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VALIDITY OF THE IMPACT POST-CONCUSSION SYMPTOM SCALE (PCSS)

AFFECTIVE SYMPTOM CLUSTERS AS A SCREENER FOR

DEPRESSION IN COLLEGIATE ATHLETES

A Thesis in

Psychology

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Kaitlin Riegler

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The thesis of Kaitlin Riegler was reviewed and approved* by the following:

Peter Arnett

Professor & Director, Neuropsychology of Sports Concussion & MS Programs

Thesis Advisor

Semyon Slobounov

Professor of Kinesiology

Frank Hillary

Associate Professor of Psychology

Melvin Mark

Professor of Psychology

Head of the Department of Psychology

*Signatures are on file in the Graduate School

ABSTRACT

Objective: The relationship between depression and sports-related concussion is complex and has implications both pre-and-post injury. The current study established the construct validity, convergent and discriminant, of the affective symptom cluster of The Immediate Post-Concussion Assessment and Cognitive Test (ImPACT) post-concussion symptom scale (PCSS) as a screening tool for depression. Method: 930 (M=695, F=235) college athletes were assessed at baseline using the ImPACT PCSS and Beck-Depression Inventory-Fast Screen (BDI-FS). Previous factor analysis identified four symptom clusters on the PCSS: affective, physical, cognitive, and sleep. Clinically significant depression was operationalized as a BDI-FS score ≥4. Receiver Operating Characteristic curves (ROC) were used to determine the ideal cutoff, Chi-square tests of independence were calculated to establish convergent validity, and Fisher's r-to-z comparisons were used to establish discriminant validity of the affective symptom cluster. Results: The 90th percentile cutoff yielded the highest sensitivity and specificity on the affective symptom cluster for males (6) and females (4). The correlation between BDI-FS and the 90th percentile cutoff was statistically significantly higher in females (φ= .96) than males (φ = .83), $Z = 9.49$, $p < .001$. When correlating the BDI-FS with each PCSS symptom cluster, the correlation with the affective symptom cluster was stronger than its correlation with cognitive, sleep, and physical clusters across gender. Discussion: By utilizing a measure of depression within an existing and commonly used assessment, clinicians can easily screen for depression and identify athletes at risk for complicated recovery even in the absence of a supplemental depression assessment.

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Chapter 1

Introduction

Sports-related concussion (SRC) is a growing concern in organized sport participation in the United States. Recent estimates suggest that as many as 3.8 million sports-related concussions occur annually in the United States (Langlois, Rutland-Brown, & Wald, 2006). Available data from the National Collegiate Athletic Association (NCAA) Injury Surveillance System (ISS) indicates that around 300,000 SRCs occur per year in collegiate sports and that concussions are the second leading cause of traumatic brain injury among people between ages 15-24 (Gessel, Fields, Collins, Dick, & Comstock, 2007). Despite the use of injury surveillance systems and epidemiological studies to identify rates of concussions, it has been well documented that these numbers may be unrepresentative, since many people suffering from SRC do not seek medical services (Gessel et al., 2007).

Depression is common following sports-related concussion and may complicate the course of recovery (Vargas, Rabinowitz, Meyer, & Arnett, 2015). Development of subclinical and clinical depression may be increased following a concussion and depression may affect performance on neurocognitive assessments frequently used in sports concussion management (Bailey, Samples, Broshek, Freeman, & Barth, 2010; Basso, Miller, Estevis, & Combs, 2013; Burt, Zembar, & Niederehe, 1995; Busch & Alpern, 1998; Christensen, Griffiths, MacKinnon, & Jacomb, 1997; Covassin, Elbin, Larson, & Kontos, 2012; Kontos, Covassin, Elbin, & Parker, 2012; McDermott & Ebmeier, 2009; Vargas et al., 2015). Depression may also be an important risk factor for prospectively sustaining a concussion and a moderator for clinical recovery time following a concussion (Iverson et al., 2017; Vargas et al., 2015). Given these potential

relationships between depression and SRC both pre-and post-injury, screening and assessment for depression in athletes deserves attention.

Increased Depression Following SRC

Research has shown that depression is fairly common following SRC, with prevalence estimates ranging from 25 to 42% (Busch & Alpern, 1998; Rapoport, Kiss, & Feinstein, 2006). In a recent study, 84 athletes and 42 undergraduate student controls were assessed using the Beck Depression Inventory-Fast Screen (BDI-FS) at baseline and post-concussion. At baseline, 11% of athletes scored above the clinically significant cutoff for depression (≥4), but post-concussion 23% of athletes met this cutoff indicating a significant increase from baseline and this significant change was not mirrored in the control group (Vargas et al., 2015). While the prevalence of depression in the athlete sample was non-significantly higher than the control sample even pre-concussion, reliable change index analysis demonstrated that 20% of the concussed athletes showed a reliable increase in depression from their baseline scores, compared to only 5% of non-concussed control group (Vargas et al., 2015). This finding of higher post-concussion rates of depression could potentially be reflective of athlete-specific events that could lead to increased rates of depression in subgroups of athletes compared to the general population (Solomon, Kuhn, & Zuckerman, 2016).

In another study, 75 athletes were assessed at baseline and several time points post-injury using the Beck Depression Inventory-II (BDI-II) and the Immediate Post-Concussion Assessment and Cognitive Test (ImPACT). At baseline, none of the athletes met criteria for mild clinical depression at baseline (≥13), yet post-injury the concussed athletes had significantly higher mean BDI-II scores compared to baseline (Kontos, Covassin, et al., 2012). Further, several studies have found that depression is increased, especially in the acute phase following concussion in athletes.

For example, a study of concussed athletes compared to athletes with ACL injuries demonstrated that concussed athletes had a spike in Depression and Total Mood Disturbance as measured on the Profile of Mood States (POMS) that resolved by three weeks post-concussion (Mainwaring et al., 2004). Another study found that athletes were more depressed compared to baseline at 1 week post-injury, but that these symptoms resolved by 1 month post-injury (Roiger, Weidauer, & Kern, 2015).

Depression and Neurocognitive Test Performance

The relationship between clinical depression and impairment in a number of neuropsychological domains, including memory recall and recognition, working memory, speed of information processing, psychomotor speed, and executive functioning, has been well established in the literature, with increased depression severity predicting higher levels of impairment (Basso et al., 2013; Burt et al., 1995; Christensen et al., 1997; McDermott & Ebmeier, 2009). Further while meta-analyses of meta-analyses have revealed that depression in general impairs performance on neuropsychological assessments, there have only been a small number of other studies that have looked specifically at the relationship between depression and neurocognitive test performance following SRC (Basso et al., 2013). Kontos and colleagues (2012) showed that performance on a visual memory test and reaction time were significantly correlated with depression at two and seven days post-concussion. Another study of collegiate football players revealed an inverse relationship between neurocognitive test performance and depression at baseline (Bailey et al., 2010). Covassin and colleagues (2012) examined 1616 collegiate and high school athletes who were assessed for depression using the BDI-II and also completed the ImPACT test. Results showed that there were significant differences on visual memory scores such that the severe depression group scored lower on the visual memory test than

those with minimal depression (Covassin et al., 2012). All of these results show some type of deficit in neurocognitive functioning that is associated with depression, suggesting that depression can have important implications for neurocognitive test performance and ultimately return to play progression following SRC.

Predictors of Clinical Recovery Time from Sport Related Concussion

The majority of collegiate athletes typically experience symptom recovery within one week of SRC and return to full play within 10 days following SRC. Yet, there is a percentage of athletes that do not follow this typical pattern and experience protracted recovery (Garden & Sullivan, 2010; McCrea et al., 2003; McCrea et al. 2013). Examining factors that may contribute to protracted recovery may be important in the clinical management of concussions for this subset of athletes. Additionally, there is evidence that depression may act as a risk factor for subsequent concussion and a moderator for clinical recovery time following a concussion (Iverson et al., 2017; Solomon et al., 2016). Vargas and colleagues found that individuals at the greatest risk for developing clinically significant depression post-concussion had higher baseline concussion symptoms (Vargas et al., 2015). A recent systematic review of the literature on predictors of clinical recovery from concussion recognized that development of problems with depression following a concussion is a risk factor for long-lasting symptoms (generally defined as lasting longer than a month). Additionally, pre-injury history of mental health problems, including diagnosis of depression, may increase the risk for longer time to return to baseline level of functioning (Iverson et al., 2017).

Many studies have shown that increases in post-concussion symptoms in the acute phase of recovery are associated with prolonged return to play. For example, a study by Putukian and colleagues (2017) found that athletes who reported more symptoms and had higher symptom

severity took longer to return to play (days to symptom free and days return to full play). Additional research has focused on individual symptoms that may be reported the most in the acute phase of injury recovery such as headache, dizziness, feeling slowed down, feeling nervous/anxious and neck pain (Greenberg & Arnett, 2017; Lau, Kontos, Collins, Mucha, & Lovell, 2011; Putukian, Riegler, Amalfe, Echemendia, & Frisina, 2017). Yet, to our knowledge, no research has looked at the role that post-injury depression plays in the pattern of symptom reporting.

Further, research has demonstrated that concussed athletes may be less familiar with coping skills and accessing resources for psychological consequences following injury than other injured athletes (Covassin, Elbin, Beidler, Lafevor, & Kontos, 2017; Kontos, Elbin, Newcomer Appaneal, Covassin, & Collins, 2013). Also, concussion may affect cognitive processes and impact athletes' ability to cope with injury (Covassin et al., 2017; Kontos et al., 2013). Additionally, research has shown that emotional disturbance following sports injuries, in general, is greatest for athletes who receive little information about their injury or the recovery process (Johnston & Carroll, 1998; Mainwaring, 1999). As discussed above, a proportion of athletes may experience protracted recovery. Furthermore, while an athlete can be provided with information about the typical recovery, there is currently no diagnostic tool to indicate the individual rate of recovery; this may add some uncertainty regarding the recovery process and potentially lead to increased affective disturbance. Identifying athletes who screen positive for depression post-concussion can help clinicians intervene early and target specific interventions for those at risk of emotional difficulties, ultimately improving clinical recovery time (Bloom, Horton, McCrory, & Johnston, 2004).

Current Assessment Practices

The current standard of care following SRC includes comprehensive and multidomain assessment including sideline concussion tools, balance and oculomotor assessments, and computerized and paper-and-pencil neurocognitive testing (Resch et al., 2016; Sufrinko, McAllister-Deitrick, Womble, & Kontos, 2017). Computerized neuropsychological assessments are widely used in concussion protocols as they are time-efficient, easy to administer, and have well-established norms. Additionally, the use of neurocognitive assessments has been supported by the most recent consensus statement on management of SRC (McCrory et al., 2017). One of the most widely used of these computerized neurocognitive assessments is the ImPACT test. The ImPACT contains a post-concussion symptom scale (PCSS) that can be administered at baseline and post-injury. The PCSS is a list of 22 common symptoms of a concussion and athletes are asked to rate each symptom on a 7-point scale (0 = no symptoms; 6 = severe symptoms) based on current severity (Lovell et al., 2006; Lovell, Collins, Podell, Powell, & Maroon, 2000). Furthermore, exploratory factor analysis has led to the identification of four symptom clusters on the PCSS: affective, cognitive, physical/somatic, and sleep (Kontos, Elbin, et al., 2012; Merritt, Meyer, & Arnett, 2015). Of note, the affective symptom cluster contains four items: irritability, sadness, nervousness, and feeling more emotional, and athletes can score between 0 (no symptoms at all) to 24 (ratings of 6 for high severity on each symptom) on the affective scale.

Currently, if clinicians want to assess depression in a SRC context they need to administer a supplemental assessment to the athlete such as the BDI-II, BDI-FS, the Patient Health Questionnaire (PHQ-9), or the Brief Symptom Inventory 18 (BSI 18). The BDI-FS was developed for use in medical populations and a hallmark of this assessment is the exclusion of neurovegetative symptoms. Neurovegetative symptoms may include difficulty concentrating, trouble sleeping, and fatigue, all of which are symptoms that overlap with the PCSS. Therefore,

this brief depression scale may be a particularly useful tool for measuring depression in concussed populations as it may be able to discriminate between depression symptoms and symptoms of a concussion (Arnett et al., in press). Despite these existing screening tools for depression, there is a lack of systematic depression screening and assessment in the field of sports concussions. A recent literature review highlighted the current lack of effective tools for screening for mental health issues, including depression, in pre-participation examinations (Valovich McLeod, Fraser, & Johnson, 2017). This may be due to lack of time and resources to administer and interpret an additional measure. Considering limited time and resources, utilizing the affective scale of the PCSS as a screener and assessment tool for depression might offer a unique opportunity to take advantage of a widely administered assessment in many sport-concussion protocols.

Current Study

As discussed above, given the potential role that depression may play both pre-and-post injury, screening and assessment for depression in the case of sport-related concussion deserves attention. With these considerations in mind, the primary objective of the present study was to establish base rates for scores on the affective symptom cluster of the PCSS and to establish construct validity for this symptom cluster as a tool for screening for depression in a large collegiate athlete sample. First, we established base rates for males and females at each possible total score for the affective symptom scale. Next, we sought to establish convergent validity for the affective scale as a measure of depression. We examined the correlation between the affective symptom scale scores and scores of clinical depression (≥4) on the BDI-FS. We hypothesized that these scores would be highly correlated, indicated by a large effect size defined as Cohen's $d > .8$ (Cohen, 1998). Then, we sought to establish discriminant validity by examining the correlation

between the scores on the three other symptom clusters: physical symptoms, sleep symptoms, and cognitive symptoms, and scores of clinical depression on the BDI-FS. We hypothesized that these three other scales would not be highly correlated to the BDI-FS, indicated by smaller effect sizes (i.e., < .5) than the affective symptom cluster.

Chapter 2

Methods

Participants

This was a prospective cohort study that included 930 (M = 695, F = 235) college athletes who were involved in a concussion management program at a Division I University. The mean age of the participants was 18.53 years (SD = 1.07) with a range from 17-24. Figure 1 displays inclusion criteria in the Standard for Reporting Diagnostic accuracy studies (STARD) flowchart. All athletes participating in the concussion management program were assessed using a hybrid neuropsychological test battery at baseline, prior to their participation in collegiate athletes. The following varsity athletic teams participated in baseline testing: football, wrestling, men's and women's basketball, men's and women's lacrosse, men's and women's soccer, men's and women's ice hockey, rugby, baseball, softball, swimming and diving, golf, cheerleading, crew, tennis, track and field, and volleyball.

Athletes were selected from a larger sample comprised of 1,013 college athletes who had been baseline tested between 2002 and 2017. Participants were excluded from this larger sample if they did not complete both the BDI-FS and ImPACT PCSS at baseline (n = 83). Participant demographics are presented in Table 1.

Table 2-1. Sample characteristics.

Variable	*M*	*SD*
Age (years)	18.53	1.07
Education (years)	12.18	.80
	N	*%*
Sex		
Male	695	74.7

Female	235	25.3
Ethnicity		
Caucasian	687	73.9
African American	178	19.1
Other	65	7.0
Concussion History		
0	575	61.8
1	240	25.8
2 or more	110	12.4
Depressed (time of testing)		
Yes	78	8.4
No	852	91.6
History of Learning disorder		
Yes	34	3.7
No	857	92.2
Sport		
Football	256	27.5
Men's Basketball	66	7.1
Men's Ice Hockey	83	8.9
Men's Lacrosse	154	16.6
Men's Soccer	103	11.1
Women's Basketball	42	4.5
Women's Lacrosse	70	7.5
Women's Soccer	111	11.9
Wrestling	31	3.3
Other	14	0.11

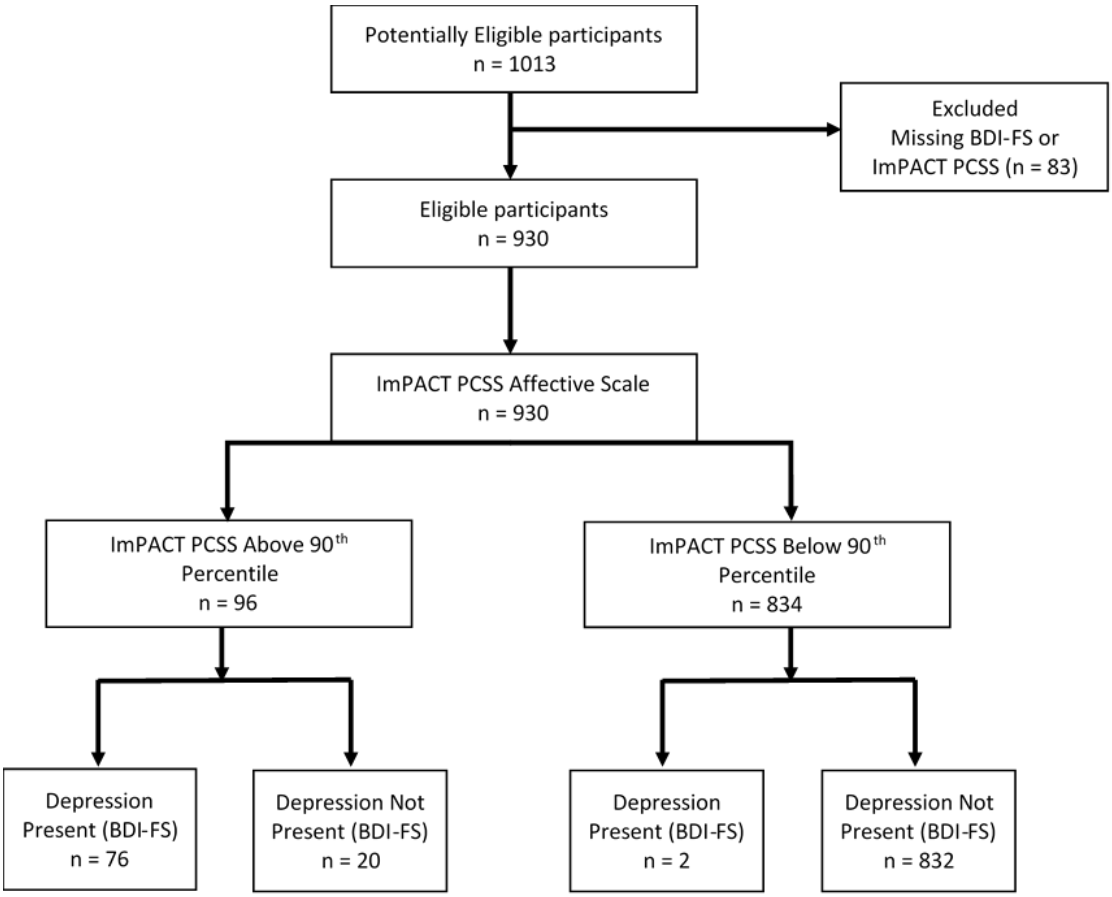


Figure 2-1. STARD Diagram

Procedures

The Sports-Concussion Program at this NCAA Division I University is based on the "Sports as a Laboratory Assessment Model (SLAM)" model (Bailey, Barth, & Bender, 2009; Barth et al., 1989). Athletes are referred to the program for baseline concussion testing from their team physician or athletic trainer. All participants completed a two-and-a-half hour comprehensive neuropsychological test battery at baseline. The battery consisted of both paper-and-pencil and computerized neuropsychological and neurobehavioral measures, including a measure of depression, the BDI-FS, and a symptom evaluation scale, the ImPACT PCSS. The neuropsychological test battery was administered by undergraduate research assistants or

graduate students who were supervised by a PhD-level clinical neuropsychologist. All participants provided written informed consent and the study was approved by the Behavioral Committee of the Institutional Review Board at the university.

Measures

The ImPACT test, a commonly used computerized neurocognitive assessment, includes the Post-Concussion Symptom Scale (PCSS) which is a self-report measure of types of symptoms and severity of symptoms associated with concussion. The PCSS consists of 22 items which are rated on a 7-point Likert scale ranging from 0 to 6 with 0 indicating no symptoms and 6 indicating severe symptoms. Previous factor analysis has identified four symptom clusters of the PCSS: cognitive, physical, affective cluster, and sleep clusters (Merritt et al., 2015). The list of symptoms that comprises each symptom cluster is listed in Table 2. Individual responses to the PCSS were transformed into these four symptom clusters for analysis.

Table 2-2. PCSS Symptom Clusters and their associated items.

Cognitive	*Physical*	*Affective*	*Sleep*
Feeling slowed down	Nausea	Irritability	Fatigue
Feeling mentally "foggy""	Vomiting	Sadness	Trouble falling asleep
Difficulty concentrating	Balance Problems	Nervousness	Sleeping less than usual
Difficulty remembering	Dizziness	Feeling more emotional	Drowsiness
	Sensitivity to light		
	Sensitivity to noise		
	Visual problems		

Note. PCSS = Post Concussion Symptom Scale. Table adapted from Merritt, V.C., & Arnett, P.A. (2014). Premorbid predictors of postconcussion symptoms in collegiate athletes. *Journal of Clinical & Experimental Neuropsychology, 36(10),* 1098-1111; Table 5, p. 1105.

The neurocognitive test battery administered at baseline consisted of both paper-and-pencil and computerized measures. The test battery is part of the standardized concussion protocol at an NCAA Division I University and has been described in detail in previous work. The battery included measures such as the ImPACT, Hopkins Verbal Learning Test-Revised, Penn State University Cancellation Task, Stroop Color-Word Test, and the Symbol Digit-Modalities Test. A full description of the test battery can be found in Merritt and colleagues' paper (Merritt et al., 2015). For the purposes of the current study the only measure from this battery that was examined was the ImPACT PCSS.

One of the neurobehavioral measures given was the BDI-FS. The BDI-FS is a brief measure of depression in medical patients. It includes 7 items related to sadness, hopelessness, feeling like a failure, anhedonia, self-esteem, self-blame, and suicidality. Previous work has identified the BDI-FS as a good screen for depression in a sport-concussion population due to the absence of neurovegetative symptoms of depression that overlap with post-concussion symptoms. A score of 4 or higher on the BDI-FS has been shown to reliably indicate clinical levels of depression (Beck, Steer, & Brown, 1996).

The procedures required for the present study took about 40 minutes to complete.

Statistical Analyses

The Statistical Package for the Social Sciences (SPSS), Version 24.0 was used for all data analyses. Descriptive statistics were calculated on all symptom clusters (i.e., cognitive physical, affective, and sleep) for the baseline sample. A summary of the means, standard deviations, medians, and interquartile ranges can be found in Table 3. The four symptom clusters were analyzed for homogeneity of variance using Levene's test for equality of variances and this test

was found to be violated for all four symptom clusters: cognitive, $F(1,928) = 193.32$, $p < .001$; physical, $F(1,928) = 242.57$, $p < .001$; affective, $F(1,928) = 281.06$, $p < .001$; sleep, $F(1,928) = 87.81$, $p < .001$. Further, as shown, the distribution of the symptom clusters and BDI-FS scores was not normal and these variables showed positive skewness and kurtosis comparable to that shown in Table 3. Since the population was skewed on all variables of interest, dichotomous variables were created for the BDI-FS and all symptom clusters. BDI-FS scores were dichotomized into two groups based on the presence of clinically significant depression (≥4) or absence of clinically significant depression (<4).

Table 2-3.Means and Standard Deviations for the Variables of Interest

	BDI-FS	Sleep Cluster	Affective Cluster	Physical Cluster	Cognitive Cluster
Total # of Items in Symptom Cluster		4	4	7	4
Males					
M (SD)	1.03 (1.74)	1.95 (3.16)	1.02 (2.50)	.52 (1.87)	.93 (2.26)
Median (IQR)	0.00 (1.00)	0.00 (3.00)	0.00 (1.00)	0.00 (0.00)	0.00 (0.00)
Females					
M (SD)	1.18 (1.84)	2.17 (3.54)	1.67 (3.09)	.51 (1.74)	1.13 (2.49)
Median (IQR)	0.00 (2.00)	0.00 (3.00)	0.00 (2.00)	0.00 (0.00)	0.00 (1.00)
All					
M (SD)	1.07 (1.76)	2.01 (3.26)	1.18 (2.67)	.52 (1.84)	.98 (2.32)
Median (IQR)	0.00 (1.00)	0.00 (3.00)	0.00 (1.00)	0.00 (0.00)	0.00 (1.00)
Skewness (SE)	-3.01 (.08)	2.31 (.08)	3.31 (.08)	5.60 (.08)	3.41 (.08)
Kurstosis (SE)	7.06 (.16)	6.17 (.16)	13.18 (.16)	39.74 (.16)	14.04 (.16)

Note: Skewness and kurtosis values refer to combined values across males and females. Values were similarly skewed when considered separately by gender.

We used Chi-Square tests of independence and receiver operating characteristic curves (ROC curves) to determine the optimal cutoff in terms of sensitivity and specificity for the four symptom clusters. For our Chi-Square tests, effect size was determined using Cohen's d criteria indicating that a phi coefficient of .1 equals Cohen's d of .2 for a small effect size, a phi coefficient of .3 equals a Cohen's d of .5 for a medium effect size, and a phi coefficient of .5 equals a Cohen's d of .8 for a large effect size (Cohen, 1998). Once the optimal cutoff for the

affective symptom cluster was established, we conducted Fisher's r-to-z transformations to compare the values of the phi correlation coefficients between the affective symptom cluster and the BDI-FS and each of the other symptom clusters and the BDI-FS separately for males and females. Additionally, to examine gender differences, we conducted Fisher's r-to-z transformations to compare the values of the phi correlation coefficients between the affective symptom cluster and the BDI-FS for males and females.

Chapter 3

Results

There were 51 males (7.34%) and 27 females (11.49%) who screened positive for depression (644 non-depressed males and 208 non-depressed females) based on BDI-FS criteria from clinically significant depression.

In order to determine the optimal cutoff for the affective symptom cluster, we examined the 85th, 90th, and 95th percentile cutoffs for males and females separately. This decision was made since preliminary data analysis suggests higher rates of symptom reporting for females, which is consistent with the literature indicating that females report higher numbers of symptoms compared to males at baseline and post-injury (Brown, Elsass, Miller, Reed, & Reneker, 2015). First, we conducted chi-square tests of independence between each of those cutoff percentiles and the BDI-FS for males and females. The 90th percentile cutoff of the affective symptom cluster resulted in the best correct classification values for males (6), $\chi 2(1, N = 695) = 578.79$, $p < .001$, $\varphi = .91$, and females (4), $\chi 2(1, N = 235) = 215.52$, $p < .001$, $\varphi = .96$. For males, the Chi-Square tests between the 85th percentile cutoff of the affective symptom cluster (4) and the BDI-FS, $\chi 2(1, N = 695) = 236.96$, $p < .001$, $\varphi = .58$, and the 95th percentile cutoff of the affective symptom cluster (6.2) and the BDI-FS, $\chi 2(1, N = 695) = 451.72$, $p < .001$, $\varphi = .81$, both resulted in worse classification values than the 90th percentile cutoff. A similar pattern was also true for females, with the chi square tests between the 85th percentile of the affective symptom cluster (4) and the BDI-FS, $\chi 2(1, N = 235) = 168.62$, $p < .001$, $\varphi = .85$, and the 95th percentile of the affective symptom cluster (8) and the BDI-FS, $\chi 2(1, N = 235) = 132.27$, $p < .001$, $\varphi = .75$, resulting in worse classification values than the 90th percentile cutoff.

Next, we conducted ROC curve analysis for each of the percentile cutoffs to examine sensitivity and specificity. Figure 2 displays the ROC curves for each cutoff of the affective symptom cluster for

males and females respectively and Table 4 contains the area under the curve (AUC) for males and females at each possible score on the affective symptom cluster in our sample. The AUC for the 90th percentile cutoffs were .98 for males and .96 for females. This resulted in the highest AUC for any of the cutoffs for males and females. Combined with the large effect size at the 90th percentile on the BDI-FS for males and females, the maximum sensitivity and specificity of this cutoff, and to maintain consistency across genders, the 90th percentile cutoff was determined to be the optimal cutoff. In addition to providing the 90th percentile cutoffs we have also included the sensitivity, specificity, and area under the curve values across the range of scores on the affective symptom cluster so that clinicians can make different determinations, as needed. The list of each of these values can be found in Table 4. Additionally, since the 90th percentile was determined to be the optimal cutoff, Table 5 provides detailed information about the number of athletes screening positive or negative for depression using the BDI-FS and the 90th percentile cutoff on the affective symptom cluster for each gender. Using the affective symptom cluster cutoff, there were 25 females who exceeded this cutoff and 210 who did not; 71 males exceeded this cutoff and 624 did not. The raw data presented in Table 5 can be used to calculate the sensitivity and specificity using this cutoff.

The positive predictive value (PPV) and negative predictive value (NPV) for the 90th percentile of the affective symptom cluster were calculated using the algorithmic table provided by Streiner (Streiner, 2003; Strober & Arnett, 2015). Using the 90th percentile cutoff for males (≥4) resulted in a PPV of 71.83% and an NPV of 100%, and using the 90th percentile cutoff for females resulted in a PPV of 100% and an NPV of 99.05%. These analyses resulted in 100% correct classification of males screening positive for depression (≥4 on BDI-FS and ≥4 on affective symptom cluster) and 96.89% correct classification of males screening negative for depression (<4 on BDI-FS and <4 on affective symptom cluster). There was a 92.59% correct classification of females screening positive for depression (≥4 on BDI-FS and ≥6 on affective symptom cluster) and 100% correct classification of females screening negative for depression (<4 on BDI-FS and <6 on affective symptom cluster). Overall, this resulted in 20 males with an affective symptom cluster score above 4 who did not score as having clinically relevant

depression on the BDI-FS, and 2 females who scored as having clinically relevant depression on the BDI-FS, but lower than 6 on the affective symptom scale.

Table 3-1. Classification Accuracy of Affective Symptom Cluster Scores

	Males			Females		
Score	**Sens.**	**Spec.**	**AUC**	**Sens.**	**Spec.**	**AUC**
0	1.00	0.00	0.50	1.00	0.00	0.50
1	1.00	0.80	0.90	1.00	0.66	0.83
2	1.00	0.88	0.94	1.00	0.78	0.89
3	1.00	0.97	0.98	1.00	0.96	0.98
4	1.00	0.97	0.98	1.00	0.96	0.98
5	0.84	1.00	0.92	0.93	1.00	0.96
6	0.84	1.00	0.92	0.93	1.00	0.96
7	0.57	1.00	0.78	0.59	1.00	0.80
8	0.37	1.00	0.69	0.37	1.00	0.69
9	0.24	1.00	0.62	0.33	1.00	0.67
10	0.24	1.00	0.62	0.33	1.00	0.67
11	0.18	1.00	0.59	0.33	1.00	0.67
12	0.16	1.00	0.58	0.30	1.00	0.65
13	0.12	1.00	0.56	0.11	1.00	0.56
15	0.06	1.00	0.53	0.00	1.00	0.50
18	0.02	1.00	0.51	0.00	1.00	0.50
21	0.00	1.00	0.50	1.00	0.00	0.50

Note: Score is total affective symptom cluster score. Sens = sensitivity, spec = specificity, and AUC = area under the curve.

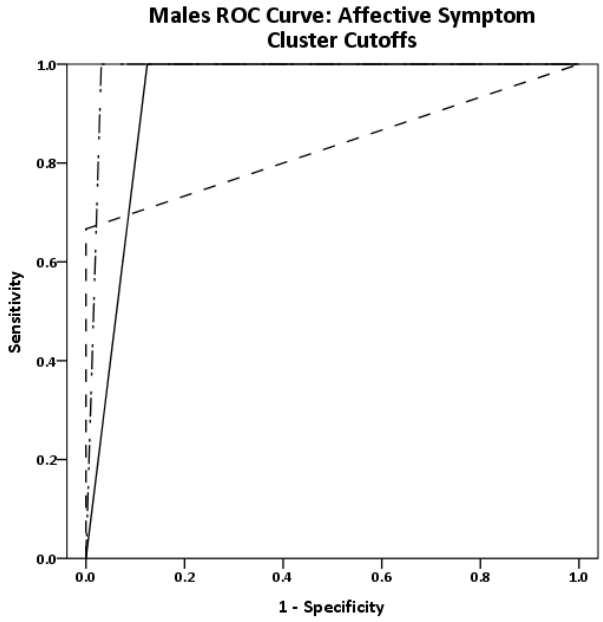
Table 3-2. ImPACT Affective Symptom Cluster 90th Percentile Classification by Gender

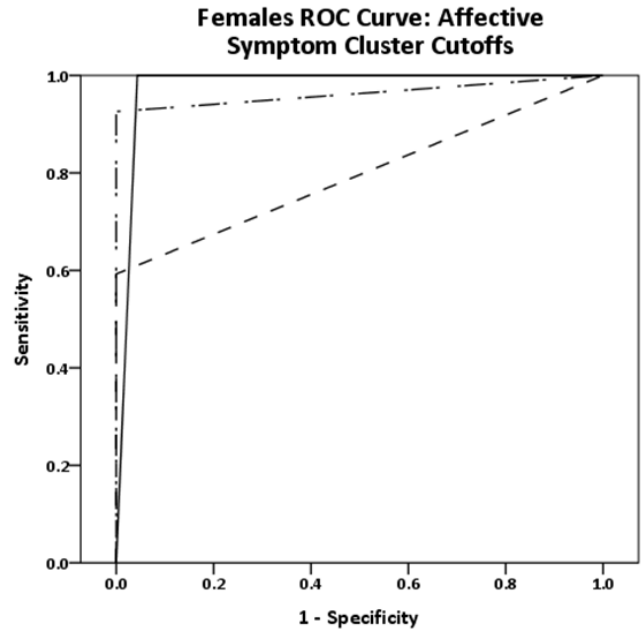
Males

	BDI-FS (≥4)	**BDI-FS (<4)**
Affective Symptom Cluster Above 90th Percentile (≥4)	51	20
Affective Symptom Cluster Below 90th Percentile (<4)	0	624

Females

	BDI-FS (≥4)	**BDI-FS (<4)**
Affective Symptom Cluster Above 90th Percentile (≥6)	25	0
Affective Symptom Cluster Below 90th Percentile (<6)	2	208





Key

Source of the Curve	
_____	**85th Percentile**
____ _ ____ _	**90th Percentile**
__ _ __ _	**95th Percentile**

Figure 3-1. Affective Cluster Cutoff-ROC Curves for Males and Females

After the 90th percentile was identified as the optimal cutoff, each of the other three symptom clusters (cognitive, physical, and sleep) were dichotomized into two groups based on the 90th Percentile cutoff for each of the symptom indices for males and females separately. Next, we conducted Chi-square tests of independence between the 90th percentile cutoff for each symptom cluster and the BDI-FS clinically depressed cutoff (≥ 4). The results of the Chi-square tests of independence between the BDI-FS and each of the symptoms clusters for males were: cognitive, $\chi2(1, N = 695) = 120.87$, $p < .001$, $\varphi = .43$; physical $\chi2(1, N = 695) = 79.31$, $p < .001$, $\varphi = .34$; affective $\chi2(1, N = 695) = 483.72$, $p < .001$, $\varphi = .84$; and sleep $\chi2(1, N = 695) = 90.36$, $p < .001$, $\varphi = .36$. The results of the Chi-square tests of independence between the BDI-FS and each of the symptom clusters for females were: cognitive, $\chi2(1, N = 235) = 33.10$, $p < .001$, $\varphi = .38$; physical, $\chi2(1, N = 235) = 13.60$, $p < .001$, $\varphi = .24$; affective, $\chi2(1, N = 235) = 215.52$, $p < .001$, $\varphi = .96$; and sleep, $\chi2(1, N = 235) = 5.95$, $p = .02$, $\varphi = .16$. Since the results were significant between the BDI-FS and each symptom cluster for males and females, we conducted Fisher's r-to-z transformations to compare the values of the phi correlation coefficient between the affective symptom cluster and the BDI-FS and each of the other symptom clusters and the BDI-FS separately for males and females. For males, the affective symptom cluster was statistically significantly ($p < .001$) more highly correlated with the BDI-FS than the cognitive cluster (Z test = -14.66), the physical cluster (Z test= -16.45), and the sleep cluster (Z test = -15.94). The same was true for females, with the affective symptom cluster significantly ($p < .001$) more highly correlated with the BDI-FS than the cognitive cluster (Z test = -17.31), the physical cluster (Z test = -18.99), and the sleep cluster (Z test = -19.96). Last, we examined gender differences in the utility of the affective symptom cluster as a screener for depression. We conducted a Fisher's r-to-z transformation to compare the affective symptom cluster and the BDI-FS correlations in males compared to in females. This correlation was statistically significantly higher in females ($\varphi = .96$) than males ($\varphi = .83$), $Z = 9.49$, $p < .001$.

Chapter 4

Discussion

The primary goal of the current study was to establish the validity of a subset of symptoms from the ImPACT PCSS to be used as a measure for depression in collegiate athletes and to provide useful cutoff points to be used by clinicians to identify athletes at risk for depression. Previous work has identified four symptom clusters of the ImPACT PCSS: affective, cognitive, physical, and sleep. The current study focused on the use of the affective cluster, consisting of four items including "sadness" and "feeling more emotional," as a measure of depression. We established the convergent validity of the affective symptom cluster as a screener for depression by conducting Chi-Square tests of independence between a well-validated depression screening tool, the BDI-FS, and the affective symptom cluster 90th percentile cutoffs for males and females. Results of these Chi-Square tests indicated convergent validity, with a large effect size.

Next, we examined the discriminant validity of the affective symptom cluster as a screening measure of depression in this population by determining whether depressed athletes specifically reported more on the affective symptom cluster compared to the other three symptom clusters or if they just generally and non-specifically reported higher numbers of symptoms on the PCSS. Results revealed that the affective symptom cluster was significantly more strongly correlated with the BDI-FS than either the physical, sleep, or cognitive clusters of the PCSS for both males and females. Thus, athletes who screen positive for clinically-relevant depression are specifically reporting symptoms on the affective scale as compared to the other scales.

After establishing both the convergent and discriminant validity of the affective symptom cluster, we provided cutoffs for clinicians to use in concussion assessment. The range of scores on the affective symptom cluster are provided for males and females so that clinicians can choose how conservative to be when screening for depression. While our analyses revealed that the 90th percentile cutoff is optimal in terms of sensitivity and specificity, it is possible that clinicians may want to be more liberal in identifying depression, emphasizing sensitivity, or be more conservative, emphasizing specificity.

Previous research has been mixed related to gender differences in symptom reporting, with some research indicating that females tend to report higher numbers of symptoms than males at baseline and that gender differences become larger following concussion (Broshek et al., 2005; Brown, Elsass, Miller, Reed, & Reneker, 2015; Covassin et al., 2012; Covassin, Schatz, & Swanik, 2007). Additionally, in the general population, the prevalence of depression in women is 1.5-3 times higher than that in men (American Psychiatric Association, 2013). Due to these potential gender differences, we conducted separate analyses for males and females. We also compared the correlation between the BDI-FS and the affective symptom cluster between males and females and found that the correlation was statistically significantly greater for females. This indicates that, while the correlations between the affective symptom cluster and the BDI-FS are high for both males and females, the affective symptom cluster may be a slightly more useful tool for identifying depression in females than in males. It is possible that this difference could be due to male depression symptoms manifesting as more cognitive, sleep, or physical symptoms on the PCSS. Additionally, previous research has indicated a general underreporting of symptoms in athletes due to motivation to return to play (Echemendia & Cantu, 2003; McCrea, Hammeke, Olsen, Leo, & Guskiewicz, 2004). While the research on gender differences is currently mixed, some studies have indicated that females are more likely to report post-concussion symptoms and concussion overall compared to males (Frommer et al., 2011; Miyashita, Diakogeorgiou, &

VanderVegt, 2016). Therefore, another possibility could be that males are generally underreporting more symptoms, including ones on the affective symptom cluster

There were limitations to the current study. First, there were a small number of athletes reporting clinically significant depression at baseline, 51 males and 27 females. Due to this small sample of depressed athletes, caution should be taken when generalizing these findings to larger samples. Furthermore, the self-report measures of symptom reporting and depression are subjective and may have resulted in inaccurate reporting versus what may be derived from a clinical interview. With that said, our comparative measure, the BDI-FS, has been shown to have a high level of concordance in diagnosing depression relative to clinical interviews (Beck, Steer, & Brown, 2000). Another potential limitation of our study is that the affective symptom cluster is not screening specifically for depression, but mood and affective disturbance more generally in athletes. However, previous literature has indicated that depression and anxiety are frequently comorbid following concussion, indicating that even if general affective disturbance is being identified using this screener that referral may still be helpful (Covassin et al., 2014; Yang, Peek-Asa, Covassin, & Torner, 2015). Due to this comorbidity, if an athlete screens positive using these affective symptom cluster cutoffs, it is recommended that they be referred for a more detailed and structured interview that can help with differential diagnosis along with potential identification of comorbid conditions.

Currently, literature indicates that depression may be a risk factor for prospectively sustaining a concussion or for prolonged or complicated return to play following concussion and thus has important implications for recovery following a concussion (Iverson et al., 2017; Vargas et al., 2015). Regularly screening for depression as part of a concussion assessment can provide valuable information to the clinician, though it is not currently widely practiced. If athletes at risk for depression could be easily identified, then clinicians could tailor treatment and return to play protocols appropriately to best benefit the athletes. By identifying a useful measure of depression

within this already existing and commonly used assessment, clinicians with limited time and resources can easily screen for depression and identify athletes at risk for complicated recovery even in the absence of a supplemental depression assessment.

It is recommended that, in order to assess for clinical depression, a structured clinical interview that has been validated should be used in treatment. However, given time constraints, this is not possible for all athletes. As a result, the screener recommended here can be used to refer athletes for a more comprehensive evaluation. The ImPACT is the most widely used neuropsychological assessment used in sport-related concussion assessment, thus utilizing a subset of items administered within this assessment is ideal for identifying a time-efficient screener. The researchers recommend that in the absence of a detailed clinical interview, the affective scale of the ImPACT PCSS can be used to screen out athletes who can be referred for more intensive follow up for potential problems with depression and complicated recovery. When individuals score above our suggested cutoff, then we note that further screening regarding the specificity of their distress would be warranted. Treatment could then proceed depending on the outcome of this further diagnostic work-up, as different approaches would be warranted for individuals presenting primarily with anxiety versus depression, versus those with comorbid conditions.

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