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). Sport-related concussion (SRC) represents the second highest cause of concussion, accounting for an estimated 300,000 annual injuries in the US (Marar et al., 2012). To combat SRC in youth and adolescents, much attention has focused on the development of return-to-play (RTP) protocols to safely return athletes to competition. The RTP literature base 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 youth athletes require to achieve RTL (McAvoy et al., 2020).

## 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 (1) development of a multi disiplinary team for concussed students and (2) integrating return to learn guidelines into return to activity guidelines.

### 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 multi disciplinary team initiates the RTP protocol set forth by the school and according to the resources available. Immediate and temporary classroom adjustments can be implemented where concussed students may receive rest breaks and reduced homework load to control concussion symptoms. while increasing the work load until the student achieves the final stage corresponding to a return to their full academic schedule (Gioia, 2016).

### 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).

### 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 Neurotrauma Supports, the State of Hawaii Department of Education and the University of Hawaii at Manoa, College of Education. Deparment 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 Concussion 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.

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 genders 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 1 displays the number of individuals per number of ImPACT tests completed.

***Insert Table 1 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 2 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 2 Here***

## Statistical Analysis

Descriptive statistics were calculated to characterize the range of symptom severity ratings between genders 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 gender, 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 gender 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 3 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 3 Here***

## Symptom Cluster Severity Rating and Gender Interaction

### Completed One Test

Table 4 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 5. The symptom cluster-by-gender 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 genders. 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 4 Here***

***Insert Table 5 Here***

### Completed Two Tests

**Test One.** Table 6 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 7. The symptom cluster-by-gender 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 genders. 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 genders, *p* > .05, but females were observed to rate both clusters significantly higher than males, *p* < .05.

***Insert Table 6 Here***

***Insert Table 7 Here***

**Test Two.** The ANOVA results corresponding to test two are presented in Table 8, and the symptom cluster-by-gender 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 genders. 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 genders, *p* > .05. However, females were observed to rate both clusters significantly higher than males, *p* < .05.

***Insert Table 8 Here***

### Completed Three Tests

**Test One.** Table 9 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 10. The symptom cluster-by-gender 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 genders. 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 genders, *p* > .05. However, females were observed to rate both clusters significantly higher than males, *p* < .05.

***Insert Table 9 Here***

***Insert Table 10 Here***

**Test Three.** The ANOVA results corresponding to test three are presented in Table 11, and the symptom cluster-by-gender 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 genders of the sleep (*p* = .066), ocular-motor (*p* = 1.00), cognitive (*p* = .112), and vestibular clusters (*p* = .988) were not significant. Within genders, 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 genders, *p* > .05.

***Insert Table 11 Here***

### Completed Four Tests

**Test One.** Table 12 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 13. The symptom cluster-by-gender 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 gender 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 genders 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 12 Here***

***Insert Table 13 Here***

**Test Four.** The ANOVA results corresponding to test four are presented in Table 14, and the symptom cluster-by-gender 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 genders 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 genders, 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 14 Here***

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

Table 15 displays descriptive statistics of test one total symptom severity scores by gender and the number of tests completed, and the ANOVA results are reported in Table 16. The total tests completed-by-gender interaction effect was not significant, *F*(3, 18,286) = 1.09, *p* = .350. Subsequently, both the main effects of total tests completed and gender were examined. The difference in test one total symptom severity rating between total tests completed was significant, *F*(3, 18,286) = 61.09, *p* < .001. The difference in test one total symptom severity rating between genders 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 severity 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 severity compared to males (*M* = 10.87, SD = 15.36), *p* < .05.

***Insert Table 15 Here***

***Insert Table 16 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 gender 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 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. While symptom severity ratings were observed to decrease with consecutive testing, symptoms from the headache-migraine, cognitive, and sleep clusters continued to be consistently rated with higher severity levels.

Another goal of this study was to evaluate the difference in test one symptom severity 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 level of symptom severity at the time of test one. The results of the analysis aligned with our hypothesis as students who completed four post-injury tests reported significantly higher severity levels compared to the other three groups. There additionally appeared to be a linear relationship between total symptom severity and eventual total number of tests completed as test one total symptom severity 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.

Besides symptom measurement, there is a need to develop measurement tools that can be utilized repeatedly to provide clinicians with valid and reliable information in determining RTL management decisions. The Concussion Learning Assessment and School Survey (CLASS) is one such measurement that provides educators with a brief survey to characterize student needs. Although it has not been evaluated on a large scale, the CLASS has been identified 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). The evaluation of the CLASS on a wide scale, or the development of tools similar to it, is an essential component of developing successful RTL protocols to make informed decisions on student needs.

### 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). 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 genders 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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