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The Fear-Avoidance Model and Persistent Post-Concussion Symptoms in University Students

Michael Broggi
University of Massachusetts Amherst

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The Fear-Avoidance Model and Persistent Post-Concussion Symptoms in University

Students

A Dissertation Presented

by

MICHAEL J. BROGGI JR.

Submitted to the Graduate School of the
University of Massachusetts Amherst in partial fulfillment
of the requirements for the degree of

DOCTOR OF PHILOSOPHY

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Clinical Psychology

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MICHAEL J. BROGGI JR.

Approved as to style and content by:

Rebecca E. Ready, Chair

Christopher Martell, Member

Lori Astheimer, Member

Douglas Martini, Member

Maureen Perry-Jenkins, Department Head
Psychological and Brain Sciences

ABSTRACT

THE FEAR-AVOIDANCE MODEL AND PERSISTENT POST-CONCUSSION SYMPTOMS IN UNIVERSITY STUDENTS

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MICHAEL J. BROGGI JR., B.A., UNIVERSITY OF RHODE ISLAND

M.A. SOUTHERN CONNECTICUT STATE UNIVERSITY

M.S., UNIVERSITY OF MASSACHUSETTS AMHERST

Ph.D., UNIVERSITY OF MASSACHUSETTS AMHERST

Directed by: Rebecca E. Ready

Ten to 20% of individuals who sustain a concussion continue to experience symptoms outside the typical window of recovery. Pre-morbid and post-injury anxiety are risk-factors for persistent post-concussion symptoms (PCS). However, mechanisms linking anxiety and persistent PCS are unclear. The fear-avoidance model of disability could add clarity to associations between anxiety and persistent PCS. This study examined if factors of the fear-avoidance model (e.g., catastrophic thinking, fear of symptoms, anxiety sensitivity) would mediate the association between persistent PCS and maladaptive coping responses (e.g., avoidance, limiting activities) following concussion. To achieve this aim, university students ($N = 43$) with resolved concussion ($n = 32$) and persistent PCS ($n = 11$) completed measures of catastrophic thinking, fear of PCS, and anxiety sensitivity during a first study session. Participants returned 1-week later to report their level of physical activity since the first study session via a smartphone pedometer app and complete measures of cognitive avoidance and limiting physical activity. This study was underpowered and unable to determine if features of the fear-avoidance model were

associated with avoidance and limiting behaviors in university students following concussion. However, the persistent PCS group reported higher levels of fear of PCS, catastrophic thinking, limiting behavior, and averaged fewer daily steps than the resolved group. Fear of symptoms, catastrophic thinking, and avoidance of physical activities could be potential psychotherapy targets for individuals who experience persistent PCS.

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CHAPTER 1

INTRODUCTION

1.1 Overview

An estimated 1.2% of the population sustains a concussion annually (Langer et al., 2020) and 10-20% of these individuals experience persistent Post Concussive Symptoms (PCS, e.g., Ruff, 2005; Stranjalis et al., 2008). PCS are a constellation of cognitive, emotional, and somatic symptoms following concussion. Persistent PCS typically refers to experiencing at least three symptoms of concussion that continue for more than 3-months after a concussion and interfere with functioning (Boake et al., 2005; Voormolen et al., 2018). One factor hypothesized to maintain or exacerbate PCS is pre-existing and/or post-injury anxiety (e.g., Broshek et al., 2015; Iverson et al., 2017; Ponsford et al., 2019), but the nature of the association between anxiety and persistent PCS is not well characterized.

The fear-avoidance model might help clarify associations between anxiety and PCS (Figure 1). This model posits that after an injury, the interpretation of symptoms can lead an individual down one of two pathways (Leeuw et al., 2007). One route leads to recovery via low anxiety responses to the symptoms, whereas the second path exacerbates disability because of anxiety-based reactions to symptoms. Anxiety-based reactions to symptoms can worsen symptoms and reduce engagement in behaviors that facilitate functional gains and recovery (Vlaeyen & Linton, 2000). The fear-avoidance model has been applied to several medical conditions (e.g., headache, knee ligament

reconstruction) to explain how anxiety-based avoidance behaviors lead to continued pain and disability (Coronado et al., 2021; Rogers et al., 2020).

Some aspects of the fear-avoidance model have been tested in people who sustained a concussion. Subtypes of anxiety that are included in the model (i.e., anxiety sensitivity, catastrophic thinking, and fear-based activity avoidance) are associated with poor outcomes over 6-months following concussion (Albanese et al., 2017; Silverberg et al., 2018; Wood et al., 2014). In non-clinical populations, persons with high levels of anxiety sensitivity and engagement in catastrophic thinking may avoid activities and limit their behaviors (Eifert & Heffner, 2003; Keough et al., 2010). Avoiding activities and limiting of behaviors after a 24-48 hour period of rest is counterproductive to concussion recovery (McCrory et al., 2017). Failure to re-engage in activities after concussion is associated with greater PCS and slower symptom resolution (Thomas et al., 2015).

A test of all components of fear-avoidance model with objective cognitive and physical outcome measures has yet to be conducted in the context of persistent PCS. Applying the fear-avoidance model to persistent PCS could be useful in identifying treatment targets (e.g., catastrophic thinking) that are associated with avoidance and behavioral limitations. Identification of treatment targets could help practitioners select appropriate psychotherapy interventions (e.g., exposure, mindfulness, thought monitoring and restructuring) to treat persistent PCS.

1.2 Concussion

A concussion, or a mild traumatic brain injury (mTBI), is caused by biomechanical forces (e.g., rapid acceleration or deceleration) to the head or body that are

transmitted to the brain (Meaney & Smith, 2011). These biomechanical forces cause neurophysiological dysfunction and result in an alteration of brain functioning (Giza & Hovda, 2001). Concussions can acutely (e.g., ≤ 7 days) alter cognitive, emotional, and motor function, often resulting in confusion, disorientation, fatigue, irritability, gait/balance disturbance, and slowed reaction times (McCrory et al., 2017). Current best practice for concussion recovery calls for a brief period of cognitive and physical rest (e.g., 24-48 hours) followed by a gradual increase in activity that does not provoke PCS (McCrory et al., 2017).

Increasing cognitive and physical activity following concussion is a relatively new concept in managing concussion. At the First International Conference on Concussion in Sport, best practices called for “complete rest” until symptom resolution (Aubry et al., 2001). However, complete cognitive and physical rest following concussion is associated with poor outcomes such as greater PCS reporting and slower symptom resolution (Thomas et al., 2015). Current best practices for concussion management call for gradual increases in activity following concussion (McCrory et al., 2017). Recent reviews and meta-analyses from randomized controlled trials find that physical activity (i.e., subthreshold aerobic activity $< 80\%$ heart rate) accelerates recovery following concussion and in persons experiencing persistent PCS (Haider et al., 2021; Shen et al., 2021). For example, individuals who engage in at least moderate activity (e.g., jogging, biking) recover from concussion on average 21-days faster than individuals who engage in no or only light activity (Coslick et al., 2020).

1.3 Persistent PCS

The classification and diagnosis of persistent PCS has been inconsistent in the concussion literature. According to the most recent consensus statement on concussion in sport (McCrory et al., 2017), persistent PCS occurs in individuals who continue to experience symptoms of concussion beyond expected recovery time (i.e., >14 days in adults). The DSM-IV-TR (American Psychiatric Association, 2000) criteria for “post-concussion syndrome” are more specific and include cognitive deficit in attention and/or memory, three or more PCS symptoms that begin or get worse following head trauma, continue for 3-months or longer, and interfere with social or occupational functioning (e.g., Boake et al., 2005; Morgan et al., 2015). Whereas ICD-10-CM (World Health Organization, 1993) criteria for persistent PCS include history of TBI and the presence of three or more PCS symptoms (i.e., headache, dizziness, fatigue, irritability, insomnia, concentration or memory difficulties, and/or intolerance of stress, emotion, or alcohol), the ICD-10 criteria does not require PCS to interfere with social or occupational functioning and also includes atypical PCS complaints not found in the concussion literature (e.g., intolerance of stress, emotion, or alcohol; Kashluba et al., 2006). Due to the different definitions of persistent PCS, rates of persistent PCS vary from study to study (Wäljas et al., 2015).

A second challenge in persistent PCS research is that PCS are not specific to concussion. Post-concussion-like symptoms (e.g., cognitive difficulties, fatigue, headache, sleep disturbances) are common in the general population (Lange et al., 2010; Petrie et al., 2014). Control participants in concussion studies often endorse some degree of PCS, which leads to difficulty distinguishing between concussion and control groups,

especially when using three symptoms as a cut-off to define group classification (Kashluba et al., 2006). Despite these challenges, progress has been made in identifying individuals who are more likely to experience persistent PCS.

Multiple pre-existing risk factors for persistent PCS have been identified such as number of previous concussions, pre- and/or post-injury psychiatric symptoms, and female sex (e.g., Broshek et al., 2015; McCrea et al., 2011; Meares et al., 2011; Ponsford et al., 2012). Some types of PCS pose greater risk for persistent PCS than others. For example, in the first week after sustaining a concussion, individuals who report more severe PCS and cognitive dysfunction are at increased risk of prolonged recovery (McCrea et al., 2013). Persons who report new PCS in the months after injury (e.g., memory and concentration problems) are also at increased risk for persistent PCS (Meares et al., 2011). Beyond 3-months post-concussion, about 21-42% of individuals report three or more PCS (Dischinger et al., 2009; Hou et al., 2012) and after 6 months, about 10-20% of individuals report persistent PCS (e.g., Ruff, 2005; Stranjalis et al., 2008).

1.4 Anxiety and Persistent PCS

Experiencing anxiety prior to concussion is a robust predictor of persistent PCS (e.g., Broshek et al., 2015; Corwin et al., 2014; Martin et al., 2020; Morgan et al., 2015). Individuals with pre-existing anxiety diagnoses are 1.4 times more likely to experience PCS 4-weeks post-concussion (Zemek et al., 2016). At 4-weeks post-concussion, 66% of adolescents and young adults with a history of anxiety disorders report PCS compared to 32% of the total sample (Eisenberg et al., 2013). Pediatric patients with a history of

anxiety take about twice as long to return to normal activities (e.g., academics, sports) following concussion than children and adolescents with no history of anxiety (Corwin et al., 2014; Martin et al., 2020). At a 1-year follow-up, adults with persistent PCS (i.e., ≥ 3 PCS symptoms and ≥ 2 functional disabilities) reported greater levels of pre-injury anxiety than adults who reported full symptom resolution (Oldenburg et al., 2018).

Individuals who experience anxiety in the weeks following concussion are also at increased risk of persistent PCS. Elevated anxiety symptoms in the first week following concussion are predictive of persistent PCS at 3-months (Dischinger et al., 2009; Ponsford et al., 2012). Anxiety symptoms at 3-months post-concussion also predict PCS severity at 12-months (Sigurdardottir et al., 2009). Further, adults who endorse clinically significant levels of anxiety at 6-months post-injury are also more likely to report higher levels of PCS and incomplete recovery from concussion (Ponsford et al., 2019).

The nature of the association between anxiety and PCS remains unclear. It is logical to assume that some individuals, especially those who experience anxiety, may develop a fear of experiencing PCS. To relieve their fear of provoking symptoms, they may avoid activities which promote recovery.

1.5 Fear-Avoidance Model

The fear-avoidance model is a useful theoretical framework to understand psychological mechanisms that lead to or exacerbate chronic medical conditions. This model was developed to describe how patients with chronic lower back pain hold beliefs about their condition which promote fear, avoidance, and continued symptoms (e.g., Lethem et al., 1983; Philips, 1987). The fear-avoidance model posits that after an injury,

the way in which symptoms are interpreted can follow one of two pathways. If an individual does not have a fearful and catastrophic interpretation of symptoms, they are likely to engage in daily activities that promote recovery (e.g., Asmundson et al., 2004; Crombez et al., 2012; Leeuw et al., 2007). However, if symptoms are catastrophized and interpreted as threatening, a fear of the symptoms may be established, which may lead to hypervigilance of bodily sensations, avoidant behaviors, and continued symptoms (Vlaeyen & Linton, 2000).

Cognitive-biases and predispositions for anxiety such as catastrophic thinking and anxiety sensitivity are potential mediators of the association between injury and disability in the second pathway in the Fear Avoidance Model (Asmundson et al., 2004; Figure 1). Catastrophic thinking is a cognitive coping-style defined as the anticipation of exaggerated negative or catastrophic consequences (e.g., Crombez et al., 2004; Sullivan et al., 2001). Whereas anxiety sensitivity is the fear of bodily-sensations and belief the sensations will have harmful consequences (Reiss & McNally, 1985). Both anxiety sensitivity and catastrophic are associated with greater symptom complaints, symptom severity, recovery time, and level of disability following musculoskeletal injury (Otto, 2019; Roh et al., 2014; Vranceanu et al., 2014).

The fear-avoidance model has proven useful in examining associations between pain, fear, and avoidance in several medical conditions. For example, patients with moderate-high levels of fear-avoidance (e.g., fear of pain/re-injury, pain catastrophizing) are significantly more likely to have poor outcomes following anterior cruciate ligament reconstruction surgery than patients with lower levels of fear-avoidance (Coronado et al., 2021). Fear, anticipation of pain, and the subsequent avoidance of headache triggers (e.g.,

cognitive effort, social activities) increases sensitivity to headache triggers, reliance on headache medication, and the development of psychological disorders (Rogers et al., 2020). Thus, there is evidence to support the application of the fear-avoidance model to medical conditions other than chronic lower-back pain.

1.6 The Fear-Avoidance Model and PCS

In applying the fear-avoidance model to persistent PCS, individuals may fear developing PCS, which may lead to the avoidance of behaviors that might promote recovery. Their fear may present as catastrophic thinking of PCS symptoms, and increased hypervigilance of symptoms (e.g., anxiety sensitivity). Indeed, catastrophizing, fear avoidance behaviors, and PCS are significantly intercorrelated in concussion samples, suggesting the fear-avoidance model might have value in accounting for persistent PCS (Wijenberg et al., 2017). Further, anxiety sensitivity and catastrophic thinking are associated with increased PCS following concussion (Albanese et al., 2017; Greenberg et al., 2020; Wood et al., 2014).

As previously discussed, a graduated stepwise return to normal activities is key to concussion recovery (e.g., McCrory et al., 2017; Schneider et al., 2017), whereas avoidance of activities may serve to maintain PCS (Mahooti, 2018). Subtypes of anxiety included in the fear-avoidance model (e.g., fear of symptoms, catastrophic thinking) are associated with avoidance of activity or exertion in concussion samples. For example, catastrophizing about pain is associated with overly limited engagement in activity following concussion (Greenberg et al., 2020). Compared to patients without fear of headache, concussion patients who avoid mental exertion due to fear of headache score

lower on performance validity testing, which may suggest avoidance of cognitive effort 2 to 3 months post-concussion (Silverberg et al., 2017). Thus, fear of PCS and catastrophic thinking are associated with avoidance behaviors in concussion samples. It remains unclear if anxiety sensitivity is associated with avoidance or if factors of the fear-avoidance model are associated with avoiding specific types of activity (e.g., cognitive, physical).

In summary, the fear-avoidance model provides a useful heuristic to investigate the association between anxiety and persistent PCS. Catastrophic thinking, anxiety sensitivity, and avoidance are building blocks of the fear-avoidance model and are common in individuals who experience anxiety (e.g., Gellatly & Beck, 2016; Olatunji & Wolitzky-Taylor, 2009; Pittig et al., 2018). Applying the fear-avoidance model to persistent PCS could characterize how features of anxiety are associated with the development of avoidance behavior and poor concussion recovery.

1.7 The Present Study

The aim of the current study was to determine if the fear-avoidance model could clarify the nature of the associations between anxiety and persistent PCS. In university students who suffered a concussion - with and without PCS – this study determined if fear of symptoms, catastrophic thinking, and anxiety sensitivity mediate the association between PCS status and avoidance of cognitive exertion and/or physical activity. It was hypothesized that fear of PCS, catastrophic thinking, and anxiety sensitivity would mediate the association between PCS status and avoidance/limiting behaviors.

Multiple methods were used to measure the outcome variables of avoiding cognitive exertion and limiting physical activity. Whereas past research has relied on self-report outcome measures, this study incorporated objective measures of avoiding cognitive exertion (e.g., neuropsychological performance validity tests) and physical activity (e.g., smartphone pedometer app). This study was the first to investigate the fear-avoidance model and PCS outcomes longitudinally as physical activity data will be collected across a 1-week period.

CHAPTER 2

METHOD

2.1 Participants

Two groups of undergraduate students from the University of Massachusetts Amherst (UMass) and the surrounding “Five College” area participated in this study across two time-points (i.e., baseline, 1-week). This study planned to recruit 88 participants who reported complete recovery and 88 participants with persistent PCS following concussion and balance biological sex across the groups. One-hundred participants completed session 1 (persistent concussion group $n = 25$, resolved group $n = 75$); however, forty-three participants (persistent concussion group $n = 11$, resolved group $n = 32$) completed both study sessions.

To determine group membership (i.e., PCS or resolved), ICD-10 criteria for “post-concussion syndrome” in assessing PCS symptoms in combination with more stringent criteria such as symptoms causing functional difficulties (e.g., academic, athletic, social, vocational) was used. Participants who reported three or more symptoms that cause functional impairment were assigned to the “PCS” group. Participants in the complete recovery group could report PCS, since symptoms are not specific to concussion, but the symptoms must not have impacted functional abilities.

Participants must have experienced a concussion as defined by the World Health Organization Neurotrauma Task Force (e.g., and at least 1 or more symptoms/signs of confusion, disorientation, loss of consciousness for less than 30-minutes, post-traumatic amnesia <24 hours; Holm et al., 2005). Participants must have been at least 3-months

from their concussion to enroll in the study. All participants were 18 years or older. Exclusion criteria were history of attention deficit hyperactivity disorder (ADHD), learning disability, moderate or severe TBI, or any health condition that limited a participant's ability to be physically active. Participants who reported sustaining concussion due to assault or domestic violence were excluded because of the traumatic nature of these injuries (Ferrari et al., 2014).

2.2 Procedure

Undergraduate students enrolled in psychology courses completed pre-screen questions through UMass's SONA student research participation system. The SONA system was used to assess concussion history (e.g., concussion history questionnaire), inclusion (e.g., at-least 3-months post-concussion), exclusion criteria (e.g., no history ADHD, learning disability, or moderate/severe TBI, mechanism of concussion), PCS, and functional difficulties due to PCS. Participants who met eligibility criteria were invited to enroll in the study and sign up for study slots using the SONA system. University students from UMass and surrounding colleges (e.g., Amherst, Hampshire) were also recruited through IRB-approved advertisements on social media, around campuses, and in the community. Prior to data collection participants were informed of the study's procedures, their rights as participants, and provided signed informed consent.

Data were collected from participants at two time points (i.e., baseline, 1-week follow-up). Participants completed the baseline session remotely and chose either a remote or in-person session for the 1-week follow-up. At baseline, participants answered questions about their demographics, concussion history, sleep (Pittsburg Sleep Quality

Index), and psychological symptoms (Beck Depression Inventory –Second Edition, State Trait Anxiety Inventory). Participants also completed questionnaires that asked about physical activity (International Physical Activity Questionnaire), catastrophizing thoughts (Post-Concussion Symptom Catastrophizing Scale), motivation (Behavioral Inhibition/Behavioral Activation Scales), and their fear about PCS and bodily sensations (Fear of Mental Activity Scale, Anxiety Sensitivity Index-3).

A 1-week time interval was necessary between study sessions to ensure reliable pedometer data. At least 5 consecutive days of pedometer data demonstrates good reliability (e.g., ICC = .80; Gretebeck & Montoye, 1992; Kang et al., 2009). At the second session, participants reported their physical activity data via pedometer smartphone application, completed questionnaires that measured avoidance of cognitive exertion (Cogniphobia Scale), limiting physical activities (Behavioral Responses to Illness Questionnaire – Limiting Behavior Subscale), a fine motor task (Purdue Pegboard), a vestibular-ocular motor screening (VOMS), and completed a neuropsychological performance validity test (e.g., Test of Memory Malingering) to measure cognitive effort. The second session lasted approximately 45 minutes.

2.3 Measures

2.3.1 Demographic Questionnaire

Participants reported their age, biological sex, race, ethnicity, number of semesters of college completed, work status, subjective social class/socioeconomic-status, undergraduate grade point average (GPA), and information on current and previous psychological diagnoses (Appendix A).

2.3.2 Concussion History Questionnaire

Participants indicated if their concussions had been diagnosed by a medical professional, the date of each injury, mechanism of injury (e.g., sports, motor vehicle accident, fall), if the individual lost consciousness, if they experienced amnesia before or after the injury, and what medical/treatment advice they received, on the Concussion History Questionnaire (Appendix B).

2.3.3 Rivermead Post-Concussion Symptom Questionnaire (RPQ)

The RPQ measures the presence and severity of post-concussion symptoms (e.g., headache, dizziness, fatigue) in the past 24 hours (King et al., 1995). The RPQ contains 16 items which are rated on a 5-point Likert scale. The RPQ has demonstrated excellent test-retest reliability for PCS severity 7-10 days ($r = 0.91$) and 6-months post-concussion ($r = 0.87$; King et al., 1995).

2.3.4 Behavioral Inhibition/Behavioral Activation Scales (BIS-BAS)

The BIS/BAS are 24-item Likert scales designed to assess motivation in pursuing goals, motivation for novel rewards, and level of response to a reward (White & Carver, 1994). The BIS/BAS has adequate internal consistency ($r = .66 - .76$) and two-month test-retest reliability ($r = .59 - .69$; White & Carver, 1994).

2.3.5 Post-Concussion Symptom Catastrophizing Scale (PCS-CS)

The PCS-CS assesses the presence of catastrophizing thoughts about concussion symptoms. The PCS-CS was adapted from the Pain Catastrophizing Scale (Sullivan & Bishop, 1995) by replacing the term “pain” with PCS (e.g., headache, dizziness, fatigue,

memory and concentration problems; Wijenberg et al., 2017). Each item is answered on a 5-point scale of 0 (i.e., not at all) to 4 (i.e., all the time). The PCS-CS has demonstrated excellent internal reliability ($\alpha = .94-.97$) in concussion samples (Wijenberg et al., 2017, 2020).

2.3.6 Fear of Mental Activity Scale (FMA)

The FMA is a 17-item self-report measure that measures respondents' fears about concussion symptoms. The FMA was developed from the Tampa Scale for Kinesiophobia (Miller et al., 1991) by replacing the term "pain" with PCS (Wijenberg et al., 2017). Participants are prompted to indicate their level of fear on a 4-point Likert scale (e.g., 1 = Strongly disagree, 4 = Strongly agree) about their PCS. The FMA has good internal reliability ($\alpha = 0.80-0.93$) in TBI groups (Wijenberg et al., 2017, 2020).

2.3.7 Anxiety Sensitivity Index – 3rd Edition (ASI-3)

The ASI-3 is an 18-item self-report measure designed to assess participants' tendency to be fearful of bodily sensations related to anxiety and arousal (Taylor et al., 2007). Participants indicate the frequency in which they agree with statements (e.g., "When my thoughts speed up I worry I might be going crazy") using a 5-point Likert scale (e.g., 0 = very little, 4 = very much). Higher scores indicate a greater tendency to be fearful of bodily sensations. According to Farris et al., (2015) the ASI-3 has demonstrated adequate internal consistency ($\alpha = 0.84 - 0.92$), test-retest reliability over 3-months ($r = 0.60 - 0.82$), and convergent validity (e.g., Body Vigilance Scale $r = .44, p < .05$).

2.3.8 Behavioral Responses to Illness Questionnaire – Limiting Behavior Subscale (LBS)

Limiting behavior was measured by using the seven-item LBS subscale from the Behavioral Responses to Illness Questionnaire (Spence et al., 2005). The LBS measures the frequency with which individuals avoid activities (e.g., exercise, usual daily activities) on a five-point scale ranging from one (i.e., not at all) to five (i.e., every day) with greater scores indicating greater avoidance of activities. The LBS subscale has demonstrated adequate test-retest reliability ($r = 0.76$) over a 1-week period and excellent internal reliability ($\alpha = 0.89$; Spence et al., 2005).

2.3.9 Runtastic Smartphone Pedometer Application (RUN)

The RUN is a free application that can be used on Apple and Android devices; it counts the number of steps taken. When set at a moderate level RUN is more accurate than traditional pedometers when the user is walking at slower speeds (e.g., < 1.11 m/s) and comparable to traditional pedometers at higher speeds (Preset et al., 2018). Participants were instructed to download the app, carry their smartphone device with them as much as possible for 12-hours per day, and report the number of steps recorded at the end of each day they are enrolled in the study.

2.3.10 Survey of Headache Impact (Cogniphobia Scale)

The cogniphobia scale was developed to measure fear-related avoidance of cognitive exertion in individuals with headache disorders (Todd et al., 1998). The cogniphobia scale contains 19 items and participants indicate their level of agreement with each statement on a 4-point Likert scale with higher scores indicating greater

avoidance behavior. Although initially developed for patients with headache disorders, the cogniphobia scale has demonstrated adequate internal reliability in concussion samples ($\alpha = 0.79-0.80$; Silverberg et al., 2017).

2.3.11 Purdue Pegboard Test (PPT)

The PPT assesses manual dexterity. Over the course of three trials (e.g., dominant hand, non-dominant hand, both hands), participants must place metal pins into a pegboard as quickly as they can (Tiffin & Asher, 1948). Intraclass correlations across the three trials have demonstrated good reliability ($r \geq .80$) in undergraduate samples (Buddenberg & Davis, 2000).

2.3.12 Vestibular/Ocular Motor Screening (VOMS)

The VOMS detects vestibular and ocular motor impairments following head injury by assessing smooth pursuit, horizontal and vertical saccades, convergence, horizontal vestibular ocular reflex, and visual motion sensitivity (Mucha et al., 2014). The VOMS has excellent internal reliability ($\alpha = .92-.97$) and sensitivity (i.e., 89%) in detecting concussion in college athletes (Kontos et al., 2016; Mucha et al., 2014).

2.3.13 Test of Memory Malingering (TOMM)

The TOMM is a performance validity test to detect exaggerated memory impairment and/or inadequate effort (e.g., O'Bryant et al., 2007; Tombaugh, 1996). During the learning trial, participants are shown 50 pictures, each for 3-seconds. After the learning trial participants must identify pictures they were previously shown from a distractor item in a recognition trial. A score of less than 45 is indicative of suboptimal

effort (Rees et al., 1998). Validation studies have found TOMM scores less than 45 cannot be attributed to depression, neurological impairment, or education (Rees et al., 2001).

2.3.14 State-Trait Anxiety Inventory (STAI)

The STAI is a self-report anxiety measure (Spielberger et al., 1971). For this study, trait anxiety was measured via 20 items. A reliability generalization study by Barnes et al. (2002) on STAI-Trait found good internal consistency ($\alpha = 0.89$) and test-retest reliability ($r = 0.88$) across 816 published studies between 1990 and 2000.

2.3.15 Beck Depression Inventory Second Edition (BDI-II)

The BDI-II is a self-report measure of depressive symptoms experienced over the past 2-weeks. The BDI-II contains 21 questions and participants indicate their level of agreement on a four-point Likert scale ranging from 0-3. The BDI-II has demonstrated excellent test-retest reliability ($r = 0.93$) and internal consistency ($\alpha = 0.93$) in college students (Beck, 1996).

2.3.16 Pittsburgh Sleep Quality Index (PSQI)

The PSQI assess sleep quality and sleep difficulties. Participants report their sleep habits (e.g., time to bed, time needed to fall asleep, hours of sleep, hours in bed) and causes for sleep difficulties (e.g., bad dreams, have to use bathroom, wake up in the middle of night/early morning) over the past month (Buysse et al., 1989). Scores can range from 0-21 with scores >5 indicative of poor sleep. The PSQI has adequate internal reliability ($\alpha = .70 - .80$; Carpenter & Andrykowski, 1998).

2.4 Analytic Plan

This research aimed to determine if subtypes of anxiety in the fear-avoidance model (e.g., catastrophic thinking, fear of pain, anxiety sensitivity) were associated with avoidance and limiting behaviors in university students following concussion. This was completed by testing if the anxiety characteristics (e.g., fear of PCS, catastrophic thinking, anxiety sensitivity) mediated the association between PCS group and avoiding cognitive exertion and limiting physical activity.

Preliminary analyses were conducted to check for normal distribution and skew for control (e.g., substance use, psychological symptoms), mediator (e.g., catastrophic thinking, fear of pain, anxiety sensitivity), and outcome variables (e.g., cogniphobia, limiting behavior scales, and the TOMM). Log¹⁰ transformations were used for variables that have skew less than -1 or greater than +1. Next, analysis of variance (ANOVA) with post-hoc comparisons were conducted to test for group differences on potential control variables (e.g., months since last concussion, number of previous concussions, depressive symptoms). If significant group differences existed on potential control variables, they were included in the mediation models.

Preliminary analyses used ANOVA and analysis of covariance (ANCOVA), to determine if groups significantly differ on anxiety subtypes (e.g., fear of symptoms, catastrophic thinking, anxiety sensitivity), cogniphobia, and limiting behaviors. ANOVAs or ANCOVA were used to determine effect sizes due to the analyses being underpowered, in addition to significant differences on mediating and outcome variables. It should be noted that mediation can still be present when there are no significant group differences on dependent variables (MacKinnon, 2008). Correlations between predictor,

mediator, and outcome variables were calculated since high inter-correlations (e.g., $>.70$) can create problems of multicollinearity (Hayes, 2018). If high inter-correlations were found, tolerance and variance inflation factors (VIF) were calculated via linear regression to assess for multicollinearity.

The primary aim of this study was to determine if the association between PCS group and avoiding cognitive exertion or limiting physical activity was mediated by fear of PCS, catastrophic thinking, and anxiety sensitivity. SPSS with PROCESS-macro 4.0 was used. PROCESS's bootstrapping processes controls for Type 1 errors while not requiring assumptions of normality (Hayes, 2018; Preacher & Hayes, 2008). Serial mediation models (Figure 2) were constructed. Serial mediation is useful in linking mediators in a specified direction (Charalambous et al., 2019). A total of four serial-mediation models were conducted because there are four outcome variables (i.e., average steps, TOMM, cogniphobia scale, limiting behavior scale). In each model, PCS group was the predictor variable, fear of PCS, catastrophic thinking, and anxiety sensitivity served as mediators; the cogniphobia scale, limiting behavior scale, TOMM performance, and pedometer data were outcome variables, with each only being tested in their own model.

2.5 Power Analysis

A power analysis in R was conducted using the “pwr2ppl” (Power to the People) package (Aberson, 2019). Pwr2ppl uses joint significance tests and bootstrapping based off correlations between variables from previous literature to conduct the power analysis. Significant correlations between the mediator variables were found in the literature

(Table 1; Drahovzal et al., 2006; Greenberg et al., 2020; Rosa Esteve & Camacho, 2008; Wijenberg et al., 2020; Wood et al., 2014) and used in the power analysis. To adequately power ANOVAs ($\alpha = .05$, $d = .25$, medium effect size) and serial mediation models above 0.80, a total of 88 participants per group are needed.

CHAPTER 3

RESULTS

3.1 Preliminary Analyses

Two hundred and twenty-six participants from various institutions of higher education in the Pioneer Valley completed the study screening assessment; however, data from 126 participants were excluded from analyses due to exclusion criteria (e.g., experiencing a concussion in the past 3 months, previous diagnosis of ADHD), thus leaving 100 participants eligible for session 2. Of these, 43 participants (persistent concussion group $n = 11$, resolved group $n = 32$) completed session 2 (Table 2); 30 of whom (persistent PCS $n = 6$, resolved $n = 24$) completed session 2 in-person and the remainder completed session 2 remotely (persistent PCS $n = 5$, resolved $n = 8$). The remote option for session 2 was offered to increase response rates for engagement in session 2 and did not include TOMM, pegboard, or VOMs data. The groups were generally well matched on demographic variables and were majority female (Table 2).

Measures to characterize resolved or persistent status (e.g., estimated physical activity per week, VOMS, pegboard) revealed the persistent PCS group reported engaging in fewer days of vigorous ($\eta^2 = .10$) and moderate ($\eta^2 = .17$) activity per week than the resolved group (Table 3). The persistent PCS group also reported more PCS ($\eta^2 = .19$) than the resolved group; however, both groups scored above the clinical cut-off of 12 (Potter et al., 2006).

Preliminary analyses were conducted to assess the distribution of the potential control (e.g., concussion history, sleep, psychological symptoms) mediator (i.e.,

catastrophic thinking, fear of pain, anxiety sensitivity), and outcome variables (i.e., cogniphobia, limiting behavior, TOMM, average daily steps; Tables 4 and 5). Log¹⁰ score transformation were calculated for several variables (i.e., AUDIT, CUDIT, PSQI, time since last concussion, number of concussions, catastrophic thinking scale, Fear of Mental Activity Scale, average daily steps, TOMM) to correct for skew in distributions in scores. Correlations between mediator and outcome variables were calculated to check for indications of multicollinearity (e.g., $r > .70$). None of the variables were correlated above .70; thus, multicollinearity was not a concern.

Group differences on potential control variables (i.e., concussion history, substance use, sleep difficulties, psychological symptoms) were explored by using ANOVA (Table 6). Levene's Test confirmed that the assumption of homogeneity of variance was not violated due to unequal group sizes ($ps > .069$). On the PSQI both groups were, on average, above the cut-off associated with poor sleep; however, there was a medium-large effect size ($\eta^2 = .12$) for sleep difficulties to be greater in the persistent group than in the resolved group. Thus, sleep difficulties were controlled in group comparisons and the primary mediation analyses.

3.2 Group Comparisons on Mediator and Outcome Variables

To test group differences on mediator variables (i.e., anxiety sensitivity, catastrophic thinking, fear of mental activity), ANCOVAs (Table 7) were conducted, which controlled for sleep difficulties. Levene's Tests confirmed equality of error variances ($ps > .884$). Partial η^2 indicated medium effect sizes for the persistent group's

report of higher fear of concussion symptoms ($\eta^2 = .05$) and catastrophizing of PCS symptoms ($\eta^2 = .10$) than the resolved group.

Group differences on outcome variables (i.e., limiting behavior scale, cogniphobia, average daily steps, TOMM) were calculated by using ANCOVA and sleep difficulties were controlled (Table 8). Equality of error variances was confirmed as Levene's Tests were not significant ($ps > .097$). There was a large effect size ($\eta^2 = .20$) for limiting behavior to be greater in the persistent group than in the resolved group. A medium effect size ($\eta^2 = .10$) for average daily steps to be greater in the resolved group than the persistent group.

3.3 Anxiety as Mediators of Avoiding and Limiting Behaviors

Serial mediation models were constructed to test the hypothesis that anxiety (i.e., anxiety sensitivity, catastrophic thinking, fear of mental activity) would mediate the association between PCS status and avoiding and/or limiting behaviors. In each of the four models, the predictor variable was PCS status (i.e., persistent = 0, resolved = 1) and mediators were anxiety sensitivity, catastrophizing, and fear of activity. Sleep difficulties were controlled in each model. Outcome variables were measures of avoiding or limiting activity (i.e., limiting behavior scale, cogniphobia scale, average daily steps, TOMM). It should be noted that calculating effect sizes for complex mediation models is not advised due to the maximum value of the indirect effect being infinite (Wen & Fan, 2015).

The first serial mediation model tested if group status was associated with limiting behavior through anxiety sensitivity, catastrophizing, and fear of activity. There was a significant direct effect of PCS status on limiting behavior (Table 9). However, the

indirect effects of PCS status on limiting behavior through anxiety sensitivity, catastrophizing, and fear of activity was not significant; but group status [$b = -4.68$, $t(28) = -3.43$, $p = .002$] and fear of mental activity [$b = 27.00$, $t(28) = 2.46$, $p = .020$] were significant predictors of limiting behavior.

The second serial mediation model tested if anxiety mediated the association between PCS status and cogniphobia. PCS status did not predict cogniphobia and there were no indirect effects for anxiety symptoms to be associated with cogniphobia (Table 10).

In the third mediation model, PCS status was the predictor and the average daily steps was the outcome variable. Anxiety sensitivity, catastrophizing, and fear of activity served as mediators. There were no significant direct or indirect effects (Table 11).

The last serial mediation model tested if forms of anxiety mediated the association between PCS status and TOMM performance. No significant direct or indirect effects were found (Table 12).

CHAPTER 4

DISCUSSION

4.1 Overview of Results

The current study determined how factors of the fear-avoidance model of chronic pain (e.g., catastrophic thinking, fear of symptoms, anxiety sensitivity) were associated with persistent PCS and avoiding or limiting activities following concussion.

Associations between factors of the fear-avoidance model and avoiding or limiting activity could not be adequately tested via serial-mediation models because of inadequate sample sizes. However, university students with persistent PCS reported greater fear of PCS and catastrophizing than students who reported full recovery from concussion. Students with persistent PCS also reported engaging in fewer physical activities than their peers who recovered from concussion.

4.2 Avoiding and Limiting Behavior

As expected, the persistent PCS group reported more limiting of behaviors than the resolved group. This finding aligns with previous findings that participants with persistent PCS report avoiding or limiting activities more than their recovered peers (Wijenberg et al., 2017). Preliminary results indicate concussion status (i.e., resolved or persistent) and fear of PCS predicted limiting behavior. Thus, fear of PCS could underlie a cycle of avoidance that has consequences for daily living and recovery. For example, avoidance of activities that trigger PCS and limiting behavior is associated with lower rates of return to normal activities 6-9 months following injury (e.g., Silverberg et al., 2018; Snell et al., 2023).

A strength of this study was the collection of number of daily steps, which is an objective indicator of physical activity. Students with persistent PCS, on average, walked/ran fewer steps per day than their recovered peers. These group differences lend support to the finding that students with persistent PCS limit behavior more often and engage in fewer days of vigorous and moderate activity than the resolved group. Currently, there are no published data that contain on objective measures of physical activity (e.g., pedometer, heart rate monitor) in post-concussive samples beyond 1-week post-injury (Sufrinko et al., 2018).

The persistent PCS group did not significantly differ from the resolved group on self-report or objective measures of avoiding cognitive exertion. These results are unlike previous findings of greater fear of cognitive exertion and avoiding cognitive exertion (Silverberg et al., 2017; Silverberg et al., 2019). One possible explanation for a lack of differences in the current study is that our sample was about 24 months since their last head injury, whereas previous samples (Silverberg et al., 2017; Silverberg et al., 2019) were 2-3 months post-concussion. Thus, it is possible fear and avoidance of cognitive exertion may dissipate over time. It is also possible that college students may not be able to avoid cognitive exertion given their primary focus is learning and completing course assignments.

Utilizing multiple measures of avoidance of physical activity (i.e., self-report and pedometer data) is another strength of this study. The persistent PCS group's significantly lower self-reported physical activity prior to the study (i.e., International Physical Activity Questionnaire) and higher frequency of limiting behaviors (i.e., Behavioral Responses to Illness Questionnaire – Limiting Behavior Subscale), was

corroborated by their pedometer data. It is not surprising that participants in the persistent PCS group avoided physical activity relative to the resolved group because physical exertion can be a trigger for headaches and migraine (Annalisa et al., 2022), which are the most common post-concussion symptom (Conidi, 2016).

4.3 Fear-Avoidance Model Variables

University students with persistent PCS reported greater fear and more catastrophic thinking about PCS than their recovered peers. Fear and catastrophizing are associated with symptom severity and level of disability up to five months following concussion (e.g., Albanese et al., 2017; Greenberg et al., 2020; Silverberg et al., 2018; Wood et al., 2014). In the current study, the persistent PCS group in this study was about 24 months since their last concussion; thus, fear of and catastrophizing about PCS may persist long after a last concussion.

Surprisingly, the persistent PCS and resolved groups did not significantly differ on reported levels of anxiety sensitivity. Further, both the persistent PCS and resolved groups' average scores of anxiety sensitivity are in the "low" range (Taylor, 2007). Previous research has identified anxiety sensitivity as a risk factor for persistent PCS and higher levels of anxiety sensitivity in persistent PCS groups (e.g., Hixson et al., 2017; Wood et al., 2014). These previous studies did not describe the amount of time since concussion in their samples, so it is unclear how long anxiety sensitivity is elevated following injury.

As previously discussed, pre- or post-injury anxiety is associated with persistent PCS (e.g., Broshek et al., 2015; Iverson et al., 2017; Ponsford et al., 2019). The current

study demonstrated the utility of applying the fear-avoidance model to persistent PCS, as some specific features of anxiety from the fear-avoidance model (i.e., fear of symptoms and catastrophizing) are greater in students who report persistent PCS, whereas others are not (i.e., anxiety sensitivity). Fear and catastrophizing are associated with symptom provocation during the VOMS which lend support to the hypothesis that PCS could be indicative of maladaptive psychological coping, and not necessarily incomplete recovery from concussion (Terpstra et al., 2023). That is, individuals with persistent PCS could be more vigilant and fearful of symptoms; and attribute their symptoms to head injury rather than other causes.

PCS are not specific to concussion and indeed are common in everyday life. For example, 31% of healthy controls meet ICD-10 criteria for post-concussion symptom despite never sustaining a concussion (Waljas et al., 2015). It is possible the greater catastrophic thinking of individuals with persistent PCS may lead them to misattribute their symptoms to concussion instead of other causes. This bias is discussed in the chronic pain literature because individuals with maladaptive cognitions to pain, such as catastrophizing, are more likely to attribute and misattribute common pain symptoms to a previous medical condition (Glare et al., 2022).

4.4 Limitations

This study has several limitations. First, analyses were not adequately powered due to low enrollment and attrition between sessions one and two. Data collection will continue to sufficiently power all analyses. Concussion diagnosis and the symptoms that determine head-injury severity were self-reported. It is also possible some participants in

the recovered group were still experiencing symptoms of head injury, as evidenced by the higher VOMS score by the recovered group and both groups scoring above the clinical cut-off on the RPQ. Future studies should rely on medical records to ensure participants have recovered, returned to normal activities, and did not experience moderate or severe TBI. Medical records may also be useful to ensure group equivalence (e.g., initial symptom severity).

It is possible that variables other than anxiety play a role in maintaining PCS. For example, recent research has identified other variables not contained in the fear-avoidance model (e.g., acceptance, flexibility) as moderators in the association between PCS and functional outcomes (Faulkner et al., 2022). Data on medical conditions that could influence the perception of PCS (e.g., migraine, chronic pain) were not collected in this study.

The fear-avoidance model is only one theory of coping following injury. Whereas some individuals may engage in avoidance of cognitive and physical activities following concussion, other individuals may deploy an endurance-style strategy. The avoidance-endurance model hypothesizes individuals respond to pain and anxiety by persisting, or over-engaging, with activities which can maintain pain and disability (Hasenbring et al., 2014). The use of an avoidance or endurance style of coping in response to anxiety and concussion was not assessed in the current study.

4.5 Future Directions

Future studies could focus on incorporating additional variables from outside the fear-avoidance model (e.g., motivation) and specific types of fear (e.g., cognitive activity,

physical pain, fear of re-injury) to identify how persistent PCS develops and is maintained. Longitudinal designs may be useful in identifying how changes in factors from the fear-avoidance model (i.e., fear, anxiety sensitivity, catastrophizing), and these additional variables, are associated with PCS-reporting and functional outcomes. For example, coping strategies such as persistence and over-engaging in activities are associated with greater perceived disability 3 months post-concussion (Cassetta et al., 2021). Investigating additional variables alongside the fear-avoidance model longitudinally could be useful in better understanding the associations between anxiety and persistent PCS.

It may be useful for future investigations of persistent PCS through chronic pain frameworks to focus on associations between sleep difficulties, features of anxiety from the fear-avoidance model, and avoidance or disability. In this study the persistent PCS group reported significantly more sleep difficulties than the resolved group. This is not a novel finding because sleep difficulties are common in persistent PCS groups and reported by 41% of all individuals in the first year following concussion (Hinds et al., 2016; Theadom et al., 2015). There are no published data on the associations between sleep difficulties and avoidance; however, in the chronic pain literature, sleep difficulties are associated with increased next day catastrophizing and pain severity (Mun et al., 2019). Further, the treatment of sleep difficulties is associated with decreased catastrophizing and symptom severity (Wilt et al., 2015). Thus, sleep difficulties could be a potential mediator in the fear-avoidance model and an important variable to consider in investigations of avoidance in PCS groups.

4.6 Implications and Conclusion

The current study investigated the associations between PCS, aspects of anxiety from the fear-avoidance model (e.g., fear of symptoms, catastrophic thinking, anxiety sensitivity), and behavior. Students who reported persistent PCS endorsed higher levels of fear and catastrophic thinking while also limiting their behavior and averaging fewer daily steps than their recovered peers. The association between factors of the fear-avoidance model (i.e., catastrophizing and fear of symptoms) and avoiding or limiting behavior remains unclear.

In the weeks following concussion, most individuals' levels of avoidance decreases but a small subgroup continues to experience fear and avoid activities (Cassetta et al., 2021). In the days following concussion, psychoeducation about PCS, treatment recommendations (i.e., brief rest followed by gradual return to normal activities), and adaptive coping strategies is beneficial and associated with decreased-risk of persistent PCS (Mollica et al., 2022). Assessing levels of fear, catastrophizing, and/or anxiety sensitivity immediately following concussion could be useful in identifying persons who are at a higher likelihood of engaging in a fear-avoidance coping strategy, so earlier interventions can be implemented. Mindfulness-based interventions, such as ACT, are effective at decreasing fear and avoidance in individuals with chronic pain (Jay et al., 2016). Thus, incorporating mindfulness-based interventions following concussion could be useful in the breaking maladaptive coping strategies used by individuals with persistent PCS.

Table 1

Variable correlations for power analysis

Variable	PCS	Fear of Symptoms	Catastrophic Thinking	Anxiety Sensitivity	Avoidance
PCS	-	-	-	-	-
Fear of Symptoms	.69 ^a	-	-	-	-
Catastrophic Thinking	.80 ^a	.70 ^b	-	-	-
Anxiety Sensitivity	.76 ^c	.50 ^d	.45 ^e	-	-
Avoidance/Limiting Behavior	.58 ^f	.50 ^f	.35 ^f	.60 ^g	-

Note:

^a Wijenberg et al., 2017

^b Wijenberg et al., 2020

^c Albanese et al., 2017

^d Drahovzal et al., 2006

^e Esteve & Camacho, 2008

^f Greenberg et al., 2020

^g Spickard, 2011

Table 2

Demographic Frequencies and Descriptive Statistics by Group		
	Persistent <i>n</i> = 11	Resolved <i>n</i> = 32
Age	20.36 (1.12)	19.94 (1.46)
Biological Sex		
Female	82%	56%
Race	-	-
White	82%	85%
Black	9%	6%
Asian	9%	9%
Hours Worked Per Week	12.05 (9.99)	3.97 (6.83)
Semesters Completed	3.82 (2.40)	3.34 (2.29)
GPA	3.70 (0.34)	3.62 (0.37)
Socioeconomic Status	-	-
Lower-Middle	9%	12%
Middle	55%	44%
Upper-Middle	36%	44%
Previous Psychological	55%	28%
Diagnosis		
Anxiety Disorder	27%	12%
Mood Disorder	27%	12%
Anxiety and Mood	9%	3%
Disorder		

Table 3

PCS, Pegboard, Vestibular Ocular Motor Screening, and Self-Reported Level of Physical Activity Data

	Resolved	Persistent	<i>F</i>	<i>P</i>	Partial η^2
PCS	17.06 (12.15)	29.91 (10.33)	9.81	.003	.19
Pegs – Dominant Hand*	12.58 (1.89)	14.00 (2.76)	2.25	.145	.07
Pegs – Non-Dominant Hand*	11.83 (1.95)	12.83 (1.84)	1.29	.266	.04
Pegs – Both Hands*	9.92 (2.15)	10.10 (2.16)	0.86	.360	.03
Pegs – Assemble*	6.17 (1.55)	6.17 (2.23)	0.00	.99	<.01
VOMS*	2.33 (1.75)	1.13 (1.45)	3.07	.091	.10
Days of Vigorous Activity	3.82 (2.09)	2.27 (2.15)	4.40	.042	.10
Hours of Vigorous Activity	1.53 (1.42)	1.36 (2.01)	0.94	.761	<.01
Days of Moderate Activity	3.57 (2.25)	1.50 (1.43)	7.99	.007	.17
Hours of Moderate Activity	1.05 (1.07)	1.02 (0.85)	0.01	.932	<.01
Hours spent walking per day	1.31 (1.56)	0.96 (0.69)	1.04	.314	.03

Note: * indicates session 2 in-person sample size (persistent PCS $n = 6$, resolved = 24).
VOMS = Vestibular Ocular Motor Screening Test

Table 4

Variable Descriptives for the Persistent Group						
Variable	Minimum	Maximum	Mean	SE	SD	Skew
AUDIT	0	9	3.46	0.98	3.24	1.16
CUDIT	0	12	2.45	1.36	4.50	1.12
PSQI	4	18	7.91	1.19	3.94	1.05
Number of Concussions	1	3	1.27	0.20	0.65	1.78
Months Since Last Concussion	5	76	24.00	7.00	22.14	1.92
BIS Total	7	26	15.04	0.94	4.69	0.17
BAS Reward	5	18	10.76	0.66	3.32	-0.42
BAS Drive	4	15	9.56	0.53	2.66	-0.33
BAS Fun Seeking	4	16	9.00	0.66	3.28	-0.36
BDI	7	28	16.00	1.64	8.19	0.33
STAI-State	38	53	44.33	1.42	7.10	-0.67
ASI-3	8	64	32.56	3.10	15.49	0.45
PCS-CS	0	50	19.76	2.89	14.43	0.25
FMA	28	52	49.20	1.44	7.21	0.13
Limiting Behavior	5	16	10.33	0.91	3.14	0.14
C-Scale	31	46	38.46	1.75	5.80	0.44
Average Weekly Steps	2291.60	13368.60	7363.46	1178.73	3909.42	0.18
TOMM	47	50	48.17	0.48	1.17	0.67

Note: AUDIT = Alcohol Use Disorders Identification Test, CUDIT = Cannabis Use Disorders Identification Test, PSQI = Pittsburgh Sleep Quality Inventory, BIS = Behavioral Inhibition Scale, BAS = Behavioral Activation Scale, BDI = Beck Depression Inventory, STAI = State Trait Anxiety Inventory, ASI-3 = Anxiety Sensitivity Index, PCS-CS = Post-Concussion Symptom Catastrophizing Scale, FMA = Fear of Mental Activity Scale, C-Scale = Cogniphobia Scale, TOMM = Test of Memory Malingering

Table 5

Variable Descriptives for the Resolved Group						
Variable	Minimum	Maximum	<i>M</i>	<i>SE</i>	<i>SD</i>	Skew
AUDIT	0	27	6.99	1.17	6.64	0.96
CUDIT	0	17	2.38	0.66	3.74	1.72
PSQI	1	9	5.31	0.39	2.18	0.22
Number of Concussions	1	5	1.69	0.19	1.06	2.16
Months Since Last Concussion	3	156	30.93	5.88	31.67	1.73
BIS Total	7	24	15.05	0.51	4.38	0.01
BAS Reward	5	18	10.18	0.37	3.14	0.54
BAS Drive	4	15	10.05	0.24	2.07	-0.41
BAS Fun Seeking	4	15	9.11	0.27	2.30	-0.01
BDI	0	24	13.51	1.38	11.95	-0.47
STAI-State	27	52	42.50	1.72	14.85	0.91
ASI-3	1	66	23.28	1.90	16.45	0.65
PCS-CS	0	36	6.63	1.07	9.25	1.53
FMA	23	56	34.64	0.79	6.85	1.04
Limiting Behavior	0	19	5.81	0.71	4.10	0.96
C-Scale	20	44	33.96	1.12	6.45	-0.37
Average Weekly Steps	3385.00	21912.00	9078.81	737.63	4273.96	1.38
TOMM	40	50	47.58	0.54	2.62	-1.50

Note: AUDIT = Alcohol Use Disorders Identification Test, CUDIT = Cannabis Use Disorders Identification Test, PSQI = Pittsburgh Sleep Quality Inventory, BIS = Behavioral Inhibition Scale, BAS = Behavioral Activation Scale, BDI = Beck Depression Inventory, STAI = State Trait Anxiety Inventory, ASI-3 = Anxiety Sensitivity Index, PCS-CS = Post-Concussion Symptom Catastrophizing Scale, FMA = Fear of Mental Activity Scale, C-Scale = Cogniphobia Scale, TOMM = Test of Memory Malingering

Table 6

Group Comparisons for Control Variables					
	Resolved (<i>n</i> = 32)	Persistent (<i>n</i> = 11)	<i>F</i>	<i>p</i>	Partial η^2
AUDIT	0.77 (0.43)	0.65 (0.45)	1.43	.234	.01
CUDIT	0.37 (0.45)	0.41 (0.48)	0.17	.683	<.01
Number of Previous Concussions	0.12 (0.19)	0.11 (0.19)	0.06	.804	<.01
Months Since Last Concussion	1.28 (0.50)	1.28 (0.45)	0.08	.784	<.01
PSQI	0.67 (0.24)	0.89 (0.17)	16.86	<.001	.15
Behavioral Inhibition	15.05 (4.38)	15.04 (4.69)	<0.01	.990	<.01
Behavioral Activation – Reward	10.18 (3.14)	10.76 (3.32)	0.63	.430	<.01
Behavioral Activation – Drive	10.05 (2.07)	9.56 (2.66)	0.92	.341	.01
Behavioral Activation – Fun Seeking	9.11 (2.30)	9.00 (3.28)	0.03	.858	<.01
BDI-II	13.51 (4.95)	16.00 (8.19)	1.17	.340	.05
STAI-State	42.50 (14.85)	44.33 (7.10)	0.28	.628	.04

Note: AUDIT = Alcohol Use Disorders Identification Test, CUDIT = Cannabis Use Disorders Identification Test, PSQI = Pittsburgh Sleep Quality Inventory, BDI-II = Beck Depression Inventory, STAI = State Trait Anxiety Inventory,

Table 7

Groups Differences on Mediating Variables

	Resolved (<i>n</i> = 32)	Persistent (<i>n</i> = 11)	<i>F</i>	<i>p</i>	Partial η^2
Anxiety Sensitivity	23.28 (16.45)	32.56 (15.49)	2.84	.095	.03
Catastrophizing	0.85 (0.47)	1.13 (0.49)	4.94	.030	.07
Fear of Mental Activity	1.53 (0.08)	1.59 (0.08)	5.45	.022	.05

Table 8

Group Differences on Mediation Model Outcome Variables

	Resolved (<i>n</i> = 32)	Persistent (<i>n</i> = 11)	<i>F</i>	<i>p</i>	Partial η^2
Limiting Behavior	5.82 (4.10)	10.33 (3.14)	12.21	.001	.23
Cogniphobia Scale	33.96 (6.45)	38.46 (5.80)	1.89	.176	.04
TOMM*	1.68 (0.03)	1.68 (0.01)	0.82	.374	.03
Average Daily Steps	3.92 (0.19)	3.80 (0.27)	4.32	.044	.10

Note: TOMM = Test of Memory Malingering. * indicates session 2 in-person sample size.

Table 9

Effects for PCS Status on Limiting Behavior through Forms of Anxiety					
	B	SE	<i>t</i>	<i>p</i>	95% CI
Total Effects	-4.89	1.40	-3.50	.001	-7.71 – -2.07
Direct Effects	-4.23	1.32	-3.20	.003	-6.90 – -1.56
Indirect Effects – Total	-0.66	1.03	-	-	-2.69 – 1.44
Anxiety Sensitivity	-0.14	0.32	-	-	-0.91 – 0.41
Catastrophizing	0.39	0.75	-	-	-1.05 – 2.03
Fear of Activity	0.31	0.64	-	-	-0.91 – 1.78
Anxiety Sensitivity – Catastrophizing	0.04	0.17	-	-	-0.24 – 0.49
Anxiety Sensitivity – Fear of Activity	-0.06	0.17	-	-	-0.53 – 0.16
Catastrophizing – Fear of Activity	-1.08	0.70	-	-	-2.57 – 0.07
Anxiety Sensitivity – Catastrophizing – Fear of Activity	-0.12	0.22	-	-	-0.62 – 0.27

Table 10

Effects for PCS Status on Cogniphobia through Forms of Anxiety					
	B	SE	<i>t</i>	<i>p</i>	95% CI
Total Effects	-3.17	2.30	-1.38	.176	-7.82 – 1.48
Direct Effects	0.36	2.11	0.17	.864	-3.90 – 4.63
Indirect Effects – Total	-3.53	2.17	-	-	-8.34 – 0.01
Anxiety Sensitivity	0.11	0.47	-	-	-0.77 – 1.22
Catastrophizing	-2.03	1.55	-	-	-5.79 – 0.09
Fear of Activity	0.16	0.78	-	-	-1.66 – 1.69
Anxiety Sensitivity – Catastrophizing	-0.21	0.41	-	-	-1.24 – 0.38
Anxiety Sensitivity – Fear of Activity	-0.08	0.22	-	-	-0.71 – 0.19
Catastrophizing – Fear of Activity	-1.34	0.81	-	-	-3.03 – 0.04
Anxiety Sensitivity – Catastrophizing – Fear of Activity	-0.14	0.26	-	-	-0.78 – 0.28

Table 11

Effects for PCS Status on Average Daily Steps through Forms of Anxiety					
	B	SE	<i>t</i>	<i>p</i>	95% CI
Total Effects	2526.52	1581.54	1.60	.118	-672.48 – 5725.52
Direct Effects	2281.11	1746.82	1.31	.199	-1261.66 – 5823.88
Indirect Effects – Total	245.41	911.96	-	-	-1827.62 – 1973.01
Anxiety Sensitivity	358.91	600.06	-	-	-679.20 – 1734.92
Catastrophizing	61.03	770.26	-	-	-1629.02 – 1498.89
Fear of Activity	43.88	287.34	-	-	-657.25 – 489.99
Anxiety Sensitivity – Catastrophizing	9.61	186.97	-	-	-393.79 – 369.59
Anxiety Sensitivity – Fear of Activity	-18.64	94.47	-	-	-165.50 – 201.21
Catastrophizing – Fear of Activity	-180.90	441.11	-	-	-1168.28 – 657.75
Anxiety Sensitivity – Catastrophizing – Fear of Activity	-28.49	111.81	-	-	-216.24 – 223.82

Table 12

Effects for PCS Status on TOMM Performance through Forms of Anxiety					
	B	SE	<i>t</i>	<i>p</i>	95% CI
Total Effects	-1.27	1.27	-1.02	.3251	-3.86 – 1.33
Direct Effects	-1.59	1.60	-0.99	.331	-4.90 – 1.72
Indirect Effects – Total	0.32	1.42	-	-	-2.21 – 3.47
Anxiety Sensitivity	-0.19	0.75	-	-	-1.67 – 1.51
Catastrophizing	1.31	1.40	-	-	-0.58 – 5.04
Fear of Activity	-0.01	0.65	-	-	-1.09 – 1.44
Anxiety Sensitivity – Catastrophizing	0.08	0.30	-	-	-0.44 – 0.71
Anxiety Sensitivity – Fear of Activity	-0.02	0.13	-	-	-0.32 – 0.18
Catastrophizing – Fear of Activity	-0.80	1.11	-	-	-3.81 – 0.32
Anxiety Sensitivity – Catastrophizing – Fear of Activity	-0.05	0.21	-	-	-0.44 – 0.28

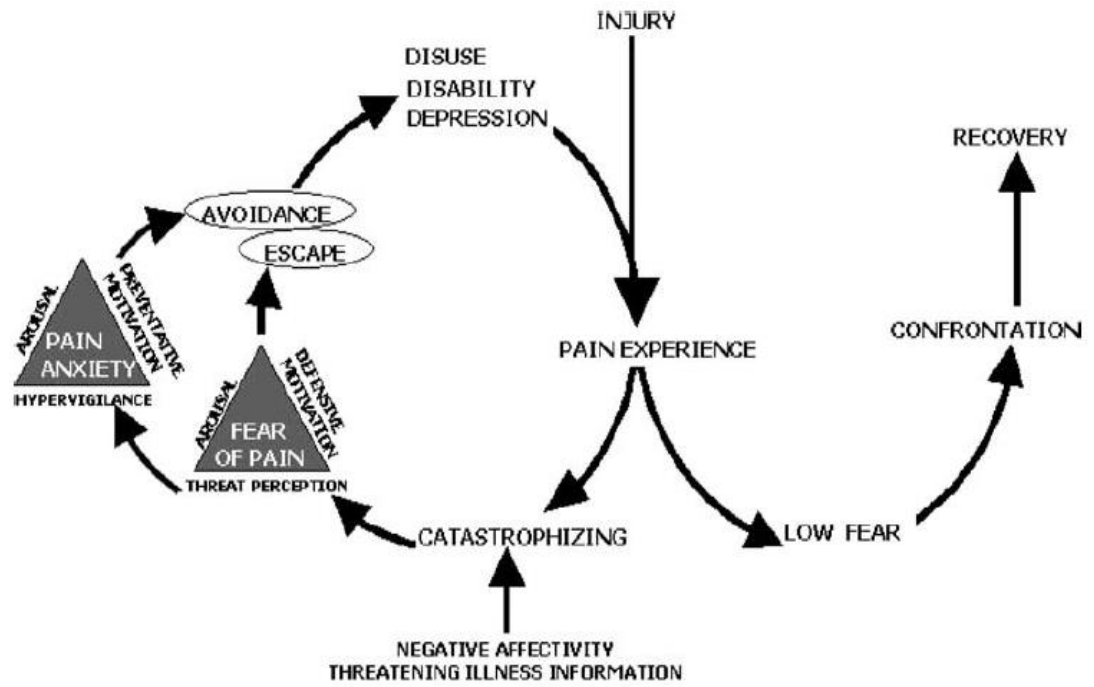


Figure 1. Asmundson et al.'s (2004) Fear-Anxiety-Avoidance Model

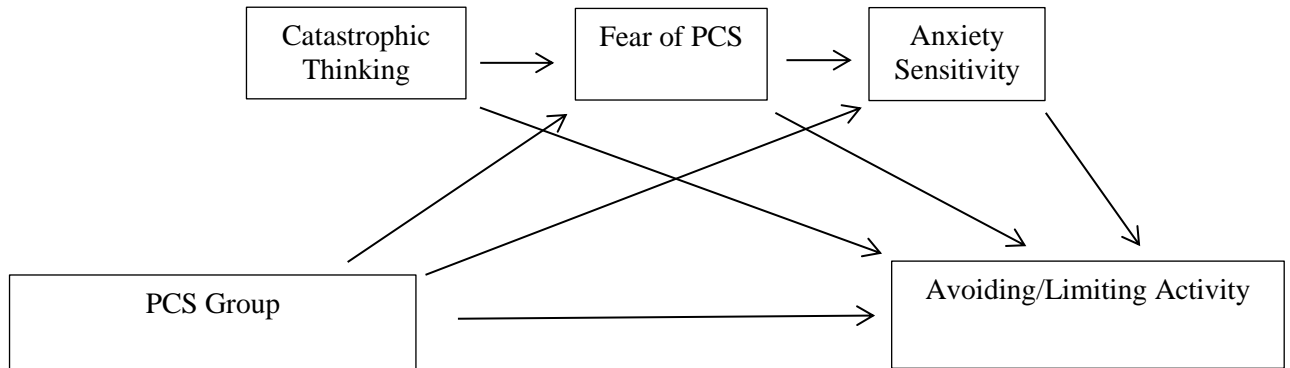


Figure 2. Serial Mediation Model Testing the Association between Persistent PCS and Avoiding Cognitive Exertion, Limiting Physical Activity through the Fear-Avoidance Model Factors of Catastrophic Thinking, Fear of Symptoms, and Anxiety Sensitivity

APPENDIX A

Demographic Questionnaire

Age: _____

Biological Sex: _____

How would you describe your race? _____

How would you describe your ethnicity? _____

How many semesters of university have you completed? _____

What is your GPA? _____

How would you define your family's social class or socioeconomic-status?

Upper Upper-middle Middle Lower-middle Lower

If you are employed, how many hours a week do you work? _____

Are you currently diagnosed with any psychological conditions? If so, please describe

Have you been previously diagnosed with any psychological conditions? If so, please describe

APPENDIX B

Concussion History Questionnaire

Please select one of the following:

- I have definitely had a concussion. It was doctor, clinician, athletic trainer, PA, or PT diagnosed.
- I have had a concussion but it was not doctor diagnosed.

Please complete your concussion history below about diagnosed concussion

Most recent concussion

Date (month/year) _____ Age _____

- Lost consciousness
- Experienced amnesia

Symptoms:

Cause:

Treatment advice (rest until symptoms subside, engage in physical activity, how long to resume normal activity):

Second most recent concussion

Date (month/year) _____ Age _____

- Lost consciousness
- Experienced amnesia

Symptoms:

Cause:

Treatment advice (rest until symptoms subside, engage in physical activity, how long to resume normal activity):

Third most recent concussion

Date (month/year) _____ Age _____

- Lost consciousness
- Experienced amnesia

Symptoms:

Cause:

Treatment advice (rest until symptoms subside, engage in physical activity, how long to resume normal activity):

Fourth most recent concussion

Date (month/year) _____ Age _____

- Lost consciousness
- Experienced amnesia

Symptoms:

Cause:

Treatment advice (rest until symptoms subside, engage in physical activity, how long to resume normal activity):

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