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Academic Difficulty and Vision Symptoms Children with Concussion

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Abstract

Purpose—Academic difficulty is reported in children with prolonged post-concussive symptoms. Despite growing evidence that vestibular-ocular and vision-specific dysfunction are common in children following concussion, vision is rarely mentioned in return-to-learn protocols. The purpose of this project was to evaluate a cohort of children with prolonged post-concussive symptoms to determine if vision symptoms are associated with those reporting academic difficulty.

Methods—Data was obtained from the Children's of Alabama Concussion Clinic REDCap dataset from the period January 2007 to October 2013. From this dataset of 1,033 concussion events, a cohort of 276 children aged 5–18 years with three or more concussion-related symptoms present for 10 days or more was identified. A cross-sectional cohort study was undertaken to evaluate the association of concussion symptoms, SCAT2 scores, demographic and concussion severity markers to reported educational difficulty among children with prolonged post-concussive symptoms. Univariate and multivariate logistic regression techniques were used to model the association of reported educational difficulty to self-reported vision abnormalities.

Results—Mean age was 13.8 years. Median time since the concussive event was 21 days, with 33% (95/276) reporting their concussion more than thirty days prior to data collection. Academic difficulty was reported by 29% (79/270) and vision abnormalities in 46% (128/274). After model reduction, vision symptoms (OR 2.17, 95% CI 1.02, 4.62), hearing disturbance (OR 2.39, 95% CI 1.06, 5.36) and concentration difficulty (OR 21.62, 95% CI 9.50, 44.47) remained associated with academic difficulty. For those with symptoms 30 days or more after concussion, only vision (OR 3.15, 95% CI 1.06, 9.38) and concentration difficulty (OR 15.33, 95% CI 4.99, 47.05) remained statistically significant.

Conclusions—Vision problems were commonly reported in children with concussions and were independently associated with those reporting academic difficulty. Comprehensive vision

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assessment should be considered in children reporting academic difficulty and in the development of return-to-learn protocols.

Keywords

concussion; school; education; vision; mild traumatic brain injury

The Center for Disease Control (CDC) reported that between the years 2001 and 2009, the estimated rate of childhood traumatic brain injury (TBI) visits to an emergency department increased by 57% from 190 to 298 per 100,000,[1] CDC data also indicate that children are more likely than any other group to present to emergency departments with concussions.[2] Fortunately, the majority of concussions resolve within 7 to 10 days without complications.[3] Reports of symptoms lingering longer than a month in the pediatric population vary widely from 1 to 38%, with longer duration often resulting in academic difficulty.[4–9] In a sample of children with concussion aged 5 to 18 years, a majority of children who were symptomatic for more than four weeks were prescribed school accommodations and reported a decline in grades.[10] The same children required a median time of over one month to return to school without accommodations and a median time of over two months before they were symptom-free.[10]

In the immediate aftermath of a concussion, the current standard treatment is a prescribed period of "cognitive rest."[11] Following cognitive rest, two main concerns remain dominant: "*when it is appropriate to "return to learn*" and "*when it is appropriate to "return to play*." In the interest of the safety of athletes, extensive literature has developed around "return-to-play" guidelines. The backbone of this literature is the Zurich Consensus Report, which provided guidelines for return to play and has received widespread adoption.[3] "Return to learn" has received less attention. In a survey submitted to athletic trainers in all NCAA member institutions, 97% of respondents had return-to-play policies, while only 63% reported having return-to-learn policies.[12]

In order to develop return-to-learn protocols, it is important to understand which symptoms are associated with academic difficulty. There is growing literature that the vestibular system is affected in children with concussion.[13,14] Not surprisingly, there have also been reports of alterations in the vestibular-ocular responses in a majority of children with concussion.[15,16] Referral to vestibular therapy in children with prolonged symptoms is common.[17,18] However, despite growing evidence that also non-vestibular oculomotor vision tasks, including convergence, accommodation, saccadic transfers of gaze, and smooth-pursuit tracking are affected in a majority of children.[19–24] and that children with convergence insufficiency have greater total symptom scores,[24] vision is rarely mentioned in return-to-learn protocols.[11,25–27] Just over one third of responding athletic trainers from the NCAA reported testing Snellen visual acuity and fewer than 5% reported testing saccadic eye movements with King-Devick.[12] The 2014 National Athletic Trainers' Position Statement recommended testing smooth pursuits, nystagmus, and pupil reflex and did not include convergence and accommodation testing, or comprehensive eye tracking evaluations in the recommended assessment protocols.[28]

Given the prevalence of vestibular, vestibular-ocular, and vision-specific dysfunction in children following concussion, there is potential to include both vestibular and vision assessments in return-to-learn protocols. The purpose of this project was to evaluate a cohort of children with prolonged post-concussive symptoms to determine if vision symptoms are associated with increased academic difficulty.

METHODS

Data Set

Children's of Alabama (COA) is the only dedicated children's hospital in the state of Alabama and is one of the largest children's healthcare facilities in the country. The hospital supports more than 600,000 outpatient visits annually.[29] In 2007, the faculty and staff of COA recognized the potential impact of concussion on their patients and began systematically collecting data on consecutive cases of children who presented to the hospital with a concussion. From 2007 to 2011, these children were evaluated by a group of physicians affiliated with the University of Alabama at Birmingham (UAB) departments of sports medicine, neurosurgery, neurology, and emergency medicine. Only data from children with a COA physician-diagnosed concussion were entered into the database system. Similar to many other states, Alabama passed mandatory concussion evaluation legislation in 2011. In Alabama, this law covers both recreational and state-supported athletic programs. It mandates that children with a suspected concussion occurring during practice or a game be immediately removed from play and medically cleared by a physician before returning to play. This law has resulted in a dramatic increase in the number of children being diagnosed with concussion in the state. To respond to this increased need, COA began a specialized multidisciplinary clinic for the evaluation and treatment of children with concussion in August 2011. Data available after August 2011 is directly from the COA Concussion Clinic. Typical entry points into the concussion clinic are from COA Emergency Department or by referral from pediatricians and primary medical care specialists within the community.

Information included in the dataset is collected from both parents and children at the point-of-care. This data includes general demographic information, concussion event history, prior medical history, symptom history, and results from the Sports Concussion Assessment Tool 2 (SCAT 2).[30] Data collected at both the concussion clinic and in that collected prior to formal concussion clinic founding have been stored in the Research Electronic Data Capture (REDCap) management system.

Analysis

A cross-sectional study nested within a cohort follow-up was undertaken to evaluate the association of concussion symptoms to reported educational difficulties among children with prolonged post-concussive symptoms. Data were obtained from the Children's of Alabama Concussion dataset from the period January 2007 to October 2013. During this time frame, 1021 children were evaluated with 1,033 concussion events. As part of the data collected each parent/subject dyad was asked to define the date on which the current concussion occurred (index date). For each subject the data analyzed was from the first COA clinic visit after the index date. Data collected included questions about thirteen symptoms typically

associated with a concussion. From this series of questions and time since index date, a subset of children with prolonged post-concussive symptoms was identified. Prolonged symptoms were defined as having three or more concussion symptoms present for 10 days or more after an acute concussive event. The subset was limited to children 5 to 18 years of age. A total of 276 children met these entry criteria. Our primary symptom of interest was reported vision problems. The University of Alabama at Birmingham Institutional Review Board approval was granted for this project and all data collection and analysis followed the tenets of the Declaration of Helsinki.

A yes/no question within the dataset specifically asked if the child was having academic difficulty after the concussive event. The response to this question was used as the dependent variable. Other variables of interest were demographic history, age at the time of concussion, race, gender, and insurance type. Race was categorized as a three level variable of white, black and other. Socio-economic status was not available and insurance type was included as a proxy. More than two-thirds of the general clinical population at COA qualifies for public assistance insurance (Medicaid and Alabama Child Health Insurance Program) due to financial status. Insurance was coded as public, private, or none. Glasgow Coma Scale scores were not available from the date of injury; however, three questions were available which gave an indication of concussion severity: whether loss of consciousness occurred, whether neuro-imaging was ordered, and whether there was amnesia associated with the event. The Sports Concussion Assessment Tool 2 (SCAT-2) is a multidimensional instrument which captures severity on a 1–6 scale about 22 concussion-related symptoms. It also includes the Glasgow Coma Scale Score results, the Maddock's sideline assessment, a brief physical assessment, a cognitive assessment, and a balance assessment. SCAT2 data available within the dataset included an overall SCAT score, and subset scores for symptoms, the symptom severity score, the cognitive sub-score and the balance sub-score. The total SCAT2 score is scaled such that higher scores indicate better performance. For the symptom subscale, the number of symptoms present is subtracted from 22 to give the final symptom score (see Table 1). For consistency in this report Symptom Scale score refers to 22 minus the number of symptoms. The cognitive assessment and balance subscales are treated similarly with errors subtracted from a best possible score of 30 for each. In contrast, the symptom severity is scored with higher numbers indicating worse symptomatology with a maximum possible of 132.

Univariate and multivariate logistic regression techniques were used to model the association of vision and reported academic difficulty. All demographic, symptom, and event variables univariately associated (Table 1) with academic difficulty were entered into a multivariate model. Backward stepwise regression was used for variable retention. Those with p value <=0.1 were retained in the subsequent models. Independent variable reduction was done till the fewest number of significant variables in a stable model was achieved. Akaike Information Criterion (AIC) and concordance c were used to compare models.[31] Concordance c provides an area under the receiver operator curve for logistic regression models while a 2 units reduction in AIC is consistent with an improved model.[31] Given that there is no clear time frame for defining post-concussion syndrome, models were repeated for those with symptoms present longer than 30 days. Since the overall SCAT2 score is a composite of sub-scale scores, separate models were completed for the SCAT2 and each

univariately associated sub-scale score. Post-hoc analyses of non-parametric correlations with the variable concentration difficulty were done. All analysis was done in SAS version 9.4.

RESULTS

Mean age of the children in this cohort was approximately 14 (SD± 2.7). The overwhelming majority were aged 11 and older (84%). Racial characteristics were representative of the area's population with the majority being white. Males (63%) were overrepresented. A much higher percentage of those in this cohort had private insurance than is seen in the hospital's general population. This is suggestive that this cohort has a higher socio-economic status than is typical for COA. Mean number of days since the concussive event was 43(SD±63) days with the median 21(range 11–397). Ninety-five children (34%) reported experiencing a concussion more than thirty days prior to intake with the most remote about 13 months prior. Two outliers with concussion 731 and 949 days prior to intake were removed for analysis as these were significantly different than the remainder of the cohort and may not represent the typical clinical patient. In analyses, their exclusion had no impact on the results.

For the majority of the sample, the presenting concussion was their first treated at the COA; however, almost 30% (75/271) reported experiencing one or more prior concussions. Loss of consciousness (25%), amnesia at around the time of the event (32.6%), and having neuro-imaging at the time of the acute event (21%) were relatively infrequent, consistent with most of this cohort having a mild TBI. Full scale SCAT scores were available for 87% (240/276), while subscales had a significantly higher amount of missing data (range 107–109 subjects). The mean number of symptoms (22-symptom scale score) for those with documented SCAT symptom subscale scores was 9 (SD ±6.7). The mean symptom severity scale was 24 (SD ±26). Coupled together with symptom numbers, this indicates that the majority of children reported having multiple relatively low severity symptoms. The general cohort characteristics are found in Table 1.

Academic difficulty at the time of the intake was reported by 29% (79/270). It was slightly more common among children under age 11(33%) compared to those 11 and older (28%). Headaches were by far the most common post-concussive symptom, and almost universal in this group (98%). This was followed in frequency by dizziness (70%) and a cluster of symptoms including fatigue, vision abnormalities, nausea, concentration difficulty each having prevalence rates between 40–50%. Balance problems, confusion, hearing disturbance, irritability, sleep disturbance, and vomiting were less common and were still noted by 20–30%.

In univariate analysis, none of the demographic variables were significantly associated with academic difficulty (see Table 1). Among the event severity related variables, only amnesia was significantly associated. With the exception of headaches (Table 1), all the symptom variables had an association with academic difficulty. Interpretation of the SCAT2 subscale scores is tempered by missing data and possible data collection bias. Subjects having subscale scores documented were far more likely (40%, $p<0.001$) to report academic difficulty than those with incomplete subscale scores (12%). This likely indicates that

subscale data was more frequently collected on more symptomatic children. Given this caution, the full scale SCAT2 score, the symptom score and symptom severity score were all associated with reported academic difficulty. (Table 1) Interestingly, the cognitive and balance subscales were non-significant. In contrast, the independently reported symptoms concentration difficulty, confusion and balance difficulty were all univariately associated with education difficulty.

The SCAT2 full scale, Symptom Scale, and Symptom Severity scores were modeled with the event related variable amnesia. Given their co-variance the Symptom Score and Severity score were evaluated separately as well as together. In each model amnesia around the time of the concussion was strongly associated with reported academic difficulty.(Table 2) The association of reported amnesia with academic difficulty was moderated when symptoms alone are controlled (OR 3) compared to the Full SCAT score (OR 5.6). As would be expected given the scoring algorithms higher SCAT2 full scale and Symptom Scale scores were associated with reduced odds of academic difficulty. The Symptom Severity scale is reversed (larger number worse) compared to the Symptom Score and Full Scale score and a higher symptom severity score was associated with increased odds of academic difficulty when modeled with amnesia. Both the Symptom Score and Severity provide an improved model compared to the Full scale score, with greater area under the ROC curve(c statistic) and better model fit(lower AIC) compared to the Full Scale score. Taken in total, this seems to point to specific symptoms as the possible drivers of the association between SCAT2 and reported academic difficulty.

All the individual symptoms for those meeting inclusion criteria (3 or more symptoms for 10 days or more), except headache, were entered into a model with amnesia. (Table 3) After reduction, three variables: concentration difficulty, vision difficulty, and hearing disturbance, were associated with reported academic problems in the most parsimonious model. The area under the ROC curve(c) for the reduced model is almost identical with better fit (AIC) than the initial. In the reduced model, vision and hearing were associated with a doubling of the odds of academic difficulty. Having both sensory problems appears not to be associated with increased odds of academic difficulty. In a sub-analysis, there was no indication of an interaction between vision and hearing (p=0.38). While the confidence limits are wide, concentration difficulty accounts for the majority of the model correlation with academic difficulty, with a 21-fold increase in the estimated odds in the final model. AIC and concordance do however indicate model improvement (c=8%, AIC-10) with the addition of the sensory variables. Similarly, for those with three symptoms present 30 days or more after a concussive event, only vision (OR 3.15, 95% CI 1.06, 9.38) and concentration difficulty (OR 15.33, 95% CI 4.99, 47.05) remained statistically significant in a reduced model.

Difficulty with concentration intuitively may have many underlying causes and was moderately to weakly associated with a number of other symptom related variables. (Table 4) The strongest correlations were with amnesia around the time of the concussion, confusion and the SCAT Symptom Score. Vision difficulty only shows modest correlation with concentration difficulty, which may explain why vision is retained in reduced models.

DISCUSSION

"Return to learn" is an important issue in concussion that would benefit from more evidence-based protocols. In this pediatric population, vision problems were independently associated with children reporting academic difficulty. This was true for those with symptoms persistent more than 10 days and more than 30 days after a concussion event. This should come as no surprise as learning is a highly vision-dependent task with more than thirty areas within the brain devoted to vision.[32] In addition, damage to central vestibular pathways may contribute to visual instability with head movement. Reports of vision-related symptoms due to mild traumatic brain injury from pressure waves have been available since the beginning of the Gulf Wars.[22] More recently, this has been extended to non-military mild TBI with an emphasis on sports-related concussion.[9,19,24,33–34]

Reporting of vision symptoms with sports-related concussion is frequently broken down into two restrictive components: light sensitivity and blurred vision. This is likely related to analyses originating in the SCAT symptom surveys, which have one question each on light sensitivity and blurred vision. Post-concussion light sensitivity has been reported in 15–52% of pediatric patients, with blurred vision reported in 23–39%.[9] Fewer reports are available of post-concussion clinical vision assessment post-concussion in children. Master et. al. have recently reported almost 70% of children 11–17 seen for clinical evaluation after concussion had accommodative, binocular vision or saccadic abnormalities.[19] Pearce and colleagues have reported that over 40% of their pediatric study population had reduced near point of convergence one month after concussion.[24] The reported rate of vision symptoms in this cohort is consistent with these previous studies. Given that poor near accommodation and convergence can cause symptoms of blurred vision, standard Snellen far distance visual acuity testing alone may not be capturing intermittent problems occurring with deskwork.

While vision problems appear to play a role in patients reporting academic difficulty, it is important to note that the key symptom identified in this study is difficulty with concentration. Difficulty with concentration is thought to be related to executive function, which involves planning and coordination of purposeful activity. Executive function is in turn related to attention. Clinical assessment and laboratory-based evaluations have shown that executive function and task attention tasks may be impaired for two months or more after concussion in adolescents.[33] An association between concussion and Attention Deficit Hyperactivity Disorder is also well documented.[34] The direction of this association is however less clear.

While there are abundant guidelines on returning to learn after concussion, there is a dearth of supporting data. Purcell and colleagues have reported a post-concussion median return-to-learn time in a group of 8–12 year olds post-concussion of 4.5 days and of 2.5 days in 13–17 year olds.[35] Baker et. al. reported on a cohort of children 13–19 post-concussion looking specifically at the issue of difficulty returning to school.[36] One-third of their subjects had difficulty with return to school. Within this study, initial concussion severity and number of symptoms were associated with academic difficulty while demographic variables were not. This is consistent with our findings as well. Corwin et. al.'s study of a hospital-based concussion clinic found a median return to school part time of 12 days and median complete

return to school without accommodations of 35 days.[10] Almost 75% of subjects in Corwin's study received academic accommodations. The number of patients reporting academic difficulty in our cohort were more similar to those in the Baker study.[10, 36] In the Corwin study, Convergence abnormalities and visual symptoms on oculomotor tasks were associated with time to partial return to school, time to complete return to school and time to complete clearance in the Corwin study.

The results of this study support an association between vision symptoms and academic difficulty after concussion. A number of limitations of this study should be noted. There is no universally agreed upon definition of what constitutes post-concussion syndrome.[37] Most working definitions include three or five symptoms still present a specified time period after a concussion. Our choice of three symptoms was based on this commonly used number. Our choice of 10 days was based on the typical time period for most concussions to become asymptomatic. Other researchers will have equally valid reasons for choosing different criteria. Secondly, the symptom surveys are based on self-report. It is unknown how subjective reports of vision problems in this group might relate to objective, quantitative data from vestibular, oculomotor, and balance tests. Our outcome measure is also self-reported and not verified by school system reports. The finding of no association between academic difficulties and SCAT cognitive scale and an inverse association with balance is counterintuitive. It is possible that these findings are spurious and related to missing SCAT data. Finally, although our findings indicate there is an association between vision and education difficulty, the direction is not known with certainty. It is possible that children with pre-existing vision abnormalities may be more susceptible to academic difficulty after concussion.

Return to learn after concussion is a delicate balance between cognitive rest and rehabilitation, and the academic success of students, which requires an individualized approach. The American Academy of Pediatrics consensus report on returning to learn after concussion prominently lists vision as a common problem, which may interfere with return to learn.[38] No vision specialists, neither optometrists or ophthalmologists, are listed among the medical specialists who may be involved in return-to-learn decisions.[38] This data and other research support vision care providers taking a greater role in the assessment of return-to-learn readiness and potential rehabilitative needs of children with concussion.

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Table 1

Cohort Characteristics and Associations with Academic Difficulty.

			Total		Educational Difficulty		
		N (%)	**Mean (SD)**	**Range**	**Without**	**With**	**p**
Age		276	13.8(2.7)	5.4–17.9	13.7(2.7)	14.1(2.8)	0.37
Days Since Concussion		276	42.7(62.9)	11–397	43.5(68.6)	40.5(45.5)	0.73
Race	White	199(73.2)			137(70.3)	58(29.7)	0.49
	African American	64(23.5)			43(68.3)	20(31.8)	
	Other	9(3.3)			8(88.9)	1(11.1)	
Gender	Male	174(63.3)			127(74.3)	44(25.7)	0.10
	Female	102(36.9)			64(64.7)	35(35.4)	
Insurance	Private	198(73.9)			140(70.7)	58(29.3)	0.91
	Public	70(26.1)			49(70.0)	21(30.0)	
Number of Previous Concussions	0	193(73.4)			137(71.0)	56(29.0)	0.78
	1	50(19.0)			34(68.0)	16(32.0)	
	2	10(3.8)			5(50.0)	5(50.0)	
	3	3(1.1)			3(100)	0	
	4	7(2.7)			6(85.7)	1(14.3)	
Loss of Consciousness	No	190(75.1)			135(71.0)	55(29.0)	0.95
	Yes	63(24.9)			45(71.4)	18(28.6)	
Imaging	No	213(9.2)			152(71.4)	61(28.6)	0.61
	Yes	56(20.6)			38(67.9)	18(32.1)	
Amnesia Event	No	182(67.4)			152(83.5)	30(16.5)	<.001
	Yes	88(32.6)			39(44.3)	49(55.7)	
SCAT Full Scale		240	79.7(10.1)	43–98	81.7(9.6)	75.3(9.6)	<.0001
SCAT Cognitive Subscale		167	25.3(2.6)	15–30	25.4(2.6)	25.2(2.6)	0.68

		Total			Educational Difficulty		
		N (%)	Mean (SD)	Range	Without	With	p
SCAT Balance Subscale		166	24.7(3.6)	12–30	24.7(3.1)	24.8(3.9)	0.85
SCAT Symptom Severity		167	24.0(26.4)	0–126	12.7(6.4)	40.3(30.2)	<.0001
SCAT Symptom Number		169	13.3(6.7)	0–22	16.3(5.5)	8.9(6.1)	<.0001
Balance Difficulty	No	223(82.9)			174(78.0)	49(22.0)	<.0001
	Yes	46(17.1)			17(37.0)	29(63.0)	
Concentration Difficulty	No	162(60.0)			152(93.8)	10(6.2)	<.0001
	Yes	108(40.0)			39(36.1)	69(63.9)	
Confusion	No	181(67.0)			144(79.6)	37(20.4)	<.0001
	Yes	89(33.0)			47(52.8)	42(47.2)	
Dizziness	No	83(30.4)			67(81.7)	15(18.3)	0.009
	Yes	191(69.6)			123(65.8)	64(34.2)	
Fatigue	No	143(52.6)			121(84.6)	22(15.4)	<.0001
	Yes	129(47.4)			68(54.4)	57(45.6)	
Headache	No	5(1.8)			4(80.0)	1(20.0)	0.67
	Yes	269(98.2)			187(71.1)	76(28.9)	
Hearing	No	206(75.2)			163(79.9)	41(20.1)	<.0001
	Yes	68(24.8)			28(42.4)	38(57.6)	
Irritable	No	203(73.8)			160(79.2)	42(20.8)	<.0001
	Yes	72(26.2)			31(45.6)	37(54.4)	
Nausea	No	156(56.5)			118(76.1)	37(23.9)	0.02
	Yes	120(43.5)			73(63.5)	42(36.5)	
Sleep Disturbance	No	214(77.8)			169(79.0)	45(21.0)	<.0001
	Yes	61(22.2)			22(39.3)	34(60.7)	
Slurred Speech	No	261(95.6)			187(72.5)	71(27.5)	0.01

		Total			Educational Difficulty		
		N (%)	Mean (SD)	Range	Without	With	p
	Yes	12(4.4)			4(36.4)	7(63.6)	
Vision	No	146(53.3)			120(82.8)	25(17.2)	<.0001
	Yes	128(46.7)			71(56.8)	54(43.2)	
Vomiting	No	216(78.7)			159(74.3)	55(25.7)	0.01
	Yes	59(21.3)			32(57.1)	24(30.4)	
Educational Difficulty	No	191(70.7)					
	Yes	79(29.3)					

Table 2

SCAT2 and Educational Difficulty.

	SCAT Full Scale			SCAT Symptom Score			SCAT Symptom Severity			Symptom Score and Severity		
	OR	**95% CI**	**p**	**OR**	**95% CI**	**p**	**OR**	**95% CI**	**p**	**OR**	**95% CI**	**p**
Amnesia Event	5.63	2.93, 10.81	<0.001	3.02	1.40, 6.48	<0.001	3.25	1.52, 6.95	0.003	2.99	1.38, 6.45	<0.001
SCAT Full Scale	0.95	0.92, 0.98	<0.001									
SCAT Symptom Score				0.84	0.79, 0.90	<0.001				0.90	0.83, 1.02	0.19
SCAT Symptom Severity							1.05	1.03, 1.07	<0.001	1.02	0.99, 1.06	0.09
c[1]	0.76			0.83			0.82			0.83		
AIC[2]	229.3			168.2			167.9			167.2		

OR- odds ratio, 95% CI- 95th percent confidence interval, 1-Concordance C 2- Akaike Information Criterion

Table 3

Educational Difficulty and Individual Concussion Symptoms.

Educational Difficulty and Symptoms 10 Days or More after Concussion								
	OR	**LCL**	**UCL**	**p**	**OR**	**LCL**	**UCL**	**p**
Amnesia Event	1.53	0.65	3.60	0.33				
Balance	1.96	0.70	5.52	0.20				
Concentration Difficulty	22.48	8.43	59.94	<.001*	20.55	9.50	44.47	<.001
Confusion	0.39	0.14	1.04	0.06*				
Dizziness	1.30	0.55	3.07	0.54				
Fatigue	1.38	0.60	3.15	0.45				
Hearing	2.20	0.90	5.35	0.08*	2.39	1.06	5.36	0.03
Irritable	0.52	0.21	1.32	0.17				
Nausea	1.29	0.52	3.20	0.58				
Sleep Disturbance	1.90	0.73	4.94	0.19				
Slurred Speech	1.59	0.19	13.57	0.67				
Vision	2.21	0.95	5.14	0.07*	2.17	1.02	4.62	0.04
Vomiting	1.68	0.57	4.97	0.35				
C[1]	0.89				0.88			
AIC[2]	214.0				207.9			

Educational Difficulty and Symptoms 30 Days or More after Concussion								
	OR	**LCL**	**UCL**	**p**	**OR**	**LCL**	**UCL**	**p**
Amnesia Event	1.62	0.34	7.65	0.54				
Balance	2.50	0.50	12.41	0.26				
Concentration Difficulty	24.28	4.40	134.10	<.001*	15.33	4.99	47.05	<.001
Confusion	0.66	0.13	3.42	0.62				
Dizziness	3.52	0.86	14.41	0.08*				
Fatigue	1.74	0.43	7.02	0.44				
Hearing	1.03	0.24	4.40	0.97				
Irritable	0.16	0.03	0.96	0.04*				

Educational Difficulty and Symptoms 30 Days or More after Concussion								
	OR	**LCL**	**UCL**	**p**	**OR**	**LCL**	**UCL**	**p**
Nausea	1.45	0.32	6.65	0.63				
Sleep Disturbance	0.76	0.15	3.88	0.75				
Slurred Speech	Tf	Tf	Tf	Tf				
Vision	4.62	1.05	20.36	0.04*	3.15	1.06	9.38	0.04
Vomiting	0.64	0.10	4.22	0.64				
C[1]	0.88				0.83			
AIC[2]	101.2				91.1			

OR –odds ratio, LCL- lower 95% confidence limit, UCL- upper 95% confidence limit, *- variable retained from initial model, Tf-too few observations for estimate, c- Concordance c value, AIC- Akaike Information Criterion

Table 4

Correlation between Concentration Difficulty and Concussion Variables.

	Amnesia Event	Loss of consciousness	Imaging	Balance	Confusion	Dizziness	Fatigue	Headache	Hearing	Irritable
Rho	0.50	−0.04	−0.02	0.34	0.41	0.17	0.39	0.06	0.32	0.50
p	<.001	0.58	0.79	<.001	<.001	0.003	<.001	0.35	<.001	<.001
N	274	257	274	273	274	273	272	273	274	275

	Nausea	Sleep Disturbance	Slurred Speech	Vision	Vomiting	SCAT Symptom	SCAT Symptom Severity	SCAT Cognitive	SCAT Balance	SCAT Full Scale
Rho	0.07	0.37	0.12	0.24	0.07	0.61	−0.59	−0.01	0.07	−0.29
p	0.26	<.001	0.06	<.001	0.24	<.001	<.001	0.85	0.35	<.001
N	275	274	273	274	275	167	169	167	166	240

Rho – Spearman's Rho, p - significance, N - number of subjects