What Thirteen Years of Educational Concussion Data Can Teach Us about the Future of Return-to-Learn

# 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 aged < 18 years sought emergency department (ED) care for sports- and recreation-related TBIs with 45% of injuries resulting from contact sports (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). To manage sports-related concussions, return-to-play (RTP) guidelines provide a framework to safely return athletes to competition following recovery. Research evaluating RTP lead to the development of a graduated 6-step RTP protocol agreed upon in the 2016 Berlin consensus statement on concussion in sport (McCrory et al., 2017). The 6-step protocol aims 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, and 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). Although the successful completion of RTP presumes a successful return-to-learn (RTL), there is limited empirical research on what supports or interventions students require to achieve RTL (McAvoy et al., 2020). It is imperative for stakeholders to evaluate how schools have incorporated RTP guidelines to facilitate return to the playing field with the intention of adopting a similar approach for RTL that successfully returns students to the classroom, PE, and other school-related activities.

## RTL in the Literature

Presently, theoretical position statements on the development of RTL protocols provide stakeholders with information on how to facilitate a student’s return to the classroom following a concussion. The two common themes identified in these statements promote (a) the development of a multidisciplinary team for concussed students and (b) the integration of return-to-learn guidelines into return-to-activity guidelines.

### Multidisciplinary Participation

Consistent across RTL position statements and proposed models is (a) the call for multidisciplinary coordination between the family, medical personnel, and school personnel to ensure successful RTL completion and (b) the consistent training of school staff (e.g., general education teachers, clinical support staff) to reduce the knowledge gap on supporting students in the classroom following a concussion (Gioia, 2016; Gioia et al., 2016; Hossler et al., 2014; McAvoy et al., 2020). Both Halstead et al. (2013) and McAvoy et al. (2020) stress the importance of first completing a medical evaluation, and, if available, a neuropsychological evaluation to establish the injury prognosis, which can influence the student’s RTL plan.

Within the school, position statements have specified the importance of establishing roles and communication between team members (Gioia et al., 2016; Halstead et al., 2013), and models have been proposed to implement such a framework. Davies (2016) discussed one model, titled the School-Based Concussion Management Program (SBCM), where one dedicated liaison was responsible for the implementation and oversight of academic supports, communication between home and school, and progress monitoring for all students recovering from a concussion in the district. The SBCM model has not been evaluated empirically, but Davies (2016) concluded such a model may be more cost-effective for a district to empower one person or a team of individuals across to oversee concussion management across an entire district rather than identifying one person within every individual school. In the proposed model Cognitive Return to Exertion (CoRTEx), RTL is facilitated through direct coordination between the school speech-language pathologist (SLP) and athletic trainer (AT), where the SLP assesses academic needs and disseminates academic adjustments to the student’s teachers followed by weekly progress monitoring of symptom severity and academic needs; once the SLP clears the student from the RTL process, the AT commences the RTP protocol (Dachtyl & Morales, 2017). Like the SBCM model, CoRTEx has not been empirically evaluated to determine its efficacy, limiting its generalizability to schools on a broader basis.

### Integrating Gradual Return to Activity into RTL for Students

Original concussion management protocols promoted total physical or cognitive inactivity until the student achieved completed symptom resolution; however, the literature has shifted over the course of the past 10-15 years to reduce prolonged inactivity as it may prolong recovery (Gioia, 2016; Halstead et al., 2013; McAvoy et al., 2020). Instead, published position statements suggest a brief period of cognitive pacing for 24 to 48 hours immediately following the injury where the student limits cognitive activities (e.g., video games, homework) that may exacerbate symptoms (Dachtyl & Morales, 2017; Gioia, 2016; Halstead et al., 2013; McAvoy et al., 2020). It has been suggested that students return to school when they can tolerate 30-45 minutes of cognitive stimulation (Halstead et al., 2013). After the student initially returns, it is suggested a multidisciplinary team initiates the RTP protocol set forth by the school and in accordance with available resources. Immediate and temporary classroom adjustments can be implemented where concussed students may receive rest breaks and a reduced homework load to control concussion symptoms. The student proceeds to increase their work load until they achieve a return to their full academic schedule (Gioia, 2016). In their review of RTP duration time, Tamura et al. (2020) identified that high school students, on average, required 13 days after the injury onset to return to school full-time providing preliminary evidence for RTL duration.

### Identification and Implementation of Academic Interventions

As the student navigates through the RTL process, the multidisciplinary team possesses several existing options to provide appropriate support. Informal academic adjustments, such as a reduced temporary workload or class schedule, provide short-term changes to the student’s schedule and correspond with Tier 1 support within a multi-tiered system of support framework (MTSS) (Halstead et al., 2013; McAvoy et al., 2018). Because most students fully recover from their concussion within 30 days, McAvoy et al. (2018) has suggested Tier 1 should be the primary level of support provided to students following a concussion as it is more efficient to implement than more formal supports provided at MTSS levels 2 or 3. For students who do not recover within the typical timeframe and develop prolonged concussion symptoms (PCS), more formal academic accommodations and modifications triggered at MTSS levels 2 and 3 are recommended (McAvoy et al., 2020). This is an important consideration due to the variability in concussion recovery. Although Tamura et al. (2020) identified an average of 13 days to return to school full-time, the standard deviation of the sample was 10 days, which suggests there will be students who require more time to achieve a full recovery. For such cases, schools must be prepared to provide higher level supports.

### The RTL Necessities

Position statements and proposed models highlight the key components of an RTL program that require empirical evaluation. In addition to multidisciplinary coordination and staff training, it is imperative to establish a method of identification for concussed students, especially for injuries that occur off campus in non-sporting events. Further, standardized methods of evaluating a student’s individualized needs following their concussion and throughout their recovery are warranted. Lastly, it is critical to develop criteria-based measurements to determine appropriate discharge from the RTL process. The identification of these RTL necessities directly influenced the present retrospective analysis of concussion data to inform the future of RTL.

## Purpose 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 steps to differentiate cognitive rest from a full return to school. RTL is considered complete at stage 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 RTP duration time of 20.2 days (Tamura et al., 2020). Of interesting note, however, is that female students were identified to require a significantly longer duration of time to achieve both the RTL (stage 3) and RTP protocols (stage 7) (Tamura et al., 2020). One possible explanation for the discrepancy in time to complete both RTL and RTP between sexes is that females have been identified to report higher symptom severity at the time of initial concussion evaluation (Alsalaheen et al., 2021; Baker et al., 2016; Colvin et al., 2009; Covassin et al., 2013; Ono et al., 2016; Zuckerman et al., 2014). Given the identified differences in both recovery time and symptom reporting, we developed the purpose of the present retrospective analysis to review symptom reporting across 13 years of Post-Concussion Symptom Scale (PCSS) results obtained at the time of Immediate Postconcussion Assessment and Cognitive Testing (ImPACT; ImPACT Applications, Inc, San Diego, CA) that students complete during their concussion recovery. Our rationale to explore trends in symptom reporting post-injury is that an increased understanding of symptom trajectories during the recovery process can influence the development and justification of an empirically driven RTL protocol to improve student outcome.

# Methods

## Setting and Participants

This study implemented retrospective analyses of 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 tests completed during the gradual RTP process. Table 2 displays the number of individuals per number of ImPACT tests completed. Post-injury ImPACT test scores were compared to baseline testing performance to make RTP progression decisions, and students typically completed baseline tests at the beginning of their freshman and junior years. The HCAMP guidelines for post-injury test administrations were the following:

1. A concussed student should complete their first post-injury test within 24-72 hours of the injury onset.
2. The second post-injury test should be administered five days after the injury onset.
3. The third post-injury test should be administered seven days after the injury onset.
4. Students should not be tested more than two times in one week.

***Insert Table 2 Here***

## Outcome Measure

The primary outcome measure analyzed for this study was PCSS severity ratings obtained at the time of ImPACT testing. The PCSS is a 22-item, formal questionnaire designed to quantify the severity of post-concussion symptoms from the six concussion symptom clusters identified by Harmon et al. (2019) and Lumba-Brown et al. (2019) 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 six symptom clusters include: (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 tests were calculated to provide insight on the time required to complete the RTP protocol.

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 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 Tests

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

***Insert Table 4 Here***

## Symptom Cluster Severity Rating and Sex Interaction

### Completed One Test

Table 5 displays descriptive statistics of non-normalized and normalized cluster severity ratings for students who completed one post-injury ImPACT test, and the ANOVA results are reported in Table 6. 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.

***Insert Table 5 Here***

***Insert Table 6 Here***

### Completed Two Tests

**Test One.** Table 7 displays descriptive statistics of non-normalized and normalized cluster severity ratings for students who completed two post-injury ImPACT tests, and the ANOVA results corresponding to test one are reported in Table 8. 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.

***Insert Table 7 Here***

***Insert Table 8 Here***

**Test Two.** The ANOVA results corresponding to test two are presented in Table 9, and 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.

***Insert Table 9 Here***

### Completed Three Tests

**Test One.** Table 10 displays descriptive statistics of non-normalized and normalized cluster severity ratings for students who completed three post-injury ImPACT tests, and the ANOVA results corresponding to test one are reported in Table 11. 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.

***Insert Table 10 Here***

***Insert Table 11 Here***

**Test Three.** The ANOVA results corresponding to test three are presented in Table 12, and 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.

***Insert Table 12 Here***

### Completed Four Tests

**Test One.** Table 13 displays descriptive statistics of non-normalized and normalized cluster severity ratings for students who completed four post-injury ImPACT tests, and the ANOVA results corresponding to test one are reported in Table 14. 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 sexs 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.

***Insert Table 13 Here***

***Insert Table 14 Here***

**Test Four.** The ANOVA results corresponding to test four are presented in Table 15, and 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.

***Insert Table 15 Here***

## Total Symptom Score at Test One across Number of Tests Completed

Table 16 displays descriptive statistics of test one total symptom scores by sex and the number of tests completed, and the ANOVA results are reported in Table 17. The total tests completed-by-sex interaction effect was not significant, *F*(3, 18,286) = 1.09, *p* = .350. Subsequently, both the main effects of total tests completed and sex were examined. The difference in test one total symptom score between total tests completed was significant, *F*(3, 18,286) = 61.09, *p* < .001. The difference in 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 tests (*M* = 18.95, *SD* = 19.51) reported significantly higher test one total symptom scores than students who completed three tests (*M* = 16.09, *SD* – 18.10), two tests (*M* = 13.31, *SD* = 16.76), and one test (*M* = 10.70, *SD* = 15.57), *p* < .05. Mean differences between students who completed one test and two tests, one test and three tests, and two tests and three tests were additionally significant, *p* < .05. On average, females (*M* = 14.74, *SD* = 17.95) reported significantly higher test one total symptom scores compared to males (*M* = 10.87, SD = 15.36), *p* < .05.

***Insert Table 16 Here***

***Insert Table 17 Here***

# Discussion

The purpose of this retrospective analysis was to evaluate trends in symptom reporting over 13 years of ImPACT testing across the state of Hawaii in 13 to 18-year-olds. Results were consistent with previous studies evaluating the relationship between symptom reporting and sex that have identified females to report higher ratings of symptom severity following a concussion (Colvin et al., 2009; Covassin et al., 2013; Ono et al., 2016; Zuckerman et al., 2014). Regardless of the number of ImPACT tests completed in the present retrospective analysis, females were generally identified to report higher symptom severity than males across the six symptom clusters. Additionally consistent with previous research was the finding that both males and females develop symptom profiles consistently rating symptoms from the headache-migraine, cognitive, and sleep clusters with the highest severity ratings following a concussion (Covassin et al., 2013; Ono et al., 2016; Zuckerman et al., 2014).

One goal of this analysis was to explore how symptom cluster ratings change with consecutive testing during the gradual recovery process with the expectation that symptom clusters would not be rated significantly different over time, especially at the time of last testing for students completing three or four post-injury tests. Although symptom severity ratings were observed to decrease with consecutive testing across all clusters, symptoms from the headache-migraine, cognitive, and sleep clusters continued to be consistently rated with higher severity scores than symptoms from other clusters both at the time of initial testing and throughout the recovery duration.

Another goal of this study was to evaluate the difference in test one total symptom scores across the four distinct groups corresponding to the total of number of tests completed with the expectation that students who eventually completed four post-injury tests would report the highest test one total symptom scores. The results of the analysis aligned with our hypothesis as students who completed four post-injury tests reported significantly higher test one total symptom scores (*M* = 18.95) than the other three groups. There additionally appeared to be a linear relationship between test one total symptom score and the eventual total number of tests completed as test one total symptom score was identified to gradually increase for more tests eventually completed.

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

The large sample size of this analysis provides insight on what symptoms burden students the most during their return to school as various concussion symptoms may interact with each other to impact student academic performance. Specifically, symptoms from the headache-migraine, cognitive, and sleep clusters, consistently rated the most severely, may impact student alertness and attention during lecture, ultimately impacting the ability to learn and retain new information (Gioia et al., 2016). With an improved knowledge of student symptom reporting and what clusters rate the most severely, it is imperative for educators to be prepared with interventions that can be personalized to the specific symptom profile of the student (Harmon et al., 2019). As previously stated, students with the highest levels of test one symptom severity required more tests to complete the protocol corresponding to a longer recovery, which further indicates the importance of having supports and protocols in place to provide early identification of students most at risk of prolonged recovery to prevent negative academic outcome. With the information obtained from this analysis, the next step is to develop and implement RTL protocols that account for the following considerations.

### Measurement Limitations

A key consideration for RTL development is the need to address the limitations to 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 identified 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 analysis 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 the individual 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, 3rd 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). 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.

### Implementation Limitations

It is necessary to consider the challenges to developing an RTL protocol that can adapt to the differences that exist in schools. The first challenge to overcome is the development of a protocol that can be implemented and adjusted across various grade levels. The differences in procedures between elementary, middle, and high schools require that an RTL protocol can adapt to the school’s setting. Second, it is vital for an RTL protocol to be adaptable to meet the needs of schools of differing socio-economic status and student population. The development of RTL protocols must be evaluated on schools with diverse and underrepresented backgrounds to ensure effective protocols can extend to all students.

## Study Limitations

It is important to acknowledge the limitations from 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 like Tamura et al. (2020) as data on RTP outcome could not be included in the analysis. Data on ImPACT scores and PCSS symptom severity ratings generate from a different data set than the data source for student RTP outcome. The two data sets were joined in RSudio to attempt to create one large data set with all information on PCSS severity ratings on 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.

## Conclusions

The results of this retrospective analysis aligned with previous research evaluating symptom reporting between sexes and type of symptom. 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 with higher severity ratings. Moreover, students with higher symptom severity at the time of post-injury test one 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 in the development of empirically driven RTL protocols that can be adapted to various school settings and prevent chronic academic difficulty in students recovering from concussion.

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