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Audiovestibular Symptoms as Predictors of Prolonged Sports-Related Concussion Among NCAA Athletes

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Objective: We looked to determine the rates of audiovestibular symptoms following sports-related concussions among collegiate athletes. Further, we assessed the correlation between these symptoms and the time to return to participation in athletic activity.

Study Design: Retrospective analysis of the National Collegiate Athletic Association Injury Surveillance System (NCAA-ISS).

Methods: The NCAA-ISS was queried from 2009 through 2014 for seven men's sports and eight women's sports across divisions 1, 2, and 3. Injuries resulting in concussions were analyzed for audiovestibular symptoms, duration of symptoms, and return to participation times.

Results: From 2009 to 2014, there were 1,647 recorded sports-related concussions, with athletes reporting dizziness (68.2%), imbalance (35.8%), disorientation (31.4%), noise sensitivity (29.9%), and tinnitus (8.5%). Concussion symptoms resolved within 1 day (17.1%), within 2 to 7 days (50.0%), within 8 to 30 days (25.9%), or persisted over 1 month (7.0%). Return to participation occurred within 1 week (38.3%), within 1 month (53.0%), or over 1 month (8.7%). Using Mann-Whitney U testing, overall symptom duration and return to competition time were significantly increased when any of these symptoms were present ($P < 0.05$). Duration of concussion symptom correlated with dizziness ($P = 0.043$) and noise sensitivity ($P = 0.000$), whereas return to participation times correlated with imbalance ($P = 0.011$) and noise sensitivity ($P = 0.000$). Dizziness and imbalance (odds ratio: 4.15, confidence interval: 3.20–5.38, $P < 0.001$) were the two symptoms with the strongest association.

Conclusion: Audiovestibular symptoms are common complaints among collegiate athletes sustaining concussions. Dizziness and noise sensitivity correlated with the duration of concussive symptoms, whereas imbalance and noise sensitivity was correlated with prolonged return to competition time.

Key Words: Concussion, audiovestibular symptoms, sports-related concussion, NCAA athletes.

Level of Evidence: 4.

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INTRODUCTION

The annual estimate of sports-related concussions in the United States is between 1.6 and 3.8 million cases,[1] with 90% resolving within 7 to 10 days.[2] Concussions produce a variety of symptoms, with headache commonly reported in 85.2%, followed by dizziness in 77.0% of collegiate athletes.[3] Vestibular disturbances such as dizziness have been well documented and play an important role in postconcussion morbidity.[4] Symptoms include imbalance, tinnitus, lightheadedness, and blurred vision and/or photophobia.[5]

There has been growing interest in predicting the natural history of concussions based on presenting symptoms,[6–8] with dizziness at the time of injury associated with protracted recovery time.[9,10] Others have found that imbalance had no association with the duration of sports-related concussion symptoms.[11] Nonetheless, determining risk factors for a prolonged concussion course provides clinicians with improved decision making with respect to return to competition.[9]

Since 1982, the National Collegiate Athletic Association (NCAA) utilizes the Injury Surveillance System (ISS) as a way to analyze injuries among their athletes and improve player safety.[12] This information has been collected and maintained by the Datalys Center for Sports Research and Prevention, Inc., Indianapolis, Indiana, and is based on a convenience sample of voluntary reporting athletic trainers.[13] A recent descriptive study of concussions from this database noted headache and dizziness as the most common symptoms, with 60.1% of concussions resolving within 1 week.[14] However, the influence a particular symptom had on the duration of sports-related concussion among these NCAA athletes was not included.

To date, there is little within the otolaryngology literature exploring the quality or natural history of postconcussive hearing or balance symptoms. We looked to determine the relationship between various vestibular symptoms and the length of concussion. Through a retrospective analysis of the NCAA-ISS, our primary objective was to determine rates of audiovestibular symptoms following sports-related concussions among collegiate athletes. As secondary outcomes, we assessed the correlation between these symptoms on

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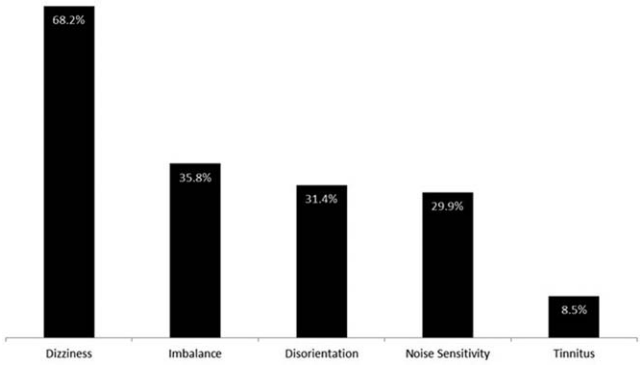

Fig. 1. Rates of vestibular symptoms among National Collegiate Athletic Association student athletes sustaining sports-related concussions. Numbers represent percent of concussions presenting with the respective symptom. Of note, athletes are able to report multiple symptoms.

duration of concussion, time to return to athletic activity, and which symptoms tended to occur together at presentation.

MATERIALS AND METHODS

The Upstate Medical University Institutional Review Board approved this retrospective study and the Datalys Center Independent Review Committee with the National Collegiate Athletic Association (NCAA) authorized the release of the data. The NCAA-ISS releases data in 5-year intervals, with the most recent release spanning the 2009 to 2010 through 2013 to 2014 academic years. A total of 15 core NCAA-sponsored team sports included in this dataset, which contains seven men's sports and eight women's sports from divisions 1, 2, and 3. A team is included based on a convenience sample of athletic trainers.

The data is divided into exposures and injuries. An exposure is an organized team practice or competition, occurring during preseason, regular season, or postseason. When an individual athlete participates in these events, it is defined as an athlete exposure. The exposure, as recorded in the dataset, includes information on the sport, year, division, competition type, and season. An injury must have occurred as a result of participation in an organized intercollegiate practice or competition and necessitated attention from an athletic trainer or physician. Each injury includes a unique identifier along information on the sport, year, division, competition type, season, injury type, mechanism, and outcome. No identifying information is included.

For the purposes of this study, we looked at the concussion information from the most recent dataset. A diagnosis of concussion was based on the medical expertise of the athletic trainer or team medical staff. The NCAA-ISS provides a 17-item checklist that an athletic trainer utilizes to describe the athlete's presenting symptoms. From this list, disorientation, dizziness, imbalance, noise sensitivity, and tinnitus were the symptoms related to hearing or balance disturbance. The dataset grouped duration of symptoms as lasting less than 1 hour, between 1 hour and 1 day, between 1 day and 3 days, between 3 days and 1 week, between 1 week and 2 weeks, between 2 weeks and 4 weeks, and over 4 weeks. For clarity purposes, we grouped these results into 1 day or less, 2 to 7 days, 8 to 30 days, or greater than 30 days. Further, the return to play time was recorded for each injury. Although grouped to less than 24 hours, 1 to 6 days, 7 to 13 days, 14 to 28 days, and over 28 days, we preferred to organize these into less than 1 week, 2 to 4 weeks, or greater than 4 weeks.

The data was organized into Microsoft Excel 2010 (Microsoft Corp., Redmond, WA). Analysis was performed using SPSS 22 (IBM Corp., Armonk, NY). Rates of specific injury, duration of concussion symptoms, and return to play time are presented in percentages based on categorical groupings. We utilized Mann Whitney U testing to determine if the presence of a particular symptom significantly increased concussion duration or return to competition. Multiple ordinal regression modeling was used to determine which symptom variables were associated with increased concussion duration or delayed return to competition. Chi-squared testing was used for categorical data to determine which pairs of audiovestibular symptoms were most strongly associated. Values were determined to be statistically significant if $P < 0.05$.

RESULTS

Between 2009 and 2014, the NCAA-ISS recorded 1,647 sports-related concussions among male and female student athletes. From the defined 17 symptom groupings, athletes reported dizziness in 68.2%, imbalance in 35.8%, disorientation in 31.4%, noise sensitivity in 29.9%, and tinnitus in 8.5% of concussions (Fig. 1). When athletes presented with any of these five symptoms, resolution of their concussion occurred within 1 day for 17.1%, within 2 to 7 days for 50.0%, within 8 to 30 days for 25.9%, or over 1 month for 7.0% (Fig. 2). Return to competition occurred for 38.3% within 1 week, 53.0% between 2 to 4 weeks, and greater than 4 weeks for 8.7% (Fig. 3).

Table I shows the results of analysis on these audiovestibular symptoms with respect to concussion duration and return to competition times. The presence of each of these symptoms strongly correlates with both the duration of concussion and the return to competition time based on Mann Whitney U testing. However, based on multiple ordinal regression modeling, concussion symptoms persisted longer when dizziness ($P = 0.043$) and noise sensitivity ($P = 0.000$) were present, and athletes

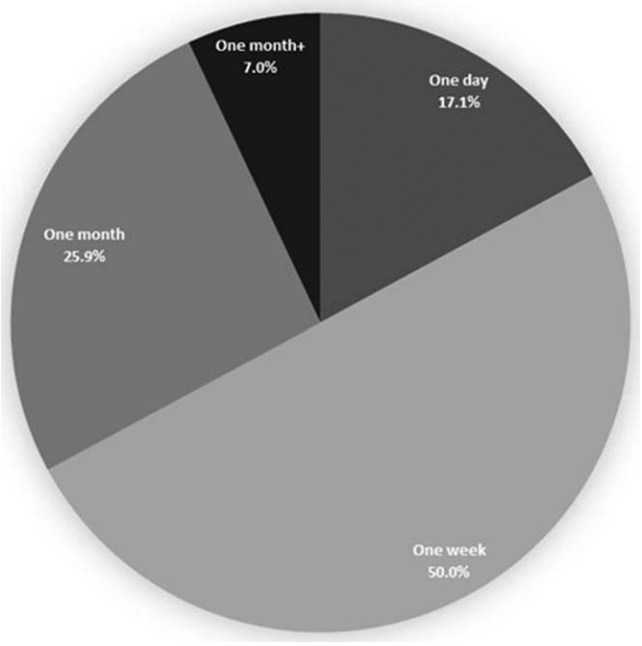

Fig. 2. Duration of sports-related concussion among athletes presenting with audiovestibular symptoms.

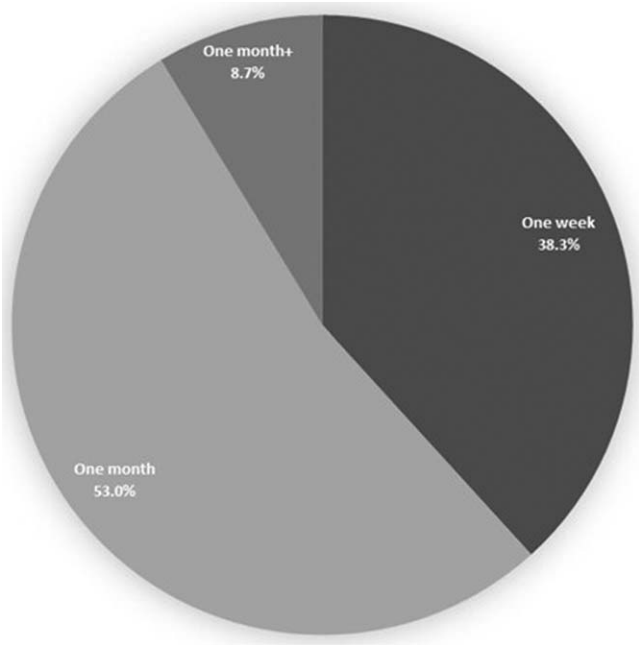

Fig. 3. Time to return to competition after sports-related concussion among athletes presenting with audiovestibular symptoms.

took longer to return to participation if they complained of imbalance ($P = 0.011$) and noise sensitivity ($P = 0.000$) (Table I).

Looking at symptoms occurring together, dizziness and imbalance (odds ratio [OR]: 4.15, 95% confidence interval [CI] 3.20–5.38, $P < 0.001$) were the most strongly associated (Table II). Imbalance and disorientation (OR 3.45, 95% CI 2.77–4.29, $P < 0.001$) and noise sensitivity with tinnitus (OR 3.21, 95% CI 2.26–4.56, $P < 0.001$) were also strongly associated. Of note was that each of the symptom groupings tended to be significantly correlated ($P < 0.05$).

DISCUSSION

This analysis of NCAA student athletes suggests that dizziness, noise sensitivity, and imbalance, if present during initial concussion evaluation, are associated with prolonged concussion duration. This is one of the largest published cohort evaluating the predictive nature of concussion symptoms. Prior literature has described delayed recovery from concussions as predicted by dizziness, visual impairment, migraines, amnesia, history of concussion, and patient age.[11] Notably, the reporting of dizziness among high school football players has been shown to have a significant impact on concussion duration[9] and has been shown to be a predictor of prolonged recovery.[10] Although loss of consciousness and retrograde amnesia traditionally have been considered severe symptoms, they have minimal impact on concussion duration based on several reports.[8,9]

The finding of longer concussion duration with dizziness should alert those evaluating that these athletes may need cautious and protracted follow-up. Given athletic demands on the vestibular system, it may not be particularly surprising that those athletes with symptoms of dizziness or imbalance are prone to prolonged return to activity.

Our focus on vestibular-specific symptoms supports an association with noise sensitivity, imbalance, and concussion duration. Of note, imbalance applied only to longer return to competition times, whereas noise sensitivity yielded longer symptom duration and return to competition. Noise sensitivity after concussion has been found in 50% to 60% of collegiate football players but was not associated with prolonged or more severe concussions within this group.[3] Imbalance, however, has been shown as having no impact on concussion duration among high school football players.[11] We believe that these vestibular symptoms warrant special focus by those caring for concussed athletes. Further, we believe

TABLE I.
Multiple Ordinal Regression Modeling of Various Audiovestibular Symptoms and Association With Resolution of Symptoms and Return to Competition.

	Resolution of Symptoms			
	Parameter Estimate	Standard Error	95% Confidence Interval	*P* Value
Dizziness	−0.229	0.113	−0.451, −0.008	0.043
Imbalance	−0.128	0.112	−0.347, 0.092	0.253
Disorientation	−0.138	0.112	−0.356, 0.081	0.217
Noise sensitivity	−0.957	0.113	−1.179, −0.734	0.000
Tinnitus	−0.096	0.182	−0.453, 0.261	0.598

	Return to Competition			
	Parameter Estimate	Standard Error	95% Confidence Interval	*P* Value
Dizziness	−0.095	0.112	−0.314, 0.125	0.400
Imbalance	−0.286	0.112	−0.506, −0.066	0.011
Disorientation	−0.087	0.112	−0.306, 0.132	0.132
Noise sensitivity	−0.829	0.115	−1.055, −0.603	0.000
Tinnitus	−0.151	0.180	−0.504, 0.202	0.403

TABLE II.
Association Between Presenting Audiovestibular Symptoms Based on Odds Ratios.

	Odds Ratio	95% Confidence Interval	*P* Value
Dizziness and imbalance	4.15	3.20, 5.38	<0.001
Imbalance and disorientation	3.45	2.77, 4.29	<0.001
Noise sensitivity and tinnitus	3.21	2.26, 4.56	<0.001
Dizziness and noise sensitivity	2.95	2.27, 3.83	<0.001
Dizziness and tinnitus	2.84	1.76, 4.57	<0.001
Dizziness and disorientation	2.67	2.08, 3.44	<0.001
Imbalance and tinnitus	2.37	1.67, 3.36	<0.001
Imbalance and noise sensitivity	2.32	1.87, 2.88	<0.001
Tinnitus and disorientation	1.46	1.03, 2.09	0.045
Noise sensitivity and disorientation	1.43	1.15, 1.79	0.002

Symptom combinations ranked in order of decreasing odds of being associated with one another.

our analysis on the association between symptom groupings to be the first of its kind in the literature. The association between dizziness and imbalance, along with imbalance and disorientation, tended to correlate the strongest. Future studies will hopefully determine why certain audiovestibular symptoms tend to occur together.

The pathophysiology of the audiovestibular symptoms in concussions is unclear. It has been found in prior work that concussion-related vestibular dysfunction may be related to injury to the peripheral vestibular system[15,16] and cerebellum.[17] Impairment of the vestibular ocular reflex has been reported[15,16] and may partially explain the delay in return to athletic activity because this is fundamental to the maintenance of balance with rapid head movements. It is not clear whether these symptoms reflect a true labyrinthine concussion. Although the etiology of the vestibular symptoms is beyond the scope of this project, this work suggests that involvement of the vestibular system in sports-related concussions may have some prognostic value. There are several limitations to this study: We are limited by the accuracy of the ISS database, including the duration of symptoms or return to competition group as time frames as opposed to specific values. Further, the description of symptoms, as provided by the athlete, are inherently subjective, with unclear definitions for dizziness versus imbalance. Athletes and the trainers who evaluate them do not have a strict definition for the symptoms recorded. Finally, the ISS relies on a convenience sample of reporting athletic trainers. Therefore, the ability to generalize to all collegiate athletes may be limited.

CONCLUSION

Audiovestibular symptoms are common complaints among collegiate athletes sustaining concussions. Dizziness and noise sensitivity correlated with the duration of concussions, whereas imbalance and noise sensitivity correlated with prolonged return to competition time. Future work will look at the role that vestibular symptoms play in scheduling the safe return for the concussed athlete.

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