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## A Retrospective Review of Concussion Symptom Reporting and Trajectory Data across the State of Hawaii: Influence on the Future of Return-to-Learn --Manuscript Draft--

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A Retrospective Review of Concussion Symptom Reporting and Trajectory Data across the State  
of Hawaii: Influence on the Future of Return-to-Learn

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## Abstract

**Purpose:** The purpose of this retrospective study was to investigate the trajectories of symptoms during concussion recovery and to investigate whether symptom cluster severity ratings are different between sexes. **Method:** This study consisted of retrospective analyses of concussion data from adolescent athletes ages 13 through 18 who sustained concussions between the 2007-2008 and 2019-2020 academic school years in the State of Hawaii. A total of 18,294 injuries were identified for analysis, which were divided into four groups corresponding to the number of Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT) post-injury tests completed. The primary outcome measure analyzed was the Post-Concussion Symptom Scale (PCSS), which was rated during every ImPACT test completion. PCSS severity ratings were rescaled with a min-max normalization, ratings were organized by symptom cluster, and a series of two-way between-subjects analysis of variance (ANOVA) were calculated to evaluate a potential interaction effect between symptom cluster severity rating and sex. **Results:** Students consistently rated symptoms from the headache-migraine, sleep, and cognitive clusters with the highest severity and frequency. Females were observed to rate symptoms with higher severity than males across direct comparison of symptom clusters. Students who completed multiple ImPACT tests during recovery reported significantly higher symptom severity at the time of post-injury test one. **Conclusions:** The results aligned with previous research evaluating symptom reporting between sexes and symptom type. Implications for how the results of symptom severity trends and trajectories may influence the development of empirically driven return-to-learn (RTL) guidelines are discussed.

**Keywords:** *concussion symptom severity and trajectory; Post-Concussion Symptom Scale (PCSS); return-to-learn (RTL)*

## Introduction

Annually, individuals in the United States (US) sustain 1.7 million traumatic brain injuries with 70-90% of all injuries classified as concussion (Arbabi et al., 2020). Between the years of 2010-2016, an average of 283,000 children under 18 years of age years sought emergency department (ED) care for sports- and recreation-related TBIs (Sarmiento et al., 2019). The highest injury rates have been identified in males and children ages 10-14 and 15-17 years, and activities associated with the highest rates of ED visits include football, bicycling, basketball, playground activities, and soccer (Sarmiento et al., 2019). Of similar concern is the temporary cognitive impairment and academic decline associated with concussion. Students with a sports or recreation related concussion were more likely to report cognitive impairments following the injury with an associated significant decrease in grade point average (Lowry et al., 2019). Additionally, students with elevated post-concussion symptom severity have been found to experience more school related problems and academic decline compared to their performance prior to the injury (Ransom et al., 2015). Due to the high concussion rates in children and adolescents, as well as the academic concerns commonly associated with concussion, it is imperative to understand the symptom profiles and trajectories of these students in order to develop and evaluate interventions.

One aspect of particular importance to returning students to pre-injury academic performance is an understanding of how symptom severity mediates and moderates overall outcome following concussion, as the most consistent predictor of concussion recovery is the number and severity of acute and subacute symptoms (Harmon et al., 2019; Iverson et al., 2017). Recent literature has categorized the variety of concussion symptoms into the following six symptom clusters: headache-migraine, cognitive, anxiety-mood, ocular-motor, vestibular, and

sleep (Harmon et al., 2019; Lumba-Brown et al., 2019). Cognitive symptoms have been found to be more commonly associated with delayed symptom resolution than other types of concussion symptoms, which put academic performance at particular risk (Grubenhoff et al., 2014). Following concussion, students also commonly rate sleep and headache-migraine symptoms as severe (Covassin et al., 2013; Ono et al., 2016). Sleep and headache-migraine symptoms have been shown to be potential drivers of cognitive symptoms and are often part of interacting symptom feedback loops that are a hallmark of concussion (Harmon et al., 2019; Kenzie et al., 2017). Another consistency in the literature examining concussion profiles is the finding that females report higher symptom severity compared to their male counterparts (Baker et al., 2016; Covassin et al., 2012; Harmon et al., 2019; Iverson et al., 2017; Ono et al., 2016; Pulsipher et al., 2021). There is less consensus, however, as to whether females experience a longer recovery time than males (Baker et al., 2016; Ono et al., 2016). Overall, the symptom profile literature suggests that management of concussion in youth needs to focus on academic supports related to cognitive symptoms. Further, work evaluating whether females are at risk for greater symptom severity and longer symptom duration is warranted.

### **Present State of Concussion Management**

The evolution of concussion management, particularly for sports-related concussion, has led the development of return-to-play (RTP) guidelines, intended to provide a framework to safely return athletes to competition following recovery. A graduated, 6-step RTP protocol was agreed upon in the 2016 Berlin consensus statement on concussion in sport (McCrory et al., 2017). It was designed to return athletes to the playing field as they gradually resolve symptoms at each step beginning with limited activity and concluding with a full return to sport. Recent studies suggest the duration of time to complete the full RTP protocol ranges from 20-30 days

following the injury (Kerr et al., 2016; McAvoy et al., 2020; Tamura et al., 2020). However, RTP studies provide limited insight into the acute window of time students may be most at risk for experiencing academic challenges following a concussion (Gioia, 2016; Tamura et al., 2020).

Although the successful completion of the step-wise RTP protocol presumes successful return to learn (RTL), there is limited empirical research on what supports or interventions students require to achieve RTL (McAvoy et al., 2020). Multiple models have been presented to guide the RTL process and share three commonalities. The first commonality is the need for multidisciplinary participation and open communication between school and medical personnel to facilitate RTL (Gioia, 2016; Gioia et al., 2016; Hossler et al., 2014; McAvoy et al., 2020). Schools are not uniform in terms of resources, staff, and access to medical personnel to coordinate the academic, physical, and psychosocial needs of students with concussion. The RTL models presented by both Dachtyl & Morales (2017) and Davies (2016) provide examples of how services can be adapted and implemented using the available resources and personnel of the school where individuals with the most knowledge on concussion management (e.g., athletic trainer, speech-language pathologist, school psychologist) are put in the position to oversee the RTL process and collaborate with each other.

The second commonality among RTL models centers on the identification and implementation of academic interventions. It has been suggested the most appropriate type of post-concussion intervention is informal academic adjustments as they can be provided on a temporary basis and the majority of students will achieve a full recovery within 30 days (Halstead et al., 2013; McAvoy et al., 2018, 2020). The third commonality is the call to integrate gradual return to activity into the RTL process (Gioia, 2016; Halstead et al., 2013; McAvoy et al., 2020) and to implement multidisciplinary coordination to initially provide, and then

gradually remove, appropriate academic adjustments as the student progresses towards recovery (Dachtyl & Morales, 2017; Gioia, 2016; Hossler et al., 2014; McAvoy et al., 2020). Critical to the provision of interventions is the need for ongoing symptom monitoring to assess the student's post-concussion academic, physical, and psychosocial needs.

Current RTL guidelines are designed to facilitate the monitoring of symptom recovery of concussed students ostensibly to be able to provide them with academic or other interventions if symptoms do not resolve, and to increase academic engagement as symptoms abate.

Unfortunately, we have limited knowledge about students' symptom recovery trajectories, which impedes the ability to identify and evaluate appropriate return to learn supports matched to student needs. This knowledge gap motivated the present study. We conducted a retrospective analysis of symptom severity data to explore potential symptom cluster severity trends and recovery trajectories in students recovering from concussion. A greater understanding of both the initial severity and the recovery trajectories of the six concussion symptom clusters can provide insight on what academic interventions students may need during their recovery and influence the development of RTL interventions that can be empirically evaluated.

### **Source of Retrospective Analysis**

The Hawaii Concussion Awareness and Management Program (HCAMP) was established in 2010 in partnership between the State of Hawaii Departments of Health and Neurotrauma Supports, the State of Hawaii Department of Education, and the University of Hawaii at Manoa, College of Education, Department of Kinesiology and Rehabilitation Sciences to research evidence-based practices for concussion management. HCAMP implements a 7-step RTP protocol across the State of Hawaii adopted from the 2009 Consensus in Sports Group Consensus Statement where the first step is divided into two phases to differentiate cognitive rest

from a full return to school. RTL is considered complete at step 3 when the student has achieved a full return to school without accommodations or adjustments, and RTP is considered complete when the student returns to their sport without limitations. Table 1 displays the HCAMP RTP protocol.

***Insert Table 1 Here***

The 7-step HCAMP protocol has previously been evaluated and identified an average RTL duration of 13 days and RTP duration time of 20.2 days (Tamura et al., 2020). In addition to data on RTL and RTP outcomes, HCAMP maintains a large database of Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT; ImPACT Applications, Inc, San Diego, CA) spanning 13 years. As the state of the research has called for a greater understanding of symptom and clinical profiles (Harmon et al., 2019), we determined it was necessary to retrospectively analyze Post-Concussion Symptom Scale (PCSS) (Lovell et al., 2006; Schatz et al., 2006) results obtained at the time of ImPACT post-injury testing to evaluate whether the symptom severity trends obtained from the HCAMP data were consistent with findings from previous studies. Ultimately, this information is important for understanding and evaluating how symptom reporting can drive RTL intervention.

The purpose of this retrospective analysis was to investigate the trajectories of symptoms during concussion recovery and to investigate whether symptom clusters are different between sexes. We were interested in examining the following in the adolescent and young adult sports concussion population: (a) relative severity and frequency of symptom clusters and (b) comparison of severity and frequency of symptom clusters between the sexes.

**Methods**



## Setting and Participants

This study consisted of retrospective analyses of concussion data from adolescent athletes ages 13 through 18 who sustained concussions between the 2007-2008 and 2019-2020 academic school years in the State of Hawaii. A total of 18,294 concussion injuries were identified for analysis, which were divided into four separate groups corresponding to the number of ImPACT post-injury tests completed during the gradual RTP process. Table 2 displays the number of individuals per number of ImPACT post-injury tests completed. ImPACT post-injury test scores were compared to ImPACT baseline testing performance to make RTP progression decisions. Students typically completed baseline tests at the beginning of the sports season during their freshman and junior years. The following were HCAMP guidelines for ImPACT post-injury test administrations during a student's recovery process:

1. A concussed student completed their first post-injury test within 24-72 hours of the injury onset.
2. The second post-injury test was administered five days after the injury onset.
3. The third post-injury test was administered seven days after the injury onset.
4. Students requiring additional testing for scores to return to baseline performance were tested no more than two times in one week.
5. All ImPACT post-injury tests were reviewed by one neuropsychologist.

*Insert Table 2 Here*

## Outcome Measure

The primary outcome measure analyzed for this study was PCSS (Lovell et al., 2006; Schatz et al., 2006) severity ratings obtained at the time of ImPACT post-injury testing. The PCSS is a 22-item, formal questionnaire designed to quantify the severity of post-concussion

symptoms where individual symptoms are rated 0 (*no symptoms*) to 6 (*severe symptoms*), and the total symptom severity score represents the sum of the 22 rated symptoms. The symptoms were then grouped into six concussion symptom clusters identified by Harmon et al. (2019) and Lumba-Brown et al. (2019). The six symptom clusters included: (a) headache-migraine symptoms, (b) cognitive symptoms, (c) anxiety-mood symptoms, (d) ocular-motor symptoms, (e) vestibular symptoms, and (f) sleep symptoms. Table 3 displays the individual symptoms from the PCSS that correspond to the six symptom clusters as well as the maximum severity ratings for each symptom cluster.

***Insert Table 3 Here***

### **Statistical Analysis**

Descriptive statistics were calculated to characterize the range of symptom severity ratings between sexes across the six symptom clusters and the total symptom severity score. Additionally, descriptive statistics on the duration of time between test dates for students completing multiple ImPACT post-injury tests were calculated to provide insight on the time required to complete the 7-step RTP protocol which included a full return to school without accommodations or adjustments at step 3.

To evaluate a potential interaction between symptom cluster severity rating and sex, the distributions of cluster severity ratings were first rescaled with a min-max normalization to compare scores on a common 0 – 1 scale. Second, a series of two-way between-subjects analysis of variance (ANOVA) were calculated with corresponding post hoc analyses. All analyses were completed with RStudio version 1.4 with alpha level established at  $p < .05$  (RStudio Team, 2020). Additionally, a two-way between-subjects ANOVA was used to calculate the interaction effect between sex and the total number of ImPACT post-injury tests completed to evaluate

differences in total symptom severity at the time of first post-injury testing. Appropriate post-hoc analyses were calculated.

## **Results**

### **Duration of Time between ImPACT Post-Injury Tests**

On average, students who completed two ImPACT post-injury tests completed the second test 5.95 days following the first test. Students who completed three ImPACT post-injury tests completed the third post-injury test an average of 11.61 days following the first post-injury test. For students who completed four ImPACT post-injury tests, the average duration of time between the first and fourth post-injury tests was identified to be 18.18 days. Table 4 provides descriptive statistics on the duration of time between post-injury tests for each set of students corresponding to the number of post-injury tests completed.

*Insert Table 4 Here*

### **Symptom Cluster Severity Rating and Sex Interaction**

#### ***Ratings for Students who Completed One Post-Injury Test***

Descriptive statistics of non-normalized and normalized cluster severity ratings for students who completed one ImPACT post-injury test are accessible in the supplemental materials. The symptom cluster-by-sex interaction effect was significant,  $F(5, 59,934) = 18.82, p < .001$ . Tukey post hoc analysis identified that females reported significantly higher symptom severity levels than males between direct comparison of symptom clusters (e.g., female vestibular cluster compared to male vestibular cluster). The headache-migraine symptom cluster was identified to be rated significantly higher than the other clusters due to the significant difference between female ( $M = 0.16, SD = 0.19$ ) and male ( $M = 0.12, SD = 0.16$ ) headache-migraine cluster severity ratings of normalized data,  $p < .001$ . Cognitive and sleep cluster

symptoms were rated with the second highest severity level across all symptom clusters for both sexes. The differences in normalized symptom severity ratings were not significant between both female cognitive ( $M = 0.11$ ,  $SD = 0.18$ ) and female sleep cluster symptoms ( $M = 0.11$ ,  $SD = 0.16$ ) as well as between male cognitive ( $M = 0.09$ ,  $SD = 0.15$ ) and male sleep cluster symptoms ( $M = 0.09$ ,  $SD = 0.15$ ),  $p > .05$ . Both females and males were observed to rate the ocular-motor, anxiety-mood, and vestibular symptom clusters significantly less than the sleep and cognitive symptom clusters.

#### ***Ratings for Students who Completed Two Post-Injury Tests***

**Post-Injury Test One.** Descriptive statistics of non-normalized and normalized cluster severity ratings for students who completed two post-injury ImPACT tests are accessible in the supplemental materials. The symptom cluster-by-sex interaction effect was significant,  $F(5, 31,758) = 12.36$ ,  $p < .001$ . Tukey post hoc analysis identified that females reported significantly higher symptom severity levels than males between direct comparison of symptom clusters except for the ocular-motor cluster ( $p = .166$ ). Both females ( $M = 0.20$ ,  $SD = 0.20$ ) and males ( $M = 0.15$ ,  $SD = 0.17$ ) rated the headache-migraine cluster significantly higher than other clusters when compared to their respective sexes. The difference between headache-migraine cluster severity ratings between males and females was significant,  $p < .001$ . Additionally, males and females were observed to both rate the sleep and cognitive clusters with the second highest level of severity. The difference between these two clusters was not significant corresponding to ratings within sexes,  $p > .05$ , but females were observed to rate both clusters significantly higher than males,  $p < .05$ .

**Post-Injury Test Two.** The symptom cluster-by-sex interaction effect was significant,  $F(5, 31,758) = 9.58$ ,  $p < .001$ . Tukey post hoc analysis identified that females reported

significantly higher symptom severity levels than males between direct comparison of symptom clusters except for the ocular-motor ( $p = .421$ ) and vestibular clusters ( $p = .559$ ). Both females ( $M = 0.07$ ,  $SD = 0.13$ ) and males ( $M = 0.05$ ,  $SD = 0.10$ ) rated the headache-migraine cluster significantly higher than other clusters when compared to their respective sexes. The difference between headache-migraine cluster severity ratings between males and females was significant,  $p < .001$ . Males and females were identified to rate the sleep and cognitive clusters significantly higher than the anxiety-mood, vestibular, and ocular-motor clusters. The difference in severity ratings between the sleep and cognitive clusters was not significant corresponding to ratings within sexes,  $p > .05$ . However, females were observed to rate both clusters significantly higher than males,  $p < .05$ .

#### ***Ratings for Students who Completed Three Post-Injury Tests***

**Post-Injury Test One.** Descriptive statistics of non-normalized and normalized cluster severity ratings for students who completed three ImPACT post-injury tests are accessible in the supplemental materials. The symptom cluster-by-sex interaction effect was significant,  $F(5, 13,356) = 7.25$ ,  $p < .001$ . Tukey post hoc analysis identified that females reported significantly higher symptom severity levels than males between direct comparison of symptom clusters except for the ocular-motor ( $p = .998$ ) and vestibular clusters ( $p = .777$ ). Both females ( $M = 0.23$ ,  $SD = 0.21$ ) and males ( $M = 0.17$ ,  $SD = 0.19$ ) rated the headache-migraine cluster significantly higher than other clusters when compared to their respective sexes. The difference between headache-migraine cluster severity ratings between males and females was significant,  $p < .001$ . Males and females were identified to rate the sleep and cognitive clusters significantly higher than the anxiety-mood, vestibular, and ocular-motor clusters. The difference in severity ratings between the sleep and cognitive clusters was not significant corresponding to ratings within

sexes,  $p > .05$ . However, females were observed to rate both clusters significantly higher than males,  $p < .05$ .

**Post-Injury Test Three.** The symptom cluster-by-sex interaction effect was significant,  $F(5, 13,356) = 2.60, p = .02$ . Females reported higher symptom severity than males for the headache-migraine ( $p = .004$ ) and anxiety-mood clusters ( $p = .001$ ). Direct comparison between sexes of the sleep ( $p = .066$ ), ocular-motor ( $p = 1.00$ ), cognitive ( $p = .112$ ), and vestibular clusters ( $p = .988$ ) were not significant. Within sexes, both females and males rated symptoms from the headache-migraine, cognitive, and sleep clusters with the highest severity. Differences between these three clusters was not significant when comparing ratings within sexes,  $p > .05$ .

#### ***Ratings for Students who Completed Four Post-Injury Tests***

**Post-Injury Test One.** Descriptive statistics of non-normalized and normalized cluster severity ratings for students who completed four ImPACT post-injury tests are accessible in the supplemental materials. The symptom cluster-by-sex interaction effect was not significant,  $F(5, 4,668) = 1.39, p = .220$ . Following the conventional ANOVA logic, the main effects of symptom cluster and sex were examined. The difference in severity rating between symptom clusters was determined to be significant,  $F(5, 4,668) = 26.71, p < .001$ . The difference in severity rating between sexes was also determined to be significant,  $F(1, 4,668) = 17.58, p < .001$ . The headache-migraine cluster was observed to be rated significantly higher than other symptom clusters. Comparisons of severity ratings for the vestibular/sleep clusters ( $p = .967$ ), vestibular/cognitive ( $p = .522$ ), and sleep/cognitive clusters ( $p = .944$ ) were not significant. Ratings for the vestibular, sleep, and cognitive clusters were all rated significantly higher than the anxiety-mood and ocular-motor clusters. The comparison of the anxiety-mood and ocular-

motor clusters was not significant,  $p = .730$ . On average, females were observed to rate higher symptom severity levels compared to males,  $p < .001$ .

**Post-Injury Test Four.** The symptom cluster-by-sex interaction effect was significant,  $F(5, 4,668) = 2.88, p = .010$ . Females reported higher symptom severity than males for both the headache-migraine ( $p < .001$ ) and cognitive clusters ( $p < .001$ ). Direct comparison between sexes of the sleep ( $p = .139$ ), ocular-motor ( $p = 1.00$ ), anxiety-mood ( $p = .162$ ), and vestibular clusters ( $p = .738$ ) were not significant. When comparing severity ratings within sexes, males were observed to not report severity ratings with significant differences across all clusters,  $p > .05$ . Females were observed to rate the cognitive cluster ( $M = 0.05, SD = 0.13$ ) significantly greater than the vestibular ( $M = 0.02, SD = 0.08$ ) and ocular-motor clusters ( $M = 0.02, SD = 0.11$ ),  $p = .008$  and  $p = .004$ , respectively. Females additionally rated the headache-migraine cluster ( $M = 0.05, SD = 0.13$ ) significantly greater than the vestibular, ocular-motor, and anxiety-mood clusters ( $M = 0.03, SD = 0.10$ ),  $p < .001$ ,  $p < .001$ , and  $p = .013$ , respectively.

#### **Total Symptom Score at Post-Injury Test One across Number of Post-Injury Tests Completed**

Table 5 displays descriptive statistics of post-injury test one total symptom scores by sex and the number of post-injury tests completed. The total post-injury tests completed-by-sex interaction effect was not significant,  $F(3, 18,286) = 1.09, p = .350$ . Subsequently, both the main effects of total post-injury tests completed and sex were examined. The difference in post-injury test one total symptom score between total tests completed was significant,  $F(3, 18,286) = 61.09, p < .001$ . The difference in post-injury test one total symptom score between sexes was also determined to be significant,  $F(1, 18,286) = 112.44, p < .001$ . Students who completed four post-injury tests ( $M = 18.95, SD = 19.51$ ) reported significantly higher post-injury test one total

symptom scores than students who completed three post-injury tests ( $M = 16.09$ ,  $SD = 18.10$ ), two post-injury tests ( $M = 13.31$ ,  $SD = 16.76$ ), and one post-injury test ( $M = 10.70$ ,  $SD = 15.57$ ),  $p < .05$ . Mean differences between students who completed one post-injury test and two post-injury tests, one post-injury test and three post-injury tests, and two post-injury tests and three post-injury tests were additionally significant,  $p < .05$ . On average, females ( $M = 14.74$ ,  $SD = 17.95$ ) reported significantly higher post-injury test one total symptom scores compared to males ( $M = 10.87$ ,  $SD = 15.36$ ),  $p < .05$ .

*Insert Table 5 Here*

## Discussion

The purpose of this retrospective analysis was to evaluate trends in symptom reporting over 13 years of ImPACT testing data across the State of Hawaii in 13 to 18-year-old students who rated symptom severity with the PCSS. The findings from the current study aligned with symptom severity trajectories reported in previous studies. Present findings and their potential application to RTL are discussed below.

Trends in student symptom ratings for the current study were similar to findings reported in previous studies (Covassin et al., 2013; Grubenhoff et al., 2014; Ono et al., 2016). Specifically, students consistently rated symptoms from the headache-migraine, sleep, and cognitive clusters with the highest severity and frequency. The only ratings where symptom severity across all clusters was rated similarly occurred at the time of the fourth post-injury test with students who completed all four ImPACT post-injury tests. This group constituted the students with the most protracted recovery. Students who completed four post-injury tests averaged 18.18 days between post-injury test one and post-injury test four. A gradual decrease of symptom cluster severity ratings across all clusters was observed. This observation may provide



insight on the duration of time for headache-migraine, sleep, and cognitive symptoms to subside to similar severity levels of the other clusters for students with a longer recovery.

Also consistent with previous research was the finding that females generally rated symptoms with higher severity than males across direct comparison of symptom clusters. It was not the purpose of the present study to analyze the cause of differences in symptom reporting between the sexes, but multiple explanations on the discrepancy between male and female symptom reporting have been documented in the literature ranging from differences in behavioral symptom reporting (Gallagher et al., 2018; Pulsipher et al., 2021) to physiological differences (Baker et al., 2016; Broglio et al., 2012) to neurophysiological differences (Bazarian et al., 2010).

It has been documented that the most consistent predictor of concussion recovery is the number and overall severity of symptoms (Harmon et al., 2019; Iverson et al., 2017). Consistent with previous studies on symptom severity and outcome was the finding from the present study that students who completed more ImPACT post-injury tests, corresponding to a longer duration of recovery, reported significantly higher severity scores across all symptom clusters at the time of the first test (i.e., post-injury test one).

#### **How Trends in Symptom Severity can Influence the Future of RTL**

The analysis of this sample provides insight into which concussion symptom clusters burden students the most during their return to school. Students consistently rated symptoms from the headache-migraine, cognitive, and sleep clusters as the most severe. This finding can help guide the provision of supports, such as strategies and adjustments to increase student alertness and attention during lectures, as these three symptom clusters ultimately impact the ability to learn and retain new information (Gioia et al., 2016). With an improved knowledge of

perceived symptom severity and recovery trajectory, educators and clinicians can be better prepared with interventions that address how a student's symptoms may impact their academics (Harmon et al., 2019). As previously stated, students with the highest levels of post-injury test one symptom severity required more post-injury tests to complete the protocol, corresponding to a longer recovery and may require higher tiered academic supports, such as a 504 Plan (McAvoy et al., 2018). This is a critical finding for RTL because it provides educators with an indicator of who is at risk for a longer recovery. Future research should consider the evaluation of severity cut-off scores that trigger the implementation of specific RTL interventions to manage symptoms and prevent academic challenges. It is also important for educators and clinicians to be mindful that females tend to be more symptomatic than males when assessing student needs and implementing supports.

## **Study Limitations**

It is important to acknowledge the limitations of the present study. Although this retrospective analysis provided the ability to characterize trends from a large sample, the lack of experimentation weakens the ability to draw strong conclusions from the findings. Another limitation to the study is that assumptions on RTP time were made based on the number of tests completed rather than the duration of time to achieve RTP as in Tamura et al. (2020) because data on RTP outcome could not be included in the analysis. The authors attempted to merge ImPACT scores and PCSS symptom severity ratings with student RTP timeline data from the Sports Injury Surveillance System. The two data sets were joined in RStudio in an attempt to create one large data set with all information on PCSS severity ratings and student RTP outcome; however, the data sets did not align directly enough to retain all observations from the ImPACT

and PCSS data source. Therefore, the decision was made to proceed with analyses from the ImPACT data set only as it provided more observations.

### ***Measurement Considerations***

A key consideration in the development of RTL interventions is the need to address the limitations on how student academic need is measured post-concussion. Although symptom severity measures like the PCSS provide a method to quantify the severity of student symptoms, these measures have been shown to underrepresent symptoms from the ocular-motor and vestibular clusters (Lumba-Brown et al., 2019). Such a bias in symptom measurement may have influenced the results of the present study as the vestibular and ocular-motor clusters were consistently rated with less severity than other clusters. Moreover, it may lead to the misidentification of students experiencing negative academic outcome because of these symptoms.

Another limitation of symptom measurement related to our methods is that our data could not consider the influence of individual symptom scores on unrelated symptom cluster scores. As outlined by Harmon et al. (2019), the interaction of symptoms from different clusters creates multiple profiles where reported symptom scores for one individual symptom or cluster are likely influenced by the symptom scores of a variety of symptoms from multiple clusters. For example, a student may rate the cognitive or sleep symptom clusters with a higher symptom score because of the influence of anxiety-mood symptoms on those clusters. Therefore, it is important to consider the interaction of all symptoms when interpreting symptom severity scores to better understand an individual student's profile.

Besides symptom measurement, there is a need to develop and implement measurement tools that can be utilized repeatedly to provide clinicians and educators with valid and reliable

information in determining RTL management decisions. The Concussion Learning Assessment and School Survey, 3<sup>rd</sup> Edition (CLASS-3) (Gioia et al., 2020) is one such tool with reasonably strong psychometric properties that provides educators with a measurement to characterize student academic needs during concussion recovery. Previous versions of the CLASS have been determined to successfully identify students experiencing academic challenges post-concussion, especially when used in tandem with symptom severity measurements like the PCSS (Ransom et al., 2015; Wright & Sohlberg, 2021). Continued evaluation of the reliability and validity of the CLASS-3 on diverse populations is certainly warranted to expand its use across the educational spectrum.

## **Conclusions**

Results of this retrospective analysis aligned with previous research evaluating symptom reporting between sexes and type of symptoms. Females were identified to report symptoms with higher severity compared to males, and symptoms from the headache-migraine, cognitive, and sleep clusters were consistently rated higher in severity. Moreover, students with higher symptom severity at the time of their first post-injury test were identified to require more tests during their recovery, suggesting a relationship between immediate post-injury symptom severity and recovery time. Results from this study contribute to the literature base of post-concussion symptom reporting and highlight the importance of considering symptom severity trends and trajectories in the development of empirically driven RTL protocols that can prevent chronic academic difficulty in students recovering from concussion.

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Table 1

*HCAMP RTP Protocol*

Step	Description	Definition
Onset	Injury onset	Date concussion occurred
1	Cognitive rest	Date athletic trainer counsels or student-athlete imitates cognitive rest
2	Full return to school	Date student returns to school full-time; school adjustments may be provided at this time
3	Light aerobic activity	<p>Date student is able to begin light aerobic activity without symptoms (stationary bike or timed run) and has completed all of the following:</p> <ul style="list-style-type: none"> <li>• Medical clearance</li> <li>• Normal results on ImPACT compared with baseline or norm</li> <li>• Normal results on Balance Error Scoring System compared with baseline <ul style="list-style-type: none"> <li>• No school adjustments or accommodations being provided</li> </ul> </li> <li>• Asymptomatic for at least 24 hours</li> </ul>
4	Running and sport-specific drills	Date student is able to perform individual strenuous running and sprints and individual noncontact sport-specific drills without symptoms
5	Noncontact drills	Date student is able to perform team noncontact and sport-specific drills without symptoms
6	Full-contact practice	Date student is able to perform a full day of full-contact practice without symptoms
7	Return to game	Date student may participate without limitations and is discharged

Table 2

*Total Number of Students Corresponding to Number of ImPACT Tests Completed*

Number of tests completed	Females	Males	Total
1	4,096	5,895	9,991
2	2,210	3,085	5,295
3	928	1,300	2,228
4	320	460	780

Table 3

*PCSS Items Corresponding to Symptom Cluster*

Symptom cluster	PCSS items	Maximum severity rating
Headache-migraine symptoms	Headache; light sensitivity; noise sensitivity	18
Cognitive symptoms	Feeling “slow”; feeling “foggy”; difficulty concentrating; difficulty remembering	24
Anxiety-mood symptoms	Irritability; sadness; nervousness; more emotional; numbness	30
Ocular-motor symptoms	Visual problems	6
Vestibular symptoms	Nausea; vomiting; balance problems; dizziness	24
Sleep symptoms	Fatigue; trouble falling asleep; excessive sleep; loss of sleep; drowsiness	30

Table 4

*Descriptive Statistics for the Duration of Time between ImPACT Tests*

Number of tests completed	<i>M</i>	<i>SD</i>	Range
Two tests			
Days between tests 1 and 2	5.95	4.72	0 – 30
Three tests			
Days between tests 1 and 2	5.69	4.19	0 – 30
Days between tests 1 and 3	11.61	6.59	1 – 45
Four tests			
Days between tests 1 and 2	5.81	3.97	1 – 29
Days between tests 1 and 3	11.69	6.33	2 – 45
Days between tests 1 and 4	18.18	8.87	4 – 55

Table 5

*Test One PCSS Total Symptom Severity Ratings by Total Number of Tests Completed and Sex*

Number of tests complete	Test one total symptom severity rating					
	Females		Males		Total	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
One	12.77	16.96	9.25	14.36	10.70	15.57
Two	15.70	18.13	11.60	15.48	13.31	16.76
Three	18.53	19.10	14.36	17.15	16.09	18.10
Four	22.15	21.04	16.72	18.06	18.95	19.51
Sex	Test one total symptom severity rating					
			<i>M</i>	<i>SD</i>		
Females			14.74	17.95		
Males			10.87	15.36		



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