The influence of athlete fear avoidance on acute concussive symptoms

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A Thesis
in
The Department
of
Health, Kinesiology and Applied Physiology

Presented in Partial Fulfillment of the Requirements
For the Degree of Master of Science (Health, Kinesiology and Applied Physiology) at,
Concordia University
Montreal, Quebec, Canada

March 2020

CONCORDIA UNIVERSITY

School of Graduate Studies

This is to certify that the thesis prepared

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Entitled: The influence athlete fear avoidance on acute concussive symptoms

and submitted in partial fulfillment of the requirements for the degree of

Master of Science (Health and Exercise Science)

complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

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ABSTRACT

The influence of athlete fear avoidance on acute concussive symptoms

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There are millions of concussions each year and the number of symptoms or severity of a sport related concussion vary significantly. Recently there is more evidence for fear avoidance being associated with the number of symptoms reported, in the chronic stage. The purpose of this thesis was to assess acute concussions in athletes using the SCAT5 as well as fear avoidance, catastrophizing, depression, and anxiety. **Main Outcomes and Measures:** We assessed 34 athletes' concussions using the SCAT5, overall general health using the Short Form General Health Survey (SF36), pain catastrophizing using the Pain Catastrophizing Scale, fear avoidance using the Athlete Fear Avoidance Questionnaire (AFAQ), and anxiety and depression using the Hospital Anxiety and Depression Questionnaire. **Results:** The participants had an average of 7.4 ± 5.1 total number of symptoms and 16.3 ± 17.0 symptom severity score on the SCAT5. The total number of symptoms reported on the SCAT5 was associated with the AFAQ score (r=0.493). The symptom severity score was associated with the AFAQ score (r=0.481). The total number of symptoms reported on the SCAT5 was associated with the HADS score (r=0.686). The symptom severity score was associated with the HADS score (r=0.602). The AFAQ score, HADS depression and HADS anxiety scores model was a significant predictor of the total number of symptoms reported on the SCAT5, accounting for 50.4% of the variance (p>0.001), and a significant predictor of the severity of symptoms reported on the SCAT5, accounting for of the 41% of the variance (p=0.001). **Discussion:** Our study identified a significant relationship between athlete fear avoidance and the number of concussion symptoms and the severity of the symptoms. A higher fear avoidance means that patients report more symptoms, and this relationship could explain why there is variability in the reporting of concussion symptoms.

Acknowledgments

I would like to thank my supervisor, Dr. Dover, for being extremely generous with his time during these three years of my Master's thesis. I am lucky that he was so comprehensive of my tough schedule and was always there to answer my questions and help guide me through the whole process. I have a learnt a lot and am very thankful for the knowledge that he has passed on to me.

Thank-you to my thesis committee external members, Dr. DeMont and Dr. Gagnon for their great advice and guiding me through the writing of my thesis.

I would like to thank my lab colleagues for their help, support, and encouragements, every step of the way.

I would also like to thank my family and friends for being supportive and encouraging me in completing this challenge that I embarked on three years ago.

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Introduction:

It is estimated there are 1.6–3.8 million sports-related concussions each year in the USA.[1] Although the majority of these patients are symptom free within the first 7-10 days, 10-30% of patients suffer from persisting symptoms. [2-6] The majority of people with severe traumatic brain injury regain functional independence 1-5 years after their injury,[7, 8] but this depends on proper rehabilitation. In practice, up to 55% are sent home or referred to a facility not specialized in concussions after initial management and are rarely referred to rehabilitation therapy.[9, 10]

In its simplest form, a concussion can be defined as the immediate and transient symptoms of a mild traumatic brain injury. However, this definition lacks explanation about the underlying processes through which the brain is impaired, the different grades of severity, or explanation on the persistence of symptoms and abnormalities on specific screening tools.[11] Sport-related concussion is a clinical diagnosis for which no single diagnostic test has been identified.[12] The fact that symptoms of sports related concussion vary, are present in non-concussed individuals, are not specific to concussion[13], and can change rapidly and unexpectedly[14] make the diagnosis even more challenging. For example, symptoms such as headache, nausea, dizziness, fatigue, and many more can be found in healthy non-concussed subjects.

One of the issues with concussion rehabilitation is that there is a great amount of variability in the number of symptoms, type of symptoms, and time to recovery in concussed patients. These variations in the clinical manifestations of traumatic brain injury are due to the complexity of the brain, and to the pattern and extent of damage, which depend on type, intensity, direction, and duration of the external forces that cause traumatic brain injury.[15] In the last three decades, many researchers have been interested in finding a possible explanation for the persistence of symptoms [in post-concussion syndrome], but no precise explanation has been found. [16, 17]

Previous studies have examined the impact of pain related fear and catastrophizing on concussion symptoms. In a study investigating whether the fear avoidance model is able to explain persistent symptoms in patients with traumatic brain injury (mild, moderate and severe), the results suggested low levels of catastrophizing and fear avoidance behavior regarding post-concussion symptoms in comparison to other pain experiences, such as chronic pain and fibromyalgia.[18, 19] However, all correlations suggested by the fear avoidance model regarding post-concussion symptom experience were significant. The correlations between post-concussion symptoms versus catastrophizing and depression were slightly higher in the mild traumatic brain injury subgroup. The researchers were interested in whether the fear avoidance model would apply to patients with post-concussion syndrome specifically, therefore, on average, the participants of this study were assessed 48.2 months after injury.[20]

Previous studies have identified pre-injury mental health status as a factor for persistent concussion symptoms. A systematic review by Silverberg found that pre-injury mental health status predicts post-concussion syndrome[17]. Early post-injury stress and anxiety levels after mild traumatic brain injury are also indicated as predictors of post-concussion syndrome.[17, 21] In a systematic review aimed at improving the SCAT tool, higher anxiety and depression scores were associated with higher SCAT2 symptom scores in college athletes.[22]

To our knowledge, no previous study has studied the impact of pain related fear, catastrophizing and depression on the acute, on-field measure of concussion within 24-48 hours after injury. The goal of this study will be to measure pain related fear using the Athlete Fear Avoidance Questionnaire, pain catastrophizing using the Pain Catastrophizing Scale and Tampa Scale of Kinesiophobia, and depression using the Hospital Anxiety and Depression scale, and compare it to the results of the SCAT5 total score and subcomponent scores. The SCAT5 is the gold standard for field immediate measurement of concussion.[23] We hypothesize that athletes with a greater score on the Athlete Fear Avoidance Questionnaire, Pain Catastrophizing Scale, Tampa Scale of Kinesiophobia and Hospital Anxiety and Depression Scale will score higher on the SCAT5 total score, and on the symptom subscale of the SCAT5.

Literature Review:

Current definition of concussion

Based on a systematic review of literature and consensus discussions during the plenary session by the conference participants and the expert panel, the 2016 Berlin Consensus Conference definition of concussion was written, “concussion is a traumatic brain injury induced by biomechanical forces”.[11] Several common features that can be used clinically to define the nature of a concussive head injury include:

- Concussion may be caused by a direct blow to the head, face, neck or by an impact to another body part with a force transmitted to the head.[24]
- A concussion usually results in the rapid onset of short-lived neurological impairment that resolves spontaneously. However, in some cases, signs and symptoms may present themselves over a number of minutes to hours.[24]
- Concussion may result in neuropathological changes, but the acute clinical signs and symptoms reflect a functional disturbance rather than a structural injury and therefore no abnormality is visible on standard structural neuroimaging studies.[24]
- Concussion results in a wide range of clinical signs and symptoms that may or may not involve loss of consciousness. Clinical and cognitive features are resolved in a sequential course, but in some cases symptoms are prolonged. [11]
- The clinical signs and symptoms of concussion cannot be explained by drug, alcohol, medication use, other injuries or other comorbidities. [11]

Although a sports-related concussion is a well-recognized clinical term, the pathophysiological basis of a concussion is still poorly understood. A concussion is frequently defined as the instantaneous and transient symptoms of a mild traumatic brain injury. This definition does not clearly explain the processes through which the brain is damaged, the different grades of severity of a concussion, or explain the reason for the persistence of symptoms and/or abnormalities on specific screening modalities.[11] During the 10th century AD, the Persian physician Rhazes first defined this condition as a transient neurological syndrome due to head shaking without structural brain injury.[25, 26] Since then, research has been done in order to explain and understand this complex brain injury better.

Biomechanical studies on concussion show various effects on brain regions depending on the force of the impact, site of impact and bony architecture of the skull, as well as individual differences in tolerance to head impacts, depending on one's energy and history of concussion. It is also speculated that genetics could play a role in concussions.[27] Factors such as brain geometry, brain tissue properties, and bony architecture of skull and connective tissue explain why brain loading patterns are not always distributed the same way. Certain anatomical areas of the brain will have different amounts of physiological or biomechanical changes depending on the external forces to the brain and the head's kinematic response to the force, and brain sensitivity. This results in clinical symptoms varying from one person to the other.[28-31]

Traumatic brain injury (TBI) is defined as an alteration in brain function, or other evidence of brain pathology, caused by an external force.[32] Traumatic brain injury varies in severity from mild TBI (which includes concussion) to moderate and severe TBI. Severe TBI has a high mortality rate, estimated at 30–40%.[33] Those affected by severe TBI, and sometimes simply mild or moderate TBI, suffer from physical, psychiatric, emotional and cognitive disabilities, which affect them and their families, as well as pose an economic burden to society.[15]

Mild traumatic brain injury is a complex condition with both pre-injury, injury-related, and post-injury factors contributing to the injury outcome. Possible pre-injury factors include demographic variables (age, gender, education), preinjury physical and psychiatric status, and history of previous head injury. Injury-related factors involve presence and severity of mild traumatic injury and associated cognitive impairments. Post-injury factors include pain, posttraumatic stress disorder, anxiety, depression, or other life stressors.[34]

Prevalence

Traumatic brain injury creates a major health issue because of its high prevalence and consequently high costs to society. [35] Traumatic brain injuries constitute a leading cause of disability around the world [36-38], with 75%-90% of traumatic brain injuries typically classified as mild traumatic brain injuries [39]. More than 50 million traumatic brain injuries occur internationally each year[40], affecting 100–300 out of 100,000 annually.[39, 41] Globally, traumatic brain injury is a leading cause of injury-related death and disability, [3, 42, 43] striking a huge burden on patients, their families, and society. Traumatic brain injury is the leading cause of death in young adults and a major cause of mortality and disability for all ages across the world, with this burden being even greater in low-income and middle-income countries. Traumatic brain injury costs the global economy around $400 billion US per year.[15] Players as young as 7 years old sustain high-magnitude impacts similar to those in college players[44] and it was observed that there was an increased risk of concussions in older players (12-17 years old) compared with younger ones (7-11 years old).[45] Advances in prevention, care and research need to be made in order to reduce this burden on society.[15]

It is estimated there are 1.6–3.8 million sports-related concussions each year in the USA.[1] Although the majority of these patients are symptom free within the first 7-10 days, 10-30% of patients suffer from persisting symptoms[2-6]. These lingering symptoms may cause morbidity, frustration for the concussed patients, and can cause lengthy absences from work, school and/or sport. Common persisting symptoms of mild traumatic brain injury and concussion are vertigo, dizziness and balance issues, all of which are linked with vestibular impairment.[46-48] The majority of people with severe traumatic brain injury regain functional independence 1-5 years after their injury[7, 8], but this depends on the right course of rehabilitation. In practice, up to 55% are sent home or referred to a facility not specialized in concussions after acute care and are rarely referred to rehabilitation therapy.[9, 10] This highlights the importance of improving the prevention, recognition, and treatment of concussions.

Concussion imaging

CT scan is the main imaging tool for TBI, determining the need for surgery for space-occupying lesions. Although the scanning times are fast and the image processing is instantaneous, only 5% of patients with a suspected traumatic brain injury will have CT abnormalities.[49-51] Recent advances in brain imaging technology demonstrate brain tissue damage in mild traumatic brain injury, mostly vascular microstructural damage, that we could not visualize before.[52] However, these test results do not predict the persistence of symptoms or occurrence of post-concussion syndrome. [53] Also, despite billions of dollars invested by pharmaceutical companies, there is no effective drug for treatment of traumatic brain injury in the acute setting. [15]

Standard structural imaging techniques such as CT scans and MRI have limited value and a low outcome in patients with persistent postconcussive symptoms. Advanced investigation techniques (such as fMRI, diffusion tensor imaging, magnetic resonance spectroscopy and quantitative EEG) have shown changes in brain function, brain activation patterns and white matter fibre tracts in those experiencing prolonged symptoms. However, these changes were present even when the athlete had recovered and returned to sport, questioning the clinical significance of those brain changes.[54] Different tools must therefore be used in order to assess concussions properly and determine the proper course of treatment, which is specific to each individual, and decide when the athlete may return to sports or activities.

On-field measurement of concussion

Sport-related concussion is a clinical diagnosis for which no single diagnostic test has been identified.[12] The fact that symptoms of sports related concussion vary, are present in non-concussed individuals, are not specific to concussion [13], and can change rapidly and unexpectedly [14] make the diagnosis even more challenging. According to a systematic review of the literature regarding assessment and treatment modalities in patients with persistent symptoms following sport-related concussion, the key domains that need to be evaluated as part of complete concussion care in the context of prolonged recovery may include (but are not limited to): somatic, cognitive, affective/mental health (depression and anxiety), physiological, cervical spine, vestibular, autonomic, sleep, hormonal, and loss of cognitive and/or physical stamina.[54] The recent Consensus Statement on Concussion in Sport recommended that persistent symptoms should be managed by a multidisciplinary team which may include: primary care physician, sports physician, physiatrist/rehabilitation physician, physical therapist, certified athletic trainer, exercise physiologist, neurologist, neurosurgeon, neuropsychologist, psychiatrist, psychologist and other specialists. Ideally, these professionals should be specialized and trained in the care of sports related concussion.[54, 55] Cognitive, physical, psychological and vestibular therapies should be included as part of complete concussion rehabilitation program.[55] Therefore, a global approach should be used when assessing concussions as there are many domains that could be affected.

SCAT

The Sport Concussion Assessment Tool (SCAT) was first introduced in 2004, after the 2nd International Conference on Concussion in Sport in Prague, Czech Republic.[56] The aim was to create a standardized tool that could be used for patient education as well as for physician assessment of sports concussion, by grouping 8 existing tools into one. The 3rd International Conference on Concussion in Sport, held in Zurich, Switzerland, in 2008, introduced the SCAT2, to be used for athletes aged 10 years and older.[57] The 4th International Consensus Conference, held in Zurich, Switzerland, in 2012, determined that a child-specific tool was required and the Child SCAT3 was developed for children aged between 5 and 12 years.[12] Following the 2016 Berlin fifth International Consensus Conference on Concussion in Sport, the SCAT5 was created.[58]

A systematic review of the literature was done related to the SCAT in order to provide recommendations for improving the tool. Several studies [59-62] showed improvement with age on SCAT performance, with adolescents performing better than younger children, and college athletes performing better than high school athletes.[59] Some studies [62, 63] did not demonstrate sex differences on total SCAT2, Standardized Assessment of Concussion or balance scores, although others found that females performed significantly better that males on total SCAT2 [60] and Standardized Assessment of Concussion scores [59, 62] and had significantly better scores on the balance score than males.[59, 60] College students playing collision/limited contact sports scored higher on the SCAT2 than those playing non-contact sports.[60] History of concussion did not have a significant difference in baseline total SCAT2/SCAT3 scores among college athletes.[64, 65] Studies found females reported more symptoms [59, 61, 62, 66] and higher symptom severity rating [59, 62] at baseline than males.

College athletes playing non-contact sports endorsed more symptoms at baseline than those playing collision/limited contact sports.[22] One study of college athletes found significant variation in Balance Error Scoring System test performance across different sports [67], which was related to height differences. Two studies stated that athletes performed worse on balance testing at a sporting event compared with a controlled setting.[68-70] Two studies suggested that balance issues are independent of headache. [70, 71]

In this systematic review, the SCAT was shown to be most effective in the first few days post injury. Studies that compared SCAT2 and SCAT 3 baseline and post-injury demonstrated that, when compared with controls, concussed athletes had more postconcussion symptoms, which remained significant until day 8 postinjury.[59] The SCAT2/SCAT3 total score differences were found within 24 hours of injury but not by day 8 post injury.[59, 72] Scores on modified Balance Error Scoring System test/Balance Error Scoring System test were significantly different initially [59, 63] but not on day 15 post injury.[59] A study using the SCAT2, neuropsychological testing and functional MRI found SCAT2 and neuropsychological testing were significantly different from baseline within 48 hours post injury but returned to normal by 2 weeks post injury. [63]

These studies suggest that symptoms commonly associated with concussion may be linked to the injury, but are not specific enough to be used as a sole assessment tool.[23] Symptoms, Standardized Assessment of Concussion and Balance Error Scoring System test/modified Balance Error Scoring System test are useful in differentiating between a concussed and non-concussed athlete immediately after the injury. The largest effect sizes occurred within 24 hours of injury across all subcomponents of the SCAT. The diagnostic utility of the SCAT and its components appears to decrease significantly after 3–5 days post injury. The use of the Standardized Assessment of Concussion and modified Balance Error Scoring System test as tools to measure recovery beyond 5 days has yet to be established although the SCAT is a useful tool in the assessment of an acute concussion, when completed in the first 48h.

Sideline assessment

Sustaining a sports related concussion may increase the chance of suffering another head or musculoskeletal injury [73], and repetitive concussions could lead to long-term effects such as such as persistent postconcussive symptoms, depression or neurodegenerative disorders.[12, 74, 75] Early screening of a suspected concussion and removal from play will limit these adverse effects, and aid in proper evaluation, management and safe return to play.[76] The goal of sideline assessment is not to give a definite diagnosis, rather than rapidly screen an athlete for a suspected concussion. Players with clear observable signs of concussion such as loss of consciousness, ataxia, or seizures may be diagnosed with concussion, while athletes with a suspected concussion can be removed from play and later receive a definitive diagnostic evaluation. Ideally, sideline testing should be done away from the field.[76] Given the absence of definitive evidence of a concussion with performance of sideline tests, experts recommend using a multimodal assessment tool, of which the Sports Concussion Assessment Tool is the most established, well developed and studied.[77]

Challenges of concussion management

Therefore, the major issues in concussion diagnosis are that there is no gold or reference standard measure of concussion and there is marked variability in the diagnostic criteria. Since there is no validated case definition of concussion, this causes information bias in concussion studies since they often have their own definition of concussion. This means that information bias would be present in studies of risk, prevention, prognosis, intervention and long-term effects, which might explain some of the variable findings in these areas.[11]

The quality and quantity of symptoms suffered by those with a mild traumatic brain injury is similar in other patient populations such as those with chronic pain syndromes [78] or other traumas such orthopedic injuries. [79, 80] Furthermore, healthy subjects also report symptoms such as cognitive problems, fatigue, and headache, which are common post-concussion symptoms. Therefore, by removing the history of a mild traumatic brain injury, a similar prevalence of post-concussion syndrome can be examined in healthy subjects.[81, 82] This advocates that post-concussion syndrome is not specific to brain injuries and psychological models should be looked at when explaining the presence of post-concussion syndrome.[20]

Public and political recognition of the degree of problems caused by traumatic brain injury, such as the clinical impact on patients, families, and society, and public health concern and costs to society, is low. There is not enough clinical recognition of the complex discrepancy of traumatic brain injury, in terms of disease type, outcome, and prognosis. Current treatment approaches do not properly target specific needs of individual patients, and acute and post acute care is not handled the same everywhere. Until recently, research has been concentrated on more severe cases of traumatic brain injury, although 70-90% of patients suffer from mild traumatic brain injury. Despite the fact that individual cases of mild traumatic brain injuries are smaller, the category as a whole has the greatest impact on the global burden of this disability, and rapid intervention and efficient follow-up for those affected by mild traumatic brain injury could improve public health and decrease the cost on society.[83] Therefore, more focus should be geared toward mild traumatic brain injury research.

The initial accurate assessment of a concussion is important because of the danger of multiple concussive and sub concussive impacts. There is increasing evidence indicating that numerous concussive and sub concussive impacts can have cumulative effects, including more severe symptoms and longer recovery time than after a single injury of similar severity, as well as increased susceptibility to brain injury and greater risk of any further injury. [84, 85] In children and adolescents, there are increased issues from cumulative effects of multiple concussions on brain development and learning, and the cognitive and behavioral sequelae. [86] Children and young adults are also at increased risk of second-impact syndrome[87, 88].These concerns highlight the importance of rapidly removing athletes from the play when a mild traumatic brain injury is suspected.

Although the recommendation to quickly remove athletes having a potential concussion from play is emphasized when training coaches and parents, it is unfortunately not always applied in professional sports. For example, during the 2014 FIFA World Cup, there were many apparently concussed players not being removed from the play. This lead to the FIFA Medical Committee protocol now requiring a team doctor to make the decisions about return to play.[89] Return to play decisions should not be taken by interested parties such as coaches, but rather by a neutral party such as the medical staff or the referee.[24, 90] Since May 2017, small mobile medical tents are found on all NFL game sidelines in order to allow doctors to assess players in a private and distraction-free environment, and in order to promote player health and safety.[91] The initial post-injury golden hour notion is especially important in traumatic brain injury. Negligent care in the prehospital phase could result in a gradual cascade of events causing adverse effects on the person’s health.[6] Therefore, creating the best possible environment with the best tools for athletic trainers, athletic therapists, physiotherapists, doctors and other medical professionals to assess athletes is a step in the right direction in order to reduce the number of undiagnosed concussions.

Variability

There is a great amount of variability in the number of symptoms, type of symptoms, and time to recovery in concussed patients. These large variations in the clinical manifestations of traumatic brain injury are a result of the complexity of the brain, and to the pattern and extent of damage, which depend on type, intensity, direction, and duration of the external forces that cause traumatic brain injury.[15] In the last three decades, many researchers have been interested in finding a possible explanation for the persistence of symptoms [in post-concussion syndrome], but no precise explanation has been found. [16, 17]

The results of a systematic review indicated that the persistence of symptoms after a sports related concussion does not represent a single pathophysiological entity.[54] The term concussion describes a group of symptoms that may also be linked to pre-existing pathologies and do not necessarily reflect the brain injury. A detailed clinical assessment is needed to evaluate factors that may be playing a role in the persistence of symptoms. This assessment must include, at least, a comprehensive history and focused physical examination (including assessment of cervical spine, vestibular and oculomotor function, and a systematic evaluation of exercise tolerance).[54]

Sports related concussion symptoms are heterogeneous and not unique to this type of injury. Symptoms involve different domains such as cognition, dizziness and balance, emotions, headache and vision.[92] Concussion can represent a wide range of somatic, cognitive, behavioural or emotional symptoms; and/or physical signs such as vestibulo-ocular deficits, loss of consciousness and ataxia.[12] There are a variety of symptoms and disturbances associated with concussions, therefore different tests and batteries are needed for the assessment of concussion. This might explain why there is inconsistency in the diagnosis of concussion. [93, 94] Although symptoms vary, the most frequent symptoms reported in a systematic review were related to issues with alertness/attention, dizziness/balance, headache/migraine and consciousness/awareness. In terms of individual symptoms, headache (n=70, 71.4%), fatigue or low energy (n=62, 63.3%), concentration problems (n=60, 61.2%), dizziness, drowsiness and feeling slowed down (each n=58, 59.2%) were frequently described, followed by fogginess (53%, 54.1%) and memory problems (n=47, 48.0%) were the most frequently reported. Neck pain was not reported in any of the studies.[92] Dizziness and fogginess were associated with a higher total number of symptoms and prolonged recovery.[95-97] This review confirmed previous findings that symptoms of concussion are heterogeneous, not specific and can be misleading during the assessment of a concussion.[59] Different studies reported various average total number of symptoms and average symptoms severity score post injury, with the highest number of symptoms and total symptom severity scores observed 24-48 hours post injury.[92] The most common symptoms reported by athletes in studies using the Postconcussion symptom scale were headache (71.4%), fatigue or low energy (63.3%), concentration problems (61.2%), dizziness, drowsiness and feeling slowed down (each 59.2%), fogginess (53%) and memory problems (48.0%). [92] It is important to note that most of these symptoms can be experienced on a daily basis for certain healthy, non-concussed people.

Multiple factors may contribute to the persistence of symptoms following a sports related concussion. Prolonged symptoms may represent a change in brain function or the coexistence of other medical issues, such as depression, headaches, vestibular or oculomotor dysfunction and many more.[98-100] Therefore, the clinical assessment should aim to identify specific pathologies that may be contributing to the persistence of symptoms, using a multi-modal assessment.[54]

Common persistent symptoms following sports related concussion such as headache, poor concentration, memory problems, fatigue, sleep difficulties, dizziness, irritability, feeling 'more emotional', nervous or anxious are non-specific and are commonly reported with orthopaedic injuries, psychological problems, chronic pain syndromes and even in healthy controls.[78, 101-104] Collins and colleagues [81] identified that 7 days after concussion, athletes with headaches experienced a large number of other postconcussion symptoms compared with athletes without headache (p=0.001). Similarly, dizziness and balance issues can have various causes since balance requires sensorimotor, visual and vestibular systems.[105] The presence of dizziness can influence the total number of symptoms[13, 106], is associated with a more than six times greater risk for protracted recovery [107] [108], and might influence neurocognitive performance.[95]

The SF-36 as a measure of pre-injury general health

Scholten et al. performed a systematic review of studies reporting the pre-injury health related quality of life of patients. This systematic review was done because getting insight on a patient's pre-injury and post-injury health related quality of life allows medical professionals to estimate the impact of the trauma on the patient's quality of life.[109] The 36-item Short-Form [21, 110-121] was the most frequently used instrument to assess the pre-injury health-related quality of life of injury patients, followed by the EuroQol-5 Dimension Questionnaire [122-129], and the SF-12. [130-133]

Furthermore, a study compared fatigue 12 months after minor trauma by participants with mild head injury with those with other injury, and identified injury and baseline predictors of fatigue. The 4-item SF-36 Vitality subscale was administered at baseline using the instruction, "Please give the answer that comes closest to the way you were feeling during the month prior to your current injury".[134] Also, a study that aimed to prospectively examine the influence of preinjury factors, injury-related factors, and postinjury factors on outcome following mild traumatic brain injury assessed preinjury physical and mental health using the SF-36 Health Survey.[34]

Mental health and concussion

A systematic review by Silverberg aimed to identify and evaluate multivariable prognostics for mild traumatic brain injury and determine which pre-, peri- and post-injury variables have independent prognostic value in the context of multivariable models. The review found no specific model that properly predicted individual patient outcomes after mild traumatic brain injury. In terms of psychological causes for mild traumatic brain injury, the most consistent finding was that pre-injury mental health status predicts post-concussion syndrome.[17] Pre-injury mental health was uniquely related to mild traumatic brain injury outcome in seven studies.[34, 80, 135-138] Early post-injury stress and anxiety levels after mild traumatic brain injury are also indicated as predictors of post-concussion syndrome,[17, 21] and appear to influence outcome from mild traumatic brain injury.[139, 140] Women and adults with early post-injury anxiety also have worse prognoses. On the contrary, the severity of mild traumatic brain injury had little impact in the prediction of long-term symptoms.[17]

The term *postconcussion syndrome* refers to the somatic, cognitive, emotional, motor, or sensory symptoms attributed to a concussion or head injury.[141] These symptoms commonly include headache, dizziness, visual disturbance, memory difficulties, poor concentration, mental slowness, difficulty dividing attention, alcohol intolerance, fatigue, irritability, depression, and anxiety. [142-145] Persistent postconcussive symptoms have been defined as symptoms that remain beyond the expected time frame for clinical recovery of 10 days, consistent with the 4th International Conference on Concussion in Sport.[12] Persistent postconcussive symptoms can be defined as symptoms remaining after 10–14 days in adults and more than 4 weeks in children.

Since there is a high number of traumatic brain injuries, it is impossible to provide treatment to all patients, but single-session therapies might be effective for at-risk patients.[146] The strongest predictors of outcome in moderate to severe traumatic brain injury: length of loss of consciousness, initial Glasgow Coma Scores, and duration of posttraumatic amnesia, have not been shown to be significant predictors of post-concussion symptoms after a mild traumatic brain injury.[142, 147] Several studies have identified the presence of preinjury psychiatric or health issues, such as anxiety and depression, and other sources of stress as significant predictors of worse mild traumatic brain injury outcomes.[142, 148] [16, 138, 149, 150] In patients in the hospital with major trauma, a diagnosis of post-concussion syndrome an average of 4.9 days postinjury was just as common in trauma controls as it was in patients with mild traumatic brain injury.[149, 151] Furthermore, post-concussion syndrome was predicted by previous affective or anxiety disorder, female gender, IQ, processing speed, and acute posttraumatic stress symptoms, but not presence of mild traumatic injury.[34] In a systematic review aimed at improving the SCAT tool, higher anxiety and depression scores were associated with higher SCAT2 symptom scores in college athletes.[22] Chin et al [59] found that male athletes diagnosed with Attention Deficit Hyperactivity Disorder had higher symptom scores than those without it, and those with ADHD or Learning Disorders had worse Balance Error Scoring System test performance than those without a diagnosis. Therefore, it is doubtful that symptoms are the sole determinants of outcome after mild traumatic brain injury.

<u>Can pre-injury mental health affect concussion symptom reporting?</u>

The aim of the study by Ponsord et al. was to prospectively examine the influence of pre-injury, injury-related and post-injury factors on post-concussion symptom outcome at 1 week and 3 months postinjury.[34] In this study, having had a mTBI (OR 3.30, p .001), more anxiety symptoms on the Hospital Anxiety and Depression scale (OR 1.32, p .001), and greater pain severity on the VAS (OR 1.03, p .001) at 1 week post-injury were the significant predictors of a greater post concussion score at 1 week post-injury. 1-week ImPACT Verbal Memory and Visual Memory score, gender, age, preinjury SF-36 Physical Health, PTA duration, and 1-week narcotic analgesia were not significantly predictive of postconcussive symptoms at 1 week. When looking at 1 week post-injury variables as predictors of postconcussive symptoms 3 months post injury, having a mild traumatic brain injury was not a significant predictor of higher post-concussion symptom score at 3 months postinjury. However, presence of more anxiety symptoms on the Hospital Anxiety and Depression scale at 1 week was a significant predictor of 3-month post-concussion symptoms (OR 1.18, p .001). One-week assessments on ImPACT Verbal and Visual Memory measures, gender, age, preinjury SF-36 Physical Health, PTA duration, and VAS pain at 1 week were not significant predictors of 3-month Pain Catastrophizing Scale. Therefore, this study found that mild traumatic brain injury predicted post-concussion symptoms during the acute phase after injury, but not at 3 months postinjury. Premorbid psychiatric factors and postinjury anxiety were the strongest predictors of persistent symptoms at 3 months postinjury.[34]

One of the traditional ways of grading brain injury severity, post-traumatic amnesia, was not linked with reported post-concussion symptoms one week and 3 months after injury. Performance on the ImPACT cognitive concussion battery, specifically the Verbal and Visual memory modules, did not predict Pain Catastrophizing Scale score both at 1 week and 3 months postinjury [142, 147, 151], even if participants scored poorly on this test at both one week and 3 months post injury. Post-concussion symptom reporting was more strongly linked with the injured person's anxiety levels at 1 week postinjury, which is associated with preinjury psychiatric history. Therefore, the post-concussion symptoms may be increasing anxiety in those a history of anxiety, simply because they not deal with stress as well, which further exacerbates the symptoms.[34]

Conventional measures of head injury severity such as duration of post-traumatic amnesia have significant limitations in moderate and mild head injuries and have been lacking when used as predictors of patients with persistent post concussion symptoms.[152] A study by King et al. explained that emotional and psychogenic problems seem to play a significant role in the postconcussion sequelae, which might be a factor explaining these inconsistent results. Post-traumatic stress [153] and pre-existing emotional problems [154] have both been shown to correlate positively with persistent post concussion symptoms.[155] 50 patients with mild or moderate head injuries had a range of measures administered 7-10 days after injury, which included the Rivermead postconcussion symptoms questionnaire, the Hospital Anxiety and Depression scalee[156], and the Impact of event scale.[157] The Rivermead Postconcussion Symptoms Questionnaire is commonly used to assess the severity of symptoms after mild or moderate TBI[158] It is a valid and reliable measure of traumatic brain injury consisting of 16 items assessing severity of symptoms in the last 24 hours in comparison to premorbid levels, [158] with total scores ranging from 0 to 64. Report of three or more remaining symptoms, indicated by an item score of two or higher, was used as criterion for post-concussion syndrome.

Their study investigated if a combination of neuropsychological, emotional, and traditional measures of severity of head injury taken 7-10 days after trauma could predict subjects likely to have persistent post concussion symptoms three months later. Results from these measures were correlated with scores from the Rivermead postconcussion symptoms questionnaire readministered 3 months after injury.[155] 50 patients with a mean age of 33 and a mean post-concussion amnesia of seven hours were visited in their home 7-10 days after injury. During this visit, a brief structured interview was conducted to note epidemiological information including duration of post-traumatic amnesia. Patients completed a Rivermead postconcussion questionnaire, a Hospital Anxiety and Depression scale and an Impact of event scale. They also completed the short orientation memory and concentration test[159] and three divided attention tests. At three months post injury the patients were sent an Rivermead post concussion symptoms questionnaire form by mail to fill out and return. Hospital Anxiety and Depression scale Anxiety score had a 0.57* correlation with the Rivermead postconcussion questionnaire score at 3 months postinjury and 0.06* with the Rivermead postconcussion questionnaire score at 7-10 days. The Hospital Anxiety and Depression scale depression score had a 0.54* correlation with the Rivermead postconcussion questionnaire score at 3 months and a 0.65* score at 7-10 days post injury. The Rivermead postconcussion questionnaire score at 7-10 days had a 0.48* correlation with Rivermead postconcussion questionnaire score at 30 days. Regression analysis with Rivermead postconcussion questionnaire score at 7-10 days as a dependent measure showed that 10 of the scores gave a coefficient of R= 0.84 accounting for 71% of the variance.[155] A combination of Hospital Anxiety and Depression scale, PTA, PASAT, AMIPB and SOMC scores accounted for 74% of the variance in Rivermead postconcussion questionnaire scores at 3 months and a combination of IES and SOMC scores accounted for 55% of the variance at 7-10 days.[155] This demonstrates that measures of emotional factors as compared to neuropsychological or other traditional measures are best as individual predictors of symptom severity at 3 months post concussion.

King et al. investigated a cross-validation sample to determine if results of their previous study would be replicated for the early prediction of those still suffering from symptoms at 6 months. A sample of 57 patients admitted to any trauma ward in Oxfordshire with a mild or moderate head injury were recruited from a largescale randomized controlled sample. The assessment measures (mentioned above) were administered at 7-10 days post injury and the Rivermead postconcussion symptoms questionnaire was also administered at 6 months post injury. Simple Pearson correlation co-efficients demonstrated: a 0.45* correlation between Hospital Anxiety and Depression scale anxiety score and Rivermead postconcussion questionnaire score at 6 months and 0.61** correlation between Hospital Anxiety and Depression scale anxiety score and Rivermead postconcussion questionnaire score at 7-10 days, a 0.32* correlation between Hospital Anxiety and Depression scale depression score with Rivermead postconcussion questionnaire score at 6 months and 0.61** with Rivermead postconcussion questionnaire score at 7-10 days, and a 0.37* correlation between Rivermead postconcussion questionnaire score at 7-10 days and Rivermead postconcussion questionnaire score at 6 months. This study confirms the conclusion presented in their original study that emotional factors such as anxiety and depression play an important role in the early presentation of post concussion symptoms, although the early measures (at 7-10 days) are less predictive of symptom severity in the long term.[160]

Pain and concussion

The American Pain Society and the Joint Commission on Accreditation of Health Care Organizations now consider pain as the fifth vital sign, and the Joint Commission has published rules requiring that pain be assessed in all individuals [161] in order for the evaluator to understand where the pain stems from and what it means to the patient. Assessing pain helps in the diagnosis, choice of therapy, and evaluation of progress and influence of the chosen therapy.[161] Self report measures of pain are the “gold standard” and the most valid approach of pain measurement.[162]

Pain is a significant problem following traumatic brain injury.[163] A vast range of explanations have been proposed for the greater pain experience in mild traumatic brain injury compared to more serious brain injuries, such as shorter recovery as well as earlier return to activities of daily,[164] as well as increased awareness of pain because of a lower injury severity or absence of loss of consciousness and posttraumatic amnesia after mild traumatic brain injury.[165] Although pain usually resolves within the first three months[142],persistent symptoms including headaches, sleep disturbances, and fatigue have been reported in 5-15% of patients months to years following the head trauma.[39, 166]

Fear avoidance model

The fear avoidance model has predicted recovery in patients with medical issues including chronic pain [167], tinnitus [168] [169], cancer survivors [170], chronic fatigue [171], fibromyalgia [171] and fatigue in multiple sclerosis.[172, 173] It represents the theory behind effective treatment options in these patient groups, such as graded exposure therapy [174] or newer generations of cognitive behavioral therapy.[172] The fear-avoidance model helps explain why some individuals with acute pain develop chronic pain and disability, whereas others do not. According to the model[175-177], the fear that physical activity will recreate pain, along with catastrophic appraisals of pain, creates a self-perpetuating cycle of avoidance, hypervigilance, depression, disuse, and pain.

When this fear avoidance model is applied to post-concussion syndrome, patients may catastrophize thoughts about the damage to their brain and the consequences of the injury, which leads to increased anxiety and avoiding behaviors that could lead to reinjury or more symptoms over time. For example, a concussed athlete may avoid doing any type of physical or mental activity fearing that it might recreate or make their symptoms worse. According to the fear avoidance model, symptoms are unfairly interpreted as a sign of serious injury or disease over which one experiences little or no control. This misinterpretation of symptoms typically leads to a disproportional fear of these symptoms and injury that, over time, becomes a disabling fear of experiencing symptoms to the point where these people will avoid doing these activities fearing that it will make their problem worse.[20]

In this text, fear avoidance and pain related fear will be used interchangeably since they represent a common construct. Depending on the scale being used in the study (Athlete Fear Avoidance Scale or Tampa Scale of Kinesiophobia), the corresponding term will be used, but always referring to the same model, seen below (figure 1).

Figure 1. Fear Avoidance model applied to TBI patients

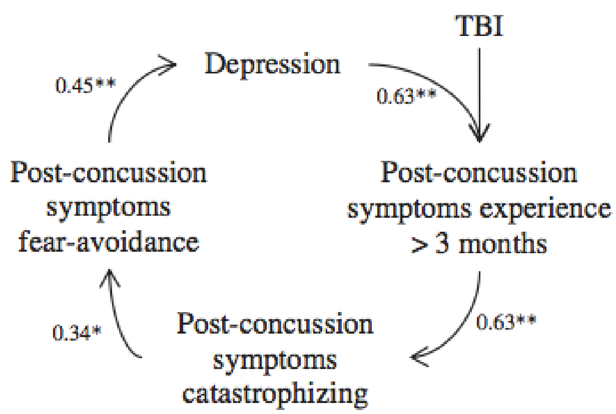


Figure 1. *Fear avoidance model in patients with TBI (n = 48).*
Notes. Values shown are Pearson correlations and based on cross-sectional data.
* $p < 0.05$, ** $p < 0.01$.

[178]

Although avoidance behavior may be adaptive in the acute phase of injury, meaning that the patient is simply getting used to the pain, it can later lead to disuse, disability and depression which paradoxically worsens the symptoms. [167] Therefore, this model demonstrates that it is not necessarily the severity of the injury, but rather the extended catastrophic thinking about the symptoms and fear avoidance behavior that will determine the timely persistence of symptoms and the level of disability.[20]

The fear avoidance model was proposed as an explanation for persistent symptoms in mild traumatic injury over two decades ago by Kay, et al.[178] They suggested the combination of two fear-avoidance cycles, one regarding the pain (headache) experience as previously validated in patients with other pain conditions, and one regarding the cognitive symptoms. According to the cognitive fear avoidance cycle, the cognitive symptoms are wrongly understood as a sign of a disease over which one has little or no control. This catastrophizing could lead to fear and avoidance of mental activities in fear that they could exacerbate those symptoms. This has been defined as cogniphobia [172, 173], which then leads to decreased activity levels and could result in disuse, disability and depression. Dean, et al. [79] stated that headache and cognitive complaints are the most specific symptoms of the post-concussion symptoms following mild traumatic brain injury, which confirms the logic behind the combination of these two fear avoidance cycles.

Pain catastrophizing is defined as an exaggerated appraisal of the negative components of an actual or anticipated pain experience.[179, 180] Pain catastrophizing is believed to be a multidimensional construct compromised of magnification, rumination, helplessness and pessisimism.[162] Studies have consistently demonstrated relationships between increased pain and catastrophizing in both healthy asymptomatic individuals [18, 180, 181] and various patient groups.[182, 183] Links between catastrophizing and abnormal changes in brain morphology and function has been shown in migraine patients[184], illness behaviors such as frequency of visits to healthcare professionals and hospital stays[185], and use of medication.[186]

Another aspect of the fear avoidance model is kinesiophobia or fear of re-injury. Previous authors have suggested that there might be a relationship between fear of re-injury throughout recovery in concussed high school athletes. 41 concussed high school athletes aged 14-18 years old with a medically diagnosed sports-related concussion were recruited from community sports-concussion surveillance programs of the U.S. At the initial visit (within 14 days of injury), patients with high fear (Tampa Scale of Kinesiophobia ≥37) had an average symptom severity score of 30.54, while those in the low fear group (Tampa Scale of Kinesiophobia < 37) had an average symptom severity score of 12.29. This suggests that kinesiophobia might be related to the severity of symptoms in concussed athletes. This study was the first to study changes in fear of re-injury throughout recovery in concussed high school athletes, with fear scores decreasing significantly from initial visit to medical clearance (average initial visit TSK= 36.78 $\pm$ 5.84, medical clearance TSK 30.02 $\pm$ 5.20). Also, athletes in the high fear group had significantly higher symptoms, cognitive-migraine-fatigue, and affective symptoms at the initial clinical visit compared to the low fear group. This study examined concussion symptoms in the more acute stage, which is what we did in our study. [187]

Pain related fear – an explanation for the variability in pain and use in concussions?

Pain sensitivity may depend on multiple factors, such as cognitive, lifespan, environmental, social/cultural, sex and gender, heritability, psychological, and biological. Pain catastrophizing is a negative cognitive style, which at the extreme includes feelings and beliefs that the pain experienced is beyond the control of the individual and will inevitably result in the worst possible outcome. The Pain Catastrophizing Scale is one example of a measure of pain catastrophizing[18]. Pain-related fear can be measured with the Fear of Pain Questionnaire which is a self-report measure of anticipated fear for hypothetical situations that assesses severe pain, minor pain and medical pain.[188] A high score on the Fear of Pain Questionnaire indicates a high level of pain-related fear. The Fear-Avoidance Beliefs Questionnaire assesses pain-related fear associated with clinical pain conditions, specifically addressing fear-avoidance beliefs of physical activity.[189] Experimental studies comparing psychosocial individual differences in relation to experimental cutaneous pain have demonstrated that higher self-reports of negative emotionality, anxiety, pain catastrophizing, and fear of pain are associated with lower pain thresholds, lower pain tolerance, and higher pain sensory and affective ratings.[190, 191]

An example of interindividual pain variability from an experimental condition can be seen in figure 2, which illustrates pain sensitivity as determined by pain intensity ratings, for young, healthy subjects receiving a standard thermal stimulus of 49°C (S. George, unpublished data). The vast range of pain responses indicates the variability of the pain experience, even under circumstances involving healthy subjects receiving a controlled stimulus. When these healthy subjects filled out the fear of pain questionnaire, higher pain ratings were positively correlated with Fear of Pain questionnaire scores, as seen in figure 3.[162] Therefore, pain-related fear variability among subjects may explain the variability in pain ratings.

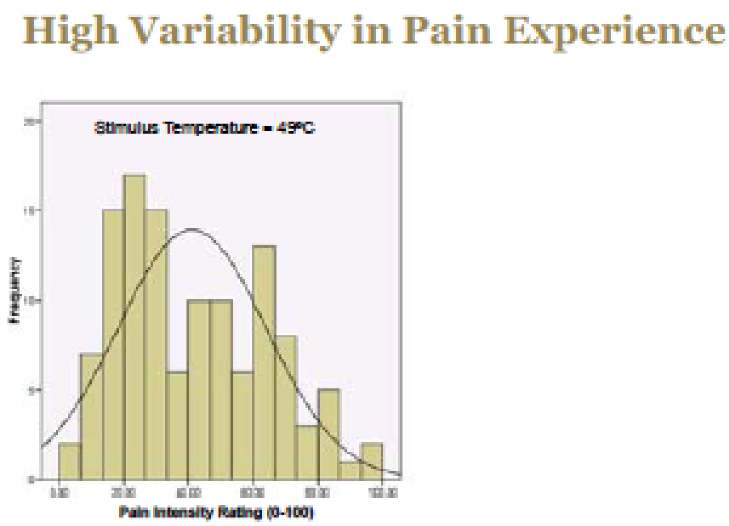


Figure 2. Pain sensitivity as determined by pain intensity ratings for young, healthy subjects receiving a standard thermal stimulus of 49°C.[162]

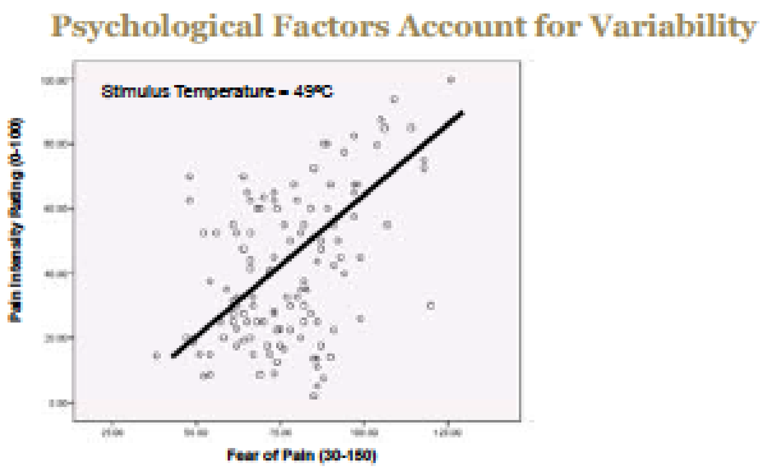


Figure 3. Fear of Pain Questionnaire score v.s. pain intensity rating. (0-100) [162]

A sample of 58 participants were recruited as part of a large-scale study studying sleep patterns in mild traumatic injury patients from the emergency department of a specialized trauma centre in Montreal from January 2006 to August 2010. Patient charts were reviewed for previous medical, surgical, and traumatic brain injury history. The 13-item pain catastrophizing scale was used to measure pain catastrophizing[18], the 16-item Rivermead Postconcussion Symptoms Questionnaire was used to measure postconcussion symptoms[192], and the Multidimensional Pain Inventory scale was used to measure behavioral, cognitive, and emotional dimensions of living with pain.[193] Subjects were asked to fill out the Rivermead postconcussion questionnaire at 1 month after mild traumatic brain injury. Participants completed the Multidimensional Pain Inventory scale, the Pain Catastrophizing scale, and a second Rivermead postconcussion questionnaire at home within 6–8 weeks of their diagnosis and returned their completed questionnaires to the hospital by mail. A cross-sectional design was used in order to examine the role of pain coping styles in mild traumatic brain injury outcome. [194] When looking at pain catastrophizing and pain severity, headache pain (from the Rivermead postconcussion questionnaire) at time 2 (6-8 weeks) was associated with pain catastrophizing magnification (r = .35, p = .02). General pain at Time 2 (MPI Pain Severity) was associated with Pain Castrophizing Rumination (r = .33, p =.02), Pain Catastrophizing Magnification (r = .31, p = .03), Pain Catastrophizing Helplessness (r = .44, p < .01), and overall Pain Catastrophizing (r = .39, p < .01) [194]. When looking at pain catastrophizing and postconcussion symptoms results, the most frequently reported Rivermead postconcussion questionnaire postconcussion symptoms at Time 1 (1 month) were fatigue (70%), sleep disturbances (66%), dizziness (52%), headaches (50%), and reduced ability to concentrate (50%). Symptoms reported at Time 2 (6-8 weeks) included fatigue (69%), sleep disturbances (63%), reduced ability to concentrate (63%), and dizziness (60%). Rivermead postconcussion questionnaire assessments at Time 1 and Time 2 were significantly correlated in terms of both total scores (r = .59 , p < .001) and number of symptoms reported as a 2 or greater (r =.63 , p < .001).The total number of postconcussion symptoms at both time points was significantly associated with all pain catastrophizing measures. Level of functionality (MPI General Activities) was negatively associated with PC Rumination (r = −.29 , p = .03); PC Magnification (r = −.43 , p < .001); PC Helplessness (r =−.38 , p = .004); and overall PC (r = −.37 , p = .004).[194]

Therefore, pain catastrophizing is linked with greater severity of headache and general pain in the first 2 months post mild traumatic brain injury, supporting clinical studies stating that pain catastrophizing negatively affects the pain experience.[184, 186, 195, 196] This study contributed a novel finding that subjects with high levels of pain catastrophizing reported a greater number of postconcussion symptoms and had a higher risk of postconcussion syndrome development at 8 weeks after mild traumatic brain injury.[194] There is evidence suggesting that coping strategies are related to emotional issues. [197, 198] In their discussion, the authors suggested that further prospective studies should determine whether these relationships can also be observed at earlier time points. If baseline catastrophizing tendencies could predict mild traumatic brain injury outcome, the pain catastrophizing scale could used as a screening tool, since it is cheap and easy to administer and interpret.[194] This early screening of pain catastrophizing might help with the application of goal-oriented psychological interventions in order to limit or prevent on-going symptoms. [199]

Melloney et al. set up a cross-sectional study design in order to investigate if the fear avoidance model, including catastrophizing thoughts and fear avoidance behaviour, poses a possible biopsychosocial explanation for lingering symptoms and delay in recovery after traumatic brain injury, with special focus on mild traumatic brain injury. Patients who had received multidisciplinary treatment at the rehabilitation centre Zuyderland, Sittard-Geleen (NL) from 2009-2012 for a traumatic brain injury were asked to participate at least 3 months after the injury to confirm the presence of persistent symptoms.[20] Without taking into account symptom severity, cognitive problems (memory, concentration, mental slowness) and fatigue were some of the most reported symptoms. 85.4% off all traumatic brain injury and 93.5% of mild traumatic brain injury reported fatigue as a symptom. The strongest link was between post-concussion symptoms and catastrophizing about these same symptoms ($r = 0.63$ in the entire sample and $r = 0.69$ in the mTBI sample). The correlations between post-concussion symptoms to depression and catastrophizing were slightly higher in the mild traumatic brain injury subsample than in the entire sample.[158] Compared to pain experiences such as chronic pain and fibromyalgia, the results of this study demonstrated low levels of catastrophizing and fear avoidance behaviour regarding post-concussion symptoms [18, 19, 200, 201], although all correlations suggested by the fear avoidance model regarding post-concussion symptom experience were significant. This study suggested that the fear avoidance model may help explain persistency of symptoms.[20] An interesting finding of this study was that prevalence of post-concussion symptoms were equal or higher in the mild traumatic brain injury group compared to the moderate or severe group, demonstrating that brain injury severity is not directly related to symptoms.[20] Some studies found similar results[202, 203], some found that increasing symptom reporting was correlated with increased brain injury severity[204], and other studies found that mild, moderate or severe group differences disappeared when controlling for post-traumatic stress complaints[202]. These varying results show that injury severity cannot be used on its own to explain persistence of symptoms[53] and emphasizes the need for a biopsychosocial explanation,[17] such as the fear avoidance model.

Knowledge gap

Present studies that have looked at pain related fear in concussions have studied it's impacts in the long-term (2 months to 3 months after the injury). To our knowledge, no previous study has studied the impact of pain related fear, catastrophizing and depression and anxiety on the acute, on-field measure of concussion within 48 hours after injury. The goal of this study was to measure pain related fear using the Athlete Fear Avoidance Questionnaire[205], pain catastrophizing using the Pain Catastrophizing Scale[206] and Tampa Scale and depression using the Hospital Anxiety and Depression scale[156], and compare it to the results of the SCAT5 subcomponent scores. The SCAT5 is the gold standard for field immediate measurement of concussion. [23] We hypothesized that athletes with a greater score on the Athlete Fear Avoidance Questionnaire, Pain Catastrophizing Scale, Tampa Scale of Kinesiophobia and Hospital Anxiety and Depression Scale would score higher on the SCAT5 total score, and on the symptom subscale of the SCAT5.

Methods

Participants

The inclusion criteria for participating in our study was being 18 years old or older, and having sustained a concussive impact in the past 48h hours. The exclusion criteria was being 17 years old or younger, having sustained an impact to the head or another part of the body but not presenting any signs and symptoms of a concussion, and presenting with a concurrent injury.

Materials

SF-36:

We used the 36-iterm short-form (SF-36) to estimate pre-injury general health status of subjects. Participants were asked to fill out the form based on how they felt prior to being concussed. The 36-item short-form was constructed to survey health status in the Medical Outcomes Study. The SF-36 was designed for use in clinical practice and research, health policy evaluations, and general population surveys. The SF-36 includes one multi-item scale that assesses eight health concepts: 1) limitations in physical activities because of health problems; 2) limitations in social activities because of physical or emotional problems; 3) limitations in usual role activities because of physical health problems; 4) bodily pain; 5) general mental health (psychological distress and well-being); 6) limitations in usual role activities because of emotional problems; 7) vitality (energy and fatigue); and 8) general health perceptions. The survey was constructed for self-administration by persons 14 years of age and older, and for administration by a trained interviewer in person or by telephone. [207] We used an on-line calculator to generate a percentage for each of the 8 subscales. [208]

Athlete Fear Avoidance Questionnaire**:**

We used the Athlete Fear Avoidance Questionnaire to measure injury-related fear avoidance in athletes. This scale can be used by sports medicine professionals, including athletic therapists and athletic trainers, as an extra rehabilitation tool to identify fear avoidance in athletes as a potential negative psychological barrier to rehabilitation.[205] Fear-avoidance scales for the general population have already been used to predict return to work and the development of chronic pain.[209, 210] Similarly, identifying athletes with high levels of fear avoidance using a sport-specific scale may allow clinicians to address this psychological barrier early in rehabilitation and reduce the time until return to play.[205]

Pain Catastrophizing Scale:

We used the Pain Catastrophizing Scale to measure pain catastrophizing about concussion. The Pain Catastrophizing Scale has adequate psychometric properties [206] and is validated in acute and chronic whiplash disorders [211-213] and was used in patients with mild traumatic brain injury [214]. It consists of 13 items measuring the self-reported frequency of catastrophizing thoughts about the experienced pain with a 5 point Likert scale. The score ranges from 0 and 52, with higher scores indicating a higher intensity of catastrophizing. A score of 30 or higher can be used for identifying a high level of catastrophizing thoughts based on patients with pain and represents the 75th percentile according to the manual.[214]

Tampa Scale of Kinesiophobia**:**

We used the Tampa Scale of Kinesiophobia to measure concussion-related fear avoidance behavior. This scale was first described by Miller [201] and then validated in chronic low back pain patients.[177] The Tampa Scale for Kinesophobia consists of 17 items and the score ranges from 17 to 68 with a score higher than 37 indicating an above average and according to the manual a high level of fear avoidance behavior in patients with pain.[20]

Hospital Anxiety and Depression scale:

We used the Hospital Anxiety and Depression Scale (HADS)[156], a valid and reliable measure for screening depression in patients with traumatic brain injury.[215] The score ranges from 0 to 21 with a higher score indicating a higher intensity of depressive symptoms. Whelan-Goodinson, et al. showed that a score of 8 or higher is an indication for depression in patients with traumatic brain injury.[215]

SCAT5

We used the SCAT5 to assess concussion in subjects. The SCAT5 is a tool to be used by healthcare professionals in the evaluation of individuals 13 years old or older, who are suspected of having sustained a sports related concussion.[58] The diagnosis of concussion relies on a clinical synthesis of complex, non-specific and at times contradictory information. Therefore, only healthcare professionals trained in assessing and managing SRC should use the SCAT5, which is not designed to be used in isolation to make or exclude the diagnosis of concussion. The SCAT5 includes complete instructions for the appropriate administration of the subscales that should be carefully studied and practiced before using it as an assessment tool.[58]

The SCAT5 is separated into an immediate or on-field assessment section and an office or off-field assessment. Step 1 of the on-field assessment notes red flags that would indicate immediate transportation to a medical facility. Step 2 contains observable signs that should be noted after an athlete a sustained concussion. Step 3 lists memory assessment Maddock's questions that should be asked. Step 4 contains the assessment of the Glasglow Coma Scale and the cervical spine assessment.[216]

Scat 5 procedures:

The office or off-field assessment must be completed in a distraction-free environment with the athlete in a resting state, at least 10 minutes after the athlete has been removed from play. Step 1 involves taking down information about the athlete's background. Step 2 involves asking the athlete to complete a symptom scale, rating a list of 22 symptoms on a scale of 0-6, 0 being none and 6 being severe. Step 3 involves cognitive screening through orientation questions, immediate memory evaluation using 5 to 10 world list groups, and concentration testing using digits backwards and months in reverse order. Step 4 involves neurological screening and balance examination. Step 5 involves delayed recall of the 5 and 10 words asked earlier in the SCAT5. Step 6 involves taking a decision about return to play. A note at the bottom of the SCAT5 reminds medical professionals using the SCAT5 as an assessment tool that scoring on the SCAT5 should not be used as a stand-alone method to diagnose concussion, measure recovery or make decisions about an athlete's readiness to return to competition after concussion.

Procedures

We approached athletes from John Abbott college, Champlain college and Concordia University sports teams. Their respective athletic therapists received an information session about our research before the start of the season and were asked to contact the researchers by phone call or text message when one of their players got concussed. Once the researcher was informed by a team's athletic therapist or physiotherapist that an athlete sustained a concussion, the researcher set up a time, to meet with the athlete. The researcher met with the concussed athletes within 48h of sustaining a concussion since the diagnostic utility of the SCAT and its components appears to decrease significantly after 3–5 days postinjury[22].The subjects were asked to complete a consent form, accepting to participate in our research after having the researcher explain the goal of the research study and what will be done during the testing. During this testing session, a full SCAT5 was completed and the athlete was asked to fill out the SF-36, Athlete Fear Avoidance Questionnaire, Pain Catastrophizing Scale, Tampa Scale of Kinesiophobia and Hospital Anxiety and Depression scale.

Statistical Analysis

Pearson correlation coefficients (r) were calculated to determine the relationship between the number of concussion symptoms, pain related fear, anxiety, and depression. Specifically, we identified the relationship between the symptom subcomponent scores of the SCAT5 and all pain related fear measures (AFAQ, Pain Catastrophizing scale, TSK) as well as anxiety and depression (HADS). We used a stepwise regression to identify the contribution of each variable (AFAQ score, HADS anxiety score, and HADS depression score), to the total number of symptoms dependent variable. A second stepwise regression was done to identify the contribution of each variable (AFAQ score, HADS anxiety score, and HADS depression score), to the severity of symptoms dependent variable.

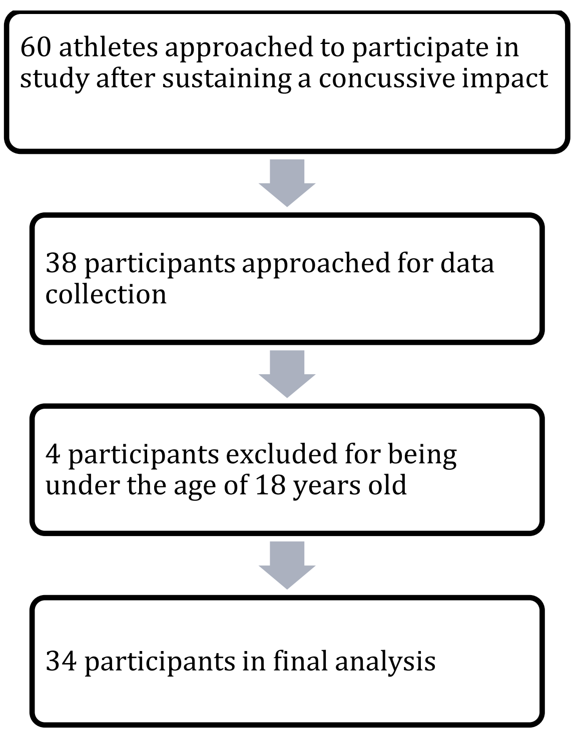
Data analyses were performed using SPSS Statistics 22.0 for Windows.

Results

Participants:

Approximately 60 athletes were approached to participate in this study after having sustained a concussive impact. We collected data from a total of 34 participants after receiving their informed signed consent. The reason why not all athletes who were approached to participate in the study actually participated is that by the time the athlete was put into contact with us, the data collection occurred after the 24-48h time frame for data collection and the symptoms started to decrease. Other times, the athletes decided to not participate, but unfortunately we didn't have the opportunity to explain our research to them, as that might have made them more inclined to say yes since they understood the goal. A few concussed athletes would also leave for home for a couple days immediately after the concussion and would not show up to school or practice, so it was impossible to be in contact with them and complete the data collection. Also, 4 athletes could not participate because they were 17 years old. The final analysis included 34 participants. Four participants were excluded from the analysis as they were under the age of 18 years old, and being 18 years of age or older was one of our inclusion criteria.

Figure 4. Participant exclusion flowchart



The average age of the participants was 20.9 ± 1.8 years old, with an average height of 178.1 ± 11.1 cm and an average weight of 84.7 ± 25.6kg. One participant had already been hospitalized for a head injury. 6 participants were diagnosed and/or treated for headaches or migraines. To the question "were you ever diagnosed with a learning disability/dyslexia?", one participant replied with "dyslexia" and one replied with "verbal dyspraxia" and the rest responded with "no". To the question, "Diagnosed with ADD/ADHD?", 2 participants replied with "ADD" and the rest replied "no". 2 participants reported that they were already diagnosed with depression, anxiety or other psychiatric disorder.

Table 1. Demographic variables of athletes participating in the study

demographic variables		frequency (n) or average
sex	male	23
	female	11
age		20.9 ± 1.8 years old
height		178.1 ± 11.1 cm
weight		84.7 ± 25.6 kg
sport	basketball	4
	cheerleading	2
	football	7
	hockey	12
	lacrosse	1
	ringuette	1
	rugby	4
	soccer	2
	volleyball	1
education level	cegep	8
	university	26

Table 2. SCAT 5 results

Hand dominance	right	32
	left	1
	neither	1
# of past concussions		1.9 ± 1.7
Total # of symptoms		7.4 ± 5.1
Symptom severity score		16.3 ± 17.0
Hours from injury to assessment		33.4 ± 17.9
Orientation score (/5)		4.94 ± 0.25
Digits backwards (/4)		3.26 ±0.93
Months score (/1)		0.90 ± 0.30
Concentration score (/5)		4.19 ± 0.91
Balance (errors /10)	Double leg	1.65 ±3.73
	Single leg	3.81 ±2.90
	Tandem stance	2.23 ±3.41

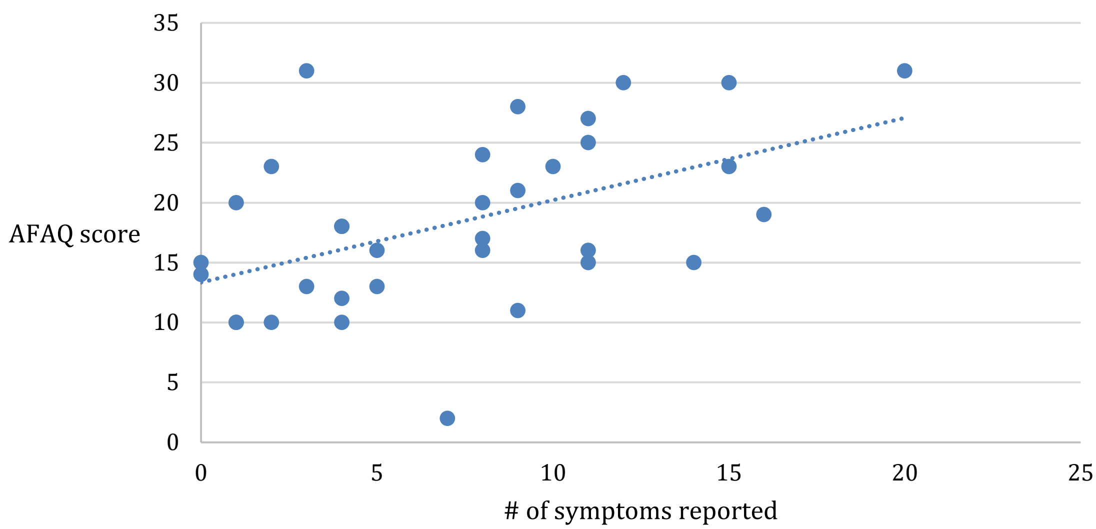
# of past concussion, total # of symptoms and symptom severity score were self-reported by the participants on the SCAT 5.
Hours from injury to assessment were the # of hours from the moment the athlete sustained a head injury to the moment they met with us to complete the questionnaires.

5 word and 10 word list score and delayed recall was not reported in results since some used the 5 word list and others used the 10 word list

Relationship between SCAT5 and psychological variables

Total number of symptoms and symptoms severity score on the SCAT5 and fear avoidance. The total number of symptoms reported on the SCAT5 was associated with the AFAQ score (r=0.493). The symptom severity score was associated with the AFAQ score (r=0.481).

Figure 5. Relationship between # of symptoms and AFAQ score



# of symptoms reported : total # of symptoms reported by participants on the SCAT 5
AFAQ score: Athlete Fear Avoidance Questionnaire score

Total number of symptoms and symptoms severity score on the SCAT5 and anxiety and depression. The total number of symptoms reported on the SCAT5 was associated with the HADS score (r=0.686). The symptom severity score was associated with the HADS score (r=0.602). In addition, the total number of symptoms was associated with the HADS depression subscore (r=0.614) and with the HADS anxiety subscore (r=0.563). The symptom severity score was associated with the HADS depression subscore (r=0.541) and the HADS anxiety subscore (r=0.492).

Total number of symptoms and symptoms severity score on the SCAT5 and mental health pre-concussion. The total number of symptoms was associated with the mental health subscore of the SF-36 questionnaire (r= -0.556) and the vitality subscore of the SF-36 questionnaire (r= -0.481). The symptom severity score was associated with the mental health subscore of the SF-36 questionnaire (r= -0.518) and the vitality subscore of the SF-36 questionnaire (r= -0.403).

Significant predictors of symptom number and symptom severity on the SCAT5. Two separate linear regressions using variables that were significantly correlated to the number of symptoms and the severity of symptoms were calculated. The AFAQ score, HADS depression and HADS anxiety scores model was a significant predictor of the total number of symptoms reported on the SCAT5, accounting for 50.4% of the variance ($p>0.001$). The AFAQ score, HADS depression and HADS anxiety scores model was also a significant predictor of the severity of symptoms reported on the SCAT5, accounting for of the 41% of the variance ($p=0.001$).

Table 3. R-values matrix between variables

Column1	total # of symptoms	symptom severity score	# of past concussions	SF-36 physical functioning subscore	SF-36 role physical subscore	SF-36 role emotional subscore	SF-36 bodily pain subscore	SF-36 mental health subscore	SF-36 vitality subscore	SF-36 social functioning subscore	SF-36 general health subscore	PCS score	TSK score	AFAQ score	HADS anxiety score	HADS depression score	HADS total score
total # of symptoms	-	0.908**	-0.003	-0.374*	-0.338	-0.314	-0.154	-0.556**	-0.481**	-0.06	-0.23	0.299	0.282	0.493**	0.563**	0.614**	0.686**
symptom severity score		-	0.109	-0.329	-0.299	-0.331	-0.316	-0.518**	-0.403*	-0.14	-0.157	0.33	0.253	0.481**	0.492**	0.541**	0.602**
# of past concussions			-	0.089	0.05	-0.197	-0.069	-0.129	-0.167	-0.388*	-0.157	0.305	0.138	0.332	-0.013	-0.029	-0.26
SF-36 physical functioning subscore				-	0.219	0.229	0.389*	0.32	0.209	-0.039	0.271	-0.347*	-0.28	-0.521**	-0.159	-0.626**	-0.485**
SF-36 role physical subscore					-	0.605**	0.195	0.247	0.235	0.327	0.014	-0.109	-0.28	-0.254	-0.057	-0.626**	-0.044
SF-36 mental health subscore								-	0.741**	0.422*	0.468**	-0.422*	-0.193	-0.515**	-0.479**	-0.398*	-0.503**
SF-36 vitality subscore									-	0.437**	0.451**	-0.197	-0.166	-0.427*	-0.318	-0.307	-0.362*
SF-36 social functioning subscore										-	0.469**	-0.048	-0.228	-0.174	-0.114	0.07	-0.014
SF-36 general health subscore											-	-0.142	-0.118	-0.185	-0.174	-0.296	-0.28
PCS score												-	0.485**	0.711**	0.526**	0.356*	0.500**
TSK score													-	0.637**	0.165	0.366*	0.321
AFAQ score														-	0.346*	0.475	0.484**
HADS anxiety score															-	0.481**	0824**
HADS depression score																-	0.893**

Discussion

Total number of symptoms and symptoms severity score on the SCAT5 and pain related fear.

Our study identified a significant relationship between pain related fear and the number of concussion symptoms and the severity of the symptoms. This relationship indicates that pain related fear may contribute to the variability of concussion symptoms. By including pain related fear in the concussion evaluation, patients with high pain related fear might benefit from this aspect being addressed in the treatment plan. Future studies should study the impact of addressing pain related fear in the treatment plan on symptom progression and concussion recovery. Past studies have identified that pain related fear is present in the chronic stage of a concussion,[20, 178, 194] but this study demonstrates that it is already be present in the acute stage. If future studies suggest that addressing pain related fear initially helps to reduce symptoms, evaluating it in the first 48h would be important and have an impact on the progression of concussion symptoms.

A few studies have examined the relationship between fear avoidance and concussion symptoms, but the physiological mechanism for this remains unclear. Fear avoidance stems from the belief about the danger in engaging in specific activities or being exposed to certain stimuli, and comes from classic conditioning. The escape and avoidance response is the conditioned response which occurs in the anticipation of an unconditioned stimuli, which may be pain or fear or reinjury in the case of concussions.[217] In the first 48h after a concussion, early attempts to participate in physical or cognitive activity, or being exposed to certain stimuli, may exacerbate certain symptoms of a concussion. This increase in symptoms may lead to fear avoidance, as athletes may view an increase in symptoms or appearance of new symptoms as “dangerous” and avoid any activity or stimulus that can increase symptoms. [218] Therefore, this may explain why an athlete with a high number of symptoms and high symptom severity score may also have a high score on the Athlete Fear Avoidance Questionnaire. Although current concussion recommendations suggest an initial period of 48h of rest before gradually reintegrating physical and cognitive activity,[219] initial fear avoidance behaviours may lead to athletes continuing to avoid physical and cognitive activity past this initial rest period.

The Trigger Avoidance Model of Headaches, similar to the Fear Avoidance model, proposes that avoidance and escape behavior, specific to headache/migraine triggers, may result in increased sensitivity to, and decreased tolerance for the triggers.[220] In the case of concussions, specifically in the acute stage, athletes do not know the specific activities or stimuli which may cause an increase in symptoms, therefore they may choose to restrict their activities to avoid symptoms. The more they avoid different stimuli, the greater their sensitivity when exposed to these stimuli. For example, they may avoid light and noise by putting sunglasses and earplugs at all times, but this would potentially make them more sensitive once they are forced to being exposed to a bright room or to a noisy area. Therefore, this may be another explanation as to why athletes with high concussion symptoms may also have a high score on the Athlete Fear Avoidance Questionnaire.

Pain related fear has been studied in the context of low back pain. According to the common-sense model, pain-related fear may be a “common-sense” problem-solving response based on a threatening representation of low back pain. The interpretation of pain is led by symptom perception, social messages, and previous experiences related to this low back pain. In the absence of a logical explanation of the cause of their pain, behaviour will be driven by the emotional response to this pain. [221] Therefore, in the context of a concussion, athletes may not understand the exact cause of the symptoms they are feeling, have had social messages about concussions that worry them, or negative previous concussion experiences. This may lead to behaviour driven by the emotional response to concussion symptoms. Therefore, athletes with higher fear avoidance, the emotional response to their symptoms, may report more symptoms.

Other pain related fear variables

In addition to fear avoidance, catastrophizing has been examined in mild traumatic brain injuries. In a study investigating if the fear avoidance model poses a biopsychosocial explanation for lingering symptoms and delay in recovery after TBI, with a special focus on mTBI, the strongest link was between post-concussion symptoms and catastrophizing about symptoms ($r = 0.63$ in the entire sample and $r = 0.69$ in the mTBI sample)[20]. The participants in their study were subjects who had or were receiving multidisciplinary treatment at the rehabilitation centre at the Zuyderland Medical Centre, Sittard-Geleen, the Netherlands. There were 23 men and 25 women, with an average age of 45.5 years. In our study, symptom severity score was not significantly correlated to Pain Catastrophizing scale score ($r= 0.330$, $p=0.057$), but we used the SCAT 5 symptom scale to assess concussion symptoms while they used the Rivermead Post-concussion questionnaire, and they used Post-concussion Symptoms Catastrophizing Scale, an adaptation of the Dutch translation of the Pain Catastophizing Scale, Their study did not only include sports-related concussions and their average age was much higher than ours. We assessed athletes within 48h of the injury, while the mean time since injury was 48.2 months in this study.[20] This may demonstrate that pain catastrophizing may help predict concussion symptoms in the chronic stage, but not in the acute stage.

In another pain catastrophizing study, the authors recruited a sample of 58 participants as part of a large-scale study studying sleep patterns in mild traumatic injury patients from the emergency department of a specialized trauma centre in Montreal from January 2006 to August 2010. They suggested that pain catastrophizing is associated with greater severity of pain (both headache pain and general pain) in the first 8 weeks following mTBI. Headache pain from the Rivermead Postconcussion Questionnaire 8 weeks post concussion was associated with Pain Catastrophizing Magnification (r = .35, p = .02), General pain from the MPI Pain Severity Questionnaire at 8 weeks was associated with Pain Catastrophizing Rumination (r = .33, p = .02), Pain Catastrophizing Magnification (r = .31, p = .03), Pain Catastrophizing Helplessness (r = .44, p < .01), and overall Pain Catastrophizing (r = .39, p < .01). We cannot compare this finding to ours as we did not measure severity of pain using the MPI Pain Severity Questionnaire, we did not do any correlations with the Pain Catastrophizing subscores and our evaluation was done in the first 48h after injury versus 4 and 8 weeks post injury. Also, the mean age in their study was 39.6 years old, which is again higher than in our study, and the concussions were not always related to sports in their study. [194]

The average Tampa Scale of Kinesiophobia score of our participants was similar to previous studies. In a study where 41 concussed high school athletes aged 14-18 years old with a medically diagnosed sports-related concussion were assessed, the TSK score was 36.78 ± 5.84 at initial visit (within 14 days of injury), while ours was 36.1 ± 6.8. In this study, the high fear group had an average symptom severity score of 30.54, while those in the low fear group had an average symptom severity score of 12.29. Our mean symptom severity score was 16.3 ± 17.0. The correlation between our mean symptom severity score and the TSK score was not significant (r=0.253). Since the overall mean symptom severity score was not reported in this study, we cannot compare it to ours.[187] The correlation between TSK score and mean symptom severity score might not be significant in our study because we didn't separate the participants into high and low fear groups. It is possible that kinesiophobia is not correlated to concussion symptoms. The Tampa Scale of Kinesiophobia may be too specific for kinesiophobia, and fear of re-injury questions may not translate to concussions as well.

Relationship between anxiety and depression and concussions symptoms and severity

Our results also indicated a significant relationship between the number of symptoms and symptom severity with anxiety and depression. This has been noted before in other post concussion symptoms studies. A previous study investigated whether a combination of neuropsychological, emotional and traditional measures of severity of head injury taken 7-10 days after injury can help predict post concussion symptom severity 3 months after injury. The 50 patients had an average age of 33 years old and the causes of concussion were 20 road accidents, 13 falls, five assaults, five horse back riding accident and seven other. The independent measures which had the strongest individual correlations with the Rivermead Postconcussion questionnaire at 7-10 days post injury were the HADS scores and the IES measures (HADS anxiety score and RPQ score r= 0.60, HADS depression score and RPQ score r= 0.65). [155] Similarly, in our study, the symptom severity score was associated with the HADS total score (r=0.602). Therefore, both studies had similar correlations even though the mean age was different, and the cause of injury was sports concussions in our study and other causes in their study.

A study by Greenberg completed self-report measures of anxiety, postconcussion symptoms, pain catastrophizing and limiting behaviour.[222] Patients (n=57) had an average age of 47.08 years old and were recruited from an mTBI clinic at the Massachussetts General Hospital. In preliminary simple mediation models, both pain catastrophizing (b= 0.24, 95% confidence interval) and limiting behaviours (b= 0.14, 95% confidence interval) partially mediated the relationship between anxiety and postconcussion symptoms, therefore addressing these two factors may be critical in concussion recovery. [222] Up to 70% of patients with mTBI report anxiety symptoms, and 21-36% meet diagnostic criteria for anxiety disorder. [223, 224] Anxiety may lead to amplified symptoms because of a misinterpretation of these symptoms as harmful, and further lead to avoiding certain activities because of that. In this study, simple mediation models indicated that the effect of anxiety on post-concussion symptoms was partially mediated by limiting behaviour and pain catastrophizing, and the multi mediation model indicated that both pain catastrophizing and limiting behaviour contributed to the relationship between anxiety and postconcussion symptoms. Their results provided evidence for the effects of pain catastrophizing and limiting behaviour on the relationship between anxiety and postconcussion symptoms.[222] Their participants were recruited in the chronic stage where as ours were recruited in the acute stage, but this explanation may also be applied to the acute stage.

Symptom level of concussed athletes in this study

The mean number of symptoms and severity score we noted in this study was a little lower than what has been previously reported. Even though we used the SCAT5, we were able to compare the number of symptoms and symptom severity score in our study to the ones in studies that used the SCAT2, SCAT3 or SCAT4 because the symptom section hasn't changed (same symptom names, rating, and number of symptoms listed). In a study that aimed to provide clinicians with standard cutoff values from the SCAT-3 to differentiate concussed nonathlete subjects from nonathlete healthy controls, 118 participants with head injury completed the SCAT 3 in the first 5 days following a concussion.[225] Participants were recruited from the Bellevue Hospital Emergency Services, trauma service and neurosurgery service and were between 18-60 years old. This group was divided between head injury with a + CT scan and head injury with a – CT scan. The mean number of symptoms was 11.6 $\pm$ 5.9 for the - CT group and 11.4 $\pm$ 6.1 for the + CT group. The mean symptom severity score was 41.0 $\pm$ 28.2 for the - CT group and 42.3 $\pm$ 29.6 for the + CT group.

[225] In our study, participants were evaluated within 48h of the injury, the mean number of symptoms was 7.4 ± 5.1 and the mean symptom severity was 16.3 ± 16.9. In their study, all participants with head injury were brought to the emergency department for evaluation of their head injury and received a head CT scan, eliminating those who may not have struck their head, did not seek care or were quickly discharged from the emergency department. 31 of the 118 participants with head injury had a + CT scan, indicating either brain damage, brain hemorrhage, or skull fracture.[225] Our numbers might have been lower because our participants didn't require going to the emergency for their concussion (and didn't have a + CT scan), therefore their concussion symptoms probably weren't as severe as those in this study who were assessed in a hospital setting. Usually, people who get a CT scan for a head injury have red flags, and therefore more severe concussion symptoms. Also, the mean age of the – CT scan group was 41.09 and the mean age of the + CT scan group was 37.86. Our mean age was 20.9 ± 1.8 years old, therefore difference in age might account for the difference in mean number of symptoms and severity score.

In a study where the SCAT2 was administered to 263 collegiate athletes, an average of 0.52 ± 1.18 days after a concussion, the mean number of symptoms reported was 9.0 ± 5.1 and the mean symptom severity score was 19.4 ± 16.9.[63] The athletes had a mean age of 20.3 years old, and their sports included football, rugby, volleyball, sprint football and men's crew. These results are similar to our study. This may be because their mean age was similar to ours, 20.9 ± 1.8 years old, and their concussions occurred during sport. Moreover the type of sports in this study (football, rugby, volleyball, sprint football and men's crew) are similar to the ones in our study (basketball, cheerleading, football, hockey, lacrosse, ringuette, rugby, soccer, volleyball). Also, the timing of measurement in this study, 0.52 ± 1.18 days after a concussion (12.48h),[63] was similar to ours, 33.9 ± 17.9 hours after a concussion.

Lastly, in terms of symptom severity our results were a little lower than compared to a previous study which used a different symptom scale.[226] In an article presenting data on the psychometric and clinical properties of a commonly used concussion symptom inventory- the Post-Concussion scale, data was collected from a group of 260 highschool (85% of the sample) and university level concussed athletes within five days of a concussion.[226] A sample of 52 concussed athletes were evaluated at 3 time periods. When evaluated at 72h, the mean reported symptom severity was 29. [226] In our study, participants were evaluated within 48h of the injury, and the mean symptom severity was 16.26 ± 16.95. Therefore, our symptom severity was slightly lower than this study, although it must be noted that the Post Concussion Symptom scale and SCAT 5 symptom scale both have 22 symptoms but there is a slight difference in the symptoms listed. The Post Concussion Symptom scale has nausea and vomiting as 2 different symptoms while it is considered 1 on the SCAT5, the Post Concussion Symptom scale has "sleeping more than usual" and “sleeping less than usual”, “numbness or tingling”, “visual problems” (instead of “double vision” on the SCAT5), and doesn’t have “irritablity”. Also, the 52 concussed athletes were a subgroup of 260 concussed athletes that were seen three times post-injury. The fact that they were seen multiple times post-concussion may indicate that their symptoms were more serious. Another reason why our mean symptom severity score might be lower than the one in this study is that 85% of the sample were highschool students, while our study included only athletes above the age of 18. There may be a difference in symptom reporting between those two age groups.

Mental health sub score of the SF-36 Questionnaire

We also had some significant results from our data involving the SF-36 questionnaire. The total number of symptoms was associated with the mental health subscore of the SF-36 questionnaire (r= -0.556) and the symptom severity score was associated with the mental health subscore of the SF-36 questionnaire (r= -0.518). This may suggest that future studies should screen for anxiety and depression since mental health prior to a concussion is correlated to mental health during a concussion. Since mental health is a component of a concussion that may lead to lingering symptoms if not dealt with, screening for it before the concussion may be important. In our study, one challenge we had was asking the participants to fill out the SF-36 based on how they felt *before* they were concussed. Therefore the data cannot be interpreted the same as filling out the SF-36 prior to being concussed. It is possible that athletes with higher mental health sub score on the SF-36 may report more symptoms after being concussed, but that will need to be completed in a future study.

Variability in concussion assessment

Since there is currently no valid diagnostic imaging tool to assess concussions, we must rely on symptoms and objective tests in the diagnosis of a concussion. Since symptoms are subjective, the rating from 0-6 of the 22 concussions found on the SCAT-5 is not necessarily representative of the severity of the concussion. One of the challenges with concussion assessment is that there is a great amount of variability in the number of symptoms, type of symptoms, and time to recovery in concussed patients. The variations in the clinical manifestations of traumatic brain injury are due to the complexity of the brain, and to the pattern and extent of damage, which depend on type, intensity, direction, and duration of the external forces that cause traumatic brain injury.[15] The variability in concussion assessment results (subjective symptoms, cranial component, visual component, cognitive component, neurological component, balance, etc.) makes concussion rehabilitation strategies challenging as not one concussion is the same, and therefore the time to recovery and symptom progression varies greatly.

Limitations

One of the limitations of our study is that some of the symptoms suffered by the participants, such as difficulty concentrating, trouble remembering, blurry vision, confusion, sensitivity to light, feeling slowed down, made it more challenging to fill out the questionnaires. For example, some patients had more difficulty reading the questions because of visual issues. Others had trouble concentrating on the questionnaires, and since they spent approximately 30-40 minutes doing the SCAT5 and filling out the questionnaires, this was a challenge.

Another limitation is that not all the questionnaires have been translated to French. Therefore, when participants were only francophone-speaking, filling out certain questionnaires was more challenging and they had to ask for clarification. Furthermore, even for English-speaking participants, the wording of certain questions in the questionnaires necessitated clarification. For example, one of the questions on the SF-36 questionnaire was “Do you feel full of pep?” and many participants didn’t understand what that meant.

Another limitation is that we do not know how many total athletes sustained a concussion from Concordia, John Abbott and Champlain during the two school years that we were collecting data. Therefore, we cannot know what percentage of total concussions is the 60 concussed athletes that we were told about, and therefore do not know if our sample is biased.

Conclusion

Since baseline athlete fear avoidance correlates with symptom number and symptom severity on the SCAT5, we suggest addressing this aspect of a concussion as part of the rehabilitation plan by implementing goal-oriented interventions. According to the fear avoidance model, symptoms are unfairly interpreted as a sign of serious injury or disease over which one experiences little or no control. This misinterpretation of symptoms typically leads to a disproportional fear of these symptoms and injury that, over time, becomes a disabling fear of experiencing symptoms to the point where these people will avoid doing these activities fearing that it will make their problem worse.[20] In the acute stage, patients with high athlete fear avoidance may report a higher number of symptoms and higher severity of symptoms because of this disproportional fear of symptoms and further damage to their brain. Therefore, including the Athlete Fear Avoidance Questionnaire in the initial assessment of a concussion may be beneficial to the treatment process.

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Appendix

Table 4. R-values between variables complete matrix

	total # of symptoms	symptom severity score	# of past concussions	SF-36 physical functioning subscore	SF-36 role physical subscore	SF-36 role emotional subscore	SF-36 bodily pain subscore	SF-36 mental health subscore	SF-36 vitality subscore	SF-36 social functioning subscore	SF-36 general health subscore	PCS score	TSK score	AFAQ score	HADS anxiety score	HADS depression score	HADS total score
total # of symptoms	-	0.908**	-0.003	-0.374*	-0.338	-0.314	-0.154	-0.556**	-0.481**	-0.06	-0.23	0.299	0.282	0.493**	0.563**	0.614**	0.686**
symptom severity score		-	0.109	-0.329	-0.299	-0.331	-0.316	-0.518**	-0.403*	-0.14	-0.157	0.33	0.253	0.481**	0.492**	0.541**	0.602**
# of past concussions			-	0.089	0.05	-0.197	-0.069	-0.129	-0.167	-0.388*	-0.157	0.305	0.138	0.332	-0.013	-0.029	-0.26
SF-36 physical functioning subscore				-	0.219	0.229	0.389*	0.32	0.209	-0.039	0.271	-0.347*	-0.28	-0.521**	-0.159	-0.626**	-0.485**
SF-36 role physical subscore					-	0.605**	0.195	0.247	0.235	0.327	0.014	-0.109	-0.28	-0.254	-0.057	-0.626**	-0.044
SF-36 mental health subscore								-	0.741**	0.422*	0.468**	-0.422*	-0.193	-0.515**	-0.479**	-0.398*	-0.503**
SF-36 vitality subscore									-	0.437**	0.451**	-0.197	-0.166	-0.427*	-0.318	-0.307	-0.362*
SF-36 social functioning subscore										-	0.469**	-0.048	-0.228	-0.174	-0.114	0.07	-0.014
SF-36 general health subscore											-	-0.142	-0.118	-0.185	-0.174	-0.296	-0.28
PCS score												-	0.485**	0.711**	0.526**	0.356*	0.500**
TSK score													-	0.637**	0.165	0.366*	0.321
AFAQ score														-	0.346*	0.475	0.484**
HADS anxiety score															-	0.481**	0824**
HADS depression score																-	0.893**