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Relationship Between Concussion Symptom Clusters and Return-to-Play Time in College Athletes with Sports-Related Concussions: 2009-2010 to 2013-2014 DISC

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RELATIONSHIP BETWEEN CONCUSSION SYMPTOM CLUSTERS AND
RETURN-TO-PLAY TIME IN COLLEGE ATHLETES WITH SPORTS-RELATED
CONCUSSIONS: 2009-2010 TO 2013-2014 DISC

By
Adrian Joseph Boltz

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Dedication & Acknowledgements

As in all scholarly endeavors, such success cannot be accomplished without help. I would like to dedicate my thesis project to those who have been instrumental in my life, namely my parents, Fred and Vanessa, and my sisters, Anna and Sofia. Undoubtedly, I would not be where I am without your continued love and support. I would also like to thank the UNF Clinical and Applied Movement Sciences Department faculty members as well as my thesis committee, including Dr. Marc Feinberg, Dr. Dan Smith, Dr. Tammie Johnson, and Professor Ryan Richardson. Your input was crucial to my success and I thank you for time spent discussing ideas for my project. I would also like to acknowledge my two fellow graduate research assistants, Brandi Rariden and Mary Summerlin. Thank you for being a part of my final year as a graduate assistant. Finally, none of this would be possible without Dr. James Churilla. Thank you for giving me the opportunity to excel not only in the classroom, but providing countless opportunities to challenge myself as a researcher and expecting nothing less than perfection. I cannot thank you enough for your continued support and guidance in my academic journey and my future successes will stem from my years in this graduate program.
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<tbody>
<tr>
<td>ATC</td>
<td>Certified Athletic Trainer</td>
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<tr>
<td>CSC</td>
<td>Concussion Symptom Cluster</td>
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<tr>
<td>CI</td>
<td>confidence interval</td>
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<tr>
<td>CFA</td>
<td>Confirmatory Factor Analysis</td>
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<td>DISC</td>
<td>Datalys Injury Statistics Clearinghouse</td>
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<td>EFA</td>
<td>Exploratory Factor Analysis</td>
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<tr>
<td>GSC</td>
<td>Graded Symptom Checklist</td>
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<tr>
<td>HIS</td>
<td>Head Injury Scale</td>
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<tr>
<td>ISP</td>
<td>Injury Surveillance Program</td>
</tr>
<tr>
<td>ISS</td>
<td>Injury Surveillance System</td>
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<tr>
<td>mTBI</td>
<td>Mild Traumatic Brain Injury</td>
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<tr>
<td>PCSS</td>
<td>Post-concussion Symptom Scale</td>
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<tr>
<td>NCAA</td>
<td>National Collegiate Athletic Association</td>
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<tr>
<td>OR</td>
<td>odds ratio</td>
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<tr>
<td>SAS</td>
<td>Statistical Analysis Software</td>
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<tr>
<td>SRC</td>
<td>Sports Related Concussion</td>
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Abstract

Objectives To examine the relationship between Concussion Symptom Clusters (CSCs) and return-to-play time using a representative sample of U.S. college athletes with sports-related concussions.

Background Recent evidence regarding concussion symptoms have been observed to be an important element of concussion severity, and potentially a predictor of return-to-play time. However, there is a paucity of data examining the associations between Concussion Symptom Clusters (CSCs) and return-to-play time in the U.S. college athlete population.

Methods Data from the 2009-2010 to 2013-2014 academic years (n=1670) were obtained from the Datalys Center for Sports Injury and Prevention Inc. database. Exploratory factor analytic methods were applied, and the resulting factors were used in multinomial regression modeling to identify associations between CSCs and return-to-play time.

Results A 4-factor solution accounted for 48.8% of the variance and included: audio-vestibular, somatic, amnesic, and affective factor structure. Audio-vestibular symptoms were associated with increased odds of prevented participation at 7-13 days, 14-29 days, greater than 30 days, and out for remainder of season, respectively (p<0.05). Somatic symptoms were associated with decreased odds of prevented participation at 7-13 days and greater than 30 days, respectively (p<0.05). Amnesic symptoms were associated with decreased odds of prevented participation at 1-6 days, 7-
13 days, 14-29 days, and greater than 30 days, respectively (p<0.05).

Affective symptoms were associated with decreased odds of prevented participation at 7-13 days, 14-29 days, greater than 30 days, and out for remainder of season, respectively (p<0.05).

**Conclusion** Specific CSCs were significantly associated with return-to-play time in college athletes, (p<0.05).
Chapter One: Introduction
A sports-related concussion (SRC) is defined as a complex pathophysiological process affecting the brain, induced by traumatic biomechanical forces (1, 2). The estimated number of SRCs has increased in college athletics calling for more attention to be directed towards ensuring brain recovery time is accurately prescribed (3). Sports-Related Concussions present concussion symptoms that vary on a case-by-case basis. Symptoms are generally present immediately after the injury occurs and in rare cases, may occur days or weeks following the injury event (4). The range of symptoms include, but are not limited to: amnesia, difficulty concentrating, feeling disoriented, dizziness, headache, hyper-excitability, sleep disturbance, fatigue, depression, and anxiety and irritability (5). Along with symptom duration, cognitive recovery can range from several hours to weeks (6); however, resolution of symptoms typically take a few days to a few weeks in most student-athletes (4). Treatment occurs immediately post-injury and includes special focus on: physical, mental, and cognitive rest. Concurrently, the concussed athlete must wait for clearance from his or her physician, pending complete resolution of concussion symptoms, before they can return to National Collegiate Athletic Association (NCAA) sanctioned team activities (7). This chapter provides background information regarding SRCs including: epidemiology, mechanism and pathophysiology, diagnostic criteria, and an abbreviated literature review. The chapter will conclude with the purpose of this research, research questions being addressed, and a brief description of the project.
Background

Epidemiology of Sports-Related Concussions

The research area and profile of SRCs has grown dramatically in the last few decades and thus, it is crucial to first examine SRCs from an epidemiological standpoint. In 2015 Zuckerman et al. (3) examined the epidemiology of SRCs in NCAA student-athletes and estimated that among 25 sports, the overall concussion rate was 4.47 per 10,000 athlete-exposures (95% Confidence Interval [CI], 4.25-4.68) with an average of 5.29 ± 2.94 symptoms per SRC (3). Further, after observing trends in SRCs across five academic years and all sports (Men’s and Women’s) researchers did not observe a linear trend in incidence of SRCs. Westermann et al. (8) observed an increase in SRC rate (in Men’s Football) in 2012-2013 – 2014-2015 when compared to 2009-2010 – 2011-2012 academic years (relative risk [RR], 1.34; 95% CI, 1.08-1.66; 3.52 vs 2.63/1000 athlete-exposures, respectively). Thus, examining SRC trends specific to a particular sport (i.e., comparing the analysis between Men’s Soccer 2010 vs. Men’s Soccer 2011) rather than examining SRC trends across all sports may be a better way to conduct SRC research.

Kerr et al. (9) investigated SRC data from the NCAA-Injury Surveillance Program across 13 sports (Men’s Baseball, Men’s and Women’s Basketball, Men’s Football, Men’s and Women’s Ice Hockey, Men’s and Women’s Lacrosse, Men’s and Women’s Soccer, Men’s Wrestling, Women’s Softball, and Women’s Volleyball) from the 2011-2012 through 2014-2015 academic years and reported the following: Athlete-Based Concussion Rates were the greatest in Men’s Wrestling; Men’s Wrestling, Men’s and Women’s Ice Hockey, and Men’s Football had the highest estimates for Athlete-Based Concussion Risk, Team-Based Concussion Rate, and Team-Based Concussion
Risk; and sex differences only in soccer for team-based measures and not athlete-based measures. It should be noted that NCAA sports rules and guidelines have been adapted and adopted over the years to mitigate the risk of severe injuries (10, 11), namely SRCs; however, with new policies and rules unintended consequences often occur such as the case in Men’s Football and the dramatic increase in lower extremity injuries possibly due to the “Targeting Rule” (8).

These findings continue to establish a need for continued SRC education and monitoring of these student-athletes, especially since the rigors of an academic semester elicit stressors of their own (e.g. grades, scholarships, relationships, etc.). Along with student-athletes, another cohort that warrants attention is the youth cohort (children and adolescents aged five to 19). Amoo-Achampong et al. (12) conducted a retrospective review of a private-payer insurance database, PearlDiver, and observed that the youth cohort were diagnosed with an SRC at an estimated mean annual rate of 3.78 ± 1.30 per 100,000 patients. Additionally, these researchers observed that concussion incidence significantly increased from 2.47 to 3.87 per 100,000 patients (P = 0.048). These observation(s) of SRC diagnostic rates increasing (2010-2014) in the youth cohort should alert medical professionals that SRCs sustained prior to college may result in more severe SRCs and symptoms. Observing trends in SRCs allow researchers to support: advancements in SRC management and treatment, detection of college-athletes who are most at-risk, and reveal predictors and biomarkers related to SRC-severity. Overall, emphasis should be geared towards strengthening existing surveillance systems (13).
Mechanisms & Pathophysiology

In general, a SRC is a type of Traumatic Brain Injury; the severity of which is estimated by the results of an administered assessment using the Glasgow Coma Scale (14). When examining the mechanism of injury in concussions, particularly in the college sports setting, head injuries can vary in their etiology, pathophysiology, clinical presentation, and treatment approach (15). Thus, it is appropriate to acknowledge general mechanisms of head injuries: focal, diffuse, and Coup-Countrecoup.

Focal (or ‘Coup’) head injuries typically involve direct impact to the head that can result in brain lacerations, contusions, and hemorrhage leading to the formation of a hematoma within the head resulting typically in soft-tissue damage (16). Alternatively, diffuse (or ‘Countre-coup’) head injuries involve a sudden head movement in which the brain marginally lags behind the cranium and comes into contact with the contralateral side of the brain, generally resulting in a diffuse axonal injury (17, 18). However, a majority of SRCs involve both focal and diffuse (also known as ‘Coup-Countrecoup’) mechanisms of injury that implicate both sides of the brain; the site of impact and opposite side of the brain (16, 19).

The pathophysiology of SRCs involves a cascade of neurometabolic changes (14, 20, 21). The biomechanical trauma leads to and causes: disruption of ionic influxes on neuronal membranes, axonal stretching, glucose metabolism and uptake, and opening of voltage-dependent potassium channels which leads to a marked increase in extracellular potassium (14, 22-25). Following the rapid neuronal excitation, there is a rapid neuronal suppression, which can cause diffuse areas of the brain to be affected simultaneously (26).
Diagnostic Criteria of a SRC

The NCAA Sport’s Science Institute, along with other sports medicine organizations, have come together and developed an inter-association consensus document entitled “Diagnosis and Management of Sports-Related Concussion Guidelines” (7). These NCAA guidelines are directed towards educating and informing athletic departments and sports medicine staffs at universities. Furthermore, these guidelines emphasize factors influencing return-to-play time. As per current NCAA Guidelines, SRCs are diagnosed in college athletes by comparing baseline (i.e., pre-season) and post-injury results from the concussion symptoms checklist, Immediate Post-Concussion Assessment and Cognitive Test (27) scores, and Balance Error Scoring System (28) test. The same baseline assessment tools should be used post-injury at appropriate time intervals (7). In addition, the use of the Standardized Assessment of Concussion (SAC) can be administered by the athletic trainer on the sideline, an assessment that was supported and reported by McCrae (29) showed a decline in SAC score at time of injury that was 95% sensitive and 76% specific in accurately classifying concussed and non-concussed subjects on the sideline.

Once a college athlete returns to his or her baseline measurements, they are then prescribed by their physician to follow (until completion) a stepwise protocol involving progressively increasing physical activity under physician or physician-designee supervision (30). One must note that the current return-to-play time consensus guidelines have yet to be validated by evidence-based studies (2); further emphasizing that concussion protocol treatment plans should be individualized to the student-athlete’s concussion symptomatology (2, 7). The “Consensus statement on concussion in sport—
the 5th international conference on concussion in sport held in Berlin, October 2016” (1) is another consensus-based sports concussion guideline reference available to sports medical professionals. Both consensus papers acknowledge the insufficient evidence that prescribing complete rest (greater than 24-48 hours after impact) results in becoming asymptomatic sooner than a gradual implementation of light physical activity; therefore, further research is thus warranted.

Abbreviated Literature Review

Though few studies have examined concussion symptoms (31, 32), with subsequent factor analyses (33-35), none have examined their relationship with return-to-play time. The few studies that did factor concussion symptoms have varied with their post-concussion item lists, thus it is imperative to examine potential differences in a student-athlete’s return-to-play time by their Concussion Symptom Cluster (CSC) using the most current post-concussion symptom item checklist. As a result, the relationship between concussion symptoms, and more specifically CSCs, call for further investigation on their contribution to return-to-play time.

Purpose & Research Questions

The purpose of this study is to examine the relationship between CSCs and return-to-play time in NCAA student-athletes. Emphasis was placed on determining which CSCs are associated with longer return-to-play times and examining the differences between CSCs based on this association. Study aims included examining the potential associations and differences between CSCs and return-to-play time by: sex, helmeted vs non-helmeted sports, and subsequent gender stratified helmeted vs non-helmeted sports.
To the best of this researcher’s knowledge, this is the first study to examine the potential CSC differences in return-to-play time in college athletes using Datalys Injury Statistics Clearinghouse inc. (DISC) 2009-2010 and 2013-2014. Ultimately, this study adds to the current evidence demonstrating the importance concussion symptoms have on determining return-to-play time based on their CSC.

**Project Description**

This study utilized four years of data from 2009-2010 and 2014-2015 academic years which were obtained from the NCAA-Injury Surveillance Program, a prospective surveillance program that is managed by the Datalys Center for Sports Injury Research and Prevention Inc. (36). This convenience sample included student-athletes 17-24 years of age and was limited to only those with complete data on all variables of interest.

Exploratory factor analysis methodology was used to establish CSCs from concussion symptoms on a 17-item post-concussion checklist. Concussion symptoms that met the ≥ 0.5 loading factor criteria were included in that factor (or CSC). Once the CSCs had been established, multinomial regression analysis was performed with the categorical responses of return-to-play time. The data was managed in Statistical Analysis Software 9.4 (SAS) (37). PROC SURVEYFREQ was used to calculate descriptive statistics for the categorical variables. Multinomial regression of the overall sample was performed Statistical Analysis Software, using PROC LOGISTIC, to observe the continuous relationship between return-to-play time (dependent variable) and CSCs (independent variable). Resulting odds ratios and 95% Wald CIs were calculated using SAS with non-overlapping 95% Wald CIs indicate significance at P < 0.05.
Strengths of the proposed study included: the use of a nationally representative sample of NCAA student-athletes, resulting in strong external validity; and large sample size providing good statistical power. Limitations included: differences in concussion management protocols; due to the nature of the cross-sectional study design, causality will not be able to be established; and the sample was derived from convenience sampling, therefore, varying ranges of participation across the sports must be taken into account.
References


Chapter Two: Review of the Literature
A Sports-Related Concussion (SRC), a form of mild-Traumatic Brain Injury (mTBI), was defined by McCrory et al. (1) as a Traumatic Brain Injury induced by biomechanical forces with regards to four common features: 1) a SRC may be the result of either a direct impact to the head, neck, or face, or anywhere that results with transmitted force to the head; 2) a SRC usually results in the prompt development of short-lived impairment of neurological function that may resolve immediately (additional symptoms may evolve over a period of time after the initial impact); 3) a SRC usually results in neuropathological changes, however the short-term clinical signs and symptoms are indicative of functional disturbances without structural injury; and 4) a SRC may exhibit a wide range of symptoms that may or may not include loss of consciousness, additional resolution of symptoms typically follow a sequential course.

The most recent estimate regarding SRCs in the U.S. was estimated at around four million concussions occurring each year due to involvement in physical activity and sports (2). Additionally, researchers’ estimated that around 300,000 concussions occur in the youth athlete cohort (ages 14 – 19) (3). Evidence suggests an association between severity-level of a SRC and the amount of time recommended to become asymptomatic prior to returning to normal physical activity habits. Moreover, with increasing amounts of involvement in collegiate athletics (4, 5), in addition to the increasing rates of SRCs occurring prior to college in young athletes; especially since adolescents have been shown to be more sensitive to SRC-symptoms of sustaining a SRC (6). Additional research is warranted to examine and provide peer-reviewed evidence-based estimates of appropriate return-to-play time guidelines according to their individualized symptomatology following a SRC.
This chapter will offer succinct analyses of current literature regarding (1) categorizing concussion symptoms according to statistical measures; (2) the relationship between SRCs and return-to-play time; and (3) the relationship between SRCs’ symptoms and return-to-play time.

Categorizing Symptoms According to Statistical Measures

Every SRC elicits symptoms are self-reported by the athlete and crucial to the diagnosis and ensuing treatment management plan. A mean of $5.29 \pm 2.94$ symptoms per SRC was reported in National Collegiate Athletic Association (NCAA) athletes (7). Self-reported symptoms and subsequent neuropsychological testing are used in tandem by physicians and/or athletic trainers (ATs) to estimate SRC severity level and post-injury recovery timeframe (8). Maroon et al. (9) conducted a review of the literature concerning the potential usefulness the Neuropsychological testing offers and established that not only are the results useful in short-term post-concussion management but long-term as well. There are various concussion symptom checklists used in college athletics with the more prevalent ones including: the Post-concussion symptom scale (10), Graded Symptom (GSC) checklist (11), and Sport Concussion Assessment Tool 3 (12). Each neuropsychological assessment tool varies slightly with regards to symptoms included (ranges from 16 – 22 symptoms) and, in addition, most include ranges (i.e. Likert Scale) of perceived severity of each symptom. For example using the GSC, a recently concussed athlete may be asked, “On a scale of 1 to 6, with ‘6’ indicating the most severe, how is your ‘Nausea’ feeling today?” The scales allow for self-reported ratings of each symptom that are ultimately summed to produce a single score in which severity level of
the injury and the time of recovery may be estimated as there is classically a direct correlation between post-concussion symptoms and their presentation on neuropsychological assessments (8, 9). Previous studies (9-11, 13, 14) have investigated the use of statistical measures to factor, or sort, concussion symptoms according to their underlying relationships through the use of Exploratory Factor Analysis (EFA) (15) and subsequent Confirmatory Factor Analysis (CFA) (16).

One of the earliest studies to examine the effects of factor analysis on a post-concussion symptom scale (PCSS) was conducted by Piland et al. (14). In 2003 researchers conducted a cross-sectional analysis and applied confirmatory factor analytic methods using their participants’ self-reported responses to a 16-item Head Injury Scale (HIS), a theoretically driven self-reported scale that was derived from the most prevalent concussion symptoms in the literature at the time (8). Their sample consisted of 279 NCAA Division I athletes, (mean age 19.49 ± 1.63 years), and were predominantly male. The results of the CFA revealed a 3-factor model, however researchers suggested that the 16-item checklist “provided a good but not excellent fit.” Thus, researchers adjusted the number of reported symptoms by using a 9-item HIS and re-ran their CFA revealing a better 3-factor model fit (improving factor validity) representing a more precise descriptor of a SRC. This landmark study contributed greatly to the validity of a 3-factor model comprising of somatic, cognitive, and neuropsychological domains of symptoms using the 9-item HIS.

In 2006, Piland et al. (11) further examined the factorial validity of the use of a self-reported concussion symptom severity scale in a large sample (n=1089) of nonconcussed U.S. high school male football players. An identical study design was used
to examine whether the 16-item HIS or 9-item HIS 3-factor model comprised of a greater factorial validity through the use of a CFA. As was the outcome in the previously mentioned study by Piland et al. (14), the 9-item HIS 3-factor model revealed an “excellent-model fit”, ($\chi^2$ statistic, $P < 0.0001$), however the Root Mean Square Error of Approximation (RMSEA) did not exceed the acceptable threshold value of 0.05 and was lower than the RMSEA of the 16-item scale. These studies set the basis for future investigations into examining factorial and construct validity evidence for not only the HIS, but for other untested concussion symptom checklists using only self-reported measures of concussion symptom severity.

The first study to examine the symptom factor structures at baseline and post-concussion in high school and college athletes was piloted by Kontos et al. (10). Researchers applied EFA methods utilizing the 22-item Post-Concussion Symptom Scale and the symptom factors were named according to the symptoms contained within each of the factors. The baseline symptom factor structure accounted for 49.1% of the variance and comprised of the four-factor model: cognitive-sensory, sleep-arousal, vestibular-somatic, and affective. There were two symptoms that were excluded from the symptom factors because they did not meet the loading criteria, “sleeping more than usual” and “numbness”; while the post-concussion symptom factor structure accounted for 58.3% of the variance and comprised of the 4-factor model: cognitive-migraine-fatigue, affective, somatic, and sensory. Whereas in the post-concussion symptom EFA, there were five symptoms that were excluded from the symptom factors because they did not meet the loading criteria: “nausea”, “balance problems”, “sleeping more than usual”, “irritability”, and “vision problems”. When the researchers examined sex differences the analysis
revealed that female athletes, compared to male athletes, reported higher frequencies of the following factor structures: cognitive-sensory, sleep-arousal, vestibular-headache, and affective. In addition, researchers found that the interaction between age and sex was not statistically significant, \(P > 0.05\).

To summarize, factorial analytic methods have been shown to elucidate novel underlying relationships between concussion symptoms and concussion symptom structures. While the previously discussed studies were cross-sectional and varied slightly with their study population characteristics, these findings still contribute to the literature with emphasis on establishing a Likert Scale based concussion symptom scale for specific populations (adolescent, young athlete, adult).

**Sports-Related Concussions and Return-to-play time**

Current NCAA Concussion Management Program guidelines have been established from consensus-based documents (1), thus it is imperative to investigate peer-reviewed evidence based studies examining the overall temporal relationship between SRCs and the time required to resolve (or become ‘asymptomatic’), and thus subsequently be physician-approved to return to competition.

Establishing and examining risk factors that are associated with the risk of a prolonged recovery period from a SRC has become instrumental in concussion management programs. Eblin et al. (17) conducted a review of the literature examining the potential and known risk factors associated with an augmented recovery period after sustaining a SRC. These researchers categorized risk factors dichotomously: 1) primary risk factors that influence and increase the risk of a SRC and 2) secondary risk factors that increase the likelihood of an amplified recovery outcome (time). Primary risk factors
Secondary risk factors included: demographic factors, on-field signs and symptoms, and acute presentation (< 1 week of injury). Equipment in sports, specifically helmets and other protective headgear, have been improved over the years in efforts to diminish the risk of more severe SRCs and ultimately to decrease the risk of SRCs. However, the most recent estimate of SRC incidence has only decreased by 2% in football when compared to older helmet models (18). Further, Giza et al. (19) conducted a systematic review of the literature (from 1955 to 2012) and reported that while helmets are designed at reducing the incidence of SRCs in football, researchers concluded that helmets do not significantly reduce the incidence of SRCs. A secondary risk factor, ‘on-field signs and symptoms’, has been irregularly investigated in the literature. Although on-field symptom presentation can fluctuate from athlete to athlete, early research suggested that specific symptoms such as “Loss of consciousness” and “Post-traumatic amnesia” may provide an indication of a longer recovery time (20), however, more recent evidence suggests the absence of an association between prolonged recovery time (≥ 21 days) and the symptoms previously mentioned (21, 22). These findings clearly illustrate an area of research that requires more attention to clarify which on-field symptoms are useful in establishing an estimated recovery time.

In 2016, Elbin et al. (23) conducted the first known prospective study to examine the difference in recovery outcomes between athletes who were immediately removed from play after their injury event and athletes who continued to engage in play with a SRC. Their study sample included 69 athletes stratified into two groups: 1) the ‘REMOVED’ group contained 35 athletes with a mean age of 15.6 ± 1.7 years, and 2) the
‘PLAYED’ group contained 34 athletes with a mean age of 15.4 ± 1.7 years. Researchers conducted neurocognitive assessments at baseline, one to seven days, and eight to 30 days after the SRC event. Athletes in the ‘PLAYED’ group were 8.80 times more likely to have an extended recovery period at ≥ 21 days (P < 0.001). Researchers also reported that the biggest predictor of return to play was if the athlete had been removed from play following the SRC event, (adjusted odds ratio [OR], 14.27; P = 0.001), when compared to other predictors such as age, sex, etc.

Wasserman et al. (24) conducted a descriptive epidemiological study of a representative sample of NCAA athletes who sustained a SRC with specific regards to symptom prevalence, symptom resolution time, and return-to-play time. Researchers utilized SRC data from the 2009-2010 to 2013-2014 academic years and their final sample included 1,670 student-athletes who sustained a SRC. As it pertains to SRC symptom duration, ~60% of SRC symptoms resolved within one week while ~6% of SRC symptoms resolved > four weeks. With regards to return-to-play time, ~9% of SRCs prevented participation at > four weeks while ~37% of SRCs prevented participation at < one week.

**Sports-Related Concussion Symptoms and Return-to-play time**

As previously mentioned in the literature, there has been an established understanding that symptoms presented after an athlete has sustained a SRC provides clinicians an indication of severity level caused by the SRC. However, a paucity of studies (21, 25-28) have examined the temporal relationship between specific concussion symptoms, or categorical defined, and their resolution timeframe, or return-to-play (RTP) time.
In a study observing audiovestibular symptoms (such as dizziness, imbalance, disorientation, noise sensitivity, and tinnitus), Chorney et al. (26) examined the rates in which they occur as well as the potential correlation between audiovestibular symptoms and RTP time. The study sample of college athletes who sustained a SRC was queried from the NCAA-Injury Surveillance System utilizing the years of data from 2009 through 2014. Researchers utilized multiple ordinal regression modeling and observed that concussion symptoms continued longer when noise sensitivity ($P = 0.000$) and dizziness ($P = 0.043$) were present. In addition, student athletes required more time to recover from their SRC if they reported symptoms of noise sensitivity ($P = 0.000$) and imbalance ($P = 0.011$). Another significant observation was that concussion symptoms of dizziness and imbalance had the greatest statistically significant odds of being associated with one another [OR: 4.15], followed by imbalance and disorientation [OR: 3.45], noise sensitivity and tinnitus [OR: 3.21], and dizziness and noise sensitivity [OR: 2.95], ($P$ value < 0.001).

While many study designs are cross-sectional in nature, a limited amount of longitudinal studies have been conducted with emphasis on investigating the incidence, clinical course, and prolonged recovery time following a SRC in a relatively large representative sample of collegiate and high school athletes. A 2013 longitudinal study conducted by McCrae et al. (27) examined the components of a prolonged recovery period in a large cohort of athletes over a 10-year period. The sample contained 166 controls and 570 athletes with a SRC (3.1%) and all underwent pre-injury baseline assessment, balance and neurocognitive functioning were re-evaluated immediately post-injury, three hours after, in addition to 1, 2, 3, 5, 7, and 45 or 90 days after the SRC.
Researchers observed that 10% of athletes experienced a prolonged (> seven days) recovery period. Further, the results of the univariate analysis logistic regression on factors associated with a prolonged recovery period revealed that within the acute injury characteristics, loss of consciousness, post-traumatic and retrograde amnesia were all significantly associated, (P < 0.001). The use and analysis of the Graded Symptom Checklist (GSC) scores were only significantly (P < 0.001) associated with a prolonged recovery period when utilized at the time of the SRC, two to three hours afterwards, and one day post-SRC. However, baseline pre-injury GSC was not associated with a prolonged recovery period, (P > 0.05).

**Summary**

While there is a limited quantity of literature demonstrating the relationship between concussion symptoms and predicting the athlete’s return-to-play time, current literature suggests not only an association between SRC severity levels in relation to reported concussion symptoms, but also the types of concussion symptoms may in fact be a stronger predictor of a longer recovery time. The reviewed literature included few studies that solely contained college athletes, while most included high school or young athletes into the study sample. Therefore, the current state of evidence warrants continued investigation of the direct relationship between concussion symptom clusters and return-to-play time. The future examination of this relationship may be done by factorial categorizing concussion symptoms and then examining the individual clusters of symptoms and their effects on return-to-play time through the use of statistical models. To this researcher’s knowledge, a study such as this has not been performed using a nationally representative sample of U.S. NCAA college athletes.
References


Chapter Three: Methodology
The purpose of this study was to examine the relationship between Concussion Symptom Clusters (CSC) and return-to-play time in a nationally representative sample of National Collegiate Athletic Association (NCAA) student-athletes who sustained a Sports-Related Concussion (SRC). Concussion Symptom Clusters were generated following the results of the exploratory factor analysis and were named according to the concussion symptoms within the CSC. Moreover, return-to-play time was the outcome variable and consisted of categorical possibilities. The primary aim in this study was centered on determining which CSC was associated with a longer, or shorter, return-to-play time. This chapter provides the details of the methodology that was utilized to answer the proposed research question(s) in this study.

**Data Collection**

The University of North Florida Institutional Review Board and the Datalys Center Independent Review Committee with the National Collegiate Athletic Association approved the release and use of the data.

This study utilized five years (2009-2010 to 2013-2014) of data from the Datalys Injury Statistics Clearinghouse (DISC) (1). Moreover, the NCAA Injury Surveillance Program (NCAA-ISP), formally known as the NCAA-Injury Surveillance System (NCAA-ISS) (1982-2009) prior to the addition and subsequent union of DISC, was created by the NCAA to collect exposure and injury information from a convenience sample of varsity NCAA teams across a variety of men’s and women’s sports including all Divisions (I-III) (2).

Athletic trainers (ATs) collected exposure and injury data from their student-athletes and then voluntarily submitted their records to the NCAA-ISP. For an injury
event report, the AT would compile information detailing the resulting injury and conditions (e.g. event type [practice or competition], mechanism of action, activity). If that student-athlete already had an injury report, the AT could view and update their electronic medical record as needed. In the case that a student-athlete sustained a SRC, the AT would report the student-athlete’s symptoms selected from the 17-item post-concussion checklist. Further, if symptoms presented hours or days later, the AT could update their electronic health record accordingly. As it pertains to the duration of the concussion symptoms and return-to-play time (or recovery period), ATs were only able to categorically report the appropriate symptom resolution time and return-to-play time.

At DISC, once an electronic health record had been constructed for a student-athlete, their corresponding common data elements (injury and exposure information) were stripped of any personally identifiable information, further, all electronic health records were required to undergo a data validation process to be certified. Continuing, the successful electronic health records were then subjected to a run of consistency checks. Data were evaluated and marked for invalid values, if any were present. Finally, data that had successfully gone through the data verification process were then placed into the aggregated data sets so that they may be packaged for researcher use. The verification and de-identification processes were compliant with the Health Insurance Portability and Accountability Act (3).

**Sampling Design**

The DISC data were obtained using a convenience sampling design. The sample selection for DISC was contingent on ATs voluntarily submitting their injury data to the
NCAA-ISP. The number of affiliated programs (i.e. men’s basketball, women’s ice hockey, etc.) offering their data varied by year and sport, thus a post stratification sampling weight is required for further analyses. The study sample was weighted in all analyses as it serves to produce estimates of the injury events occurring in collegiate sports that would have been observed had the entire NCAA athlete population been measured. A sampling weight, at its basis, is the measure of the number of persons represented by a single surveyed participant. The DISC sampling weight (WGT_FINAL) was designed to accomplish the following goals: 1) account for year to year variations in sample, and 2) underreporting of injury events. Where weight_{ijk} is the appropriate weight for sport (i), division (j), and year (k).

\[
weight_{ijk} = \left( \frac{No. ISS Schools_{ijk}}{No. Sponsoring weight_{ijk}} \right)^{-1}
\]

In 2011, a validation study conducted by Kucera et al. (4) compared and contrasted ISS data with data collected by other types of clinical records preserved by ISS ATs and reported that the ISS captures an estimated ~88% of all time-loss medical-care injury events. Thus suggesting the ISS captures a high level of injury events and sampling weights were further adjusted by a factor of 0.833^{-1}.

Sample

The final sample contained 1,670 NCAA student-athletes, ages 17 to 24, who sustained a SRC. Data was queried from the 2009-2010 and 2013-2014 NCAA-academic years. The sample for this study met the following conditions: 1) men and women student-athletes who sustained a Sports-Related Concussion (SRC); 2) completed self-
reported concussions symptoms; and 3) had provided complete data on all other variables of interest.

**Study Measures**

**Dependent measure(s): Return-to-play time**

The dependent variable in this analysis was return-to-play time, or time loss, defined as time between the original injury and return to participation at a level that would allow competition participation. Return-to-play time data was assessed by the verification engine at the DISC to ensure that time-loss and return-date data were consistent. Return-to-play time was a categorical variable and consisted of eight possible responses: (1) did not interfere with activity; (2) returned to team activity within same session; (3) removed from team activity session; (4) prevented participation for 1-6 days; (5) prevented participation for 7-13 days; (6) prevented participation for 14-29 days; (7) prevented participation for greater than 30 days; and (8) out for remainder of season.

**Primary Independent Measure(s): Concussion Symptom Clusters**

The independent variable(s) in this study were the four-factored CSCs. An exploratory factor analysis (5) was conducted to sort the 17-item post-concussion symptom checklist symptom(s) into factor structures, or CSCs. The following CSCs were named by the symptoms that were present within each CSC: (1) audio-vestibular; (2) somatic; (3) amnesic; (4) affective.
Data Analysis

The data in this analysis were managed using SAS 9.4 (6). SAS was used to conduct both complex variable recodes and data coding validation. Subjects who had missing measures or responses for any of the variables in question were then excluded from the analyses. PROC SURVEYFREQ was used to calculate descriptive statistics for the categorical variables. An exploratory factor analysis, using PROC FACTOR, was performed to statistically factor concussion symptoms from the 17-item post-concussion symptom checklist to create CSCs (independent variable). Symptoms that met the loading criteria (≥ 0.5) (7, 8) exemplified a strong underlying relationship within the factor (CSC) and thus were kept. Items that were cross-loaded (> 0.4) across more than one factor were kept for further analysis given that the main loading was (> 0.6) in addition to the difference between the main and cross-loaded item being (≥ 0.2). The item(s) that did not meet these criteria were subsequently removed from further analysis.

The use of multi-nomial logistic regression, using PROC LOGISTIC, was applied to observe the association between CSCs and return-to-play time (a categorical variable) using the resultant odds ratios and 95% Wald Confidence Intervals. Best fit model(s) were generated and assessed for their significance by either the presence or absence of significant Wald F-test result(s). Statistical significance was set at \( P < 0.05 \) for all tests.

Limitations

The present study has several intrinsic limitations. Foremost, the nature of cross-sectional analysis suggests that causality cannot be confirmed. Additionally, concussion symptoms were self-reported and are subjected to report and recall bias. Given that
student-athletes suspected of having a SRC are required to be removed from NCAA sanctioned participation, underreporting of symptoms must be taken into account. The NCAA ISP comprises of a convenience sampling of varsity teams with varying ranges of participation as well as varying concussion management protocols in effect in each college or university. Lastly, self-reported data may also be subject to the social desirability effect, potentially concussed athlete’s telling ATs what they want to hear.

**Summary**

The primary aims of this study: (1) examine the underlying relationships between concussion symptoms of the same factor structure following an exploratory factor analysis; and (2) examine the relationship between CSC and return-to-play time in NCAA athletes by applying multi-nomial logistic regression modeling techniques. To this researcher’s knowledge, this is the first study to examine the potential relationship between CSCs and return-to-play time in NCAA athletes in the 2009-2010 to 2013-2014 DISC. This study adds to the limited evidence demonstrating potential predictors of return-to-play time using only self-reported symptoms that have been categorized by factor analysis.
References


Chapter Four: Relationship between Concussion Symptom Clusters and Return-To-Play Time in College Athletes with Sports-Related Concussions: 2009-2010 to 2013-2014 DISC
Objectives  To examine the relationship between Concussion Symptom Clusters (CSCs) and return-to-play time using a representative sample of U.S. college athletes with sports-related concussions.

Background  Recent evidence suggests that concussion symptoms are an important element of concussion severity, and potentially a predictor of return-to-play time. However, there is a paucity of data examining the associations between CSCs and return-to-play time in the U.S. college athlete population.

Methods  Data from the 2009-2010 to 2013-2014 academic years (n=1670) were obtained from the Datalys Center for Sports Injury and Prevention Inc. database. Exploratory factor analytic methods were applied, and the resulting factors were used in multinomial regression modeling to identify associations between CSCs and return-to-play time.

Results  A 4-factor solution accounted for 48.8% of the variance and included: audio-vestibular, somatic, amnesic, and affective factor structure. Audio-vestibular symptoms were associated with increased odds of prevented participation at 7-13 days, 14-29 days, greater than 30 days, and out for remainder of season, respectively (p<0.05). Somatic symptoms were associated with decreased odds of prevented participation at 7-13 days and greater than 30 days, respectively (p<0.05). Amnesic symptoms were associated with decreased odds of prevented participation at 1-6 days, 7-13 days, 14-29 days, and greater than 30 days, respectively (p<0.05).
Affective symptoms were associated with decreased odds of prevented participation at 7-13 days, 14-29 days, greater than 30 days, and out for remainder of season, respectively (p<0.05).

**Conclusion**  Specific CSCs were significantly associated with return-to-play time in college athletes, (p<0.05).
Introduction

A Sports-Related Concussion (SRC) is defined as a complex pathophysiological process affecting the brain, induced by traumatic biomechanical forces (1). Recent evidence regarding concussion symptoms has been observed to be an important element of concussion severity, and potentially a predictor of return-to-play time. Zuckerman et al. (2) examined the epidemiology of SRCs in National Collegiate Athletic Association (NCAA) student-athletes and estimated that among 25 sports, the overall concussion rate was 4.47 per 10,000 athlete-exposures (95% Confidence Interval, 4.25-4.68) with an average of 5.29 ± 2.94 symptoms per SRC. The estimated number of SRCs has increased; calling for more attention directed towards ensuring brain recovery time is being accurately assessed.

Concussion symptoms vary from person to person and may not present immediately after the injury occurs (sometimes taking days or weeks to present). Current concussion guidelines are present but lack specificity pertaining to athletes’ symptoms (1, 3). By examining Concussion Symptom Clusters (CSCs), guidelines may be adapted to design more specific treatment plans. Concussion symptom duration and cognitive recovery can range from several hours to weeks (4), however, resolution of symptoms typically takes a few days to a few weeks in most student-athletes (5). Treatment immediately post-injury includes physical, mental, and cognitive rest; concurrently, the concussed athlete must wait for clearance from his/her physician, pending complete resolution of concussion symptoms, before they can return to sanctioned team activity (6). However, there remains a paucity of research examining the relationship between CSCs and return-to-play time (7); thus further studies are necessary to elucidate which
CSCs warrant special monitoring. The purpose of this study was to examine the relationship between CSCs and return-to-play time using a representative sample of U.S. college-aged athletes that sustained an SRC.

Methods

The University of North Florida Institutional Review Board and the Datalys Center Independent Review Committee with the National Collegiate Athletic Association (NCAA) approved the release and use of the data.

This study utilized five years of data from 2009 to 2010 through 2013 to 2014 academic years that were collected by the National Collegiate Athletic Association-Injury Surveillance Program (NCAA-ISP) (8). The NCAA-ISP is a prospective surveillance program that works in conjunction with the Datalys Center for Sports Injury Research and Prevention Inc. (DISC) to verify, clean, and package datasets for researchers use. The study sample consisted of an independent sample of U.S. college athletes (17-24 years of age) that had data collected during 2009-2010 (n=824) and 2013-2014 (n=850) NCAA-academic years and had sustained a SRC.

The independent variable(s) in this study were the four-factored CSCs. An exploratory factor analysis (9) was utilized and subsequently categorized concussion symptom(s) that met the loading criteria ($\geq 0.5$) into the following clusters: (1) Audio-Vestibular; (2) Somatic; (3) Amnesic; (4) Affective.

The dependent variable in this study was return-to-play time and was defined as the number of days between injury date and the date the athlete returned to scheduled team activities, even with limitations and accommodations. Return date was verified to correspond correctly with the outcome so return-to-play time and outcome will match. To
further examine return-to-play time, eight categorical response classes were utilized: 1) Did not interfere with activity; 2) Returned to team activity within same session; 3) Removed from team activity session; 4) Prevented participation for 1-6 days; 5) Prevented participation for 7-13 days; 6) Prevented participation for 14-29 days; 7) Prevented participation for greater than 30 days; 8) Out for remainder of season.

Statistical Analysis

The data in this study was managed using SAS 9.4 (10). SAS was used to conduct both complex variable recodes and data coding validation. PROC SURVEYFREQ was used to calculate descriptive statistics for the categorical variables. An exploratory factor analysis (EFA) (11) was performed using PROC FACTOR to define factor structures (or CSCs). Symptoms that met the loading criteria (≥ 0.5) (12, 13) exemplified a strong underlying relationship within the factor (CSC) and thus were retained. Items that were cross-loaded (> 0.4) across more than one factor were retained for further analysis given that the main loading was (> 0.6) in addition to the difference between the main and cross-loaded item being (≥ 0.2). The items that did not meet these criteria were subsequently removed from further analysis. Furthermore, multiple-nomial regression models were performed using PROC LOGISTIC to examine the relationship between CSCs and return-to-play time.

The DISC sampling weight (WGT_FINAL) was applied to each analysis and was designed to accomplish the following goals: 1) account for year to year variations in sample, and 2) underreporting of injury events (14).
Results

Between 2009 and 2014, the NCAA-ISP recorded a total of 1,670 SRCs among male and female student-athletes across 25 NCAA varsity sports. The weighted population that sustained a SRC was 60.5% males and 39.5% females, respectively. Table 1 illustrates the study sample characteristics.
<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Overall</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N=1670</td>
<td>N=1129</td>
<td>N=541</td>
</tr>
<tr>
<td></td>
<td>n</td>
<td>Weighted % (SE)</td>
<td>n</td>
</tr>
<tr>
<td><strong>SRC By Academic Year</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2009-2010</td>
<td>187</td>
<td>13.0 (1.1)</td>
<td>129</td>
</tr>
<tr>
<td>2010-2011</td>
<td>354</td>
<td>21.0 (1.1)</td>
<td>234</td>
</tr>
<tr>
<td>2011-2012</td>
<td>356</td>
<td>23.7 (1.4)</td>
<td>226</td>
</tr>
<tr>
<td>2012-2013</td>
<td>372</td>
<td>19.8 (1.3)</td>
<td>264</td>
</tr>
<tr>
<td>2013-2014</td>
<td>401</td>
<td>22.9 (1.3)</td>
<td>276</td>
</tr>
<tr>
<td><strong>Division</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Division I</td>
<td>871</td>
<td>40.5 (40.5)</td>
<td>657</td>
</tr>
<tr>
<td>Division II</td>
<td>178</td>
<td>16.4 (1.3)</td>
<td>118</td>
</tr>
<tr>
<td>Division III</td>
<td>614</td>
<td>43.1 (1.6)</td>
<td>354</td>
</tr>
<tr>
<td><strong>Class Year</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>First Year</td>
<td>32</td>
<td>2.0 (0.4)</td>
<td>27</td>
</tr>
<tr>
<td>Freshman</td>
<td>549</td>
<td>34.7 (1.5)</td>
<td>268</td>
</tr>
<tr>
<td>Sophomore</td>
<td>388</td>
<td>23.4 (1.3)</td>
<td>248</td>
</tr>
<tr>
<td>Junior</td>
<td>355</td>
<td>19.1 (1.1)</td>
<td>240</td>
</tr>
<tr>
<td>Senior</td>
<td>246</td>
<td>14.0 (1.0)</td>
<td>165</td>
</tr>
<tr>
<td>Unknown</td>
<td>100</td>
<td>6.8 (0.8)</td>
<td>81</td>
</tr>
<tr>
<td><strong>Concussion Symptom Clusters</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Audio-Vestibular</td>
<td>433</td>
<td>25.5 (1.3)</td>
<td>299</td>
</tr>
<tr>
<td>Somatic</td>
<td>197</td>
<td>10.6 (0.9)</td>
<td>142</td>
</tr>
<tr>
<td>Amnesic</td>
<td>200</td>
<td>11.3 (1.0)</td>
<td>151</td>
</tr>
<tr>
<td>Affective</td>
<td>211</td>
<td>13.4 (1.1)</td>
<td>130</td>
</tr>
<tr>
<td><strong>Return-to-play time</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Did not interfere with activity</td>
<td>30</td>
<td>1.7 (0.4)</td>
<td>17</td>
</tr>
<tr>
<td>Returned to Team Activity within same session</td>
<td>18</td>
<td>0.8 (0.2)</td>
<td>11</td>
</tr>
<tr>
<td>Removed from team activity session</td>
<td>44</td>
<td>2.6 (0.5)</td>
<td>27</td>
</tr>
<tr>
<td>Prevented participation for 1-6 days</td>
<td>523</td>
<td>32.0 (1.4)</td>
<td>355</td>
</tr>
<tr>
<td>Prevented participation for 7-13 days</td>
<td>602</td>
<td>37.6 (1.5)</td>
<td>412</td>
</tr>
<tr>
<td>Prevented participation for 14-29 days</td>
<td>249</td>
<td>13.8 (1.0)</td>
<td>167</td>
</tr>
<tr>
<td>Prevented participation for greater than 30 days</td>
<td>53</td>
<td>2.3 (0.4)</td>
<td>44</td>
</tr>
<tr>
<td>Out for remainder of season</td>
<td>87</td>
<td>5.2 (0.8)</td>
<td>58</td>
</tr>
<tr>
<td>Missing</td>
<td>64</td>
<td>3.9 (0.6)</td>
<td>38</td>
</tr>
</tbody>
</table>

Values are expressed n (%) for categorical variables.
Table 2 illustrates post-concussion symptom factors and item loadings extrapolated from the exploratory factor analysis. The results from the exploratory factor analysis for post-concussion data supported a four-factor solution with the Tucker and Lewis’s Reliability coefficient at 0.89, indicating good reliability (larger value indicating better reliability) (15). Preliminary eigenvalues for each of the four factors were: 39.6, 4.8, 3.1, and 1.4 (respectively). Eigenvalues represent directionless scalars associated with linear regression that illustrate magnitude. Each factor was named from the predominating symptoms within each factor. Overall, the 4-factor solution accounted for 48.8% of the variance. The four-factor model included 15 of the original 17 symptoms from the 17-item post-concussion symptom checklist and comprised of the following factor structures: 1) audio-vestibular: 15.9% of the variance (weighted), five symptoms associated to audio-related symptoms (sensitivity to noise, tinnitus) and vestibular-related symptoms (balance issues, sensitivity to light, visual impairment); 2) somatic: 11.8% of the variance (weighted), six symptoms associated to somatic symptoms (difficulty concentrating, disorientation, dizziness, headache, loss of consciousness, and nausea ); 3) amnesic: 8.9% of the variance (weighted), two symptoms primarily related to amnesic symptoms (amnesia post-traumatic and retrograde); and 4) affective: 12.2% of the variance (weighted), two symptoms primarily related to affective symptoms (irritability and hyper-excitability). The following symptoms, drowsiness and insomnia, were excluded from the analysis because of low (<0.5) loadings or cross-loadings (>0.4) in two or more factors.
Table 3 illustrates the findings from the multi-nomial regression analysis with respect to CSCs and return-to-play time by the referent group “did not interfere with activity”. Athletes that displayed symptoms from the Audio-Vestibular cluster possessed significantly greater increased odds of being prevented from participation for 7-13 days (odds ratio [OR]: 2.51, 95% Wald confidence interval [CI] 1.59-3.97), 14-29 days (OR 3.74, 95% CI 2.35-5.95), greater than 30 days (OR 5.22, 95% CI 3.14-8.66), and out for the remainder of the season (OR 2.36, 95% CI 1.44-3.87), \((P < 0.05)\). In stark contrast, athletes with the affective CSC contained symptoms of hyperexcitibility and irritability and were at significantly lower odds of prevented participation at 7-13 days (OR 0.53, 95% CI 0.34-0.82), 14-29 days (OR 0.42, 95% CI 0.26-0.66), greater than 30 days (OR 0.30, 95% CI 0.18-0.50).
0.53, 95% CI 0.30-0.92), and out for the remainder of the season (OR 0.42, 95% CI 0.25-0.70), \((P < 0.05)\). Overall, ~35% \((R^2 = 0.348)\) of the variance with regards to return-to-play time was accounted for by CSC modeling, \(P < 0.001\).

**Table 3. Association between Concussion Symptom Clusters and Return-to-Play Time in U.S. NCAA athletes: 2009-2010 to 2013-2014 DISC.**

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Audio-Vestibular</th>
<th>Somatic</th>
<th>Amnesic</th>
<th>Affective</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OR 95% CI</td>
<td>OR 95% CI</td>
<td>OR 95% CI</td>
<td>OR 95% CI</td>
</tr>
<tr>
<td>Did not interfere with activity</td>
<td>1.00 -</td>
<td>1.00 -</td>
<td>1.00 -</td>
<td>1.00 -</td>
</tr>
<tr>
<td>Returned to Team Activity within same session</td>
<td>0.85 0.28-2.61 &lt;0.001</td>
<td>&lt;0.001- &gt;999.99</td>
<td>&lt;0.001</td>
<td>&lt;0.001- &gt;999.99</td>
</tr>
<tr>
<td>Removed from team activity session</td>
<td>1.24 0.69-2.25 1.57 0.89-2.74 0.56 0.32-1.01 &lt;0.001</td>
<td>&lt;0.001- &gt;999.99</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prevented participation for 1-6 days</td>
<td>1.04 0.65-1.65 1.01 0.64-1.59 0.43* 0.28-0.65 0.70 0.45-1.08</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prevented participation for 7-13 days</td>
<td>2.51* 1.59-3.97 0.48* 0.30-0.76 0.38* 0.25-0.58 0.53* 0.34-0.82</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prevented participation for 14-29 days</td>
<td>3.74* 2.35-5.95 0.76 0.47-1.21 0.46* 0.30-0.71 0.42* 0.27-0.66</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prevented participation for greater than 30 days</td>
<td>5.22* 3.14-8.66 0.24* 0.13-0.48 0.55* 0.31-0.97 0.53* 0.30-0.92</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Out for remainder of season</td>
<td>2.36* 1.44-3.87 0.74 0.44-1.24 0.81 0.50-1.29 0.42* 0.25-0.70</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Significant predictors \((P < 0.05)\).

Abbreviations: OR, odds ratio; 95% CI, 95% Wald confidence interval.

**Discussion**

Current NCAA Concussion Management Program guidelines have been established from consensus-based documents (1), thus it is imperative to investigate the
overall temporal relationship between SRCs and the time required to resolve (or become ‘asymptomatic’), and subsequently be physician-approved to return to competition.

Self-reported symptoms and ensuing neuropsychological testing are used in tandem by physicians and athletic trainers (ATs) to estimate SRC severity level and post-injury recovery timeframe (16). Maroon et al. (17) conducted a review of the literature concerning the potential usefulness the Neuropsychological testing offers and established that not only are the results useful in short-term post-concussion management but long-term as well. There are various concussion symptom checklists used in college athletics with the more prevalent ones including: the Post-concussion symptom scale (18), Graded Symptom checklist (19), and Sport Concussion Assessment Tool 3 (20). Each Neuropsychological assessment tool varies slightly with regards to symptoms included (range from 16 – 22 symptoms). Additionally, most include ranges (i.e. Likert Scale) of perceived severity of each symptom.

Results from our EFA statistically support a four-factor structure utilizing the NCAA 17-item post-concussion symptom checklist. Previous studies have utilized factor analysis techniques to statistically factor symptoms (18, 19). However, due to the variability of symptoms included in those checklists, the NCAA should examine the available data and begin a dialogue regarding a standardized post-concussion symptom checklist to accommodate for the wide range of concussion symptoms an athlete can experience. Moreover, this would allow researchers to examine the spectrum of concussion symptoms and subsequent factor analysis results, possibly identifying new factor structures that encompass all concussion symptoms.
Our analysis detected significant novel associations between CSCs and specific return-to-play time(s) that have not been exclusively reported in the current literature. Our finding of longest return-to-play time within the Audio-Vestibular CSC (Table 3) should alert the ATC or clinician during the evaluation process that these athletes may warrant cautious and protracted follow-up as was also reported in a study conducted by Chorney et al. (7). Their study’s aims were focused on observing audiovestibular symptoms (such as dizziness, imbalance, disorientation, noise sensitivity, and tinnitus) and the rates in which they occur as well as the potential correlations between audiovestibular symptoms and return-to-play time. The study sample of college athletes who sustained a SRC was queried from the NCAA-ISP utilizing the years of data from 2009 through 2014. Researchers utilized multiple ordinal regression modeling and observed that the student-athlete’s concussion symptoms continued longer when noise sensitivity (P = 0.000) and dizziness (P = 0.043) were present. In addition, student athletes required more time to recover from their SRC if they reported symptoms of noise sensitivity (P = 0.000) and imbalance (P = 0.011). Another significant observation was that concussion symptoms of dizziness and imbalance had the greatest statistically significant odds of being associated with one another [OR: 4.15], followed by imbalance and disorientation [OR: 3.45], noise sensitivity and tinnitus [OR: 3.21], and dizziness and noise sensitivity [OR: 2.95], (P value < 0.001).

Previous research by Collins et al. (21) suggested that specific symptoms such as “Loss of consciousness” and “Post-traumatic amnesia” may provide an indication of a longer recovery time (21). However, recent evidence suggests the absence of an association between prolonged recovery time (≥ 21 days) (22, 23) and was consistent
with the findings in our study (Table 3). Other researchers have reported that balance and dizziness symptoms within the Somatic CSC only cause athletes to typically recover in less than seven days (24), consistent with the findings observed in our study (Table 3). Additionally, findings from our study may illustrate SRC severity-component by presented CSC, not previously observed in the literature, demanding special focus by those caring for the concussed athlete.

The present study has intrinsic limitations. First, due to the nature of cross-sectional study design, suggests that causality cannot be inferred. Additionally, concussion symptoms were self-reported and are subjected to report and recall bias. Given that athletes suspected of having a SRC are required to be removed from NCAA sanctioned participation, underreporting of symptoms must be taken into account. Self-reported data may also be vulnerable to the social desirability effect. A primary strength of our study is that the NCAA-ISP is comprised of a convenience sample of varsity teams with varying ranges of participation and concussion management protocols in effect. Thus, due to how the NCAA collected the student-athlete data across Division’s I, II, and III, our findings can be generalized to a broad range of student athletes.

Conclusion

In conclusion, NCAA athletes who displayed audio-vestibular CSC symptoms were significantly associated with a prolonged return-to-play time compared to the other CSCs such as somatic, affective, and amnesic. To this researcher’s knowledge, this is the first study to conduct an EFA using the 17-item post-concussion symptom checklist currently in use by NCAA-affiliated ATs and then subsequently examine the odds
associated with CSCs as it pertains an estimated return-to-play time. The current study will add to the present, albeit, limited literature pertaining to identifying appropriate estimates of return-to-play time by the college athlete’s concussion symptomology. Future research should examine combinations of CSCs associated with longer return-to-play time(s) as well as examining sport-specific CSC symptomatology.

Acknowledgements

The NCAA Injury Surveillance Program data were provided by the Datalys Center for Sports Injury Research and Prevention. The Injury Surveillance Program was funded by the National College Athletic Association (NCAA). The content of this manuscript is solely the responsibility of the authors and does not necessarily represent the official views of the Datalys Center or the NCAA. We thank the many athletic trainers who have volunteered their time and efforts to submit data to the NCAA Injury Surveillance Program. Their efforts are greatly appreciated and have had a tremendously positive effect on the safety of collegiate athletes.
References


Appendices
MEMORANDUM

DATE: October 24, 2016

TO: Mr. Adrian Boltz

VIA: Dr. James Chinulla
Clinical and Applied Movement Sciences

FROM: Dr. Jennifer Wesely, Chairperson
On behalf of the UNF Institutional Review Board

RE: “Examine the relationship in SRCs between location of injury, concussion symptomatology, and Return to Play time: 2009-2010 and 2013-2014”

This is to advise you the Human Subject Research Determination Form for the project named above was reviewed on behalf of the UNF Institutional Review Board, and has subsequently been granted this waiver of IRB review. As such, this project was declared “not research involving human subjects” based on the federal definition as stated in the U.S. Department of Health and Human Services Code of Federal Regulations 45 CFR 46.102. Therefore, it is not necessary for this project to be reviewed and approved by the UNF IRB. However, the principal investigator is not absolved from complying with other federal, state, or local laws or institutional policies and procedures.

Thank you for submitting the HSR Determination Form for IRB consideration. We appreciate that you understand the value of IRB review of human subject research and projects conducted at UNF. Any unanticipated problems involving risk and any occurrence of serious harm to subjects and others shall be reported promptly to the IRB. This waiver should be kept for your records and applies to your project in the form and content as submitted to the IRB for review. Any variations or modifications to this waived project as related to dealing with human subjects must be cleared with the IRB prior to implementing such changes.

Should you have questions regarding your project or any other IRB items, please contact the research integrity unit of the Office of Research and Sponsored Programs by emailing IRB@unf.edu or calling (904) 620-2455.

This letter has been electronically signed in accordance with all applicable regulations, and a copy is retained within UNF’s records.
February 28, 2017
Datalys Tracking Number: RR-101

Good afternoon,

Thank you for making the requested changes to your proposal. We are happy to report that your application has been approved by the IRC. As part of this process, you are required to return a signed copy of the Data Use License Agreement (attached). Your application, proof of human subjects’ review or exemption, and this decision letter will be forwarded to the NCAA for final approval upon receipt of your signed Data Use License Agreement. Please note that the NCAA owns the data and must provide final approval of your request. All individuals involved in the proposed research project must review, sign, and provide a completed Data User License Agreement. Editing or otherwise failure to sign the agreement may delay or prevent approval of your request.

In the License Agreement, there are 3 referenced exhibits:
1. Exhibit A - The Work. This exhibit will be a listing of the data set(s) content and will be included in the final signed copy of the License agreement which I will provide to you after the NCAA has signed it. For now, this exhibit refers to the variables you requested in your accepted proposal.
2. Exhibit B – User Application. This is the proposal you submitted, which was reviewed and accepted.
3. Exhibit C – Evidence of Outcome of IRB Review. We already have your exemption determination on file and we will include in the final signed packet.

After the NCAA has approved your study application, both parties have signed the agreement, and I have received the documentation, Datalys will begin to create the datasets.

Please let us know if you have any questions or concerns regarding this decision referring to the tracking number above.

Thank you.
Appendix C

May 3, 2017

Ms. Sara Dalton, M.Ed.
Statistical Analyst
Datalys Center for Sports Injury Research and Prevention
Indianapolis, Indiana 46202

Dear Ms. Dalton:

The following scientific research proposals requesting specified NCAA sports injury data submitted as part of the Datalys Center’s Independent review Committee (IRC) data request process have been reviewed and approved by the NCAA.


Please contact me with any questions.

Sincerely,

John T. Parsons, PhD, ATC
Director, NCAA Sport Science Institute

P.O. Box 6222
Indianapolis, Indiana 46206
Telephone: 317/817-6222
Shipping/Overnight Address:
1802 Atanza Wood St. Drive
Indianapolis, Indiana 46202

WWW.NCAA.ORG

National Collegiate Athletic Association
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Equal Opportunity/Affirmative Action Employer
Appendix D

Associations between Concussion Symptom Clusters and Return-to-Play Time in U.S. NCAA Athletes who sustained a Sports-Related Concussion: 2009-2010 to 2013-2014 DISC
Objectives The purpose of this study was to examine the differences between Concussion Symptom Clusters in helmeted and non-helmeted sports, males and females, and SRCs sustained between 2009-2011 and 2012-2014 in college athletes who sustained a Sports-Related Concussion.

Background Anecdotal evidence suggests that helmets apply a protective factor to ameliorate force imposed on an athlete, however evidence based research suggests the contrary. Moreover, since concussion legislative efforts began in 2009, evidence based research examining the effects have been largely un-studied at the collegiate level.

Methods The study sample included 1670 college aged athletes who sustained a SRC between 2009-2010 and 2013-2014 academic years. Data was obtained from the Datalys Center for Sports Injury and Prevention Inc. database. Logistic regression modeling was utilized to examine the association and differences between CSCs in helmeted and non-helmeted sports, male and female athletes, and SRCs sustained between 2009-2011 and 2012-2014 by return-to-play time.

Results Analysis revealed that athletes in helmeted sports are still significantly at higher odds of prevented participation at 1-6 and 7-13 days (odds ratio: 1.24 and 1.15, respectively) when compared to non-helmeted athletes at 1-6 and 7-13 days (odds ratio: 0.81 and 0.87, respectively), (p<0.05). When examining the same outcomes starting at “prevented participation at 1-6 days” to “out for the remainder of the season” males were at higher odds of a longer return-to-play time when compared to female athletes,
(p<0.05). Lastly, SRCs sustained between 2012 and 2014 academic years had significantly lower odds of prevented participation when compared to SRCs sustained between 2009 and 2011, (p<0.05).

**Conclusions**  These data suggests that athletes in helmeted sports are still at risk of a prolonged return-to-play time when compared to non-helmeted athletes, male athletes have greater odds of prevented participation when compared to female athletes, and concussion legislative efforts have lowered the odds of prevented participation in athletes who sustained a SRC.
Introduction

A Sports-Related Concussion (SRC) is defined as a complex pathophysiological process affecting the brain, induced by traumatic biomechanical forces (1). The most recent estimate regarding SRC prevalence in the U.S. was estimated at around four million concussions occur each year due to involvement in physical activity and sports (2). Current evidence regarding concussion symptoms has been observed to be an important element of concussion severity, and potentially a predictor of return-to-play time. Zuckerman et al. (3) examined the epidemiology of SRCs in National Collegiate Athletic Association (NCAA) athletes and estimated the proportion of SRCs that needed at least one week to resolve, subsequently allow the athlete to return to competition, increased in a linear trend from 42.7% to 70.2% (2009-2010 vs 2013-2014, respectively), \( P < 0.001 \).

Giza et al. (4) conducted a systematic review of the literature (from 1955 to 2012) and reported that while helmets are designed at reducing the incidence in SRCs in football, researchers concluded that helmets do not significantly reduce the incidence of SRCs. Equipment in sports, specifically helmets and other protective headgear, have been improved over the years to diminish the risk of more severe SRCs and ultimately to decrease the risk of SRCs. However, the most recent estimate of SRC incidence has only decreased by 2% in football when compared to older helmet models (5).

The estimated number of SRCs has increased, calling for more attention directed towards ensuring brain recovery time is being accurately prescribed. The first state to put forth and pass concussion-related legislation was Washington in 2009. As of 2014, there are currently no federal sports-related concussion laws (6). States, however, have
responded to concerns stemming from sports-related concussion by passing laws intended to protect young athletes and as of 2014 all 50 states have adopted a variation of the law. Concussion laws are centered on three specific tenets: education, removal from play, and clearance for return to play (7). Educating athletes, coaches, and parents (or guardians) about concussion entails an informational document(s) that must be signed by all parties. Removal of play must occur if the athlete is suspected of sustaining a concussion. Lastly, return to practice (or play) can only occur with the written permission by the licensed healthcare provider who is of the correct qualifications.

In 2014, Bompadre et al. (8) conducted a retrospective cross-sectional analysis examining the effects of the Lystedt concussion law on concussion documentation in the Seattle public high school system in students (aged 13-19) in the school years: 2008–2009 (n=4348), 2009–2010 (n=4925), and 2010–2011 (n=4806). Researchers reported that the concussion documentation rates doubled after the institution adopted and adhered to the law. Further, the mean number of days removed from participation, post-2009, was approximately seven days more after the Lystedt concussion law went into effect. This suggests that institutions adhering to the law increased awareness and quicker observing. Moreover, the effects of the concussion legislation has been exclusively examined in a sample of NCAA collegiate athletes since the NCAA’s adoption of its Concussion Policy and Legislation in 2010 (9).

Current concussion guidelines are present but lack specificity pertaining to athletes’ symptoms (1, 10) and even gender. Concussion symptom duration and cognitive recovery can range from several hours to weeks (11), however, resolution of symptoms typically take a few days to a few weeks in most student-athletes (12). Current treatment
post-injury involves includes physical, mental, and cognitive rest. Concurrently, the concussed athlete must wait for clearance from his/her physician, pending complete resolution of concussion symptoms, before they can return to sanctioned team activity (13). There is a paucity of research examining the relationship between Concussion Symptom Clusters in helmeted and non-helmeted sports, male and female athletes, and SRCs sustained between 2009-2011 and 2012-2014 by return-to-play time.

Thus the purpose of this study was to examine the relationship between in: helmeted and non-helmeted sports, male and female athletes, and SRCs sustained in 2009-2011 and 2012-2014 by return-to-play time using a representative sample of U.S. college-aged athletes who sustained an SRC.

Methods

The University of North Florida Institutional Review Board approved this retrospective study in addition to the Datalys Center Independent Review Committee with the National Collegiate Athletic Association approved the release of the data.

This study utilized five years of data from 2009 to 2010 through 2013 to 2014 academic years that were collected by the National Collegiate Athletic Association-Injury Surveillance Program (NCAA-ISP) (14). The NCAA-ISP is a prospective surveillance program that works in conjunction with the Datalys Center for Sports Injury Research and Prevention Inc. (DISC) to verify, clean, and package datasets for researchers use. The study sample consisted of an independent sample of U.S. college athletes (17-24 years of age) that had data collected during 2009-2014 (n=1670) NCAA-academic years and had sustained a SRC.
The independent variable(s) in this study were Concussion Symptom Clusters (CSCs). An exploratory factor analysis (15) was utilized and subsequently categorized concussion symptom(s) that met the loading criteria ($\geq 0.5$) into the following clusters: (1) Audio-Vestibular; (2) Somatic; (3) Amnesic; (4) Affective.

The dependent variable in this study was return-to-play time and was defined as the number of days between injury date and the date the athlete returned to scheduled team activities, even with limitations/accommodations. Return date was verified to correspond correctly with the outcome so return-to-play time and outcome will match. To further examine return-to-play time, eight categorical response classes were utilized: 1) Did not interfere with activity; 2) Returned to team activity within same session; 3) Removed from team activity session; 4) Prevented participation for 1-6 days; 5) Prevented participation for 7-13 days; 6) Prevented participation for 14-29 days; 7) Prevented participation for greater than 30 days; 8) Out for remainder of season.

**Study Conditions**

Sports were dichotomized by presence of required protective headgear and were termed either ‘helmented’ or ‘non-helmented’. Helmented sports consisted of: men’s football, men’s and women’s ice hockey, and men’s lacrosse. Non-helmented sports consisted of: men’s and women’s basketball, men’s baseball, women’s cross country, women’s field hockey, women’s gymnastics, women’s lacrosse, men’s and women’s soccer, men’s and women’s swimming, men’s and women’s tennis, men’s and women’s indoor track and field, men’s and women’s outdoor track and field, women’s volleyball, and men’s wrestling. Sports containing student-athletes who sustained a SRC were included. Gender was stratified by either male or female student athletes who sustained a
SRC. Finally, academic school years were dichotomized into two groups: SRCs occurring between 2009-2011 and 2012-2014.

**Statistical Analysis**

The data in this study was managed using SAS 9.4 (16). SAS was used to conduct both complex variable recodes and data coding validation. PROC SURVEYFREQ was utilized to calculate descriptive statistics for the categorical variables. Logistic regression analysis was performed using PROC LOGISTIC to examine the relationship between the previously mentioned independent variables and return-to-play time to calculate odds ratios with corresponding confidence intervals. Non-overlapping 95% Wald confidence intervals indicate significance at $P < 0.05$. The DISC sampling weight (17) ($WGT\_FINAL$) was applied to each analysis and was designed to accomplish the following goals: 1) produce nationally representative NCAA estimates, 2) account for year to year variations in sample, 3) underreporting of injury events (18).

**Results**

Between 2009 and 2014, the NCAA-ISP recorded a total of 1,670 SRCs among male and female student-athletes across 25 NCAA varsity sports. Within the weighted population, 60.5% were males and 39.5% were females that had sustained at least one SRC. Table 1 illustrates study sample characteristics. The most prevalent CSC across every study sample characteristic, when stratified by, was the Audio-Vestibular CSC (25.5%), $P < 0.05$. The second most CSC varied between the Affective CSC (13.4%) and Amnesic CSC (11.3%). Further, in the 2012-2014 academic years, the prevalence of having symptoms related to the Affective CSC was greater than in 2009-2011, $P < 0.05$. 
Table 1. Study sample characteristics by Concussion Symptom Cluster: 2009-2010 to 2013-2014 DISC.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Audio-Vestibular</th>
<th>Somatic</th>
<th>Amnesic</th>
<th>Affective</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>Weighted n% (CI)</td>
<td>n</td>
<td>Weighted n% (CI)</td>
</tr>
<tr>
<td>Overall</td>
<td>433</td>
<td>25.5 (23.0-28.1)</td>
<td>197</td>
<td>10.6 (8.9-12.4)</td>
</tr>
<tr>
<td>Male</td>
<td>299</td>
<td>26.3 (23.1-29.4)</td>
<td>142</td>
<td>11.2 (9.1-13.3)</td>
</tr>
<tr>
<td>Female</td>
<td>134</td>
<td>24.3 (20.0-28.6)</td>
<td>55</td>
<td>9.8 (6.8-12.8)</td>
</tr>
<tr>
<td>Sports Head Equipment</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Helmeted</td>
<td>258</td>
<td>28.5 (25.0-32.1)</td>
<td>131</td>
<td>13.3 (10.7-15.9)</td>
</tr>
<tr>
<td>non-Helmeted</td>
<td>175</td>
<td>23.5 (20.0-27.0)</td>
<td>66</td>
<td>8.9 (6.6-11.2)</td>
</tr>
<tr>
<td>Academic Years</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2009-2011</td>
<td>249</td>
<td>26.3 (22.9-29.6)</td>
<td>96</td>
<td>8.9 (7.0-10.9)</td>
</tr>
<tr>
<td>2012-2014</td>
<td>184</td>
<td>24.5 (20.3-28.5)</td>
<td>101</td>
<td>12.9 (9.8-16.0)</td>
</tr>
</tbody>
</table>

Values are expressed n (%) for categorical variables.
Abbreviations: DISC: Datalys Injury Statistics Clearinghouse; CI: 95% confidence interval.

Table 2 illustrates the estimated odds of return-to-play time in both helmeted and non-helmeted athletes who sustained a SRC. Athletes who participated in helmeted sports were 24% (odds ratio [OR] 1.24; 95% confidence interval [CI] 1.08-1.42) more likely to be prevented from participation for 1-6 days while non-helmeted athletes had 19% (OR 0.81; 95% CI 0.70-0.93) lower odds, P < 0.05. Moreover, athletes in helmeted sports were 15% more likely to be prevented from participation for 7-13 days in stark contrast to non-helmeted athletes who had 13% lower odds (OR 0.87; 95% CI 0.76-1.00), P < 0.05.
Table 2. Odds of return-to-play time in U.S. NCAA athletes by Head Equipment sports: 2009-2010 to 2013-2014 DISC.

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Helmeted (n=934)</th>
<th>Non-Helmeted (n=672)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OR</td>
<td>95% CI</td>
</tr>
<tr>
<td>Did not interfere with activity</td>
<td>Ref</td>
<td>-</td>
</tr>
<tr>
<td>Returned to Team Activity within same session</td>
<td>0.77*</td>
<td>0.60 - 0.98</td>
</tr>
<tr>
<td>Removed from team activity session</td>
<td>0.83*</td>
<td>0.70 - 0.99</td>
</tr>
<tr>
<td>Prevented participation for 1-6 days</td>
<td>1.24*</td>
<td>1.08 - 1.42</td>
</tr>
<tr>
<td>Prevented participation for 7-13 days</td>
<td>1.15*</td>
<td>1.00 - 1.31</td>
</tr>
<tr>
<td>Prevented participation for 14-29 days</td>
<td>0.95</td>
<td>0.83 - 1.10</td>
</tr>
<tr>
<td>Prevented participation for greater than 30 days</td>
<td>1.06</td>
<td>0.89 - 1.27</td>
</tr>
<tr>
<td>Out for remainder of season</td>
<td>0.95</td>
<td>0.81 - 1.11</td>
</tr>
</tbody>
</table>

Abbreviations: DISC: Datalys Injury Statistics Clearinghouse; Ref: Referent; OR: odds ratio; 95% CI: 95% Wald confidence interval.
Non-overlapping 95% Wald confidence intervals indicate significance at \( P < 0.05 \).
* \( P < 0.05 \)

Table 3 illustrates the estimated odds of return-to-play time in helmeted sports with regards to CSCs. Athletes who participated in helmeted sports and displayed symptoms of the Affective CSC had lower odds of prevented participation at 1-6, 7-13, 14-29, greater than 30 days, and out for the remainder of the season, \( P < 0.05 \), respectively.
Table 3. Association between Concussion Symptom Clusters and Return-to-Play time in Helmeted sports: 2009-2010 to 2013-2014 DISC.

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Audio-Vestibular</th>
<th>Somatic</th>
<th>Amnesic</th>
<th>Affective</th>
</tr>
</thead>
<tbody>
<tr>
<td>Did not interfere with activity Return Team Activity within same session</td>
<td>Ref - Ref - Ref -</td>
<td>- - Ref -</td>
<td>- - Ref -</td>
<td>- - Ref -</td>
</tr>
<tr>
<td>Removed from team activity session</td>
<td>3.74* 1.00-13.95</td>
<td>&lt;0.001</td>
<td>&gt;999.999</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Prevented participation for 1-6 days</td>
<td>8.20* 3.33-20.21</td>
<td>&lt;0.001</td>
<td>&gt;999.999</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Prevented participation for 7-13 days</td>
<td>1.12 0.49-2.58</td>
<td>1.28</td>
<td>0.62-2.62</td>
<td>0.32*</td>
</tr>
<tr>
<td>Prevented participation for 14-29 days</td>
<td>3.87* 1.70-8.80</td>
<td>0.13*</td>
<td>0.06-0.26</td>
<td>0.35*</td>
</tr>
<tr>
<td>Prevented participation for greater than 30 days</td>
<td>8.94* 3.91-20.42</td>
<td>0.27*</td>
<td>0.13-0.58</td>
<td>0.32*</td>
</tr>
<tr>
<td>Out for remainder of season</td>
<td>19.11* 8.11-45.05</td>
<td>1.04</td>
<td>0.43-2.53</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>4.84* 2.04-11.44</td>
<td>0.13*</td>
<td>0.05-0.31</td>
<td>0.96</td>
</tr>
</tbody>
</table>

Abbreviations: DISC: Datalys Injury Statistics Clearinghouse; Ref: Referent; OR: odds ratio; 95% CI: 95% Wald confidence interval. Non-overlapping 95% Wald confidence intervals indicate significance at P < 0.05. * P < 0.05

Table 4 illustrates the estimated odds of return-to-play time in both males and female athletes who sustained a SRC. Female athletes were 75% (OR 0.25; 95% CI 0.20-0.30) lower odds to be prevented from participation for greater than 30 days while male athletes were four times greater odds (OR 4.1; 95% CI 3.38-4.90), P < 0.05. Further, males were twice as likely to be prevented from participation for 7-13 days in contrast to female athletes who had 41% lower odds (OR 2.03 vs 0.49, respectively), P < 0.05.
Table 4. Odds of Return-to-Play time in U.S. NCAA athletes by Gender: 2009-2010 to 2013-2014 DISC.

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Male (n=1091)</th>
<th>95% CI</th>
<th>Female (n=515)</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Did not interfere with activity</td>
<td>Ref</td>
<td>-</td>
<td>Ref</td>
<td>-</td>
</tr>
<tr>
<td>Returned to Team Activity within same session</td>
<td>0.90</td>
<td>0.71 - 1.14</td>
<td>1.11</td>
<td>0.88 - 1.41</td>
</tr>
<tr>
<td>Removed from team activity session</td>
<td>1.17</td>
<td>0.99 - 1.39</td>
<td>0.85</td>
<td>0.72 - 1.01</td>
</tr>
<tr>
<td>Prevented participation for 1-6 days</td>
<td>2.03*</td>
<td>1.78 - 2.32</td>
<td>0.49*</td>
<td>0.43 - 0.56</td>
</tr>
<tr>
<td>Prevented participation for 7-13 days</td>
<td>1.92*</td>
<td>1.68 - 2.19</td>
<td>0.52*</td>
<td>0.46 - 0.60</td>
</tr>
<tr>
<td>Prevented participation for 14-29 days</td>
<td>2.04*</td>
<td>1.77 - 2.34</td>
<td>0.49*</td>
<td>0.43 - 0.56</td>
</tr>
<tr>
<td>Prevented participation for greater than 30 days</td>
<td>4.07*</td>
<td>3.38 - 4.90</td>
<td>0.25*</td>
<td>0.20 - 0.30</td>
</tr>
<tr>
<td>Out for remainder of season</td>
<td>1.22*</td>
<td>1.05 - 1.41</td>
<td>0.82*</td>
<td>0.71 - 0.95</td>
</tr>
</tbody>
</table>

Abbreviations: DISC: Datalys Injury Statistics Clearinghouse; Ref: Referent; OR: odds ratio; 95% CI: 95% Wald confidence interval.
Non-overlapping 95% Wald confidence intervals indicate significance at $P < 0.05$.
* $P < 0.05$

Table 5 illustrates the estimated odds of return-to-play time in male athletes with regards to CSCs. Males who displayed symptoms of the Affective CSC had lower odds of prevented participation at 1-6, 7-13, greater than 30 days, and out for the remainder of the season, $P < 0.05$, respectively. In contrast to male athletes who displayed symptoms of the Audio-Vestibular CSC who were at least three times more likely of prevented participation at 7-13 days (OR 3.08; 95% CI 1.38-6.87), 14-29 days, greater than 30 days, and out for the remainder of the season, $P < 0.05$. 
Table 5. Association between Concussion Symptom Clusters and Return-to-Play time in U.S. Male NCAA athletes: 2009-2010 to 2013-2014 DISC.

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Audio-Vestibular</th>
<th>Somatic</th>
<th>Amnesic</th>
<th>Affective</th>
</tr>
</thead>
<tbody>
<tr>
<td>Did not interfere with activity</td>
<td>Ref</td>
<td>Ref</td>
<td>Ref</td>
<td>Ref</td>
</tr>
<tr>
<td>Returned to Team Activity within same session</td>
<td>2.72</td>
<td>0.74-10.0</td>
<td>&lt;0.001</td>
<td>&gt;999.999</td>
</tr>
<tr>
<td>Removed from team activity session</td>
<td>2.04</td>
<td>0.82-5.06</td>
<td>2.49</td>
<td>1.14-5.44</td>
</tr>
<tr>
<td>Prevented participation for 1-6 days</td>
<td>1.43</td>
<td>0.64-3.20</td>
<td>1.29</td>
<td>0.64-2.61</td>
</tr>
<tr>
<td>Prevented participation for 7-13 days</td>
<td>3.08*</td>
<td>1.38-6.87</td>
<td>0.09*</td>
<td>0.04-0.18</td>
</tr>
<tr>
<td>Prevented participation for 14-29 days</td>
<td>5.1*</td>
<td>2.27-11.42</td>
<td>0.28*</td>
<td>0.13-0.58</td>
</tr>
<tr>
<td>Prevented participation for greater than 30 days</td>
<td>7.52*</td>
<td>3.26-17.38</td>
<td>0.21*</td>
<td>0.08-0.54</td>
</tr>
<tr>
<td>Out for remainder of season</td>
<td>4.12*</td>
<td>1.78-9.54</td>
<td>0.18*</td>
<td>0.07-0.43</td>
</tr>
</tbody>
</table>

Abbreviations: DISC: Datalys Injury Statistics Clearinghouse; Ref: Referent; OR: odds ratio; 95% CI: 95% Wald confidence interval. Non-overlapping 95% Wald confidence intervals indicate significance at $P < 0.05$.

Table 6 illustrates the estimated odds of return-to-play time in both 2009-2011 and 2012-2014 academic years. Athletes who sustained a SRC between 2009-2011 were twice as likely to be prevented from participation for 1-6 days while athletes who sustained a SRC between 2012-2014 had 54% lower odds (OR 2.16 vs 0.46, respectively), $P < 0.05$. Moreover, SRCs occurring between 2012-2014 were 45% less likely to prevent the athlete from participation for greater than 30 days while athletes that sustained a SRC in 2009-2011 were almost twice as likely to be prevented from predication at greater than 30 days (OR 0.55 vs 1.81, respectively), $P < 0.05$. 
Table 6. Odds of Return-to-Play time in U.S. NCAA athletes by academic years: 2009-2010 to 2013-2014 DISC.

<table>
<thead>
<tr>
<th>Outcome</th>
<th>2009 - 2011 (n= 541)</th>
<th></th>
<th>2012-2014 (n=737)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OR</td>
<td>95% CI</td>
<td>OR</td>
<td>95% CI</td>
</tr>
<tr>
<td>Did not interfere with activity</td>
<td>Ref</td>
<td>-</td>
<td>Ref</td>
<td>-</td>
</tr>
<tr>
<td>Returned to Team Activity within same session</td>
<td>2.18*</td>
<td>1.63 - 2.92</td>
<td>0.46*</td>
<td>0.34 - 0.61</td>
</tr>
<tr>
<td>Remained from team activity session</td>
<td>1.64*</td>
<td>1.33 - 2.02</td>
<td>0.61*</td>
<td>0.50 - 0.75</td>
</tr>
<tr>
<td>Prevented participation for 1-6 days</td>
<td>2.16*</td>
<td>1.8 - 2.57</td>
<td>0.46*</td>
<td>0.39 - 0.55</td>
</tr>
<tr>
<td>Prevented participation for 7-13 days</td>
<td>0.99</td>
<td>0.83 - 1.17</td>
<td>1.01</td>
<td>0.85 - 1.20</td>
</tr>
<tr>
<td>Prevented participation for 14-29 days</td>
<td>0.93</td>
<td>0.77 - 1.10</td>
<td>1.08</td>
<td>0.91 - 1.29</td>
</tr>
<tr>
<td>Prevented participation for greater than 30 days</td>
<td>1.81*</td>
<td>1.46 - 2.24</td>
<td>0.55*</td>
<td>0.45 - 0.69</td>
</tr>
<tr>
<td>Out for remainder of season</td>
<td>1.35*</td>
<td>1.12 - 1.64</td>
<td>0.74*</td>
<td>0.61 - 0.90</td>
</tr>
</tbody>
</table>

Abbreviations: DISC: Datalys Injury Statistics Clearinghouse; Ref: Referent; OR: odds ratio; 95% CI: 95% Wald confidence interval.

Non-overlapping 95% Wald confidence intervals indicate significance at P < 0.05.

* P < 0.05

Table 7 illustrates the estimated odds of return-to-play time in athletes that sustained a SRC between 2012 and 2014 with regards to CSCs. Athletes that sustained a SRC between 2012 and 2014 and were prevented from participation for 7-13 days had three times increased odds if they displayed symptoms from the Audi-Vestibular CSC (OR 3.38, 95% CI 1.57, 7.25), 89% lowered odds in the presence of symptoms from the Somatic CSC (OR 0.11, 95% CI 0.06, 0.20), 58% lowered odds in the presence of symptoms from the Amnesic CSC (OR 0.42, 95% CI 0.22, 0.80), and 57% lowered odds in the presence of symptoms from the Affective CSC (OR 0.43, 95% CI 0.21, 0.89), P < 0.05 respectively.
Table 7. Association between Concussion Symptom Clusters and Return-to-Play time in athletes who sustained a SRC between 2012 and 2014.

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Audio-Vestibular</th>
<th>Somatic</th>
<th>Amnesic</th>
<th>Affective</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OR</td>
<td>95% CI</td>
<td>OR</td>
<td>95% CI</td>
</tr>
<tr>
<td>Did not interfere with activity</td>
<td>Ref</td>
<td>-</td>
<td>Ref</td>
<td>-</td>
</tr>
<tr>
<td>Returned to Team Activity within same session</td>
<td>2.70</td>
<td>0.75-9.72</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Removed from team activity session</td>
<td>5.14*</td>
<td>2.19-12.02</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Prevented participation for 1-6 days</td>
<td>1.39</td>
<td>0.64-3.02</td>
<td>0.35*</td>
<td>0.19-0.65</td>
</tr>
<tr>
<td>Prevented participation for 7-13 days</td>
<td>3.38*</td>
<td>1.57-7.25</td>
<td>0.11*</td>
<td>0.06-0.20</td>
</tr>
<tr>
<td>Prevented participation for 14-29 days</td>
<td>6.62*</td>
<td>3.01-14.27</td>
<td>0.64</td>
<td>0.35-1.17</td>
</tr>
<tr>
<td>Prevented participation for greater than 30 days</td>
<td>5.54*</td>
<td>2.37-12.99</td>
<td>0.27*</td>
<td>0.09-0.80</td>
</tr>
<tr>
<td>Out for remainder of season</td>
<td>2.54*</td>
<td>1.13-5.74</td>
<td>0.02*</td>
<td>0.01-0.06</td>
</tr>
</tbody>
</table>

Abbreviations: DISC: Datalys Injury Statistics Clearinghouse; Ref: Referent; OR: odds ratio; 95% CI: 95% Wald confidence interval. Non-overlapping 95% Wald confidence intervals indicate significance at P < 0.05. * P < 0.05

Discussion

Eblin et al. (19) conducted a review of the literature relating to potential and known risk factors associated with an augmented recovery period after sustaining a SRC. Researchers categorized risk factors dichotomously: 1) primary risk factors that influence and increase the risk of a SRC and 2) secondary risk factors that increase the likelihood of an amplified recovery outcome (time). Primary risk factors included: sport type and setting, equipment, genetics, history of concussion, etc., while, secondary risk factors included: demographic factors, on-field signs and symptoms, and acute presentation (< 1
week of injury). Equipment in sports, specifically helmets and other protective headgear, have been improved over the years to diminish the risk of more severe SRCs and ultimately to decrease the risk of SRCs.

However, the most recent estimate of SRC incidence has only decreased by 2% in football when compared to older helmet models (5) in addition to the findings displayed in this study (Table 2) suggesting that the presence of a helmet does not significantly lower the odds of prevented participation after sustaining a SRC when compared to non-helmeted sports in outcomes greater than 24 hours.

Another study conducted by Elbin et al. (20) conducted the first known prospective study to examine the difference in recovery outcomes between athletes who were immediately removed from play after their injury event and athletes who continued to engage in play with a SRC. Their sample contained 69 athletes and were stratified into two groups: 1) the ‘REMOVED’ group contained 35 athletes with a mean age of 15.6 ± 1.7 years, and 2) the ‘PLAYED’ group contained 34 athletes with a mean age of 15.4 ± 1.7 years. Researchers conducted neurocognitive assessments at baseline, 1 to 7 days, and 8 to 30 days after the SRC-event. Athletes in the ‘PLAYED’ group were 8.80 times more likely to have an extended recovery period at ≥ 21 days (P < .001). Researchers also reported that the biggest predictor of return to play was if the athlete had been removed from play following the SRC event, (adjusted odds ratio, 14.27; P = .001), when compared to other predictors such as age, sex, etc.

The present study is not without limitations. First, the cross-sectional study design does not permit causality to be concluded. Second, the sample came from the NCAA-ISP which stemmed from the convenience sampling of colleges and universities across the
Thus the generalizability of the findings is limited to a degree. Third, concussion symptoms were self-reported by the concussed athlete and is thus subjected to recall and reporting bias.

**Conclusions**

In conclusion, the present study illustrates previously un-reported analysis of CSCs with respect to sports that require headgear and gender-stratified athletes not previously seen in the literature. Across every study sample characteristic, athletes reporting symptoms from the Audio-Vestibular CSC exemplified greater risk of a prolonged return-to-play time compared to every other CSC. Further research should be directed at studying CSCs and return-to-play time as a continuous variable in addition to incorporating

**Acknowledgement**

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References


5. Collins M, Lovell MR, Iverson GL, Ide T, Maroon J. Examining concussion rates and return to play in high school football players wearing newer helmet


Vita

Adrian Boltz is a graduate research and teaching assistant in the Clinical and Applied Movement Sciences department at the University of North Florida in Jacksonville, Florida. He completed his undergraduate coursework at Appalachian State University located in Boone, NC, where he earned his Bachelors of Science degree in Exercise Science in addition to a Minor in Chemistry.

His research study and primary focus has been on associations between specific types of concussion symptoms and their risk of prolonged return-to-play time in U.S. NCAA student athletes. He is from Boca Raton, FL and currently resides in Jacksonville, Florida.