These modalities do not comprise an appropriate analog to musculoskeletal injury as they do not share many characteristics with musculoskeletal pain. As an example, each of the above pain modalities are of highly limited duration and within the participant’s control (i.e., in the case of CPT, participants could withdraw their hand). Further, Trost et al. (2012) was the only study to utilize a video prime conveying information about pain in response to actual back injury rather than an experimentally induced state of pain. It is also the only study to examine the effect of observational learning on appraisal of physical activity. However, although the prime (athletic injuries) and assessment instrument (daily activities depicted in the PHODA-M) utilized by Trost et al. (2012) have high ecological relevance to back pain, the prime did not correspond to tasks for which the participants subsequently provided appraisals, thus obscuring the mechanisms of the observed effects.

Perhaps the most pronounced limitation yet to be addressed in observational learning studies of pain is whether the effects of observed learning actually translate into changes in behavioral responses to pain. To date, observational learning effects have been measured via changes in self-reported pain, self-reported fear of pain, or physiological indices of fear. In the case of the study by Trost et al. (2012), changes in appraisal of physical activities served as the dependent measure. In sum, studies have observed significant changes in fearful orientation to specific physical tasks; while these results suggest that avoidant behavior would follow, no study to date has actually examined this hypothesis.

Present Study

Building on previous research, the present study examined the role of observational learning and pain-related fear on appraisal of physical activity and physical exertion in the
context of acute injury. Healthy individuals without history of chronic pain or disability participated in two sessions of an experimental protocol. During the first session (baseline session), participants completed a measure of pain-related fear and provided baseline ratings regarding their expectations of pain and harm (activity appraisals) prior to performing a series of standardized movement tasks. Next, participants performed a back-stressing activity to induce DOMS to the lower back. During the second session (DOMS session), which occurred approximately 48 hours after the first session, participants were randomly assigned to one of two conditions. Participants in one condition viewed a video prime depicting actual CLBP patients performing a series of identical standardized tasks while displaying a low level of pain behavior (low pain prime); participants in a second condition observed a video prime in which CLBP patients performed the same standardized tasks while displaying a high level of pain behavior (high pain prime). After observing the video primes, participants in both groups repeated the standardized movement tasks originally performed in the first session, and again provided their appraisals of pain and harm. Participants’ degree of physical exertion was assessed during baseline and DOMS sessions using a test of maximal isometric strength and a self-selected exertion task.

The primary hypotheses of the present study were as follows:

(1) Following DOMS induction, participants assigned to view the high pain prime would report higher elevations in pain and harm appraisals of physical activity than participants assigned to view the low pain prime.

(2) The impact of video prime upon appraisals (i.e., greater increase in appraisals in response to the high pain prime compared to the low pain prime) would be particularly pronounced among participants with high pain-related fear.
(3) Following DOMS induction, participants assigned to view the high pain prime would show greater reduction in physical exertion (maximal isometric strength and self-selected exertion) than participants assigned to the low pain prime.

(4) The impact of video prime upon physical exertion (i.e. greater decrement in response to the High Pain Prime compared to the Low Pain Prime) would be particularly pronounced for participants with high pain-related fear.
METHODS

Design

This study employed a 2 (Time: baseline session, DOMS session) x 2 (Condition: high pain prime, low pain prime) repeated-measures design. Condition was a between-participant factor while Time was a within-participant factor. Participants’ pain-related fear was examined as a covariate to determine whether the impact of condition on change in physical activity appraisals and physical exertion over time (i.e., from baseline to DOMS session) was dependent upon (moderated by) participants’ level of pain-related fear.

Participants

Eligibility criteria included individuals aged at least 18 years who were enrolled as undergraduate students at the University of North Texas. Potential participants were excluded if they endorsed a history of back pain or interference with daily function due to back pain, or if they endorsed a history of spinal surgery or other medical condition (e.g., arthritis) which would have precluded strenuous physical activity. Additionally, participants were excluded if they reported engagement in regular back strength training (more than two times per week). Lastly, women with confirmed or suspected pregnancy were also excluded from participation. The present sample was recruited through the university online research portal and received course credit in their undergraduate coursework in exchange for their participation in the study. All procedures were approved by the University of North Texas Institutional Review Board (IRB).

Self-report Questionnaires

*Tampa Scale of Kinesiophobia* (TSK; Kori, Miller, & Todd, 1990). The TSK is a 17-item measure of fear of movement and/or (re)injury during movement. The TSK contains statements such as “If I were to try to overcome it, my pain would increase” and “Pain always means I have
injured my body.” Respondents rate their agreement to items on a 4-point Likert scale ranging from 1 (Strongly disagree) to 4 (Strongly agree). Item scores are summed, including 4 items reverse-scored, to calculate a total score ranging from 17 to 68 with higher scores indicating higher levels of pain-related fear. The TSK has been previously validated in healthy, adult populations and has demonstrated high reliability and validity (Clark, Kori, & Brockel, 1996; Goubert et al., 2004).

Visual Analog Scale (VAS). Participants used a VAS to provide ratings of expected pain and expected harm (potential injury to the back) with each trial comprising the standardized movement task (see Procedure section). Each VAS is a 100-mm horizontal line with no numbers, marks, or descriptive vocabulary along its length. Participants responded to the question, “How much pain do you expect when performing this movement?”; the VAS was anchored with the descriptors “No pain” and “Worst possible pain” at each end of the 100-mm line. Similarly, participants responded to the question, “How concerned are you about harming/injuring your back while performing this movement/activity?” before each trial of movement performance. The VAS word anchorings that most clearly delineate extremes and are 100 to 150 mm in length have been shown to have the greatest sensitivity and to be the least vulnerable to distortions or biases in rating (Price & Harkins, 1992). VAS has demonstrated reliability, validity, construct validity, and minimal inherent bias in a variety of clinical and experimental pain studies (Kendall, 2000; Williams et al., 2004). In addition, VAS responses have previously discriminated between low and high fear response as well as responses to visual pain primes (Trost et al., 2012).

McGill Pain Questionnaire – Short Form (MPQ-SF; Melzack, 1987). The MPQ-SF is a widely used method of pain evaluation in both clinical and experimental research, yielding a
quantitative, multidimensional pain score. The pain rating index (PRI) of the MPQ-SF comprises the summed rankings of 15 adjectives that describe sensory (11 words) and affective (4 words) dimensions of pain. The adjectives are ranked on a four-point scale from 0 (none) to 3 (severe). The Visual Analog Scale (VAS) comprises a 100 mm line (anchored with “No pain” and “Worst possible pain”) and a 0-5 pain intensity rating. In adult populations, the MPQ-SF has demonstrated high reliability with reported Cronbach alpha values ranging from 0.71 to 0.94 (Kilminster & Mould, 2002), good validity, and sensitivity to change across a variety of pain and illness categories (Burckhardt & Jones, 2003), making it an appropriate instrument to measure and/or validate an increase in pain symptoms over time following experimentally-induced muscle soreness.

Measures of Physical Exertion

*Maximal isometric strength task.* Participants were asked to perform three trials of maximal isometric trunk extension while positioned in a commercial back exercise machine (MedX, Medical Lumbar Extension Machine, Ocala, FL, USA) such that the trunk was vertical and the hips were flexed approximately 70°. A load cell recorded the maximal force (measured in foot-pounds) generated by the trunk extensors. Maximal trunk performance was then determined by averaging participants’ two highest extension trials (Trost et al., 2011). Further description of data collection for the isometric strength task can be found in the “trunk extensor muscle exercise” and “DOMS session” sub-sections of the Procedure section.

*Self-selected exertion.* To further assess participants’ self-selected activity engagement, participants were asked to select from eight standard weights arranged horizontally at floor-level (see Figure 3). Weights ranged from 5 to 40 lbs., in 5 lb. increments, with their numeric weight visually displayed for participants. Participants indicated the maximal weight they would be able
to pick up from the floor, place on a table adjusted to waist level, and return to the floor position, having been given instructions that they would be performing this activity multiple times.

![Figure 3. Weight apparatus for self-selected physical exertion task.](image)

Video Prime Stimuli

The high pain prime utilized in this protocol contained 6 video segments of actual CLBP patients displaying high pain behavior (wincing, straining, facial pain, etc.) while completing a series of everyday activities. Activities included lying down and getting up from a bed, sitting down and getting up from a chair, and picking up a weighted crate from the floor to a table surface. The video segments in the high pain video prime are each approximately 30 seconds in length and the order in which video segments were presented was randomized. The low pain prime contained 6 video segments of CLBP patients displaying low pain behavior while completing these activities. Video segments in the low pain prime were each approximately 15 seconds long, which was half the duration of those in the high pain prime. Therefore, each low pain video segment was shown twice to control for any potential timing effect between the two video primes. All patient videos of were obtained from the Ghent Pain Videos of Daily Activities (G-PAVIDA; De Ruddere et al., 2013) and with patients’ permission at the University of Ghent, Belgium. Videos were determined to be depictions of “high” and “low” pain behavior based on a standardized scoring system developed by researchers at the University of Ghent, and validated in previous studies (De Ruddere et al., 2011).
Procedure

Figure 4 provides an overview of the study protocol across both testing sessions.

*Baseline session.* Upon arrival to the laboratory, participants provided written consent and completed a number of questionnaires, including demographic surveys, the Tampa Scale of Kinesiophobia (TSK) and the McGill Pain Questionnaire – Short Form Visual Analog Scale and Pain Rating Index (MPQ-SF-VAS & MPQ-SF-PRI).

*Standardized movement task* (Figure 5a-c). Upon completion of surveys, participants were asked to perform two successive trials of three standardized movements: (1) lying down on a bed and standing up, (2) sitting down on a chair and standing up, and (3) picking up a weighted crate from the ground, putting it on a table and replacing it on the ground. The order of movement performance was fixed across participants. The movement tasks were identical to those performed by CLBP patients in video primes and based on methodology developed by De Ruddere and colleagues (2011) and previous research indicating that these routine daily tasks require movement that is sufficient to induce discomfort in those experiencing low back pain. Prior to each movement, participants were provided verbal instructions by the investigator, without modeling (e.g. “When I say go, please lie down on the bed on your back, pause for a few seconds, and then stand up when you feel ready”). Prior to each trial of movement performances, participants were asked to provide appraisals of anticipated levels of pain and harm using the 100 mm VAS (described above). Participants were allowed to perform each movement at a self-selected speed and at self-selected intervals, taking breaks as needed.
Figure 4. Study protocol.
Figure 5a. Movement task – Laying down on bed.

Figure 5b. Movement task – Sitting in chair.

Figure 5c. Movement task – Picking up weighted crate.
Trunk Extensor Muscle Exercise (Figure 6). Following standardized movement task performance, participants were directed to a standard weight-training apparatus that was used to complete a series of resisted trunk exercises designed to induce DOMS in the lower lumbar region of the back. To determine appropriate resistance, participants completed a measure of maximal isometric strength capacity (described above); exercise (resistance) load was then set to 80% of their average maximal trunk performance\(^2\). Participants then performed 25 repetitions of seated lumbar flexion (eccentric contraction). Starting from an initial upright seated posture, participants slowly flexed their trunk 30° against the load. To ensure appropriate eccentric resistance, participants were told to complete each flexion in time to 4 beats of a metronome, set to one beat per second. To ensure that participants performed only resisted eccentric contractions, the investigators used a lever to move the load for the participants on the return (concentric contraction) phase of the exercise. Participants’ maximal trunk extensor muscle

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure6.jpg}
\caption{Trunk extensor muscle exercise apparatus – exercise performance.}
\end{figure}

\(^2\) The test of maximal isometric strength is used both to configure the appropriate resistance for the trunk extensor exercise and as a dependent variable of physical exertion in the current study.
capacity was measured following each set of 25 trials, and participants were instructed to repeat the exercise protocol until they could no longer achieve 50% of their maximal trunk performance. This trunk extensor muscle exercise protocol has been used in previous studies to induce Delayed Onset Muscle Soreness (DOMS) of the trunk extensor muscles (Undermann, Mayer, Graves, & Ploutz-Snyder, 2002). It should be noted that the exercise machine utilized in this paradigm is designed specifically to limit the amount of trunk flexion within the normal range of motion for a healthy population, thus preventing end-range loading of ligaments and other non-contractile tissues. As a result, exercise-induced muscle soreness could be achieved without risk of injury to the trunk extensor muscles or the posterior ligaments (Stauber, 1989).

Following completion of the exercise protocol, participants were asked to avoid strenuous exercise that would further aggravate back pain symptoms prior to the next testing session. They were also urged not to take pain medication prior to follow-up measurement unless they were experiencing significant discomfort.

**DOMS session.** Participants attended a second laboratory-based session (DOMS session) approximately 48 hours (+/- 3 hours) following Baseline testing. Upon arrival, participants again completed the TSK and MPQ-SF-VAS and MPQ-SF-PRI. Participants were then randomly assigned to view either the low pain prime or the high pain prime. The following instructions were provided prior to viewing either prime: *Now you will be watching a brief video on this monitor, showing several people performing the movements you perform during this study. There will be no sound on these videos. Please pay attention to the behavior of each person in the video, as you will be asked about it at the conclusion of the study.* Participants were left alone in the room for the duration of the video prime. Following administration of the video prime,
participants performed the same series of standardized movement tasks as during the Baseline Session, again providing ratings of their expected pain and harm. This was followed by performance of the self-selected exertion and maximal isometric strength tasks.

Data Reduction and Analyses

Participants’ 100mm VAS appraisal ratings of expected pain and expected harm prior to movement task performance were averaged across 6 trials (3 movements, 2 trials of each). As such, the measures of pain and harm appraisal used in final analyses comprised composite measures of all expectancies across all movement trials. For ease of interpretation, averages, rather than raw summations of these variables were used. For example, participants’ ratings of expected pain across their enactment of standardized movement tasks was conducted via summation of 6 ratings on the 100mm VAS and then dividing by 6 to yield a single composite measure of pain appraisal. The same procedure was performed for VAS ratings of expected harm to yield a single composite measure of expected harm. This approach was supported by the high correlations between pain and harm appraisals across each trial of the standardized movement tasks (all \( r's = .85 - .98, \ p < .001 \)). For ease of examining/interpreting hypothesized interaction effects, difference/change scores were calculated for all dependent measures by subtracting scores collected during baseline from those collected during the DOMS session. For physical exertion measures (maximal isometric strength task, self-selected exertion), change scores yielded negative values, indicating a decrement or decline in performance from baseline to DOMS session. For example, a performance of 100 lbs. on the maximal isometric strength task during the DOMS session minus a performance of 150 lbs. at baseline would yield a change score of -50 lbs.

To examine whether, following DOMS induction, participants assigned to view the high
pain prime reported higher elevations in pain and harm appraisals than participants assigned to the low pain prime (Hypothesis 1), pain and harm change scores were entered into separate univariate analyses of variance (ANOVA) with Condition (high pain prime, low pain prime) as a between-participants factor. To determine whether the effect of Condition upon change in pain and harm appraisals was moderated by pain-related fear (Hypothesis 2), participants’ pain-related fear/TSK score (collected at baseline) was entered as a covariate in the above analyses.

In the event of a significant moderation effect (Condition x TSK interaction), post-hoc moderation analyses were conducted to determine whether the effect(s) were especially pronounced for individuals who exhibited high vs. low levels of pain-related fear. Post-hoc moderation analyses were conducted following the procedure described by Holmbeck (2002). This required additional ANOVA analyses performed using two new variables calculated based on the continuous centered moderator variable (TSK score). A “high fear” variable was generated by subtracting the value of one standard deviation (-1 SD) from centered TSK scores for all participants. Similarly, a “low fear” variable was created by adding the value of one standard deviation (+1SD) to all centered values of pain-related fear. This procedure did not categorize participants into two groups (i.e., high and low fear individuals), but rather, through manipulation of the 0 point of the moderator, allowed for examination of group effects of a continuous moderator variable upon the outcome. This was used to determine whether the moderating influence of pain-related fear was in the hypothesized direction (see hypotheses above) without the reduction in statistical power incurred through procedures such as grouping based on mean/median split or upper/lower quartiles or tertiles (Rose, Holmbeck, Coakley, & Franks, 2004; Holmbeck, 2002).

To examine whether, following DOMS induction, participants assigned to view the high
pain prime demonstrated greater decrement in performance on maximal isometric strength and self-selected exertion than participants assigned to the low pain prime (Hypothesis 3), change scores on these indices of physical exertion were entered into separate univariate analyses of variance (ANOVA) with Condition (high pain prime, low pain prime) as a between-participants factor. To determine whether the effect of Condition upon change in measures of physical exertion was moderated by pain-related fear (Hypothesis 4), participants’ pain-related fear/TSK score (collected at baseline) was entered as a covariate in the above analyses. In the event of a significant moderation effect (Condition x TSK interaction), the post-hoc moderation analyses described above conducted to determine whether the effect(s) were especially pronounced for individuals who exhibited high vs. low levels of pain-related fear.
RESULTS

Participant Sample Characteristics

The present sample consisted of 40 individuals (27 female; 13 male), aged 19 - 26 years ($M = 21.1; SD = 1.8$). The self-identified race ethnicity of participants was as follows: 19 Caucasian, 7 African-American; 6 Hispanic/Latino; 4 Asian; 3 multi-racial; 1 other. As displayed in Table 6, participants’ reported levels of pain-related fear at baseline, as measured by the TSK were comparable to mean levels obtained in healthy, non-clinical samples ($M = 38.93; SD = 10.79$; see e.g., Trost et al., 2011). Similarly, participant’s average level of pain upon arrival to the Baseline Session, as measured by the MPQ-SF-VAS ($M = 1.93; SD = 6.15$) and MPQ-SF-PRI ($M = .60; SD = 1.15$) indicated negligible pain symptoms during baseline. One-way ANOVA analyses using gender as a between-participant factor indicated that, with respect to both baseline and DOMS sessions, male and female participants did not significantly differ on self-report measures (MPQ-SF, TSK, activity appraisals) or physical performance (maximal isometric strength, self-selected exertion) ($F = .05 - 3.55; all p’s > .05$).

To ensure random assignment, one-way ANOVA indicated that participants assigned to the high pain prime and low pain prime conditions ($n = 20$ per group) did not differ at baseline with respect to self-reported pain intensity (MPQ-SF-VAS, MPQ-SF-PRI), pain-related fear, or pain and harm appraisals. Similarly, one-way ANOVA indicated that participants assigned to the high pain prime and low pain prime conditions did not differ at baseline with respect to physical performance measures (maximal isometric strength, self-selected exertion).

Table 6 shows means and standard deviations of the full sample at baseline and DOMS sessions. Using paired-sample t-tests, analyses indicated that participants demonstrated a
significant increase in self-reported pain from baseline to DOMS sessions (MPQ-SF-VAS; \( t = -6.28; p < .001 \), MPQ-SF-PRI; \( t = -17.97; p < .001 \)). Significant elevations were also observed in pain and harm appraisals of standardized movement tasks from baseline to DOMS sessions. Finally, analyses indicated significant decrements in maximal isometric strength and self-selected exertion (all \( p \) values <.001) from baseline to DOMS sessions. The above findings suggest that, following DOMS induction, participants experienced an increase in pain symptoms with co-occurring changes in activity appraisals and decrement in physical performance. Of note, no significant change was observed for participants’ pain-related fear (as measured by the TSK) from baseline to DOMS session. This lack of change, along with similar findings demonstrated by previous studies (see Trost et al., 2011), supported the use of baseline TSK score in moderation analyses. Therefore, all subsequent analyses refer only the TSK score collected during baseline session.

Table 6

*Means and Standard Deviations at Baseline and DOMS Sessions for Full Sample*

<table>
<thead>
<tr>
<th>Measure</th>
<th>Baseline session M (SD)</th>
<th>DOMS session M (SD)</th>
<th>( t )</th>
</tr>
</thead>
<tbody>
<tr>
<td>MPQ-SF-VAS</td>
<td>1.93 (6.14)</td>
<td>22.35 (19.97)</td>
<td>-6.28*</td>
</tr>
<tr>
<td>MPQ-SF-PRI</td>
<td>.60 (1.15)</td>
<td>22.28 (7.42)</td>
<td>-17.97*</td>
</tr>
<tr>
<td>TSK</td>
<td>38.93 (10.79)</td>
<td>39.23 (10.04)</td>
<td>-0.48</td>
</tr>
<tr>
<td>Expected appraisal (0-100mm VAS)</td>
<td>8.52 (11.69)</td>
<td>16.65 (19.58)</td>
<td>-4.32*</td>
</tr>
<tr>
<td>Experienced appraisal (0-100mm VAS)</td>
<td>7.90 (11.07)</td>
<td>15.96 (19.78)</td>
<td>-4.14*</td>
</tr>
<tr>
<td>Self-selected exertion task (lbs.)</td>
<td>26.63 (8.80)</td>
<td>21.25 (9.72)</td>
<td>4.59*</td>
</tr>
<tr>
<td>Maximal isometric strength (lbs.)</td>
<td>111.81 (56.64)</td>
<td>79.44 (47.51)</td>
<td>4.02*</td>
</tr>
</tbody>
</table>

*Note. N = 40. *\( p < .001 \)*
Correlation of Pain-related Fear and Dependent Measures

Table 7 shows Pearson product-moment correlation coefficients for pain-related fear and all dependent measures used in analyses. Participants’ pain-related fear, as measured by the TSK, was not significantly correlated with pain intensity (as measured by the MPQ-SF-VAS and MPQ-SF-PRI) during the baseline session, but was significantly correlated with both indices of pain intensity during the DOMS session. In addition, pain-related fear was significantly correlated with expected pain and expected harm both at baseline and DOMS sessions. As with pain intensity, pain-related fear was significantly correlated with performance on the self-selected exertion task during the DOMS session, but not during baseline. Surprisingly, pain-related fear was not significantly associated with performance of the maximal isometric strength task at baseline or DOMS sessions. Measures of pain intensity did not significantly co-vary with any other measures during the baseline session. However, during the DOMS session, pain intensity (MPQ-SF-PRI) was significantly correlated with all measures of appraisal and exertion. The MPQ-SF-VAS was significantly correlated with appraisals and self-selected exertion, but not maximal isometric strength. As expected, pain and harm appraisals at baseline and DOMS sessions were highly inter-correlated. There was likewise a significant correlation among measures of exertion (maximal isometric strength and self-selected exertion) during both baseline and DOMS sessions. During the baseline session, pain and harm appraisals were significantly correlated with the self-selected exertion, but not maximal isometric strength. During the DOMS session, a similar pattern was observed with pain and harm appraisals significantly associated with self-selected exertion, but not maximal isometric strength.
<table>
<thead>
<tr>
<th>Variable</th>
<th>1.</th>
<th>2.</th>
<th>3.</th>
<th>4.</th>
<th>5.</th>
<th>6.</th>
<th>7.</th>
<th>8.</th>
<th>9.</th>
<th>10.</th>
<th>11.</th>
<th>12.</th>
<th>13.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Pain-related fear (TSK)</td>
<td>-</td>
<td>.22</td>
<td>.13</td>
<td>.52**</td>
<td>.52**</td>
<td>.18</td>
<td>-22</td>
<td>.61**</td>
<td>.78**</td>
<td>.68**</td>
<td>.63**</td>
<td>-15</td>
<td>-46</td>
</tr>
<tr>
<td>2. Baseline pain intensity (MPQ-SF-VAS)</td>
<td>-</td>
<td>.47**</td>
<td>-12</td>
<td>-12</td>
<td>.17</td>
<td>.14</td>
<td>.05</td>
<td>-10</td>
<td>-19</td>
<td>-20</td>
<td>.27</td>
<td>.41**</td>
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<td>3. Baseline pain intensity (MPQ-SF-PRI)</td>
<td>-</td>
<td>.03</td>
<td>.06</td>
<td>.16</td>
<td>-12</td>
<td>-15</td>
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<td>-14</td>
<td>.28</td>
<td>.08</td>
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<tr>
<td>4. Baseline expected pain</td>
<td>-</td>
<td>.99**</td>
<td>.05</td>
<td>-37*</td>
<td>.43**</td>
<td>.55**</td>
<td>.79**</td>
<td>.81**</td>
<td>-16</td>
<td>-42**</td>
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<tr>
<td>5. Baseline expected harm</td>
<td>-</td>
<td>.02</td>
<td>-37*</td>
<td>.39*</td>
<td>.53**</td>
<td>.77**</td>
<td>.80**</td>
<td>-13</td>
<td>-44**</td>
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<td>6. Baseline max isometric strength</td>
<td>-</td>
<td>.34*</td>
<td>.20</td>
<td>.14</td>
<td>.24</td>
<td>.19</td>
<td>.53**</td>
<td>.21</td>
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<tr>
<td>7. Baseline self-selected exertion</td>
<td>-</td>
<td>.12</td>
<td>-28</td>
<td>-31</td>
<td>-.33*</td>
<td>.41**</td>
<td>.68**</td>
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<tr>
<td>8. DOMS pain intensity (MPQ-SF-VAS)</td>
<td>-</td>
<td>.70**</td>
<td>.55**</td>
<td>.54**</td>
<td>-18</td>
<td>-34*</td>
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<tr>
<td>9. DOMS pain intensity (MPQ-SF-PRI)</td>
<td>-</td>
<td>.81**</td>
<td>.79**</td>
<td>-.32*</td>
<td>-.62**</td>
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<tr>
<td>10. DOMS expected pain</td>
<td>-</td>
<td>.98**</td>
<td>-.21</td>
<td>-.54**</td>
<td></td>
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<tr>
<td>11. DOMS expected harm</td>
<td>-</td>
<td>-.26</td>
<td>-.55**</td>
<td></td>
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<tr>
<td>12. DOMS max isometric strength (lbs.)</td>
<td>-</td>
<td>.52**</td>
<td></td>
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<tr>
<td>13. DOMS self-selected exertion (lbs.)</td>
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*Note. *p<.05 **p<.01.*
Test of Hypotheses

Hypothesis 1: Following DOMS induction, participants assigned to view the high pain behavior video prime would report higher elevations in expected pain and expected harm appraisals of physical activity than participants assigned to view the low pain behavior video prime.

A univariate ANOVA of participants’ appraisal changes scores indicated that there was a significant between-group difference in change in expected pain. As seen in figure 7, participants assigned to the high pain prime reported greater increase in pain appraisal from baseline to DOMS session than participants in the low pain prime condition ($F[1, 39] = 5.76; p = .021$). A similar pattern was observed for harm appraisal scores. As seen in Figure 8, participants in the high pain prime condition showed greater increase in expected harm than those assigned to the low pain prime ($F[1, 39] = 7.6; p = .009$).

Figure 7. Changes in pain appraisals: Main effect of video prime.
Hypothesis 2: The impact of video prime upon appraisals (i.e., greater increase in appraisals in response to the high pain behavior video prime compared to the low pain behavior video prime) would be particularly pronounced among participants with high pain-related fear.

When entered as a covariate in the above analyses, pain-related fear was found to moderate the impact of Condition on participants’ pain appraisal change scores ($F[2, 38] = 5.2; p = .03)$. Specifically, individuals with higher pain-related fear showed a significant Condition main effect – i.e., high fear participants assigned to the high pain prime showed greater increase in pain appraisal from baseline to DOMS session (higher change score) compared to high-fear participants assigned to the low pain prime ($F[1, 39] = 13.02; p = .001)$. In contrast, low fear participants did not show a main effect of Condition. Specifically, individuals with lower pain-related fear did not show differential changes in pain appraisal from baseline to DOMS session as a function of viewing the high or low pain prime ($F[1, 39] = .13; p = .72$). See Figure 9.

Similarly, the between-group difference in change in expected harm also had a significant interaction with pain-related fear ($F[2, 38] = 7.93; p = .008$), such that high fear individuals
experienced a significant group effect ($F[1, 39] = 15.17; p < .000$), while their low fear counterparts did not ($F[1, 39] = .08; p = .78$). See figure 10.

*Figure 9.* Changes in pain appraisals: Interaction with pain-related fear.

*Figure 10.* Changes in harm appraisals: Interaction with pain-related fear.
Hypothesis 3: Following DOMS induction, participants assigned to view the high pain behavior video prime would show greater reduction in physical exertion (maximal isometric strength and self-selected exertion) than participants assigned to the low pain behavior video prime.

A univariate ANOVA of participants’ change in performance on the maximal isometric strength task indicated that there was a significant between-group difference in change physical exertion. As seen in figure 11, participants assigned to the high pain prime demonstrated larger decrement in performance from baseline to DOMS session than participants in the low pain prime condition ($F[1,39] = 4.73; p = .036$). A similar pattern was observed for change in performance on the self-selected exertion task. As seen in Figure 12, participants in the high pain prime condition showed greater decrease in selected weight than those assigned to the low pain prime ($F[1,39] = 5.15; p = .03$).

![Figure 11](image_url)

**Figure 11.** Changes in maximal isometric strength: Main effect of video prime.
Hypothesis 4: The impact of video prime upon physical exertion (i.e. greater decrement in response to the high pain behavior video prime compared to the low pain behavior video prime) would be particularly pronounced for participants with high pain-related fear.

When entered as a covariate in the above analyses, pain-related fear was found to moderate the impact of Condition on participants’ change in maximal isometric strength performance ($F[2,38] = 4.90; p = .033$). Specifically, individuals with higher pain-related fear showed a significant Condition main effect – i.e., high fear participants assigned to the high pain prime showed larger decline in maximal isometric strength performance from baseline to DOMS session (lower change score) compared to high-fear participants assigned to the low pain prime ($F[1,39] = 9.62; p = .004$). In contrast, low fear participants did not show a main effect of Condition. Specifically, individuals with lower pain-related fear did not show differential changes in maximal isometric strength performance from baseline to DOMS session as a function of viewing the high or low pain prime ($F[1,39] = .002; p = .96$). See Figure 13.

Figure 12. Changes in self-selected weight task: Main effect of video prime.
Similarly, the between-group difference in change in self-selected exertion also had a significant interaction with pain-related fear (F[2, 38] = 4.08; \( p = .05 \)), such that high fear individuals experienced a significant group effect (F[1, 39] = 6.73; \( p = .014 \)), while their low fear counterparts did not (F[1, 39] = .078; \( p = .78 \)). See figure 14.

Figure 13. Changes in maximal isometric strength: Interaction with pain-related fear.

Figure 14. Changes in self-selected weight task: Interaction with pain-related fear.
DISCUSSION

Review and Examination of Findings

The present study sought to examine the role of observational learning and pain-related fear in appraisals of physical activity and physical exertion following an analog to acute back injury. Participants engaged in a procedure to induce low back pain muscle soreness (DOMS) and subsequently observed a video prime showing either high or low pain behavior. In line with hypothesized effects, participants assigned to view the high pain video prime showed greater elevation in pain appraisal in anticipation of standardized movement tasks from baseline to DOMS session. Those assigned to the high pain prime condition demonstrated greater decrement across two indices of physical exertion (isometric strength and self-selected weight). Likewise, in line with hypotheses, the impact of the video prime upon changes in appraisal and physical exertion was moderated by baseline ratings of pain-related fear. Specifically, only those with high pain-related fear exhibited a significant differential effect in change in appraisal and exertion when exposed to high expressions of pain vs. low expressions of pain in video models performing similar physical activities.

From a methodological perspective, the current study sought to address limitations in existing studies of observational learning and pain. Trost et al. (2014) found a significant observational learning effect among healthy individuals such that pain and harm appraisals of daily tasks increased following participants’ observing high expressions of pain in other individuals. To address limitations noted by Trost and colleagues regarding the ecological validity of the sample, the present study utilized DOMS induction as an analog of acute musculoskeletal injury. Another key limitation is that prior studies required participants to provide appraisals of imagined physical activities, for instance, by having them rate photographs
of individuals engaging in physical tasks. Accordingly, findings are the first to demonstrate that observation of pain in others affects both appraisals of corresponding physical activity and actual physical exertion. As such, this study supports the importance of processes/mechanisms that may facilitate observational learning responses. Discussion of such processes spans behavioral, attentional, cognitive, and interpersonal domains.

The behavioral perspective (e.g., Bandura, 1969) proposes that observation of the behavior of others, along with observation of its consequences, has an effect of both conveying information and shaping behavior. Social learning theory (Bandura, 1963) emphasizes that direct contact with environmental contingencies is not necessary for learning to occur. Broadly, learning can be considered any change in behavior as a result of environmental contingencies, even if the nature these contingencies is observed rather than experienced (Bandura, 1963). A visual stimulus such as the video prime viewed by participants in the present study can thus serve to define environmental contingencies. Participants in the current study viewed video subjects performing movement (behavior), while exhibiting high or low expressions of pain; pain expression is reasonably conceptualized as an aversive consequence of behavioral performance and accompanying pain, harm, or injury. The potential impact of this visual information may have promoted patterns of avoidance observed among a segment of the sample. According to social learning theory, and in line with the fear-avoidance model (Vlaeyen & Linton, 2000), behavioral avoidance during physical exertion would be negatively reinforced by a perceived evasion and/or removal of perceived aversive consequences. Ironically, a pattern of behavioral avoidance reinforced by perceived escape from pain and harm is hypothesized to facilitate the transition from acute pain following injury to a more long-standing pattern of pain, avoidance, and disability (Vlaeyen & Linton, 2000).
The results of this study, together with previous findings such as those of Trost and colleagues (2014) suggest that observational learning effects in the context of pain appear, in part, to be dependent on pre-established psychological characteristics – namely, pain-related fear. The results also suggest that observational learning processes may, in turn, play a prominent role in the maintenance or exacerbation of pain-related fear and fear-based behaviors, enabling the path to disability. In sum, it appears plausible that pain-related fear and associated negative outcomes can be maintained by observation of environmental pain cues.

With respect to learning about pain, the current findings call attention to the importance of observer characteristics such that individuals with high pain-related fear selectively responded to stimuli linking pain with injury (i.e., high pain prime) whereas there was no behavioral impact (and perhaps no informational value) for low fear participants. To account for this differential effect, it may be important to consider attentional bias. Attentional bias has been defined previously in cognitive psychology literature as the tendency for perception to be selective due to the influence of cognitive or affective processes (see Bar-Haim et al., 2007). The basic attentional demand of pain has been well-documented in both clinical and nonclinical populations (Eccleston & Crombez, 1999). Importantly, the attentional prioritization of pain and its disruptive function has been shown to be enhanced among individuals expressing greater fear of pain or catastrophic pain cognitions (Keogh et al., 2001); high fear individuals likewise show difficulty disengaging from pain cues (Van Damme et al., 2004a, b) and performing distraction tasks (Goubert et al., 2004a, b; Van Damme et al., 2008). Previous research has suggested that individuals with high fear of pain are attentionally biased towards not only pain itself, but any cues relevant to pain, including expression of pain in others (Vervoort, Trost & Van Ryckeghem, 2013; Sullivan et al., 2006).
In the context of this study, participants’ acquisition of information from video primes may have been impacted by attentional processes mediated by pain-related fear. High fear participants in the current study may have preferentially directed attention toward (or, possibly had difficulty discounting or disengaging from) threatening pain-salient information in the High Pain Prime. Further, the current study introduced pain cues in the form of video of pain expression relevant to participants’ physical condition, situational demands (i.e., movement performance), possibly making threatening information more salient. Unlike their high fear counterparts, individuals with low pain-related fear may not have readily directed attention to the painful or threatening aspects of the high pain video, or may have more readily disengaged/coped with threatening cues, thereby minimizing any potential for observational learning.

While the role of attentional bias in the present study is speculative, seminal social learning theory identified attention to the information displayed by models as a key prerequisite for observational learning to occur (Bandura, 1977). Future iterations of this research would be enhanced by inclusion of methods to measure attentional bias to pain cues such as those presented in the video prime. A variety of methods for assessing attentional bias have been established in cognitive psychology literature, in particular the “visual dot-probe” paradigm (MacLeod, Mathews, & Tata, 1986). The dot-probe and similar paradigms have already been applied to examination of attentional bias toward pain cues in pain research with both children and adult samples (Vervoort, Trost, & Van Ryckeghem, 2013; Trost et al., 2016).

Expanding on this concept, attentional processes may be guided by existing pain schemas which include pain-related fear. High fear individuals are hypothesized to have pre-established schemas which emphasize the painful/harmful nature of movement (Pincus & Morley, 2001). As
such, observation of high expressions of pain during movement are likely to support this schema, reinforcing the connection between pain, harm, and avoidance. Further, as pain-related fear is associated with behavioral avoidance of painful physical exertion, opportunities to receive corrective feedback regarding maladaptive beliefs are limited, further strengthening the schematic structure. Similar schema-confirming processes are demonstrated by high fear pain sufferers’ difficulty generalizing information about the safety (or, pain-free consequences) of physical activity across various physical tasks (Crombez et al., 2002; Goubert et al., 2002, 2005). By contrast, high fear pain sufferers demonstrate relative ease in generalizing information about potential pain and harm (Goubert et al., 2005).

In future studies, it would be valuable to examine how observational learning and underlying processes may be used to challenge existing pain-related schemas. For example, would viewing others’ participation in potentially painful/injurious behavior that was observed to not result in negative repercussions (e.g., pain or injury) produce changes in appraisal and/or exertion for individuals with high pain related fear? It is worth noting that current clinical approaches aimed at reducing pain-related fear and, by extension, disability center on the idea of challenging established fear of movement/(re)injury. Graded exposure in-vivo (Vlaeyen et al., 2001; Leeuw et al., 2008) encourages patients to perform specific physical activities in order to disconfirm fears regarding the potential for harm and (re)injury. Present study findings suggest that another possible avenue of disconfirmation may be via observation of others engaged in threatening movement and activity. In addition, it is worth considering whether interpersonal factors such as observers’ perceived similarity with the observed models would mediate these disconfirming effects or, in fact, result in further reinforcement of maladaptive pain schemas. That is, if patients did not consider observed models to be similar (i.e., not in pain and therefore
not disabled), would it detract from the potential for adaptive learning effects to occur? There are numerous untapped directions for exploring the effect of observation on learning and behavior in the pain context. Such research would likely provide useful input for therapeutic interventions in the clinical setting.

As noted above, pain is a subjective process, which occurs within an interpersonal environment. Accordingly, it is important to examine how potential interpersonal factors may moderate the effect of observational learning on responses to pain. High fear individuals showed greater response to high expressions of pain which may, in part, be due to common factors shared between the participants and the individuals depicted in the video. Bandura and colleagues (1977) noted that interpersonal factors modified the observational learning process. For example, participants’ positive or negative impressions of subjects depicted in video primes would have likely enhanced or reduced learning effects, respectively. It is conceivable that high fear individuals displayed more positive attitudes toward subjects expressing high pain behavior during movement than their low fear counterparts, though this hypothesis was not directly tested. In addition, Helsen et al. (2015) found that dispositional “empathy” was significant in acquiring fear-based cognitive responses to pain. The investigators suggests that the capacity to engage in “perspective-taking” of another in pain is fundamental to observational learning acquisition (Goubert et al., 2011; Goubert et al, 2013).

A discussion of empathy in this context is relevant in that, while it is considered a dispositional construct it, in effect, has been shown to influence an interpersonal process such as observational learning. As noted in the background section, models of chronic pain, including the Fear-Avoidance Model, have historically made a distinction between intrapersonal factors (e.g., pain-related fear, catastrophizing) which influence responses to pain as opposed to interpersonal
factors from one’s social environment (e.g., spousal responses) which serve as contingencies which establish or maintain pain behavior (see Fordyce, 1976; Crombez et al., 2012). However, recent research including the results of the current study obscure this distinction as intrapersonal factors are increasingly shown to moderate and be moderated by, environmental factors. This acknowledgement in the field of pain research has been reflected in the most recent iteration of the Fear Avoidance Model (Vlaeyen, Crombez, & Linton, 2016). These revisions continue to emphasize the centrally important role of pain-related fear in driving avoidant responses post-injury but also likewise acknowledge the apparent reciprocal interaction of these factors within the social environment.

**Limitations to the Current Study and Future Directions**

In addition to the noted directions for future research, the current study is characterized by a number of limitations which can be addressed in future investigations. It is worth noting that the scope the study was limited to the examination of one potential mechanism (i.e., observational learning) by which fearful responses are maintained. This study did not examine mechanisms related to initial acquisition or development of pain-related fear. The question of whether fear of pain is a dispositional characteristic versus a learned phenomenon has garnered some interest, including studies of the heritability of fear of pain (see Trost et al., 2015). Echoing findings by Trost et al. (2011), a study which also induced DOMS in healthy participants, the present study demonstrated that participants’ ratings of pain-related fear (as measured by the TSK) did not significantly differ between baseline and DOMS sessions. That is, participants’ pain-related fear did not change following induction of low-back pain. One possible interpretation of these findings is that pain-related fear is a construct stable across situations, times, and even in the presence or absence of pain. However, this finding may also illustrate a
weakness in the ecological validity of DOMS as an experimental model of acute/subacute pain from injury. As noted above, the DOMS conferred a number of benefits as an experimental pain-induction. Specifically, it allowed for localization of pain to the lower back and generally mimics symptoms of musculoskeletal injury. Nevertheless, the present sample’s average pain intensity ratings of 22.35 and 22.28 on the MPQ-SF VAS and PRI, respectively following DOMS induction are significantly lower than those reported in clinical subacute and chronic low back pain samples (Chandra et al., 2011). In addition to ecological differences in the intensity/severity of pain, the temporal nature of DOMS may differ compared with that of actual injury. As noted previously, DOMS is a time-limited condition, typically peaking within 36 - 48 hours, and resolving within 72 hours post-induction. In the case of actual musculoskeletal injury, individuals often have no knowledge of resolution.

Specific limitations of the current investigation can inform future methodology. One such limitation was the use of physical exertion measures only proximal to actual behavioral engagement or avoidance. It is noteworthy that these performance measures were conducted in laboratory conditions under observation of research personnel. Further, they do not necessarily address the impact of pain on performance of everyday tasks (e.g., physical function). In their examination of pain-related fear in prediction of responses to DOMS, Trost et al., (2011) included a measure of “interference” to account for this parameter. Future studies might be well-served to incorporate measures of interference due to DOMS which span social, occupational, and daily-living tasks (for example, see Amtmann et al., 2010). To account for inter-individual variation in the timing of the peak of DOMS symptoms, it may be beneficial to conduct ambulatory data collection on pain intensity and in-vivo levels of activity/interference. Previous studies have made effective use of mobile data collection through phone and web-based
interfaces (Jacob et al., 2012). Future studies would also benefit from measurement of participant’s own pain behavior expressions while performing movement tasks. Given the subjective nature of nonverbal facial and postural expressions of pain, quantification of the “amount” or “intensity” of pain expression can be problematic. Nevertheless, highly elaborate, quantitative methods for measuring and scoring pain expression have been developed for adults (Ekman & Friesen, 1978; Prkachin & Mercer, 1989) and children (Chambers et al., 1996; McGrath et al., 1985). Measurement of pain expression behavior would comprise behavior which most closely corresponds to that observed by participants in the video primes and which is subsequently projected to others in the environment.

Conclusion

The current study examined whether observing a video prime showing high expression of pain could impact the appraisals and exertion of individuals who received an experimental form of back pain. Of further interest was whether this relationship was moderated by participants’ level of pain-related fear. Consistent with hypotheses, observational learning responses were observed for all outcome measures and significantly differed for individuals reporting high versus low levels of pain-related fear. In response to a video prime showing high expressions of pain, participants with high pain-related fear showed elevated pain appraisals and lower physical exertion. By contrast, participants with low pain-related fear showed no difference in change in appraisal and exertion from baseline to DOMS sessions regardless of which video prime was viewed, indicating that the prime had a selective impact on high fear participants. Importantly, no significant differences between video prime groups were observed at baseline (prior to prime exposure), but only emerged after participants viewed the video prime. The current findings offer insight regarding a possible mechanism by which pain-related fear is maintained via
interpersonal processes. The results of the present investigation underscore the need for further research into the impact of observation on pain responses, and more broadly, the impact of *interpersonal* processes as they relate to the formation and maintenance of *intrapersonal* processes such as pain-related fear. Improvements in methodology, including ecologically-valid methods of pain-induction and more comprehensive behavioral metrics would be of significant benefit. Nevertheless, the current study is among the first to demonstrate that a central orientation to pain (i.e., pain-related fear) differentially facilitates the impact of observational learning.
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