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). Due to the high concussion rates in children and adolescents, it is imperative to understand the academic needs of students recovering from concussion to develop and implement effective interventions to efficiently return them to the classroom.

# 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). Cognitive symptoms have been found to be more commonly associated with delayed symptom resolution than other types of concussion symptoms, highlighting the vulnerable academic state students are susceptible to after an injury (Grubenhoff et al., 2014). Sleep and headache-migraine symptoms additionally have been found to be reported with high levels of severity after an injury (Covassin et al., 2013; Ono et al., 2016), demonstrating the potential interaction of symptoms and the likelihood of students to present with overlapping clinical profiles after an injury (Harmon et al., 2019). Another consistency across the literature 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). There is less consensus as to whether females experience a longer recovery time than males (Baker et al., 2016; Ono et al., 2016), but the present state of the research on symptom profiles provides stakeholders with the necessary insight on acute concussion needs to develop and implement interventions that prevent chronic academic challenges.

## 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, which 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) and is 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), which provides insight on the acute window of time students may be most at risk for experiencing academic challenges following a concussion.

# 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). Multiple models have been presented to guide the RTL process and all share specific commonalities. The first commonality is the need for multidisciplinary participation 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 RTL; therefore, RTL models presented by both Dachtyl & Morales (2017) and Davies (2016) provide examples of how RTL can be adapted and implemented using the available resources and personnel of the district 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 coordinate 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 intervention to provide students post-concussion 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 and final commonality across RTL models is the call to integrate gradual return to activity into the RTL process (Gioia, 2016; Halstead et al., 2013; McAvoy et al., 2020). Critical to this step is to provide ongoing symptom monitoring to assess student need 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).

# Although there remains limited empirical evidence to evaluate proposed RTL guidelines, the state of the research influenced the present study to retrospectively analyze symptom severity data to explore potential symptom trends in students recovering from concussion. We believe the ability to obtain a greater understanding of the symptom severity profiles of students who navigated the RTP protocol will provide much needed insight into 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 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 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 Postconcussion 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) results obtained at the time of ImPACT testing to contribute to the knowledge base on how symptom reporting can drive RTL intervention. Additionally, we were interested in evaluating whether the symptom severity trends obtained from the HCAMP data were consistent with findings from previous studies. Specifically, we hypothesized that cognitive symptoms would be rated with high severity relative to other symptom clusters and that females would rate symptoms with higher severity compared to males across all symptom clusters. We additionally hypothesized that symptom severity would be highest immediately after the injury and decrease over time as measured by repeated testing.

# 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 descriptive statistics on 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

Descriptive statistics of non-normalized and normalized cluster severity ratings for students who completed one post-injury ImPACT 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.

### Completed Two Tests

**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.

**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.

### Completed Three Tests

**Test One.** Descriptive statistics of non-normalized and normalized cluster severity ratings for students who completed three post-injury ImPACT 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.

**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.

### Completed Four Tests

**Test One.** Descriptive statistics of non-normalized and normalized cluster severity ratings for students who completed four post-injury ImPACT 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.

**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 Test One across Number of Tests Completed

Table 5 displays descriptive statistics of test one total symptom scores by sex and the number of tests completed. 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 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 our hypotheses and are consistent with symptom severity trends identified in previous literature. Present findings and their potential impact on RTL are discussed further.

Similar to findings from previous studies (Covassin et al., 2013; Grubenhoff et al., 2014; Ono et al., 2016), the results of the present study identified that students develop specific symptom profiles, consistently rating symptoms from the headache-migraine, sleep, and cognitive clusters with the highest severity. Symptom severity ratings obtained at the time of the fourth test for students who completed four ImPACT tests during recovery were observed to be the only ratings where symptom severity across all clusters was rated with relative equality. As symptom severity was observed to gradually decrease across all clusters with consecutive testing, the average of 18.18 days between tests one and four for the sample of students who completed four tests provides 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. The presence of overlapping clinical profiles has been previously documented in the literature as a key consideration of concussion management (Harmon et al., 2019). The headache-migraine/cognitive/sleep symptom profile that emerged from the present study aligns with Harmon et al. (2019); further, this symptom profile impacts RTL by providing educators insight on what symptoms their students are most likely to be experiencing in order to provide earlier and more targeted supports.

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) to physiological differences (Baker et al., 2016; Broglio et al., 2012) to neurophysiological differences (Bazarian et al., 2010). In consideration of the RTL process, it is important for educators to be mindful that females tend to be more symptomatic and implement supports appropriately.

It has been documented that 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 tests, corresponding to a longer duration of recovery, reported significantly higher severity scores across all symptom clusters at the time of test one completion. 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.

## 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 evaluate 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 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 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.

# References

Arbabi, M., Sheldon, R. J. G., Bahadoran, P., Smith, J. G., Poole, N., & Agrawal, N. (2020). Treatment outcomes in mild traumatic brain injury: a systematic review of randomized controlled trials. *Brain Injury*, *34*(9), 1139–1149. https://doi.org/10.1080/02699052.2020.1797168

Baker, J. G., Leddy, J. J., Darling, S. R., Shucard, J., Makdissi, M., & Willer, B. S. (2016). Gender differences in recovery from sports-related concussion in adolescents. *Clinical Pediatrics*, *55*(8), 771–775. https://doi.org/10.1177/0009922815606417

Bazarian, J. J., Blyth, B., Mookerjee, S., He, H., & McDermott, M. P. (2010). Sex differences in outcome after mild traumatic brain injury. *Journal of Neurotrauma*, *27*, 527–539.

Broglio, S. P., Surma, T., & Ashton-Miller, J. A. (2012). High school and collegiate football athlete concussions: A biomechanical review. *Annals of Biomedical Engineering*, *40*(1), 37–46. https://doi.org/10.1007/s10439-011-0396-0

Colvin, A. C., Mullen, J., Lovell, M. R., West, R. V., Collins, M. W., & Groh, M. (2009). The role of concussion history and gender in recovery from soccer-related concussion. *American Journal of Sports Medicine*, *37*(9), 1699–1704. https://doi.org/10.1177/0363546509332497

Covassin, T., Elbin, R. J., Bleecker, A., Lipchik, A., & Kontos, A. P. (2013). Are there differences in neurocognitive function and symptoms between male and female soccer players after concussions? *American Journal of Sports Medicine*, *41*(12), 2890–2895. https://doi.org/10.1177/0363546513509962

Covassin, T., Elbin, R. J., Harris, W., Parker, T., & Kontos, A. (2012). The role of age and sex in symptoms, neurocognitive performance, and postural stability in athletes after concussion. *American Journal of Sports Medicine*, *40*(6), 1303–1312. https://doi.org/10.1177/0363546512444554

Dachtyl, S. A., & Morales, P. (2017). A collaborative model for return to academics after concussion: Athletic training and speech-language pathology. *American Journal of Speech-Language Pathology*, *26*, 716–728.

Davies, S. C. (2016). School-based traumatic brain injury and concussion management program. *Hellenic Journal of Psychology*, *53*(6), 567–582. https://doi.org/10.1002/pits

Gallagher, V., Kramer, N., Abbott, K., Alexander, J., Breiter, H., Herrold, A., Lindley, T., Mjaanes, J., & Reilly, J. (2018). The effects of sex differences and hormonal contraception on outcomes after collegiate sports-related concussion. *Journal of Neurotrauma*, *35*(11), 1242–1247. https://doi.org/10.1089/neu.2017.5453

Gioia, G. A. (2016). Medical-school partnership in guiding return to school following mild traumatic brain injury in youth. *Journal of Child Neurology*, *31*(1), 93–108. https://doi.org/10.1002/oby.21042.Prevalence

Gioia, G. A., Babikian, T., Barney, B. J., Chrisman, S. P. D., Cook, L. J., Didehbani, N., Richards, R., Sady, M. D., Stolz, E., Vaughan, C., Rivera, F., & Giza, C. (2020). Identifying school challenges following concussion: Psychometric evidence for the Concussion Learning Assessment & School Survey, 3rd Ed. (CLASS-3). *Journal of Pediatric Neuropsychology*, *6*, 203–217. https://doi.org/https://doi.org/10.1007/s40817-020-00092-5

Gioia, G. A., Glang, A. E., Hooper, S. R., & Brown, B. E. (2016). Building statewide infrastructure for the academic support of students with mild traumatic brain injury. *Journal of Head Trauma Rehabilitation*, *31*(6), 397–406. https://doi.org/10.1097/HTR.0000000000000205

Grubenhoff, J. A., Deakyne, S. J., Brou, L., Bajaj, L., Comstock, R. D., & Kirkwood, M. W. (2014). Acute concussion symptom severity and delayed symptom resolution. *Pediatrics*, *134*(1), 54–62. https://doi.org/10.1542/peds.2013-2988

Halstead, M. E., McAvoy, K., Devore, C. D., Carl, R., Lee, M., & Logan, K. (2013). Returning to learning following a concussion. *Pediatrics*, *132*(5), 948–957. https://doi.org/10.1542/peds.2013-2867

Harmon, K. G., Clugston, J. R., Dec, K., Hainline, B., Herring, S., Kane, S. F., Kontos, A. P., Leddy, J. J., McCrea, M., Poddar, S. K., Putukian, M., Wilson, J. C., & Roberts, W. O. (2019). American Medical Society for Sports Medicine position statement on concussion in sport. *British Journal of Sports Medicine*, *53*(4), 213–225. https://doi.org/10.1136/bjsports-2018-100338

Hossler, P., McAvoy, K., Rossen, E., Schoessler, S., & Thompson, P. (2014). A comprehensive team approach to treating concussions in student athletes. *National Association of Secondary School Principles*, *9*(3), 1–7. https://doi.org/10.1089/acm.2009.0309.In

Iverson, G. L., Gardner, A. J., Terry, D. P., Ponsford, J. L., Sills, A. K., Broshek, D. K., & Solomon, G. S. (2017). Predictors of clinical recovery from concussion: A systematic review. *British Journal of Sports Medicine*, *51*(12), 941–948. https://doi.org/10.1136/bjsports-2017-097729

Kerr, Z. Y., Zuckerman, S. L., Wasserman, E. B., Covassin, T., Djoko, A., & Dompier, T. P. (2016). Concussion symptoms and return to play time in youth, high school, and college American football athletes. *JAMA Pediatrics*, *170*(7), 647–653. https://doi.org/10.1001/jamapediatrics.2016.0073

Lumba-Brown, A., Ghajar, J., Cornwell, J., Bloom, O. J., Chesnutt, J., Clugston, J. R., Kolluri, R., Leddy, J. J., Teramoto, M., & Gioia, G. (2019). Representation of concussion subtypes in common postconcussion symptom-rating scales. *Concussion*, *4*(3). https://doi.org/10.2217/cnc-2019-0005

McAvoy, K., Eagan-Johnson, B., Dymacek, R., Hooper, S., McCart, M., & Tyler, J. (2020). Establishing consensus for essential elements in returning to learn following a concussion. *Journal of School Health*, *90*(11), 849–858. https://doi.org/10.1111/josh.12949

McAvoy, K., Eagan-Johnson, B., & Halstead, M. (2018). Return to learn: Transitioning to school and through ascending levels of academic support for students following a concussion. *NeuroRehabilitation*, *42*(3), 325–330. https://doi.org/10.3233/NRE-172381

McCrory, P., Meeuwisse, W., Dvořák, J., Aubry, M., Bailes, J., Broglio, S., Cantu, R. C., Cassidy, D., Echemendia, R. J., Castellani, R. J., Davis, G. A., Ellenbogen, R., Emery, C., Engebretsen, L., Feddermann-Demont, N., Giza, C. C., Guskiewicz, K. M., Herring, S., Iverson, G. L., … Vos, P. E. (2017). Consensus statement on concussion in sport—the 5th international conference on concussion in sport held in Berlin, October 2016. *British Journal of Sports Medicine*, *51*(11), 838–847. https://doi.org/10.1136/bjsports-2017-097699

Ono, K. E., Burns, T. G., Bearden, D. J., McManus, S. M., King, H., & Reisner, A. (2016). Sex-based differences as a predictor of recovery trajectories in young athletes after a sports-related concussion. *American Journal of Sports Medicine*, *44*(3), 748–752. https://doi.org/10.1177/0363546515617746

Ransom, D. M., Vaughan, C. G., Pratson, L., Sady, M. D., McGill, C. A., & Gioia, G. A. (2015). Academic effects of concussion in children and adolescents. *Pediatrics*, *135*(6), 1043–1050. https://doi.org/10.1542/peds.2014-3434

Sarmiento, K., Thomas, K. E., Daugherty, J., Waltzman, D., Haarbauer-Krupa, J. K., Peterson, A. B., Haileyesus, T., & Breiding, M. J. (2019). Emergency department visits for sports- and recreation-related traumatic brain injuries among children - United States, 2010-2016. *MMWR. Morbidity and Mortality Weekly Report*, *68*(10), 237–242. http://www.embase.com/search/results?subaction=viewrecord&from=export&id=L626806097%0Ahttp://dx.doi.org/10.15585/mmwr.mm6810a2

Tamura, K., Furutani, T., Oshiro, R., Oba, Y., Ling, A., & Murata, N. (2020). Concussion recovery timeline of high school athletes using a stepwise return-to-play protocol: Age and sex effects. *Journal of Athletic Training*, *55*(1), 1–4. https://doi.org/10.4085/1062-6050-452-18

Zuckerman, S. L., Apple, R. P., Odom, M. J., Lee, Y. M., Solomon, G. S., & Sills, A. K. (2014). Effect of sex on symptoms and return to baseline in sport-related concussion: Clinical article. *Journal of Neurosurgery: Pediatrics*, *13*(1), 72–81. https://doi.org/10.3171/2013.9.PEDS13257