VALIDATING THE SPORT CONCUSSION ASSESSMENT TOOL TO IMPROVE SURVEILLANCE OF MENTAL HEALTH ISSUES AMONG CANADIAN VARSITY ATHLETES

GIULIA FILOMENA FABIANO

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Abstract

Varsity athletes experience an array of stressors as they are expected to excel in their schooling and athletic competition. This study examined the Sport Concussion Assessment Tool-5 (SCAT-5) symptom evaluation scale as a potential screening tool for anxiety and depression symptoms among varsity athletes at baseline. The sample consisted of 436 varsity athletes from York University. Two model structures of the SCAT-5 symptom evaluation scale were compared to identify which model best represents varsity athlete's symptom profiles at baseline. Structural equation modelling and receiver operating characteristic analysis were conducted to assess construct validity and discriminative ability in identifying mental health concerns across both models. Anderson's model provided a better model fit, structure, and discriminative ability than the ICD-10 PCS model. These findings support the SCAT-5 as a dual-purpose tool for concussion assessment and mental health screening, facilitating earlier support for athletes and informing future sport policies on mental health.

Keywords: SCAT-5 Symptom Evaluation Scale, Mental Health Screening, Varsity Athletes, Construct Validity

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Introduction

The World Health Organization (WHO) defines mental health as a state of mental well-being that enables individuals to cope with the normal stresses of life, work productively, and aid in making a contribution to their community (WHO, 2022). According to Statistics Canada, in 2022 over 5 million Canadians (18%) aged 15 and older met the diagnostic criteria for a mood, anxiety, or substance use disorder in the previous 12 months (Statistics Canada, 2023). In addition, it was also reported that that the prevalence of mood and anxiety disorders was highest among young females (Statistics Canada, 2023). Depression is defined as a negative affective state characterized by mood changes, loss of interest or pleasure that interferes with daily life. Depression is often associated with symptoms including altered eating or sleeping habits, low energy or motivation, difficulty concentrating, and withdrawal from social activities (APA, 2018). Anxiety is defined as an emotion characterized by apprehension and somatic symptoms of tension in which an individual anticipates an impending dangerous or misfortune situation that can have debilitating effects on daily activities and performance (APA, 2018). A reaction to a perceived stressful situation can result in muscles becoming tense, breathing becomes faster, and a rapid heartbeat. Mental health concerns, including anxiety and depression are common in athletes, in addition to substance misuse and eating disorders (Cresswell & Eklund, 2017; Reardon & Factor, 2010). It is reasonable to believe that numerous student-athletes participate in their sport while managing the signs, symptoms, and known risk factors of depression and anxiety.

Mental Health Among Athletes

Among the general undergraduate population, mental health concerns are notable. A recent umbrella review reported that 40% of student experience mild anxiety symptoms and 35%

mild depressive symptoms, while 16% experience severe anxiety and 13% experience severe depressive symptoms (Paiva et al., 2025). This elevated baseline highlights the mental health vulnerability in university settings, even before considering the additional demands of sport involvement. There has been a recent increase in attention surrounding athletes' mental health highlighting that this population has greater mental health problems relative to the general population (Rice et al., 2016; Gorczynski et al., 2017; Poucher et al., 2021). The intense mental and physical demands placed on athletes likely increases their susceptibility to certain mental health problems (Rice et al., 2016). Numerous studies have demonstrated high levels of mental health concerns among athlete populations and therefore illustrate a cause for concern (Foskett & Longstaff, 2018; Schaal et al., 2011). Specifically, for athletes in their emerging adult years, this timeframe is associated with their peak athletic performance, but simultaneously tends to overlap with the peak age for the risk of onset of mental health disorders (Gulliver et al., 2012).

A systematic scoping review demonstrated that this research area has grown substantially, with 57.2% of studies in this area having been published between 2010-2019 and another 20.8% published since 2020 (Kegelaers et al., 2022). Within the literature, there is evidence of a positive relationship between physical activity and mental health, suggesting physical activity is a possible protective factor against mental health problems in individuals (Pascoe et al., 2020; Guo et al., 2018; Lourenço et al., 2017). However, the current research tends to group physical activity, exercise, and sport together, despite each having distinct characteristics and implications (Bezerra et al., 2016; Hsu et al., 2020). Recent articles have illustrated that there is an association between mental health and the stressors inherent in competitive sport participation (Reardon et al., 2019). Society is under the assumption that athletes are immune to mental health challenges because of their ability to pursue high goals and excel at a high level; however, the

reality is that athletes are as likely, and in some cases more likely to experience compromised mental health (Moesch et al., 2018; Reardon et al., 2019; Åkesdotter et al., 2020). Among varsity athletes, the lifetime prevalence of mental health issues is estimated at 51.7%, with the highest incidence of onset occurring around 19 years of age, and 50% of cases emerging between the ages of 17 and 21 (Åkesdotter et al., 2020). By uncovering the reality of mental health concerns, it has captured the daily demands placed on student-athletes, both physical and psychological that may represent additional risk factors that increase vulnerability to mental health concerns, such as depression and anxiety.

Student-athletes experience a unique range of stressors such as balancing school, sport, and social demands that may potentially increase their vulnerability to mental health problems (Miller & Kerr, 2002). As a result of their dual-role, they have significantly different university experiences than their non-athlete peers, including unique stressors (e.g., demanding or negative coaching behaviours, academic anxiety, injury risk, and sleep quality) that may affect rates of mental health disorders (Davoren & Hwang, 2014; Wolanin et al., 2016). Research has shown that Canadian university student-athletes face a range of mental health challenges such as elevated rates of psychological distress and depressive episodes (Sullivan et al., 2019; Hammond et al., 2013). In addition, varsity athletes have reported lower levels of life satisfaction due to the demands and expectations of their dual-role situation (van Rens et al., 2019). A study based in the United Kingdom reported that 47.8% of varsity athletes met the screening criteria for a depression and/or anxiety disorder (Foskett & Longstaff, 2018). Furthermore, a recent study conducted by Weber and colleagues (2023) found that 22.3% of student-athletes were at risk for depression and 12.5% were at risk for anxiety with females being at a higher risk than male athletes. The observed trend aligns with the idea that social-emotional disorders (i.e., anxiety,

depression, eating disorders) are common during the peak identity development phase that takes place during emerging adulthood (Potterton et al., 2022). By gaining valuable insights in this area, it may help to improve prevention and intervention efforts for student-athletes exhibiting symptoms of social-emotional disorders.

Mental Health Among Female and Male Student-Athletes

In the sports context, male and female athletes face similar physical and mental demands, however, there is evidence to suggest that female athletes are particularly at risk of experiencing more mental health concerns and disorders compared to male athletes. Specifically, the literature has highlighted that female athletes are significantly more likely than male athletes to report higher rates of mental health symptoms and twice as likely to experience symptoms of depression and anxiety (Rice et al., 2016; Gorczynski et al., 2017). Studies focusing on mental health issues among student-athletes have discovered a common theme that female student-athletes struggle more with mental health compared with their male counterparts (Brown et al., 2021; Sullivan et al., 2020). These findings also align with previous literature indicating that female student-athletes frequently endorse higher levels of mental health symptoms compared to male student-athletes (Rice et al., 2019). However, it is possible that male student-athletes may experience equal rates of mental health issues compared to female student-athletes but are less likely to report these issues due to denial, shame, and/or stigma (Watson, 2005). At its core, competing at the varsity level presents distinct and demanding challenges that can impact athletes' mental health and well-being, regardless of the sex of the student-athlete.

The Relationship Between Sport-Related Injury and Mental Health

Injury is an inherent aspect of sport, present across all levels of competition and types of play. Factors such as the rules of the game, biomechanics of movement, playing surfaces, and the unpredictability of opponents all contribute to the overall risk of injury. A study based in Alberta found that more than 1 in 4 student-athletes seek medical attention for a sport-related injury each year (Black et al., 2021). In this vein, musculoskeletal injuries are common challenges among athletes, often resulting in significant downtime, diminished performance, and in severe cases, prematurely ending a sporting career (Iolascon et al., 2022). These injuries can range from acute conditions such as fractures and sprains, to overuse injuries such as tendinitis and stress fractures (Aicale et al., 2018). Chronic pain that may result from these injuries can contribute to psychological distress, including symptoms of depression and anxiety, which in turn can further degrade an athlete's physical health and athletic performance (Woo et al., 2010).

Varsity athletes are also at risk for sustaining a sport-related concussion (SRC) which is a type of mild traumatic brain injury (mTBI). A mTBI refers to a temporary disruption in brain function and mental status, resulting from blunt trauma to the head or body that results in rapid movement of the brain within the skull (Silverberg et al., 2023). Loss of consciousness may or may not be present, and standard structural neuroimaging methods generally do not detect any abnormalities (Patricios et al., 2023). A variety of neurological symptoms may emerge, largely reflecting disruptions in brain function rather than structural damage (McCrory et al. 2017). It is important to note that all concussions are considered a mTBI, but not all mTBIs are categorized as concussions, due to concussions representing the less severe end of the mTBI spectrum (Harmon et al., 2013). Understanding this distinction is important as mTBI encompasses a broad spectrum of presentations from mild sport-related concussions to more complex injuries involving visible structural abnormalities on neuroimaging (Brolio & Puetz, 2008; Dougan et al.,

2014). For example, a more complex or “complicated mTBI” may involve structural abnormalities on neuroimaging such as bleeding, bruising, or skull fracture. These injuries still meet the Glasgow Coma Scale criteria for a mild classification but are not considered a concussion (Iverson, 2006; Williams et al. 1990).

A SRC represents a significant neurological concern that athletes commonly encounter during their athletic careers. A SRC may be caused by a direct impact to the head, neck, or elsewhere on the body which transmits an impulsive force to the brain during sports or exercise-related activities (Patricios et al., 2023). With this forceful motion, it triggers a cascade of neurotransmitter and metabolic changes, potentially leading to axonal injury, blood flow changes, and inflammation affecting the brain (Patricios et al., 2023). Symptoms and signs of a SRC may appear immediately or develop over minutes to hours and is typically resolved within days but sometimes persist for a longer duration. SRCs encompass a variety of symptoms and impairments including balance, cognitive, ocular, vestibular, and psychological (Kontos & Collins, 2018; McCrory et al., 2017). To diagnose SRC, it is necessary to assess multiple domains including somatic, cognitive, and emotional symptoms after impact during athletic activity (Patricios et al., 2023).

SRC is a complex injury that requires the coordinated efforts of a multidisciplinary medical team that may include medical doctors, athletic trainers or therapists, and neuropsychologists (Patricios et al., 2023). Sports neuropsychology has emerged as a relatively recent subspeciality within clinical neuropsychology, dedicated to its application in athletic contexts. Its development has been primarily driven by research on traumatic brain injury, along with growing clinical and socio-cultural interest in SRC (Patricios et al., 2023; McCrory et al., 2017). This momentum has positioned neuropsychologists at the forefront of both scientific and

clinical initiatives aimed at identifying the symptoms and problems associated with concussions, monitoring recovery, and facilitating return to school and sports (Moser et al., 2007; Echemendia et al., 2009; Echemendia, 2012). Neuropsychologists have also played a key role in advancing the field by contributing to the development of standardized sideline concussion assessment tools and objective approaches to symptom evaluation (Barr & McCrea, 2001; McCrea et al., 1998; Gioia et al., 2009; Lovell, 1999; Lovell & Collins, 1998; Lovell et al., 2006; Randolph et al., 2011). Traditionally, neuropsychologists have been solely viewed as specialists in assessing athletes' cognitive functioning, but their role is far more multifaceted. They are key members of the multidisciplinary medical team as they offer expertise in the cognitive, behavioural, and socio-emotional aspects of brain functioning. Their specialized training is highly relevant following a SRC given the impact on various cognitive domains and potential emergence of affective symptoms in athletes. This is reflected in deficits detected through neuropsychological assessment, with observable changes in attention/concentration, speed of information processing, verbal learning, visuo-spatial memory, working memory, verbal memory, and reaction time (Echemendia et al., 2001; Gronwall et al., 1975; Macciocchi et al., 1996; Lovell et al., 2003; Voller et al., 1999). Affective symptoms may include irritability, sadness, and anxiety along with changes in athletes sleep functioning that may manifest as sleeping less or more than usual, trouble falling asleep, and drowsiness (Pardini et al., 2004). The use of baseline neuropsychological assessments may benefit post-concussion evaluations as they are thought to enhance diagnostic accuracy when compared to post-injury scores (Echemendia et al., 2013). Overall, a neuropsychological perspective is useful in supporting athletes at both baseline and post-injury by helping to identify and address cognitive and emotional changes.

Concussion research has primarily focused on cognitive impairments, vestibular, and ocular dysfunction (Broglio et al., 2007; Collins et al., 1999; Mucha et al., 2014). However, it is important to note that SRC can disrupt daily functioning and has been associated with impairments in physical performance, academic achievement, as well as mental health, and quality of life concerns (Pearce et al., 2019; Wasserman et al., 2016; Doroszkiewicz et al., 2021; McCuddy et al., 2018; Vargas et al., 2015). Recently, there has been a growing interest in the psychological consequences of concussion, including anxiety and depression (Yang et al., 2015; Kontos et al., 2012; Donohue et al., 2023). This shift algins with clinical research findings suggesting that anxiety and mood-related symptoms may be the predominant manifestations in nearly 30% of concussion cases (Kontos et al., 2019).

Emotional and mood changes after a concussion are influenced by the immediate changes in the brain and how the athlete mentally responds to the injury, both having the potential to affect how the athlete recovers. Psychological responses to a SRC may involve affective symptoms (e.g., anxiety, depression, sleep changes) as well as behavioural changes (social withdrawal, minimizing symptomology, malingering) (Covassin et al., 2017). Affective responses following SRC may be influenced by both psychosocial and neurobiological factors. For instance, research has shown that individuals with clinical depression often display structural and morphological changes in brain regions associated with mood regulation including the hippocampus, amygdala, and prefrontal regions which may be affected after concussion (Sheline et al., 1996; Chen et al., 2008). Additionally, emotional responses following SRC may also stem from psychological and social factors such as frustration over uncertain recovery timelines, isolation from teammates and sports, and perceived lack of support (Kontos et al., 2015). Most injured athletes experience symptom improvement within two weeks and return to play

commonly occurring within 10 days (Williams et al., 2015; Kontos et al., 2014; Pfaller et al., 2016; McCrea et al., 2003; McCrea et al., 2020; Pellman et al., 2005). However, existing literature suggests that the normative recovery course may not apply to athletes with preinjury mental health conditions. A systematic review found that pre-existing mental health conditions were associated with delayed recovery from a SRC in student-athletes (Iverson et al., 2020). Student-athletes who have a history of mental health problems such as anxiety and depression are more likely to experience prolonged or severe recovery after a SRC (Iverson et al., 2017). This highlights the importance of screening for mental health symptoms during baseline testing as it is crucial to identify athletes at-risk. With screening protocols in place, this may inform concussion management practices. Early intervention and personalized care may support recovery and reduce the likelihood of prolonged or complicated outcomes following SRC.

Screening for mental health conditions and assessing concussion symptoms can be challenging due to the overlap of psychological symptoms. For instance, research has shown that in the absence of a concussion history, student-athletes with elevated anxiety levels report more severe concussion like symptoms and are significantly more likely to meet criteria for mild to moderate post-concussional syndrome (PCS) compared to those with lower anxiety (Champigny et al., 2020). These findings are consistent with prior research indicating that a high proportion of individuals with depression meet the International Classification of Disease-10 (ICD-10) criteria for PCS despite having no concussion history, and that many healthy individuals also report concussion-like symptoms (Iverson, 2006; Iverson et al., 2015; Iverson et al., 2003; Wäljas et al., 2015).

In line with these findings, there is evidence that athletes with pre-existing mental health conditions have a significant greater number of symptoms and higher symptom severity

compared with individuals without a pre-existing mental health condition (Collings et al., 2017; Cook et al., 2019; Thomas et al., 2021). For example, varsity athletes with depression have been shown to report significantly more symptoms on their baseline Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT) compared to those without depression (Covassin et al., 2012). These findings highlight the importance of recognizing that athletes with pre-existing mental health conditions may report greater number and severity of symptoms during baseline, which can help clinicians interpret post-injury assessments and make more informed return-to-play decisions.

Given the focus on symptom elevation as a key aspect of concussion management, it is essential that providers consider an athlete's full neuropsychological profile. This includes both objective test results and self-report measures (i.e., post-concussion symptom scale) to inform more individualized recommendations, especially when other factors may be affecting how the athlete feels and recovers after a concussion. Prior research has demonstrated that baseline mood disturbances may adversely impact performance. As such, neuropsychological research has shown that athletes exhibiting co-occurring elevated symptoms of depression and anxiety at baseline have reported significantly greater cognitive difficulties compared to those without such mood disturbances (Thomas et al., 2022). In the aforementioned study, they also demonstrated that athletes with co-occurring depression and anxiety exhibited reduced attention and slower processing speed compared to healthy controls. This suggests that these cognitive difficulties may impair their ability to effectively focus on and process information during competition, which can potentially increase their risk of injury. In line with these findings, Champigny and colleagues (2020) found that high school athletes with high baseline anxiety reported significantly more physical, cognitive, and emotional symptoms during preseason testing, and

scored lower on neurocognitive tests compared to athletes in the low-anxiety group. In a follow-up study, Champigny and colleagues (2022) showed that these same athletes experienced greater symptom severity following an injury. Collectively, these findings suggest that pre-injury anxiety may inflate symptom reporting and complicate concussion assessment. Extending this line of research, Thomas and colleagues (2024) reported that athletes with co-occurring depressive and anxiety symptoms at baseline demonstrated a significantly higher risk of receiving a future concussion diagnosis, even after controlling for sport. This suggests that the presence of these mental health symptoms may represent a unique risk factor associated with increased vulnerability to concussion diagnosis. This finding underscores the importance of incorporating mental health screeners during baseline to allow for the early identification of athletes who may be at-risk for mental health conditions such as anxiety and depression. This is important for not only athletes' well-being but also for enhancing performance as mental health challenges can negatively affect athletic outcomes (Lochbaum et al., 2021). By screening for mental health symptoms, the athletic team can then refer athletes who screen positive for elevated depressive or anxiety symptoms to mental health professionals for further evaluation and treatment.

Mental Health Screeners

Despite the prevalence of anxiety and depression symptoms in athletes, clinical mental health screeners are infrequently used by sports teams for a variety of reasons, including lack of expertise, resources (e.g., access to mental health specialists), and time constraints (Henriksen et al., 2020). For efficacy, researchers have suggested using validated post-concussion scales as screeners to assess athletes with pre-injury mental health concerns in place of adding measures or lengthening routine testing procedures (Champigny et al., 2022; Shulze et al., 2022). These scales include the Sport Concussion Assessment Tool-5th edition (SCAT-5), Post-Concussion

Symptom Scale (PCSS), Head Injury Scale (HIS), Graded Symptom Checklist (GSC), and Rivermead Post-Concussion Symptoms Questionnaire (RPQ). As athletes may experience up to 22 post-concussion symptoms (e.g., somatic, cognitive, emotional, or sleep disturbances) these scales are used as indicators of number of symptoms and injury severity (Collins et al., 2014; Joyce et al., 2015; Kontos et al., 2012; Merritt & Arnett, 2019).

Researchers have used factor analytic approaches to better conceptualize symptom evaluations and identify patterns in symptom reporting (Pardini et al., 2004; Piland et al., 2003; Barker-Collo et al., 2018; Kontos et al., 2012). Establishing symptom factors can support health care professionals in clinical management approaches, treatment strategies, and rehabilitation plans for athletes. It is important to identify these factors pre-injury as it may provide insight into post-injury symptom reporting, particularly, how an athlete's endorsements may influence the assessment and potentially the management of a concussion (Nelson et al., 2016). Additionally, recognizing post-injury symptom factors may help to enhance the clarity of symptom reporting along with implementation of treatment approaches (McCrory et al., 2017). Symptom factor structures on commonly used concussion symptom checklists such as the PCSS, HIS, GSC, and the RPQ have been explored via exploratory factor analysis (EFA) (Pardini et al., 2004; Kontos et al., 2012; Merritt & Arnett, 2014; Piland et al., 2003; Piland et al., 2006; Herrman et al., 2009; Baker et al., 2018). In a preliminary EFA study on the PCSS on concussed athletes aged 12 to 25 years old, the authors found a 4-factor solution: somatic, cognitive, emotional and sleep symptom factors (Pardini et al., 2004). However, there are few studies that investigate factor analytic methods on a concussion symptom checklist using uninjured athletes at baseline. To explore this, Kontos and colleagues re-evaluated the PCSS on uninjured athletes at baseline and concussed athletes within 7 days of injury (Kontos et al., 2012). They found a 4-factor solution

for athletes tested at baseline (cognitive-sensory, sleep-arousal, vestibular-somatic, and affective) and a 4-factor solution post-concussion (cognitive-migraine-fatigue, affective, somatic, and sleep).

The WHO developed the ICD in 1943 which has been used worldwide to systematically classify and code health conditions, diseases, and related health problems (WHO,1992). Post-Concussion syndrome (PCS) is identified in the ICD-10 and is characterized by the persistence of physical, cognitive, emotional, and psychological symptoms following a concussion or mild traumatic brain injury (WHO, 2019). In ICD-10, Criterion C for PCS outlines several symptom domains including, physical symptoms, cognitive symptoms, emotional symptoms, and insomnia, alcohol intolerance, and hypochondriasis or adoption of the sick role that qualified for the diagnosis of ICD-10 PCS. Several papers have adopted the ICD-10 PCS symptom domain grouping to the corresponding SCAT Symptom Evaluation symptoms, employing a 4-symptom domain structure with domains being: physical/somatic, cognitive, emotional, and sleep/insomnia (Asken et al., 2017; Langer et al., 2021; Roberts et al., 2023).

The SCAT-5 is a well-established and comprehensively developed sport concussion evaluation tool and is divided into five sections: athlete background, symptom evaluation, cognitive screening, neurological screening, and delayed recall. The symptom evaluation scale was derived from the Post-Concussion Scale and further developed through Concussion in Sport Group consensuses (Echemendia et al., 2017; Aubry et al., 2002). It is important to note that the SCAT-5 symptom inventory is not equivalent to the PCSS due to the additional 5 symptoms (“pressure in the head”, neck pain, blurred vision, “don’t feel right”, and confusion) that are not included in the PCSS along with nausea and vomiting being combined on the SCAT-5 (McCrory et al., 2017). It is important to note that with the release of the SCAT-6, the symptom evaluation

scale has remained consistent with that of the SCAT-5. Refer to Table 1 for PCSS and SCAT-5 symptom item distinction.

Table 1. *PCSS and SCAT-5 Shared and Distinct Symptom Items*

Shared Symptom Items	**Distinct Symptom Items**
- Headache - Nausea* - Vomiting* - Balance Problems - Trouble Falling Asleep - Drowsiness - Sensitivity to Light - Sensitivity to Noise - Irritability - Sadness - Nervous/ Anxious - More Emotional - Feeling Slowed Down - Feeling like "in a fog" - Difficulty Concentrating - Difficulty Remembering	*PCSS:* - Visual Problems - Sleeping More than Usual - Sleeping Less than Usual - Light-Headedness - Numbness or Tingling *SCAT-5:* - Blurred Vision - "Pressure in head" - Neck Pain - "Don't Feel Right" - Confusion

*In SCAT-5 Nausea and Vomiting are combined, in PCSS they are separate items.

Despite the SCAT-5 being a widely used instrument to evaluate concussion, limited research has been done on the factorability of the symptom evaluation of this tool (Anderson et al., 2020; Alsalaheen et al., 2022). To address this gap, Anderson and colleagues (2020) performed two separate EFA's on the SCAT-5 symptom evaluation scale completed by high school and collegiate athletes who were either uninjured or had a concussion within 72 hours. They found a 3-factor solution for the uninjured athletes (cognitive-fatigue, migraine, and affective) and a 3-factor solution for the acutely concussed athletes (migraine-fatigue, cognitive-ocular, and affective). All unique SCAT symptom inventory items, except for blurred vision, were found to load onto factors associated with healthy uninjured athletes. This result is consistent with prior research indicating that symptoms that are commonly attributed to

concussion such as fatigue, difficulty concentrating, and poor sleep are frequently reported by healthy varsity athletes (Iverson et al., 2003). The 3-factor model observed in uninjured athletes aligns with prior research identifying a 3-factor solution on the GSC and HIS in this population (Piland et al., 2006; Piland 2003). In another study exploring the factor structure of the symptom evaluation scale of the SCAT-5, Alsalaheen and colleagues identified a 5-factor model (energy, mental health, migrainous, cognitive, and vestibular-ocular) using adolescents during their recovery period following a concussion (within 30 days) and factors were consistent across the sexes. Sport-related injuries accounted for the majority of concussions in this sample (84%), followed by non-sport related injuries (14%), which included falls, motor vehicle accidents, accidental contact with an object, and assault. However, to the author's knowledge, a confirmatory factor analysis (CFA) has not been conducted on the SCAT-5 symptom evaluation scale to validate the 3-factor model on uninjured athletes during baseline testing.

In a study conducted by Burger and colleagues (2023), the authors investigated the psychometric properties of the SCAT-5 symptom evaluation scale to explore its potential as a mental health screening tool. When comparing the SCAT-5 symptom evaluation scale to several anxiety and depression screeners, Burger and colleagues found moderate convergent validity with the Centre for Epidemiologic Studies- Depression scale. However, the generalizability of the findings is limited by the study's exclusive focus on male athletes and depression as the only mental health concern. This is problematic as it overlooks potential sex and gender differences in concussion outcomes, as well as the impact of other common psychological conditions, such as anxiety.

Research from our lab resulted in one of the few studies to assess the SCAT-5 symptom evaluation scale to screen for anxiety and depression symptoms in male and female varsity

athletes during pre-season testing. Roberts and colleagues (2023) examined the associations between individual symptoms on the symptom evaluation scale of the SCAT-5 and gold-standard measures of anxiety and depression, along with evaluating the predictability of the subscales from the SCAT-5 to identify anxiety and depression symptoms. The symptom domain grouping that was employed was from the ICD-10 4-symptom domain structure (cognitive, emotional, somatic, and sleep). Strong correlations were found between SCAT-5 symptoms and gold-standard measures for anxiety and depression. Findings from the aforementioned study have suggested that the SCAT-5 evaluation scale can provide essential information that will help to identify athletes experiencing elevated symptoms of anxiety and depression. However, the prior study did not validate the use of the SCAT-5 symptom scale for identifying elevated mental health symptoms at baseline. The present study seeks to address this gap by validating the SCAT-5 in this context and evaluating critical threshold values that can reliably differentiate between typical and clinically significant symptom presentations. Establishing construct validity and critical thresholds will enhance the SCAT-5 symptom scale's ability to identify pre-existing mental health concerns, thereby improving baseline screening accuracy. By extending this research, the study aims to support more precise clinical interpretation, tailored care, and ultimately better mental health outcomes for student-athletes.

Current Research

Exploring baseline mental health in student-athletes is imperative as psychological symptoms such as anxiety and depression can affect performance, increase injury risk, and complicate post-injury recovery. In the literature, there have been studies that investigated factor domains of the SCAT-5 through EFA or reported symptom domain groupings. However, to the authors knowledge, there has not been a CFA conducted on these model structures among

uninjured athletes during pre-season testing. Although the SCAT-6 has been released, the unchanged symptom evaluation scale ensures that findings based on the SCAT-5 remain applicable to the SCAT-6. The current study aims to evaluate two model structures. The first is the ICD-10 4-symptom domain grouping, which builds upon prior research conducted in our lab and reflects a classification informed by established diagnostic criteria (Roberts et al., 2022; WHO 2019). The second is a 3-factor model developed by Anderson and colleagues (2020), derived from an EFA, and representing a data-driven approach to symptom clustering. While the ICD-10 model reflects a framework informed by clinical practice, Anderson's model may offer additional strengths as it captures empirically observed symptom patterns. This dual approach provides a more comprehensive evaluation of the SCAT-5 symptom domains and aids in determining which model best fits student-athletes at baseline, ultimately enhancing the precision of mental health assessment in this population. Being able to validate previously established symptom domains in the SCAT-5 will guide future assessments in whether these domains within these measurement models capture underlying mental health constructs at baseline. Findings from this study will contribute to both research and clinical practice by providing foundational evidence for the construct validity of SCAT-5 symptom domains for student-athletes at baseline. Establishing valid symptom clusters at baseline may enhance the ability to distinguish between pre-existing mental health symptoms and those emerging post-concussion. This may lead to more accurate clinical interpretations, more tailored care and ultimately, improve early identification and support for student-athletes at risk for mental health challenges. By informing mental health screening protocols, this research supports more proactive, individualized approaches to athlete well-being. The specific objectives of this project are to: 1) establish construct validity of the symptom evaluation scale in the SCAT-5 for screening symptoms of

anxiety and depression among varsity athletes during pre-season and 2) to evaluate the discriminative ability of the SCAT-5 symptom evaluation scale in identifying mental health concerns when applying these two model structures. Clinically significant scores on the GAD-7 and/or PHQ-9 will be used to identify individuals who may meet criteria for a clinical diagnosis of anxiety and/or depression. It is hypothesized that the Anderson and colleagues (2020) 3-factor model will produce a better fit and discriminative ability compared to ICD-10 4-symptom domain grouping as it is empirically derived and reflects the symptom structure observed in student-athlete data.

Methods

Study Design

The design of this study was a secondary data analysis of a cross-sectional study, as data were collected during the York University varsity pre-season testing in 2019, 2022, and 2023.

Participants

University-level varsity athletes (N = 436) from York University, Toronto, were recruited for study participation from the following competitive teams: soccer (16.5%), hockey (14.9%), football (13.5%), basketball (11%), track and field (11%), volleyball (9.6%), rugby (9.4%), field hockey (7.1%), wrestling (3.2%), tennis (2.1%), and cross country (1.6%). Participants completed study measures as part of their pre-season baseline testing in August 2019, August 2022, and August 2023. A portion of the 2019 pre-season testing data (N = 296) has been published in Roberts et al. (2023). Participants were between the ages of 17 and 25 years (M = 19.78, SD = 1.79) and 49.3% were female. Of the total sample, 47.7% were first year students.

Participants were excluded if they reported a personal history of seizures, any neurodegenerative disease, or sustained a concussion 6 months before baseline testing.

Measures

Demographic Information

Participant demographic information was collected as part of a questionnaire. Participants self-reported their medical history, including history of migraines, headaches, concussion, and neurodevelopmental or psychological conditions (e.g., anxiety, depression, learning disorder, attention-deficit/hyperactivity disorder).

Sport Concussion Assessment Tool-5 (SCAT-5) Symptom Evaluation Scale

The symptom scale is a 22-item questionnaire that measures the severity of commonly experienced post-concussion symptoms on a 7-point Likert type scale, with 0 indicating no symptom and 6 indicating a very severe symptom (Davis et al., 2017). Participants are instructed to respond to the symptom items based on how they were feeling at the time they filled out the questionnaire. The total number of symptoms (i.e., number of symptoms from 22 total) and symptom severity score (i.e., sum of the severity of all the symptoms, possible total of 132) were recorded.

Generalized Anxiety Disorder – 7th Edition (GAD-7)

The GAD-7 is a screening tool for anxiety with strong criterion validity and test-retest reliability (Löwe et al., 2008). This tool screens for the presence and severity of symptoms of anxiety. The symptoms included on the screening questionnaire are based on the DSM-5 criteria for generalized anxiety disorder and assess how often the individual was bothered by a given symptom over the past two weeks, with scoring from 0 (“not at all”) to 3 (“nearly every day”)

(Spitzer et al., 2006; Kertz et al., 2013). The questionnaire's total severity scores can range from 0 to 21 and an individual screens positive for possible generalized anxiety disorder if they obtain a score of 10 or greater (Kertz et al., 2013). Threshold values are defined as minimal (0-4), mild (5-9), moderate (10-14), and severe (15-21) levels of anxiety (Mossman et al., 2017). The GAD-7 total score was calculated by summing the severity endorsed for each symptom.

Patient Health Questionnaire- 9th Edition (PHQ-9)

The PHQ-9 is used to assess for the presence of depression and is sensitive in detecting clinically significant symptoms (Kroenke et al., 1999; Kroenke et al., 2001). Similar to the GAD-7, the PHQ-9 evaluates how often the athlete is bothered by a given symptom over the past two weeks, with severity scored from 0 ("not at all") to 3 ("nearly every day"). The PHQ-9 total scores range from 0 to 27. Screening positive for possible depression requires a score of 10 or greater. Threshold values are defined as none-minimal (0-4), mild (5-9), moderate (10-14), and sever (20-27) levels of depression. The PHQ-9 total score was calculated by summing the severity endorsed for each symptom.

Procedure

As part of varsity athletes regular pre-season baseline testing, informed consent was obtained from varsity athlete participants from the York University Sport Medicine team. All participants provided informed written consent. The North Lab graduate students and research assistants collected the data during pre-season baseline testing in 2019, 2022, and 2023. The measures took 20-30 minutes for participants to complete the demographic information, GAD-7, PHQ-9, and the SCAT-5. Ethics approval was obtained from the Human Participants Review subcommittee of York University Ethics Review Board. Description of the procedure can also be found in Roberts et al. (2023).

Statistical Analysis

Descriptive statistics were used to explore symptom endorsement and severity across measures. Two different measurement models were evaluated for model fit using structural equation modeling (SEM). The first model was a four-factor model (i.e., cognitive, emotional, somatic, and sleep) categorized by the International Classification of Disease, 10th Revision (ICD-10) diagnosis of PCS (WHO, 2019). Please see Table 2 with the ICD-10 PCS symptom domain and corresponding SCAT-5 symptom evaluation symptoms. The second model was a three-factor model (i.e., cognitive-fatigue, migraine, and affective) established by Anderson and colleagues (2020) through a prior exploratory factor analysis, see Table 3 with the SCAT-5 symptom domain loading on each factor.

Table 2. *ICD-10 PCS and corresponding SCAT-5 symptom evaluation symptom*

Symptom Domain	**SCAT-5 Symptom**
Somatic	Headache
	Pressure in Head
	Neck Pain
	Nausea/vomiting
	Dizziness
	Balance Problems
	Sensitivity to Light
	Sensitivity to Noise
	Fatigue or Low Energy
Cognitive	Feeling like “in a fog”
	Difficulty Concentrating
	Difficulty Remembering
	Confusion
Emotional	More emotional
	Irritability
	Sadness
	Nervous or Anxious
Sleep	Drowsiness
	Trouble Falling Asleep

Table 3. *SCAT-5 Symptom Factor Loading Structure from Anderson et al. (2020)*

Symptom Domain	SCAT-5 Symptom
Migraine	Headache
	Pressure in Head
	Neck Pain
	Sensitivity to Light
	Sensitivity to Noise
Cognitive- Fatigue	Feeling like "in a fog"
	Feeling Slowed Down
	"Don't Feel Right"
	Confusion
	Drowsiness
	Fatigue
Affective	More emotional
	Irritability
	Sadness
	Nervous or Anxious
	Trouble Falling Asleep

For both measurement models, a SEM was conducted following a two-step approach. First, a confirmatory factor analysis (CFA) was performed to test the measurement models and evaluate the adequacy of the latent symptom factors structures. Since the SCAT-5 Symptom Evaluation scale involves a 7-point Likert-type scale, a maximum likelihood with robust standard errors (MLR) estimation method was utilized. It has been suggested in the literature that when an ordinal variable has at least five response categories or greater, a MLR could be applied (Johnson & Creech, 1983; Rigdon, 1998; Raykov, 2012). Multiple fit indices for the CFA were calculated, including robust comparative fit index (CFI), robust Tucker-Lewis index (TLI), robust root mean square error of approximation (RMSEA), and the Standardized Root Mean Square Residual (SRMR). For the CFI and TLI, a value $\geq .95$ is considered an optimal fit and a value of .90 is considered an acceptable fit (Hu & Bentler, 1999). For RMSEA, a value of ≤ 0.06 is considered an optimal fit and values between 0.06 and 0.08 offers a good fit (Hu & Bentler, 1999). The RMSEA is presented with an accompanying 90% confidence interval. For SRMR, a

value of ≤ 0.08 is considered an optimal fit (Hu & Bentler, 1999). Standardized factor loadings were examined to assess the strength of the relationship between observed variables and latent factors. In line with commonly accepted criteria, loadings of 0.40 or higher will be considered acceptable for interpretation (Stevens, 1992).

In the second step of the SEM, a structural model was specified to estimate the linear regression paths from the latent symptom factors to the observed outcome variables (PHQ-9 and GAD-7 total scores). This evaluated the predictive ability of the factors established from the SCAT-5 to identify anxiety and depression symptoms. All SEM analysis was conducted using the Lavaan package in R.

Receiver operating characteristic (ROC) analysis (i.e., area under the curve, AUC) was conducted to evaluate the discriminative ability of the SCAT-5 symptom evaluation in identifying mental health concerns compared to GAD-7 and PHQ-9 cut-off scores. ROC curves were calculated (sensitivity and specificity) separately for each SCAT-5 domain. Sensitivity, or the true positive rate, is operationalized as the percentage of participants with depression/anxiety symptoms who are correctly classified using the score obtained from the specific domain from the SCAT-5 symptom evaluation. Specificity, or the true negative rate, is operationalized as the percentage of participants that do not present depression/anxiety symptoms and who are identified using the score obtained from the specific domain from the SCAT-5 symptom evaluation. Qualitative interpretations of AUC values were derived from the following scale: <0.60, no discrimination; 0.60-0.70, poor discrimination; 0.70-0.80, acceptable discrimination; 0.8-0.90, excellent discrimination; >0.9, outstanding discrimination (Mandrekar, 2010; Li & He, 2018). Youden's Index was used to identify a threshold that provided maximum classification accuracy.

Results

Descriptive statistics, means (SD), and frequencies (%) among all study variables are presented in Table 4. Fatigue/low energy was the most reported symptom on the symptom scale from the SCAT-5 with 35.4% of participants reporting this symptom. Nervousness or anxious feelings and trouble falling asleep were the next commonly endorsed symptoms, with endorsement rates of 24.9% and 24.8%, respectively. The mean total score on the GAD-7 was 2.51 (SD 3.63) with a range of 0-21 and the mean total score on the PHQ-9 was 2.72 (3.71) with a range of 0-25. For anxiety, 14.4% of participant endorsed symptoms in the mild range, 3.7% in the moderate range, and 2.8% in the severe range. For depression, 16.1% of participants endorsed symptoms the mild range, 4.1% were in the moderate range, and 2.1% were in the severe range. There were no significant differences between sexes in individual SCAT-5 symptoms, however, females endorsed more severe symptoms of anxiety (p <.001) and depression (p <.001), when compared with males.

Table 4. *Participant Demographics and Symptom Frequency*

N = 436	**M (SD) or n (%)**
Age	19.78 (1.79)
Range	17-25
Females	215 (49.3%)
GAD-7 total score	2.51 (3.63)
Range	0 - 21
Mild (5-9)	63 (14.4%)
Moderate (10-14)	16 (3.7%)
Severe (15+)	12 (2.8%)
PHQ-9 total score	2.72 (3.71)
Range	0 - 25
Mild (5-9)	70 (16.1%)
Moderate (10-14)	18 (4.1%)
Severe (15+)	9 (2.1%)
SCAT5 Symptom Scale	

Total number of symptoms	3.10 (4.38)
Total symptom severity	5.33 (9.02)
Endorsed Symptoms	
Headache	74 (17%)
"Pressure in head"	50 (11.5%)
Neck Pain	83 (19.1%)
Nausea or Vomiting	17 (3.9%)
Dizziness	29 (6.7%)
Blurred Vision	25 (5.7%)
Balance Problems	44 (10.1%)
Sensitivity to Light	47 (10.8%)
Sensitivity to Noise	36 (8.3%)
Feeling Slowed Down	62 (14.2%)
Feeling like "in a Fog"	44 (10.1%)
"Don't Feel Right"	53 (12.1%)
Difficulty Concentrating	82 (18.8%)
Difficulty Remembering	79 (18.1%)
Fatigue or Low Energy	154 (35.4%)
Confusion	26 (6%)
Drowsiness	55 (12.7%)
More Emotional	61 (13.9%)
Irritability	72 (16.5%)
Sadness	49 (11.2%)
Nervous or Anxious	109 (24.9%)
Trouble Falling Asleep	108 (24.8%)

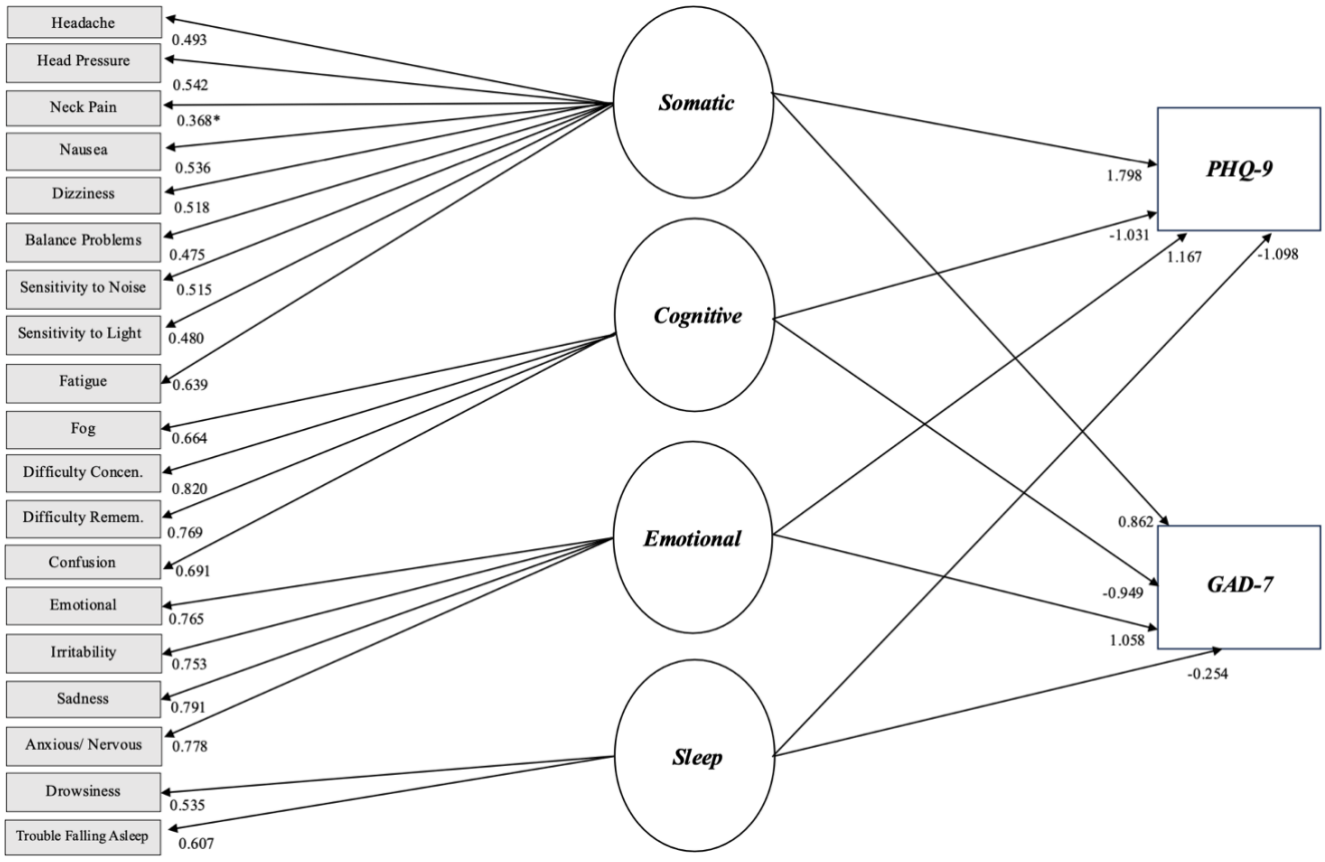
ICD-10 PCS 4-Symptom Domain Grouping:

Structural Equation Modeling

The first phase of the SEM, a CFA was conducted to validate the measurement model outlined by the ICD-10 PCS by confirming that the observed variables load appropriately on the latent factors as hypothesized. The four-factor model should be interpreted with caution, as the covariance matrix of latent variables was not positive definite, suggesting the presence of multicollinearity. The model demonstrated poor to marginal fit, $\chi^2 = 402.050$, df = 171, $p < 0.001$, robust CFI = 0.877, robust TLI = 0.851, robust RMSEA = 0.084 (90% CI: 0.074, 0.095), SRMR = 0.070. The robust CFI and TLI fell below the commonly accepted threshold of 0.90

indicating a poor model fit. Although the RMSEA suggests mediocre fit and the SRMR was within acceptable limits, the overall pattern of fit indices suggest that this model does not adequately represent the data. Please refer to Figure 1 for this model, along with factor loadings. Of note, neck pain (0.368) was the only symptom with a standardized factor loading below the commonly accepted cutoff 0.40, which is generally considered the minimum threshold for indicating a meaningful association with the latent factor (Matsunaga, 2010; Stevens, 1992).

Figure 1. *Confirmatory Factor Analysis for ICD-10 4-Symptom Domain Grouping*



In the second phase of the SEM, regression paths were estimated to assess the predictive effects of the latent symptom factors (i.e., cognition, emotional, somatic, sleep) on the observed outcome variables (PHQ-9 and GAD-7 total scores). Table 5 summarizes the structural regression paths within the SEM model. For anxiety symptoms (using the GAD-7 total score), only the emotional cluster was a significant predictor of anxiety symptoms (b = 7.28, SE = 3.13, z = 2.33, $p < 0.02$, β = 1.058) in athletes. However, the standardized estimate exceeds 1.0, potentially reflecting high collinearity. For depression symptoms (using the PHQ-9 total score), all four factors were a non-significant predictor of depression symptoms in athletes.

Table 5. *ICD-10 PCS 4-Symptom Domain Grouping: Structural Linear Regression Paths Within SEM Model*

Test	Domain	Estimate (b)	Standard Error	z-value	*p*	Standard Estimate (β)
GAD-7	Cognitive	-9.815	7.122	-1.378	0.168	-0.949
	Emotional	7.284	3.131	2.327	0.020*	1.058
	Somatic	17.563	19.627	0.895	0.371	1.798
	Sleep	-2.888	9.156	-0.315	0.752	-0.254
PHQ-9	Cognitive	-10.875	15.403	-0.706	0.168	-1.031
	Emotional	8.191	7.800	1.050	0.294	1.167
	Somatic	17.563	19.627	0.895	0.371	1.798
	Sleep	-12.751	20.312	-0.628	0.530	-1.098

Note: interpret with caution, *p <0.05

Receiver Operating Characteristic

Receiver operating characteristic AUC was conducted to evaluate the discriminative ability of the SCAT-5 symptom evaluation using the latent symptom factors (cognitive, emotional, somatic, and sleep) defined by the ICD-10 PCS in identifying athletes with or without depressive and anxiety symptoms, using the PHQ-9 and GAD-7 as the criterion measure. Two classification thresholds were examined.

In the first comparison, individuals were categorized with binary PHQ-9 and GAD-7 total score outcomes: no symptoms (scores < 5) vs. mild symptoms or higher (scores ≥ 5). Somatic (AUC = 0.74), emotional (0.73), and cognitive (AUC = 0.73) symptom domains demonstrated acceptable discriminatory accuracy to detect PHQ-9 scores of mild or greater. The sleep (AUC = 0.69) symptom domain demonstrated marginally acceptable discriminatory accuracy. Please refer to Figure 2 which displays the receive operating characteristic curve comparison of ICD-10 PCS symptom grouping domains based on PHQ-9 mild or higher total symptom score. A similar pattern emerged for GAD-7 scores of mild or greater. Emotional (AUC = 0.77), somatic (AUC = 0.73), and cognitive (AUC = 0.71) symptom domains demonstrated acceptable discriminatory accuracy to detect GAD-7 scores of mild or greater. The sleep (AUC = 0.66) symptom domain demonstrated poor discriminatory accuracy. Please refer to Figure 3 which displays the receiving operating characteristic curve comparison of ICD-10 PCS symptom grouping domains based on GAD-7 mild or higher total symptom score. See Table 6 for each symptom domain's specificity and sensitivity rate.

Figure 2. *ROC Curves for ICD-10 4 symptom domain group for PHQ-9 Mild and Higher Total Symptom Score Threshold*

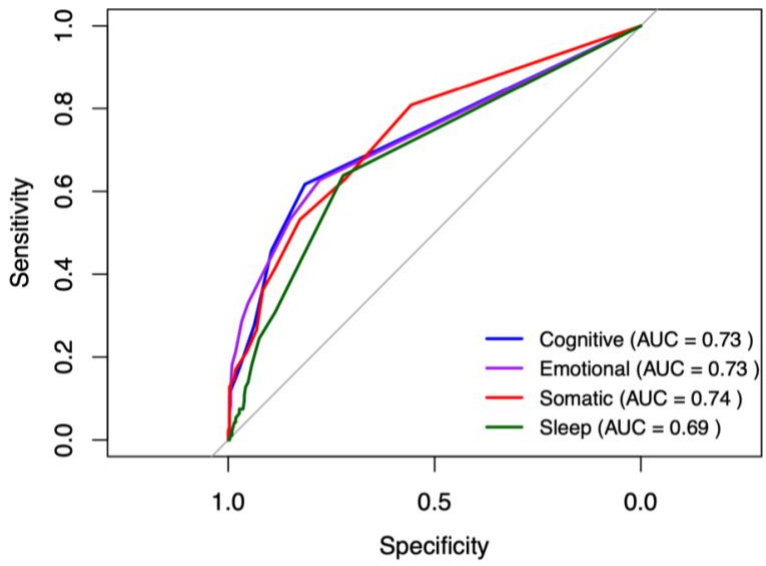


Figure 3. *ROC Curves for ICD-10 4-symptom domain group for GAD-7 Mild and Higher Total Symptom Score Threshold*

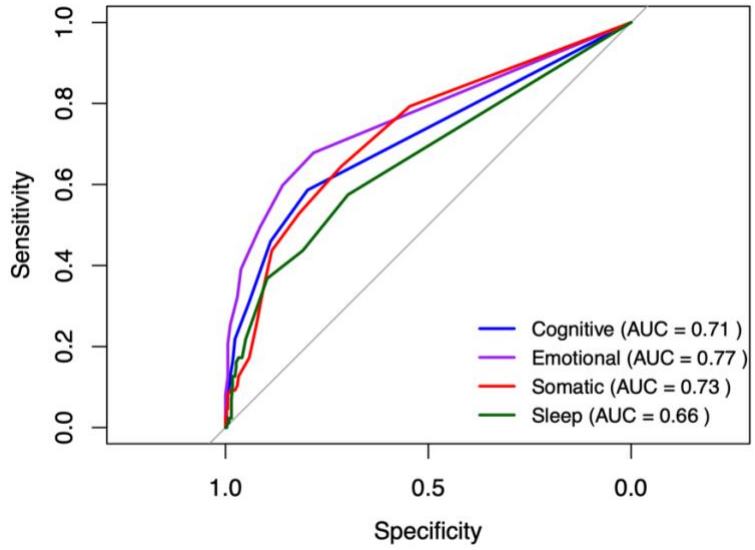


Table 6. *ROC and AUC of ICD-10 PCS SCAT-5 Domains for Anxiety and Depression Detection using GAD-7 and PHQ-9 Mild+ Total Scores as Reference*

Test	Domain	Phase	Threshold	Specificity	Sensitivity	Youden's Index
GAD-7	Cognitive	0.7125	0.173	0.798	0.586	0.384
	Emotional	0.767	0.137	0.783	0.678	0.461
	Somatic	0.7276	0.175	0.716	0.644	0.360
	Sleep	0.6625	0.175	0.687	0.575	0.262
PHQ-9	Cognitive	0.7287	0.186	0.814	0.617	0.431
	Emotional	0.7299	0.165	0.778	0.628	0.406
	Somatic	0.7399	0.145	0.557	0.801	0.358
	Sleep	0.688	0.197	0.722	0.638	0.360

In the second comparison the cut-off for PHQ-9 and GAD-7 was adjusted to reflect a higher threshold for clinical concern: none and mild symptoms (scores ≤ 9) vs. moderate symptoms or higher (scores ≥ 10). Emotional (AUC = 0.82), somatic (AUC = 0.81), and cognitive (AUC = 0.81) symptom domain demonstrated excellent discriminatory accuracy and sleep (AUC = 0.77) symptom domain demonstrated acceptable discriminatory accuracy to detect PHQ-9 scores of moderate or greater. Please refer to Figure 4 which displays the ROC curve comparison of ICD-10 PCS symptom grouping domains based on PHQ-9 moderate or higher

total symptom score. For GAD-7, the emotional (AUC = 0.86) symptom domain demonstrated excellent discriminatory accuracy, somatic (AUC = 0.77) and sleep (AUC = 0.71) symptom domains demonstrated acceptable discriminatory accuracy, and the cognitive (AUC = 0.68) symptom domain demonstrated poor discriminatory accuracy to detect GAD-7 scores of moderate or greater. Please refer to Figure 5 which display the receive operating characteristic curve comparison of ICD-10 PCS symptom grouping domains based on GAD-7 moderate or higher total symptom score. See Table 7 for each symptom domain's specificity and sensitivity rate.

Figure 4. *ROC Curves for ICD-10 4-symptom domain group for PHQ-9 Moderate and Higher Total Symptom Score Threshold*

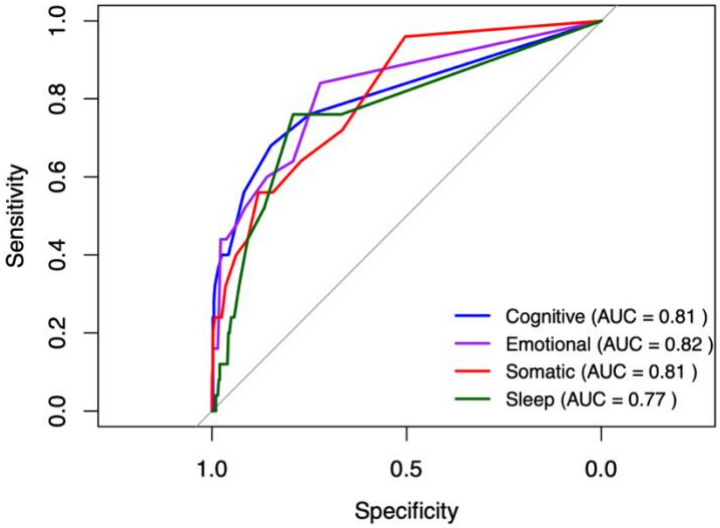


Figure 5. *ROC Curves for ICD-10 4 symptom domain group for GAD-7 Moderate and Higher Total Symptom Score Threshold*

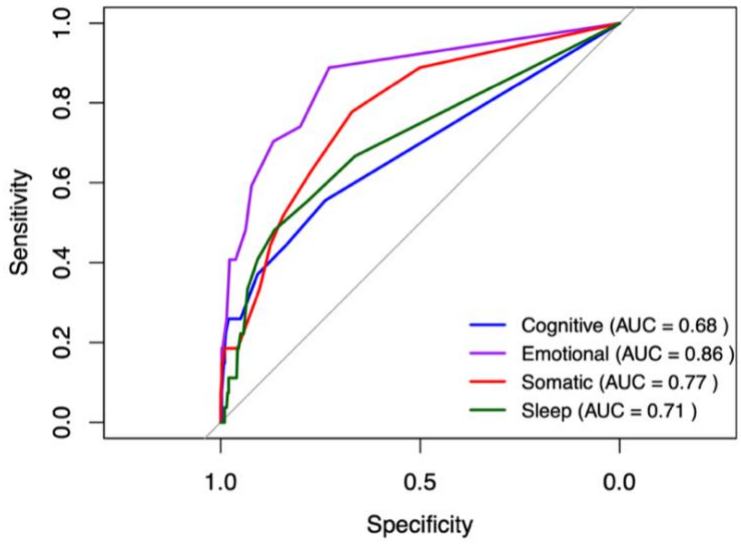


Table 7. *ROC and AUC of ICD-10 PCS SCAT-5 Domains for Anxiety and Depression Detection using GAD-7 and PHQ-9 Moderate+ Total Scores as Reference*

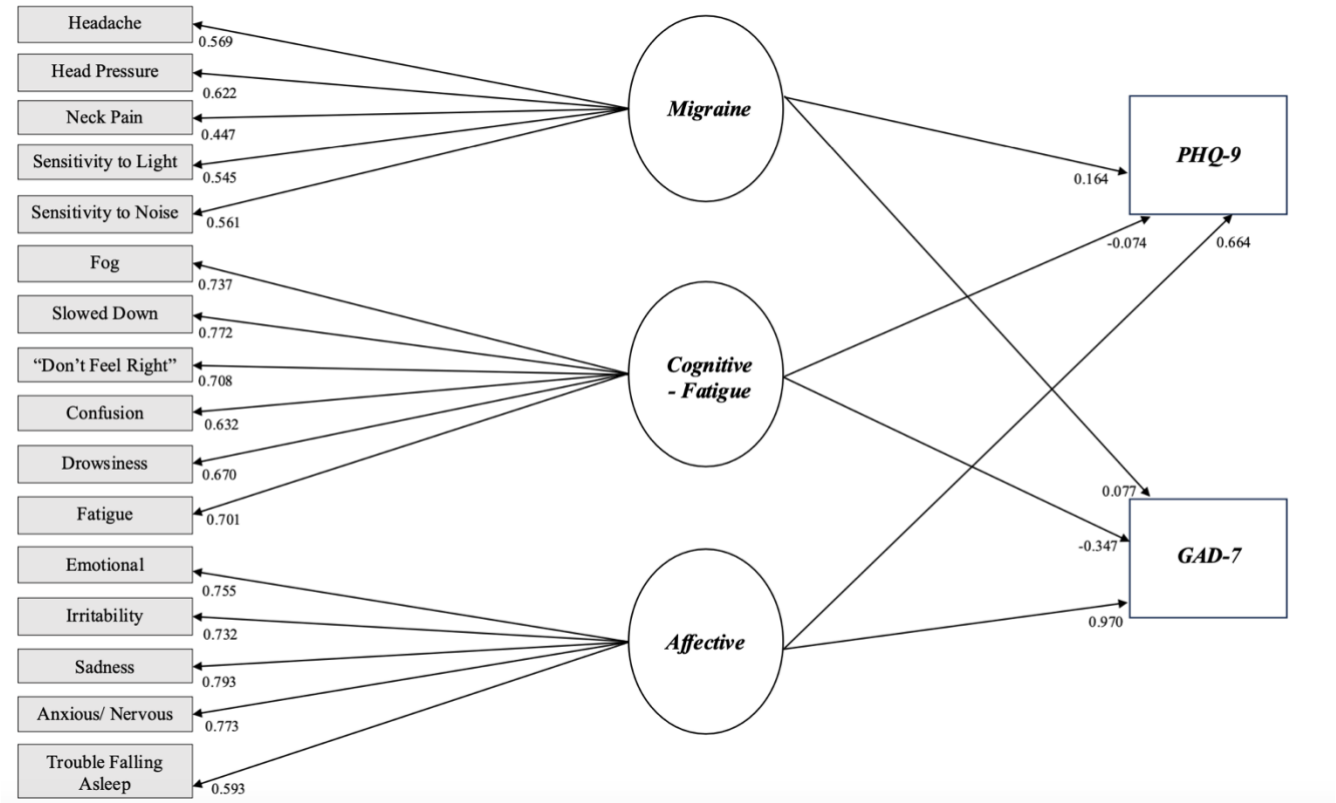
Test	Domain	Phase	Threshold	Specificity	Sensitivity	Youden's Index
GAD-7	Cognitive	0.6765	0.048	0.738	0.555	0.293
	Emotional	0.8614	0.032	0.729	0.888	0.617
	Somatic	0.7747	0.045	0.671	0.777	0.448
	Sleep	0.7055	0.064	0.865	0.481	0.384
PHQ-9	Cognitive	0.8076	0.052	0.849	0.68	0.529
	Emotional	0.8226	0.033	0.722	0.84	0.562
	Somatic	0.81	0.028	0.504	0.96	0.464
	Sleep	0.7682	0.052	0.792	0.76	0.552

Anderson's EFA 3-Factor Model:

Structural Equation Modeling

In the first phase of the SEM, a CFA was conducted to validate the measurement model outlined by the exploratory factor analysis conducted by Anderson and colleagues (2020) by confirming that the observed variables load appropriately on the latent factors as hypothesized. The three-factor model demonstrated marginal to acceptable fit, $\chi^2 = 292.191$, df = 125, $p < 0.001$, robust CFI = 0.897, robust TLI = 0.874, robust RMSEA = 0.085 (90% CI: 0.072, 0.098), SRMR = 0.064. The robust CFI and TLI approached the acceptable cutoff of 0.90, suggesting borderline adequacy, while the RMSEA indicated mediocre fit. The SRMR was within acceptable limits, supporting the model's overall adequacy despite some limitations in fit. Please see Figure 6 for this mode, along with factor loadings.

Figure 6. *Confirmatory Factor Analysis for Anderson et al., 3-Factor Model*



In the second phase of the SEM, linear regression paths from the three latent symptom factors (cognitive-fatigue, affective, and migraine) to PHQ-9 and GAD-7 total score were estimated within the SEM model. Out of the 3 factors, only the affective cluster was a significant predictor of anxiety symptoms (b = 6.76, SE = 1.52, z = 4.45, p = <0.001, β = 0.970) in athletes. These results suggest that affective symptoms, more than cognitive-fatigue or migraine symptoms, uniquely contribute to anxiety severity. Table 8 summarizes the structural regression paths within the SEM model.

Table 8. *Anderson's 3-Factor Model: Structural Linear Regression Paths Within SEM Model*

Test	Domain	Estimate (b)	Standard Error	z-value	*p*	Standard Estimate (β)
GAD-7	Cognitive-Fatigue	-3.230	2.049	-1.580	0.114	-0.347
	Affective	6.758	1.517	4.454	0.000*	0.970
	Migraine	0.642	0.986	0.651	0.514	0.077
PHQ-9	Cognitive-Fatigue	-0.702	1.793	-0.391	0.695	-0.074
	Affective	4.719	1.412	3.342	0.001*	0.664
	Migraine	1.390	0.878	1.583	0.113	0.164

*p <0.05

Similarly, out of the 3 factors, only the affective cluster was a significant predictor of depression symptoms (b = 4.72, SE = 1.41, z = 3.34, p = 0.001, β = 0.66) in athletes. These results suggest that affective symptoms, more than cognitive-fatigue or migraine symptoms, uniquely contribute to depression and anxiety severity.

Receiver Operating Characteristic

Receiver operating characteristic AUC was conducted to evaluate the discriminative ability of the SCAT-5 symptom evaluation using the latent symptom factors (cognitive-fatigue, affective, and migraine) in identifying athletes with or without depressive and anxiety symptoms, using the PHQ-9 and GAD-7 as the criterion measure. The same two classification thresholds were examined, as with the prior model.

In the first comparison, individuals were categorized with binary PHQ-9 and GAD-7 total score outcomes (i.e., no symptoms versus mild symptoms or higher). Affective (AUC = 0.77) and cognitive-fatigue (AUC 0.73) symptom domains demonstrated acceptable discriminatory accuracy to detect PHQ-9 scores of mild or greater. The migraine symptom domain demonstrated poor discriminatory accuracy (AUC = 0.68). Please refer to Figure 7, which displays the ROC curve comparison of Anderson's 3-factor model based on PHQ-9 mild or

higher total symptom score. A similar pattern emerged for GAD-7 scores of mild or greater. Affective (AUC = 0.78) and cognitive-fatigue (AUC = 0.73) symptom domains demonstrated acceptable discriminatory accuracy to detect GAD-7 scores of mild or greater. Migraine symptom domain demonstrated poor discriminatory accuracy (AUC = 0.67). Please refer to Figure 8, which displays the ROC curve comparison of Anderson's 3-factor model based on GAD-7 mild or higher total symptom score. See Table 9 for each symptom domain's specificity and sensitivity rate.

Figure 7. *ROC Curves for Anderson 3-Factor Model for PHQ-9 Mild and Higher Total Symptom Score Threshold*

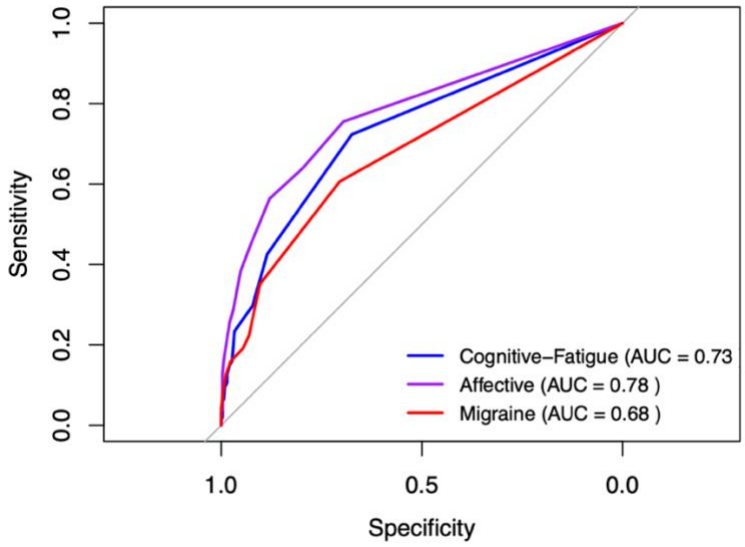


Figure 8. *ROC Curves for Anderson 3-Factor Model for GAD-7 Mild and Higher Total Symptom Score Threshold*

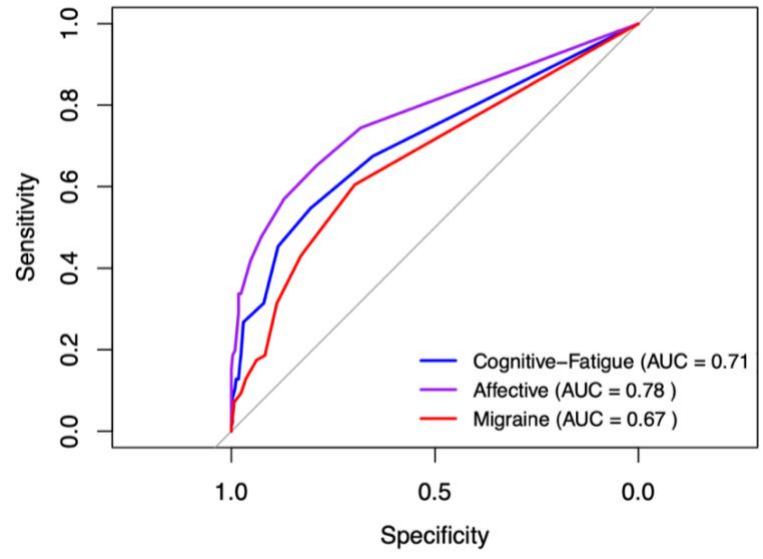


Table 9. *ROC and AUC of Anderson 3-Factor Model for Anxiety and Depression Detection using GAD-7 and PHQ-9 Mild+ Total Scores as Reference*

Test	Domain	Phase	Threshold	Specificity	Sensitivity	Youden's Index
GAD-7	Cognitive-Fatigue	0.7118	0.194	0.806	0.547	0.353
	Affective	0.7752	0.166	0.791	0.651	0.442
	Migraine	0.6676	0.170	0.697	0.605	0.302
PHQ-9	Cognitive-Fatigue	0.7316	0.169	0.675	0.723	0.398
	Affective	0.774	0.140	0.696	0.755	0.451
	Migraine	0.6803	0.179	0.705	0.607	0.312

In the second comparison the cut-off for PHQ-9 and GAD-7 was adjusted to reflect a higher threshold for clinical concern (i.e., none and mild symptoms versus moderate symptoms or higher/more). Affective (AUC = 0.85) and cognitive-fatigue (AUC = 0.84) symptom domains demonstrated excellent discriminatory accuracy to detect PHQ-9 scores of moderate or greater. Migraine (AUC = 0.69) symptom domain demonstrated marginally acceptable discriminatory accuracy. Figure 9 displays the ROC curve comparison of Anderson's 3-factor model based on PHQ-9 moderate or higher total symptom score. A similar pattern emerged for GAD-7 scores of mild or greater. Affective (AUC = 0.85) symptom domain demonstrated excellent discriminatory accuracy, cognitive-fatigue (AUC = 0.77) symptom domain demonstrated acceptable discriminatory accuracy, and migraine (AUC = 0.67) symptom domain demonstrated poor discriminatory accuracy to detect GAD-7 scores of moderate or greater. Figure 10 displays the ROC curve comparison of Anderson's 3-factor model based on PHQ-9 moderate or higher total symptom score. See Table 10 for each symptom domain's specificity and sensitivity rate.

Figure 9. *ROC Curves for Anderson 3-Factor Model for PHQ-9 Moderate and Higher Total Symptom Score Threshold*

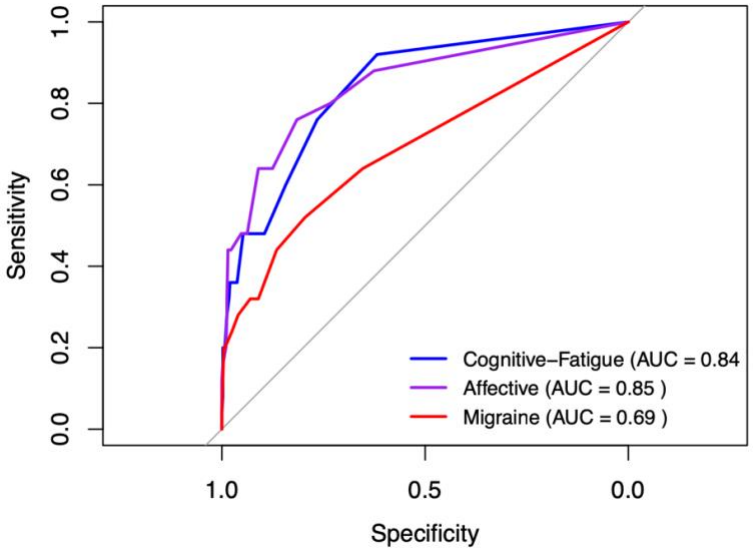


Figure 10. *ROC Curves for Anderson 3-Factor Model for GAD-7 Moderate and Higher Total Symptom Score Threshold*

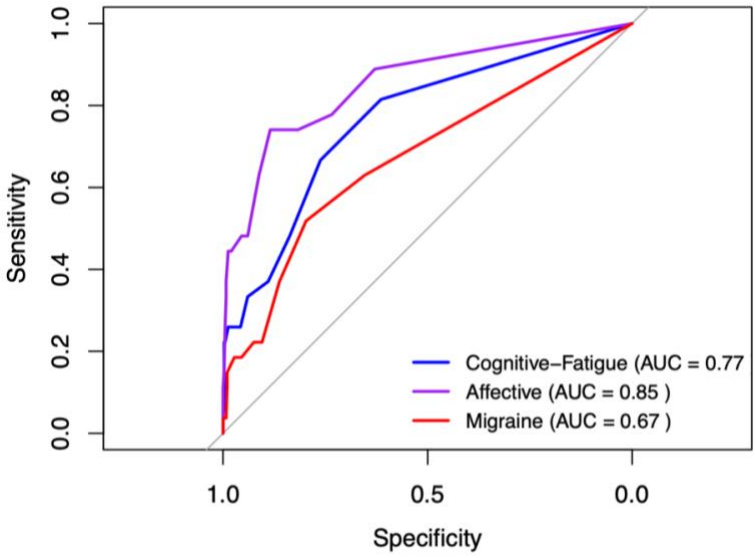


Table 10. *ROC and AUC of Anderson 3-Factor Model for Anxiety and Depression Detection using GAD-7 and PHQ-9 Moderate+ Total Scores as Reference*

Test	Domain	Phase	Threshold	Specificity	Sensitivity	Youden's Index
GAD-7	Cognitive-Fatigue	0.7664	0.038	0.614	0.815	0.429
	Affective	0.8548	0.064	0.885	0.741	0.626
	Migraine	0.6738	0.060	0.797	0.519	0.316
PHQ-9	Cognitive-Fatigue	0.8405	0.030	0.618	0.92	0.538
	Affective	0.8474	0.044	0.815	0.76	0.575
	Migraine	0.693	0.053	0.795	0.52	0.315

Discussion

Understanding student-athletes' mental health is important because emotional difficulties, even when not immediately apparent, can significantly affect both athletic performance and the recovery process following an injury. The current study's results converge with prior research reporting that more than one-fifth of varsity athletes reported symptoms of depression and those with baseline depressive symptoms were 4.59 and 3.40 times more likely to experience symptoms of depression and anxiety, respectively following an injury (Yang et al., 2015). This may be attributed to the fact that an injury can magnify pre-existing mental health symptoms and complicate concussion recovery, including endorsement of persistent symptoms (LoGalbo et al., 2022). Signs and symptoms of depression and anxiety are prevalent in the student-athlete population, as a recent study found that nearly 65% reported mild to severe anxiety symptoms and 63% reported mild to moderately severe depression symptoms (Moore et al., 2025). In the aforementioned study, females represented the majority of the individuals that demonstrated elevated levels of anxiety scores. This result aligns with previous literature where female student-athletes experience symptoms associated with anxiety and depression in higher frequencies compared to their male counterparts (Rice et al., 2019; Rice et al., 2016; Henderson

et al., 2023). These findings align with the current study's results, which showed that female student-athletes endorsed more severe symptoms of both anxiety and depression compared to male student-athletes. This sex-based difference in symptom severity suggests that female student-athletes may be at greater risk for underlying mental health concerns. Consistent with existing literature, identifying as a female student-athlete is a key risk factor for increased symptoms of depression and anxiety (Armstrong et al., 2009; Cox, 2015; Garver et al., 2021; Roby et al., 2021; Weber et al., 2023). Wolanin and colleagues (2016) found that female student-athletes were 1.84 times more than male student-athletes to endorse clinically relevant depression symptoms. Regarding anxiety, female student-athletes were reported to be nearly three times more likely than their male counterparts to report experiencing symptoms (Brenner et al., 2023). Given the heightened vulnerability among female student-athletes, the current study's findings underscore the importance of implementing mental health screening at baseline to identify those at elevated risk for post-concussion psychological symptoms. Furthermore, such baseline measures can help distinguish between pre-existing mental health concerns and newly emerging post-concussive symptoms.

The SCAT-5 is a common outcome measure in research in athletes that includes a symptom evaluation scale that assesses a range of cognitive, emotional, and somatic domains. While EFAs and symptom domain groupings have been conducted to examine the SCAT-5 symptom structure on uninjured athletes, to the author's knowledge, a CFA has not yet been performed to validate these findings. The current study evaluated two theoretical models of the SCAT-5 symptom structure using SEM and ROC curves. Anderson's empirically serviced 3-factor model demonstrated marginal to acceptable model fit, whereas the ICD-10 4-symptom domain grouping model showed poor performance and notable statistical concerns.

In the first phase of the SEM, a CFA supported that Anderson's model demonstrated a better overall fit to the data compared to the ICD-10 model, although neither met ideal thresholds for model fit. The 3-factor model yielded a robust CFI of 0.897 and a robust TLI of 0.874, both approaching the conventional cut-off (Hu & Bentler, 1999). The RMSEA was 0.085, reflecting mediocre fit, while the SRMR of 0.064 fell within acceptable limits. In contrast, the ICD-10 model exhibited poor to marginal fit, with lower CFI (0.877) and TLI (0.851), both below accepted standards. Although its RMSEA (0.084) was nearly identical to Anderson's model, the SRMR (0.070) remained acceptable but did not compensate for the weaker global fit indices. Additionally, the ICD-10 model encountered issues with non-positive definite covariance matrices, suggesting multicollinearity between latent factors. These results suggest that a 3-factor model covering cognitive-fatigue, affective, and migraine-related symptoms offer a more psychometrically sound representation of symptom reporting of pre-season athletes at baseline. A 3-factor structure aligns with previous research validating a 3-factor structure on the GSC and HIS on uninjured athletes (Piland et al., 2006; Piland 2003). Taken together, these results suggest that concussion symptom checklists, such as that from the SCAT-5, are structurally multidimensional, capturing distinct symptoms rather than an overall symptom score (Kontos et al., 2012). With Anderson's 3-factor model demonstrating a marginal to acceptable fit, the findings suggest that the model is sufficiently robust to improve identification of student-athletes at risk for depression and/or anxiety, as these psychological concerns might be overlooked by unidimensional symptom scoring.

The second phase of the SEM, involving structural regression paths to gold-standard mental health outcomes (GAD-7, PHQ-9), provided additional support for Anderson's model. Only the affective symptom cluster emerged as a significant predictor of both anxiety and

depression symptoms on the GAD-7 and PHQ-9, respectively. These findings signify those affective symptoms (i.e., sadness, irritability, nervousness), reported at baseline may serve as a meaningful early indicator of underlying psychological distress. The current results align with research from our lab, that the SCAT-5 symptom evaluations scale can provide vital information that will help to identify athletes at baseline experiencing elevated symptoms of anxiety and depression (Roberts et al., 2023). Overall, although the fit indices for the two models were relatively similar, Anderson's model was slightly favoured as it demonstrated not only marginally better fir but also a more stable and parsimonious structure. In contrast, the ICD-10 PCS model showed evidence of multicollinearity, indicating substantial overall among factors that reduced reliability of the model. This issue was not observed in Anderson's model, further supporting it as the more stable and reliable representation of the data.

In the current study, the ICD-10 emotional and Anderson's affective symptom domains demonstrated the strongest discriminative ability to identify athletes at baseline with anxiety and depression symptoms using the GAD-7 and PHQ-9 respectively as the criterion measure. Both domains presented an acceptable discriminative ability across symptom severity levels, with sensitivity and specificity often exceeding 0.70 at the mild threshold and improving further at the moderate threshold. These findings provide support for their clinical utility as screening indicators for identifying both subclinical and clinically significant symptoms of anxiety and depression in athletes at baseline. Findings from the current study align with prior research indicating that the emotional symptom domain is predictive of clinically significant anxiety or depression (Roberts et al., 2023; Arnett et al., 2019). Roberts and colleagues (2023) found that the ICD-10 emotional symptom domain from the SCAT-5 symptom evaluations scale was a significant predictor of mild to severe levels of anxiety and depression in varsity athletes. These

findings reflect a similar pattern with other PCSS-based structures as Riegler and colleagues (2019) reported that the emotional cluster from the ImPACT was predictive of clinically significant depression on the PHQ-9.

The cognitive related domains (cognitive in ICD-10, cognitive-fatigue in Anderson) also showed acceptable discriminatory ability, particularly for depression detection, with sensitivity and specificity rates commonly above 0.70 in the moderate symptom threshold. When comparing the moderate threshold to the mild symptom threshold, cognitive-related domains demonstrated some discriminatory value, although sensitivity and specificity were generally less balanced compared to the moderate threshold. This may indicate that the cognitive-related domains may be more limited in detecting early or subclinical mental health symptoms, highlighting the stronger screening utility of emotional and affective domains at lower severity levels. These findings not only emphasize the clinical relevance of cognitive-related symptoms in baseline assessments as a potential indicator of underlying mental health concerns, but also as factors that may influence neurocognitive performance. Notably, cognitive changes such as difficulty concentrating and indecisiveness that significantly impair an individual's ability to function are included in the diagnostic criteria for depressive disorders in the DSM-5 (American Psychiatric Association, 2013). This connection points to the importance of accounting for emotional and cognitive symptom burden when interpreting baseline testing results in athletes. Since symptom ratings scales and neurocognitive measures are frequently used in concussion assessment, it is important to understand the prevalence of mental health concerns and how they may influence the interpretation of these evaluation tools. Bailey and colleagues (2010) found that student-athletes that reported a greater endorsement of mental health symptoms (anxiety, depression, substance misuse, suicidal ideations) were linked with lower baseline neurocognitive test

performance, indicating that athletes with greater mental health endorsement demonstrated reduced cognitive performance. These findings highlight the importance of considering mental health symptoms when interpreting baseline neuropsychological test scores. It is imperative to recognize that if an athlete is experiencing emotional distress during baseline testing, their performance may not accurately reflect their cognitive ability. This could lead to inaccurate comparisons post-injury and potentially complicate return to play decisions.

In contrast, the migraine domain from the Anderson model and the somatic and sleep domains from the ICD-10, generally demonstrated lower accuracy and less consistent sensitivity and specificity. It is important to note that the somatic symptoms in the ICD-10 model reached excellent sensitivity in the moderate threshold for depression symptoms (0.96). However, its specificity was relatively poor, indicating a higher likelihood of false positives. Symptoms in these domains should not be overlooked as pre-existing issues such as migraine history may magnify psychological issues such as anxiety and mood disorders (Sufrinko et al., 2018). As such, clinicians should be aware of baseline levels of migraines. Lower accuracy in the ICD-10 sleep domain (trouble falling asleep and fatigue) may be partly due to the stricter wording of the SCAT-5 sleep item, which only asks about difficulty falling asleep. In contrast, other PCSS measures include a broader range of sleep presentations such as sleeping too much, sleeping too little, and trouble falling asleep (Alsalaheen et al., 2021). Although sleep problems are common, especially for student-athletes having to balance academic demands and an intense athletic schedule, the SCAT-5 symptom scale only inquires about trouble falling asleep, which likely does not capture the full spectrum of sleep problems (i.e., sleeping too much, sleeping too little, poor sleep). It should be noted that in Anderson's model, trouble falling asleep and fatigue symptoms are classified under the affective and cognitive-fatigue domains respectively, both of

which demonstrated an acceptable discriminative ability. This provides additional support for the clinical utility of Anderson's model. Overall, these findings suggest that when comparing to emotional and cognitive symptom domains, these factors may offer a more supplementary role in baseline mental health screening.

Taken together, Anderson's model provided a more consistent balance of sensitivity and specificity across domains, as reflected in Youden's Index. This index captures the trade-off between correctly identifying athletes with symptoms while minimizing false positives, a balance that is essential for meaningful screening. Although both models produced similar AUC values, Anderson's framework demonstrated a greater stability across mild and moderate thresholds. This suggests that Anderson's model offers a more reliable basis for consistent mental health screening compared to the ICD-10 PCS model. In practice, this greater balance observed with Anderson's framework indicates that it may serve as a more practical tool for detecting early signs of anxiety and depression symptoms at baseline.

Affective symptoms often overlap with or conflate with concussion-related symptoms, making differentiation challenging (Sandel et al., 2017). Specifically, symptoms of anxiety and depression are difficult to disentangle from post-concussion symptoms due to their similarities of symptoms and underlying physiology (Bloom et al., 2004; Covassin et al., 2017; Champigny et al., 2022). The current study emphasizes the clinical relevance that information on baseline psychological symptoms could improve understanding of the psychological impact of concussions. Pre-injury mental health problems, including anxiety and depression, are associated with greater risk of adverse recovery outcomes in athletes following a concussion (Zemek et al., 2016, Iverson et al., 2017; Yang et al., 2015). For these at-risk varsity athletes, it can be difficult for clinicians to disentangle whether symptoms stem from pre-existing psychological

predispositions, ongoing neurobiological effects of the concussion, emotional reactions to ongoing symptoms, or situational stressors such as academic difficulties or removal of sport. With the current study validating the latent symptom factors through a SEM and a ROC analysis exploring both models' discriminative abilities, it aids in strengthening the clinical utility of the SCAT-5 for baseline mental health screening in athletes. From a concussion management perspective, understanding the underlying structure of SCAT-5 symptoms can enhance clinical decision-making. Neuropsychologists play a vital role in concussion evaluation and management by providing specialized assessment and interpretation of cognitive and emotional symptoms (Echemendia et al., 2018). The dual impact of concussion on both brain function and mental health highlights the essential role of neuropsychologists in assessment and recovery (Echemendia et al., 2012; Echemendia et al., 2013). Their specialized training allows them to assess and manage the complex interplay between neurological and psychological factors in concussion recovery. Early screening of mental health symptoms in athletes is critical for identifying pre-existing mental health concerns that may influence symptom presentation and recovery following a concussion (Purcell et al., 2019). Findings from the current study can aid clinicians in identifying athletes at elevated risk for underlying mental health issues, thus facilitating early intervention and targeted supports. Notably, the SCAT-5 emotional cluster demonstrated the strongest discriminative ability across symptom severity levels for detecting anxiety and/or depression at baseline. These findings offer sport personnel, such as athletic therapists and coaches, a practical tool for identifying athletes who may benefit from a referral to a mental health professional. This approach can support more efficient triage and resource allocation in high demand environments where access to individualized clinical assessments for all athletes may not be feasible. Providing non-clinical sport staff with a validated screening

approach may also facilitate earlier recognition of mental health concerns and encourage more proactive intervention efforts. This may be especially valuable in school or community sport settings where mental health resources are limited, and early identification is critical for timely support. In addition to supporting screening efforts, establishing an accurate baseline for athletes, combined with a better understanding of how depression and anxiety may influence neuropsychological performance and symptom reporting, can guide return to play decisions. Taken together, integrating a neuropsychological perspective ensures that both mental health and cognitive functioning are appropriately addressed within concussion management thereby improving athlete safety, brain health, and promoting better long-term outcomes.

Limitations and Future Directions

Several limitations should be considered. First, generalizability may be limited by using secondary data for the current study. Utilizing an existing database rather than collecting primary data, constrained the ability to tailor variables and measurements to the specific objectives of the research. As a result, the findings may be less applicable to broader or different populations such as athletes outside of the university setting. Second, data collection was paused for the 2020 and 2021 pre-season testing due to the COVID-19 pandemic. In turn, there is no data collected from varsity athletes during these time points. Third, the current study is a cross-sectional design. This study only assessed student-athletes at one point in their sporting career, which does not allow for analysis of change over time and trend development. It is also important to consider survey bias due to the sensitivity that comes with answering questions about mental health (i.e., some participants may have felt uncomfortable answering certain questions, which could have affected their results). Lastly, a limitation of the current study is that the SCAT-5 collects symptoms in the present moment when an athlete is completing the form, whereas the GAD-7 and PHQ-9 asks

about symptoms in a 2-week period. Despite the different time frames, Roberts et al., (2023) still found moderate correlations using these measures. The current study provides an important starting point for increasing mental health awareness in student-athletes during baseline testing. Student-athletes with pre-existing mental health symptoms may represent a particularly vulnerable subgroup and should be prioritized for preventive interventions (Harmon et al., 2013). Future studies should focus on the development and implementation of preventive programs for student-athletes identified as being at-risk for mental health conditions. Findings from the current study may inform early identification of psychological distress, with the goal of mitigating the progression of mental health concerns and improving long-term outcomes. In addition to targeted prevention efforts, mental health screening should be considered an essential component of a broader, continuous strategy to support student-athlete's psychological well-being. Future studies should explore longitudinal monitoring, examine the effectiveness of mental health education, and investigate strategies to reduce stigma associated with help-seeking.

Clinical Implications

These findings highlight the potential for the SCAT-5 symptom scale to serve a dual purpose, not only to identify concussion symptoms, but also to screen for mental health concerns when used at baseline. Although this study was conducted using the SCAT-5, the SCAT-6 has since been released. Importantly, the symptom evaluation scale remains unchanged, which enhances the translation relevance of these findings. As the scales are identical, the current results can be applied in clinical practice and Anderson's 3-factor model can be mapped onto the SCAT-6 symptom evaluation scale without modification. Early identification of mental health symptoms or risk factors may significantly reduce the long-term burden of these conditions. In athletes, early identification offers the advantage of minimizing the potential negative effect the

disorder may have on athletic performance (Kroshus, 2016; Iverson et al., 2020). Establishing empirically validated symptom domains through SEM enhances the structural precision of the SCAT-5 and supports its value in distinguishing overlapping symptom profiles. Due to many of the SCAT-5 symptom evaluation scale items overlapping with symptoms of anxiety and depression, particularly in the affective domain as highlighted in the current study, the tool may offer an underutilized opportunity to flag athletes who are struggling emotionally, even before injury occurs. Utilizing items from the SCAT-5 symptom scale as a mental health screening tool could offer a practical method for assessing anxiety and depression without introducing additional measures that extend standard testing protocols and can be administered by the athletic team. This may allow for a more feasible and time-efficient strategy for detecting anxiety and depression symptoms in student-athletes. This approach allows for seamless integration into standard baseline procedures managed by athletic personnel, offering a valuable opportunity in sport settings where mental health symptoms often go unrecognized or are attributed to physical causes. Overall, incorporating mental health awareness into baseline assessments can facilitate early detection of psychological symptoms in athletes and can lead to more holistic, athlete centred care.

Conclusion

The current study is the first to validate the SCAT-5 symptom scale symptom domains. Overall, Anderson's 3-factor model demonstrated a better model fit and structure compared to the ICD-10 PCS symptom grouping domains. Furthermore, Anderson's affective symptom domain and the ICD 10- PCS emotional domain showed the highest discriminative ability in identifying athletes experiencing anxiety and depression at baseline, across varying levels of symptom severity levels. However, Anderson's model demonstrated a more balanced accuracy

across both mild and moderate thresholds, underscoring its potential value for supporting consistent screening of mental health outcomes. Findings from the current study support the utility of a widely used tool within the sports community, highlighting its potential for effective surveillance of mental health issue in athletes at baseline. By promoting mental health among varsity athletes, this approach may expand the scope of mental health treatment and prevention for student-athletes, ultimately improving their well-being. Taken together, the results from this study provide a foundation for informing sport-based polices aimed at improved mental health among Canadian athletes.

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