

The Impact of the COVID-19 Pandemic on Concussion Symptoms and Recovery Times in Adolescents

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ABSTRACT

After the event of a concussion, patients may experience a combination of cognitive, physical, and affective symptoms that impact their daily life. Management of concussion should consider the various personal histories and external stressors that contribute to a patient's symptom burden and recovery. The aim of this study is to quantify the impact of the COVID-19 pandemic on concussion symptoms and recovery time in a cohort of adolescents. The study is a secondary data analysis of ImPACT Concussion Test symptom scores and electronic health records from a cohort of adolescents between the ages of 12-18, pre-pandemic (January 1, 2015 - March 20, 2020) and pandemic (March 21, 2020 - April 1, 2022). Symptom prevalence of trouble falling asleep, irritability, nervousness, sadness, feeling more emotional, headache, nausea, balance problems, dizziness, sensitivity to noise, sensitivity to light and visual problems were recorded. Recovery times were pulled from patient records on return to full competition. A total of pre-pandemic non-concussed ($n=2104$), pre pandemic concussed ($n=437$), pandemic non-concussed ($n=492$) and pandemic concussed ($n=71$) were included in the final analysis. Adolescents concussed during the pandemic experienced statistically significantly more irritability ($p=0.0008$), nervousness ($p=0.0048$), sadness ($p=0.0018$), feeling more emotional ($p=0.0060$), balance problems ($p=0.0310$), and visual problems ($p=0.0002$) than adolescents concussed before the pandemic. Owing to multiple biopsychosocial considerations, return to activity was prolonged in adolescents concussed during the pandemic as compared to before. Affective symptoms increased during the pandemic in the general pediatric population, however this study demonstrates the additional burden the pandemic had on adolescents with concussion. These findings suggest that affective symptoms place burden on somatic healing from injury, and further encourages a biopsychosocial approach to injury management, in which social and emotional challenges of a patient's life are considered.

Keywords

Adolescents, Concussion, COVID-19, mTBI, Pediatrics, Post-concussion symptoms.

Introduction

Clinical presentation after the event of a concussion often involves cognitive symptoms as well as a combination of affective (nervousness, sadness, irritability, emotionality, depression) and physical symptoms (headaches, nausea, vision issues, balance issues). While affective symptoms resolve in the vast majority of cases, there is a growing body of literature showing that concussions

are associated with increases in mood disorder diagnoses [1-3]. For example, children who experience a mTBI are at increased risk of developing emotional and behavioral challenges following injury [4]. The association is bidirectional as pre-existing depression and anxiety diagnoses were predictors in determining patients at risk for persisting concussion symptoms [5-9]. Taken together, a large body of evidence suggests that mental health factors play an important role in the development of, and risk for, persisting symptoms of concussion in adolescents following head injury. While this research demonstrates an association between mental health diagnoses and concussion symptoms and recovery, less

research looks at the impacts of transient emotional stressors on those with concussion – the COVID-19 pandemic provides a unique setting to do so.

During the COVID-19 pandemic, adolescents reported increases in depression and anxiety symptoms as well as decreased life satisfaction compared to rates before the pandemic, likely owing to limited social interaction, physical activity, and increased isolation [10-13]. These findings are especially concerning when considering adolescents dealing with concussion, where increased external stressors can compound clinical symptoms and impact recovery times [5,14,15]. The emotional burden of physical injury, in addition to the psychosocial challenges of the COVID-19 pandemic, poses challenges for adolescents experiencing concussion during the time of the pandemic. The aim of this study is to quantify the impact of the COVID-19 pandemic on both concussion symptoms and recovery time in a pediatric population experiencing concussion. Our hypothesis was that there would be no difference between pre-pandemic and pandemic symptom reporting in either the non-concussed or concussed adolescent groups, nor would there be any differences in symptom reporting based on gender or age. Also, we anticipated that recovery times would be similar in both groups.

Methods

Study Design

The study is a secondary data analysis of the ImpACT neurocognitive test. Additional data was retrieved from Sportsware database used by our certified athletic trainers (AT) and clinical electronic medical records. All data was de-identified. Waiver of informed consent was approved from St. Charles Health System IRB.

Patients

Data included in the study was extracted from adolescents between the ages 12-18, presenting for ImpACT concussion testing in the Central Oregon region. Pre-pandemic data was pulled between January 1, 2015 - March 20, 2020, and pandemic data was collected from March 21, 2020 - April 1, 2022. To assess non-concussed individuals, data was collected from Baseline ImpACT tests. To

assess individuals experiencing concussion, data was collected from Post-Injury ImpACT tests. A total of four groups were assessed: Pre-pandemic non-concussed, pre-pandemic concussed, pandemic non-concussed and pandemic concussed. Subjects were excluded from the study if they indicated, or failed to indicate, if they received special education, had a previous diagnosis of learning disabilities, attention deficit disorder, autism, or received treatment for headaches, migraines, epilepsy, brain surgery, meningitis, substance use or psychiatric conditions. Exclusion criteria is detailed in Figure 1. Post-Injury ImpACT tests were correlated with injury reports in Sportsware and electronic medical records which confirmed diagnosis of concussion. Definition of concussion was based on injury and presenting symptoms, evaluation by AT with SCAT3 or SCAT5 assessment, BESS testing and ImpACT neurocognitive testing. Release to return to competition was based on The Center Foundation Concussion Protocol: asymptomatic with mental and physical activity, return to learn without accommodations, normalized balance, return to baseline cognitive testing or if no baseline is available then testing within a normalized range and successful completion of return to play protocol. The minimum days to completion of the protocol is 7 days. Student athletes released to full competition less than the minimum of 7 days were defined as not concussed and excluded.

Data Collection

ImpACT is a computerized test that assesses an individual's neurocognitive state before a concussion occurs (Baseline) to provide a reference state for assessment after an injury to the head occurs (Post-Injury). In both the Baseline and Post-Injury test, the user is asked to numerically rate symptoms; data collection on symptoms was extracted from here. If a subject rated a 0, that indicated an absence of that symptom. If a subject rated > 0, that indicated the presence of a symptom. A total of twelve symptoms were assessed and classified as either affective or physical symptoms. Included in affective symptoms were trouble falling asleep, irritability, nervousness, sadness, and feeling more emotional. Included in physical symptoms were headache, nausea, balance problems, dizziness, sensitivity to light, sensitivity to noise and visual problems.

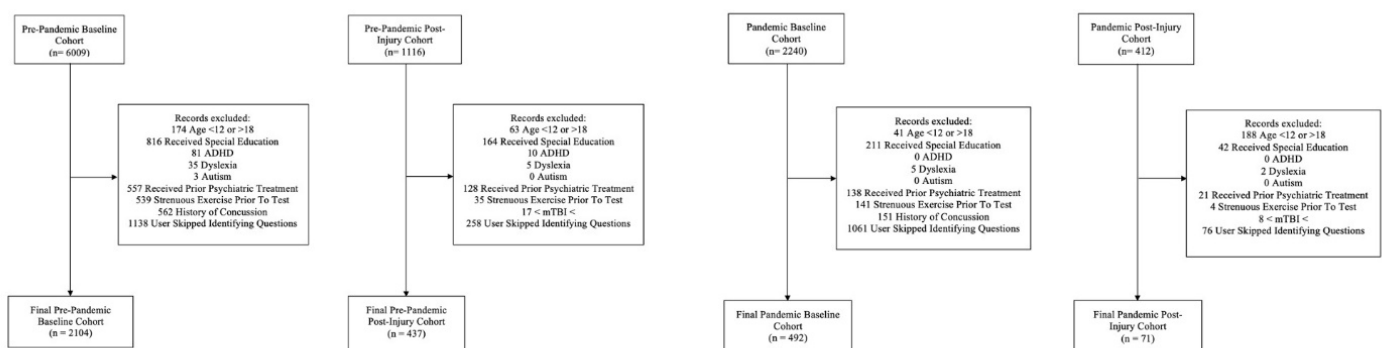


Figure 1: Exclusion criteria.

Data collection for recovery times was pulled from the pre-pandemic concussed and pandemic concussed groups from Sportsware database and electronic medical records. Recovery time was measured from date of injury to date of return to competition.

Prolonged recovery was defined as those with return to competition dates greater than or equal to 50 days post-injury date. Fifty days was chosen based on prior assessments in our population; the average return to play for our student athletes was 30 days and we included an additional 20 days for a conservative estimate of prolonged symptoms. Reasons for the difference in prolonged recovery for the COVID period compared to pre-pandemic period was analyzed qualitatively. Using the return to play date as an outcome has inherent error as an athlete might wait until the start of the next season to complete clearance, summer break might disrupt the clearance date for a spring injury and there may be access issues to ATs and clinics particularly during the COVID period. Assessing common predictors of prolonged post concussive symptoms was used as well as other reasons such as system issues and delays due to COVID infection, clinic access, etc. Previously described predictors of prolonged recovery include gender, prior concussion, duration of recovery from prior concussions, mechanism of injury, initial symptoms number reported, initial symptoms severity reported, prior history of affective/psychiatric symptoms of disorders, prior history of headache, and family history of headache [9].

Statistics

All statistical analyses were conducted using the SAS software for Windows version 9.4 (Cary, North Carolina, USA). Statistics were presented as frequencies and percentages for categorical variables. Chi-square tests were conducted to identify the association between pre-pandemic and pandemic in regards to self-reported symptoms and demographic variables for concussion and non-concussion groups separately. Fisher's exact tests were used if the expected cell count is less than 5. Wilcoxon rank sum tests were conducted to assess the difference in the symptoms between pre-pandemic and pandemic for concussion and non-concussion groups separately. All statistical analyses were two-sided. P value <0.05 was considered to be statistically significant.

Results

Data from a total of 3,104 patients met the exclusion criteria from Figure 1. A total of 2,104 were included in the pre-pandemic non-concussed group, 492 were included in the pandemic non-concussed group, 437 were included in the pre-pandemic concussed group and 71 were included in the pandemic concussed group. Comparison of demographics within each group is noted in Table 1.

Symptom Analysis

Affective Symptoms - Non-Concussed

Affective symptoms between non-concussed adolescents pre-pandemic and during the pandemic were compared in Table 2.

Table 1: Age and sex demographics.

	Pre-Pandemic Non-Concussed N = 2104	Pandemic Non-Concussed N = 492	Pre-Pandemic Concussed N = 437	Pandemic Concussed N = 71	P value
Age					
12-14	1149	256	138	21	0.001
15-18	955	236	299	50	
Sex					
Female	889	189	167	36	0.07
Male	1215	303	270	35	

Table 2: Comparison of affective symptoms between non-concussed pre-pandemic and pandemic cohorts. Presented as n (%).

Symptom	Pre-Pandemic Non-Concussed	Pandemic Non-Concussed	P value
Trouble Falling Asleep			
Yes	593 (28.20)	151 (30.69)	0.2709
No	1510 (71.80)	341 (69.31)	
Irritability			
Yes	291 (13.84)	72 (14.63)	0.6465
No	1812 (86.16)	420 (85.37)	
Nervousness			
Yes	550 (26.15)	151 (30.69)	0.0413
No	1553 (73.85)	341 (69.31)	
Sadness			
Yes	251 (11.94)	74 (15.04)	0.0610
No	1852 (88.06)	418 (84.96)	
Feeling More Emotional			
Yes	357 (16.98)	79 (16.06)	0.6236
No	1746 (83.02)	413 (83.94)	

Between non-concussed pre-pandemic and pandemic adolescents there was a significant increase in the symptom of nervousness in the pandemic group.

Affective Symptoms - Concussed

Affective symptoms between concussed adolescents pre-pandemic and during the pandemic were compared in Table 3. There were significant increases in irritability, nervousness, sadness and feeling more emotional in the pandemic concussed group.

Table 3: Comparison of affective symptoms between concussed pre-pandemic and pandemic cohorts. Presented as n (%).

Symptom	Pre-Pandemic Concussed	Pandemic Concussed	P value
Trouble Falling Asleep			
Yes	86 (19.68)	17 (23.94)	0.4072
No	351 (80.32)	54 (76.06)	
Irritability			
Yes	69 (15.79)	23 (32.39)	0.0008
No	368 (84.21)	48 (67.61)	
Nervousness			
Yes	51 (11.67)	17 (23.94)	0.0048
No	386 (88.33)	54 (76.06)	
Sadness			
Yes	31 (7.09)	13 (18.31)	0.0018
No	406 (92.91)	58 (81.69)	
Feeling More Emotional			
Yes	52 (11.90)	17 (23.94)	0.0060
No	385 (88.10)	54 (76.06)	

Physical Symptoms - Non-Concussed

Physical symptoms between non-concussed adolescents pre-pandemic and during the pandemic were compared in Table 4. There was a significant increase in visual problems in the non-concussed pandemic adolescents as compared to non-concussed pre-pandemic adolescents.

Table 4: Comparison of physical symptoms in non-concussed pre-pandemic and pandemic cohorts. Presented as n (%).

Symptom	Pre-Pandemic Non-Concussed	Pandemic Non-Concussed	P value
Headache			
Yes	408 (19.40)	82 (16.67)	0.1630
No	1695 (80.60)	410 (83.33)	
Nausea			
Yes	97 (4.61)	29 (5.89)	0.2337
No	2006 (95.39)	463 (94.11)	
Balance Problems			
Yes	93 (4.42)	22 (4.47)	0.9619
No	2010 (95.58)	470 (91.06)	
Dizziness			
Yes	143 (6.8)	44 (8.94)	0.0979
No	1960 (93.20)	448 (91.06)	
Sensitivity to Noise			
Yes	117 (5.56)	36 (7.32)	0.1371
No	1986 (94.44)	456 (92.68)	
Sensitivity to Light			
Yes	152 (7.23)	42 (8.54)	0.3204
No	1951 (92.77)	450 (91.46)	
Visual Problems			
Yes	176 (8.37)	63 (12.80)	0.0022
No	1927 (91.63)	429 (87.20)	

Physical Symptoms - Concussed

Physical symptoms between concussed pre-pandemic and pandemic adolescents were compared in Table 5. Pandemic concussed adolescents experienced significant increases in balance problems and visual problems compared to the pre-pandemic concussed cohort.

Table 5: Comparison of physical symptoms in concussed pre-pandemic and pandemic cohorts. Presented as n (%).

Symptom	Pre-Pandemic Concussed	Pandemic Concussed	P value
Headache			
Yes	146 (33.41)	32 (45.07)	0.0561
No	291 (66.59)	39 (54.93)	
Nausea			
Yes	44 (10.07)	9 (12.68)	0.5050
No	393 (89.93)	62 (87.32)	
Balance Problems			
Yes	66 (15.10)	18 (25.35)	0.0311
No	371 (84.90)	53 (74.65)	
Dizziness			
Yes	66 (15.10)	13 (18.31)	0.4892
No	371 (84.90)	58 (81.69)	
Sensitivity to Noise			
Yes	81 (18.54)	18 (25.35)	0.1787
No	356 (81.46)	53 (74.65)	
Sensitivity to Light			
Yes	94 (21.51)	20 (28.17)	0.2123
No	343 (78.48)	51 (71.83)	
Visual Problems			
Yes	36 (8.24)	15 (21.13)	0.0008
No	401 (91.76)	56 (78.87)	

Gender Comparison Non-concussed

Before the pandemic, non-concussed females reported significantly more trouble falling asleep ($p = 0.0001$), irritability ($p = 0.0001$), nervousness ($p = 0.0001$), sadness ($p = 0.0001$), feeling more emotional ($p = 0.0001$), headache ($p = 0.0001$), nausea ($p = 0.0003$), balance problem ($p = 0.0003$), dizziness ($p = 0.0001$), sensitivity to noise ($p = 0.0028$), sensitivity to light ($p = 0.0008$), and visual problems ($p = 0.0001$) than males. During the pandemic, non-concussed females reported statistically significantly increased irritability ($p = 0.0067$), nervousness ($p = 0.0049$), sadness ($p = 0.0027$), feeling more emotional ($p = 0.0001$). However, females and males had similar somatic/physical complaints.

Concussed

Before the pandemic, concussed females experienced more trouble falling asleep ($p = 0.0440$) and nervousness ($p = 0.0213$) than concussed males. During the pandemic, concussed females reported significantly more dizziness ($p = 0.0356$) and visual problems ($p = 0.0344$) compared to males. Interesting, in the concussed state females and males had similar affective symptoms.

Age Comparison

Analysis of age was not performed as the groups were statistically different. Pre-pandemic had greater numbers of younger age 12-14 year old students compared to pandemic reflective of reduced access to ImPACT baseline testing clinics in the middle schools during the pandemic.

Recovery Time Analysis

Median days for recovery were statistically significantly increased in the pandemic concussed adolescents as compared to the pre-pandemic concussed adolescents, as seen in Table 6. Significantly less pandemic concussed adolescents recovered in the <25 day period as compared to the pre-pandemic concussed adolescents, as seen in Table 7. Pre-pandemic concussed adolescents who reported trouble falling asleep and nervousness had statistically significantly increased recovery times as compared to adolescents who did not report those symptoms, as seen in Table 8.

Analysis of reasons for prolonged recovery (> 50 days) are shown in Table 10. While both groups were similar in age and gender, there

was a higher percentage of students with non-sport mechanisms of injury during the pandemic (likely due to less organized sports during the pandemic), ($p = 0.04$). Comparison of sports injuries and prolonged recovery were 38 in pre-pandemic and 8 in pandemic groups versus all other mechanisms. Both groups had a greater percentage of initial presenting higher number of symptoms and severity. The most common reason for prolonged recovery at 50% in both groups was prolonged symptoms, particularly headaches. Prior history of concussion was the most common past medical history associated with prolonged recovery. Systems delay versus those without a systems delay was not more common in the pandemic cohort. However, the low numbers evaluated likely impacted the analysis.

Discussion

Consistent with studies on the mental health impacts of the COVID-19 pandemic on the general pediatric population, our data shows that non-concussed adolescents experienced increases in self-reported sadness, trouble falling asleep, irritability, and significantly more nervousness, during the pandemic as compared

Table 6: Comparison of recovery days between Pre-Pandemic and Pandemic Concussed Cohorts.

Recovery Days								
Cohort	N	Mean	Std Dev	Min	Max	Median*	Lower Quartile	Upper Quartile
Pre-Pandemic Concussed	251	33.65	49.96	7	425	18	13	30
Pandemic Concussed	26	92.46	105.25	8	338	36	19	125

Table 7: Comparison of concussed pre-pandemic and pandemic cohorts based on recovery time periods. Presented as n (%).

Recovery Days	Pre-Pandemic Concussed	Pandemic Concussed
<25	175 (69.72)	11 (42.31)
26-50	42 (16.73)	4 (15.38)
51-100	18 (7.17)	3 (11.54)
>100	16 (6.37)	8 (30.77)

Table 8: Comparison of concussed pre-pandemic and pandemic mean recovery times with the presence or absence of symptoms.

Symptom	Pre-Pandemic Concussed	Pandemic Concussed	Combined Samples Recovery Time
Headache			
Yes	34.03	117.18	44.19
No	33.47	74.33	36.75
P Value	0.0842	0.0516	0.0578
Trouble Falling Asleep			
Yes	53.93	155.0	65.82
No	29.21	73.70	33.15
P Value	0.006	0.068	0.004
Irritability			
Yes	43.853	81.00	49.435
No	32.046	95.90	37.434
P Value	0.1700	0.3617	0.3082
Nervousness			
Yes	60.885	155.25	73.467
No	30.498	81.045	35.000
P Value	0.0109	1.00	0.004
Sadness			
Yes	23.294	102.60	41.328
No	34.397	90.047	38.980
P Value	0.785	0.623	0.435
Feeling More Emotional			
Yes	36.519	100.75	44.806
No	33.299	90.954	38.455
P Value	0.952	0.286	0.876

Table 9: Gender comparison of mean recovery times.

Demographic	Pre-Pandemic Recovery Times	Pandemic Recovery Times	Combined Sample Recovery Time
Gender			
Male	28.103	73.461	31.435
Female	44.092	111.462	52.850
P Value	0.2181	0.2486	0.118

Table 10: Qualitative comparison between concussed pre-pandemic and pandemic adolescents with prolonged recovery.

Symptoms > 50 days	Pre-Pandemic	Pandemic	P value
Sample Number	43	16	
Females	19	8	0.96
Males	22	8	
Gender not specified	1		
Age < 14	4	3	0.38
Sports mechanism of injury	36	8	0.04
Motor vehicle crash mechanism	5	1	
Bicycle, ski, or snowboard crash mechanism	2	6	
Fall from a height (horse) mechanism	0	1	
Initial number of symptoms reported > 4	18	11	0.12
Initial symptom severity score > 33	17	9	0.39
Prior concussions	18	5	0.61
> 2 concussions	6	1	
Prior concussion prolonged recovery	3	0	
Prior anxiety/depression	6	4	0.44
Prior headache history	5	3	0.67
Ongoing symptoms = HA, dizzy	22	8	0.83
Summer break	2	3	0.71
Systems delay	8	2	
Persistent abnormal ImPACT -not returning to baseline	5	1	
Ortho injuries delayed RTP clearance	1		
Due to repeat concussion recommended delay in RTP	1		
COVID during concussion recovery		1	
COVID exposure delayed return to clinic		1	

to adolescents before the pandemic [10,12,13]. Increases in affective moods among general pediatric populations could be explained by external consequences of the pandemic such as disruption of daily routine, alterations in school schedules, increased internet usage, decreases in sport and extracurricular activities, and family conflict [10-13]. Statistically significant nervousness among non-concussed adolescents during the pandemic is likely related to nervousness regarding uncertainty of the future and possible infection [10-13].

Difficulties of the COVID-19 pandemic impacted concussed adolescents to a greater extent, as adolescents concussed during the pandemic experienced more affective symptoms of concussion as compared to their pre-pandemic concussed counterparts. Common neurobehavioral symptoms of concussion in children include sadness, irritability, and being “more emotional” [16], and our cohort of pandemic concussed adolescents reported statistically significant increases in these symptoms as well as increases in others compared to pre-pandemic concussed adolescents. Hypotheses on the causes of affective concussion symptoms in adolescents fall under both pathophysiologic and psychosocial realms. The pathophysiologic causes of affective symptoms are not fully understood, but there seems to be an association between damage to brain regions involved in emotional functioning [4]. Alternate theories suggest that a concussion can cause cell membrane disruptions involved in the central nervous system

pathways that precede neuropsychiatric conditions [3,4]. While it is important to understand the mechanisms and pathophysiological causes, our findings focus on the impact of psychosocial challenges on the differences between affective symptoms in our cohorts of pre-pandemic and pandemic concussed adolescents. The increased symptom burden in our pandemic concussed group, was likely explained by increased external stress and anxious states during the pandemic.

Physical injury restricts daily activity causing emotional challenges such as increased depressive symptoms in pediatric populations [14]. The challenge of dealing with a physical injury alone could contribute to increased symptoms in our pandemic concussed cohort. In particular, post-concussive management disrupts routine physical activity, social interaction, and engagement in school and extracurriculars, all of which are crucial factors in adolescent quality of life and psychological well-being [16,17]. In fact, substantial restriction in activity has been implicated in negative consequences in concussion, such as feelings of irritability, sadness, and increased emotionality [18-20]. In the context of the pandemic, an important protective factor for all adolescents was access to daily activity and leisure [12]. Understandably, adolescents undergoing post-concussive management during the pandemic were at particular risk for experiencing emotional challenges from activity disruption.

Current research on post-concussion management shows significant benefit when incorporating some level of physical and cognitive activity within the early phases of concussion recovery [17,19-25]. This post-injury management approach is associated with emotional symptom improvements and shorter recovery times in pediatric populations [19,24]. Pandemic restrictions limited the outlets of activity and socialization integral in improving symptom outcomes in concussed adolescents, and therefore could have an impact on increases in both affective and physical symptoms seen in our concussed cohort.

Some pandemic constraints were predicted to possibly decrease symptom load for concussed adolescents, allowing them to conduct school from home with less noise and light stimulation [18]. Conversely, our pandemic concussed cohort showed significant increases in visual problems and balance problems, as well as increases in headache, nausea, dizziness, sensitivity to noise and sensitivity of light as compared to pre-pandemic concussed adolescents. This points to a role that affective symptoms may have in mediating experiences of physical symptoms in concussion patients [25]. This is not a new finding in pediatric concussion research. MaCartney et al.'s [26] found that pediatric concussion patients who reported more depression symptoms also reported increased severity of somatic symptoms such as post-injury headache, fatigue and feelings of head pressure [21,26].

Children of primary age increased their leisure and total screen time during the pandemic, likely due to online schooling and increased sedentary lifestyles [27]. Several negative correlates were associated with increased screen time, including diet, sleep, mental health, and eye health [27]. We did not measure screen time in our groups, but both our non-concussed and concussed pandemic cohorts reported significantly more visual problems when compared to their pre-pandemic counterparts. Screen time has been linked to eye health problems and therefore managing pediatric patients' screen time could serve as a viable lifestyle modification in addressing both physical and affective symptoms in adolescents.

Overall, our sample of adolescents concussed during the pandemic experienced a triad of the usual neurobehavioral symptoms of concussion, restrictions from post-concussive management, and disruptions of normal daily life from the pandemic. The combination of these factors likely contributed to increases in affective and physical concussion symptoms in the pandemic concussed group. Given that increased depression and anxiety symptoms are associated with longer recovery times, it is also critical to consider how the pandemic impacted appropriate concussion recovery and management [8,9,15].

Recovery Times

In our study, adolescents concussed during the pandemic had longer median recovery times than adolescents concussed before the pandemic. A greater percentage of adolescents concussed before the pandemic recovered in under 25 days than adolescents

concussed during the pandemic. Conversely, a greater percentage of adolescents concussed during the pandemic had recovery times greater than 100 days as compared to adolescents before the pandemic. We couldn't find a significant difference between the pre-pandemic and pandemic groups other than mechanism of injury.

Commonly, symptoms of concussion improve within a month, though in certain instances patients experience persisting symptoms of concussion (PSaC) beyond the expected recovery time of a concussion. Pre-existing mood disorders and immediate symptom load are greatest predictors of persisting symptoms, though many factors can contribute [5,6,15]. Personal or family history of mood disorders, substance use disorder, and pre-injury diagnoses of learning difficulties are factors in prolonged recovery of concussion [9,15], but would be less likely given our exclusion criteria. More relevant to our concussed adolescents is that individuals with post-injury anxiety states, overall high symptom loads after injury, previous history of concussion and family/social stressors are at risk for persisting symptoms [8,9]. For example, consistent with studies on post-injury anxiety and symptom load, adolescents who reported trouble falling asleep and nervousness had significantly longer recovery times than adolescents who did not report those symptoms, though this observation was only in the pre-pandemic group. In the pandemic group, increased family and social stressors present during the pandemic could explain increased recovery times seen in this group [13]. Overall, significant biopsychosocial factors contribute to a patient's symptom load and recovery from concussion and should be addressed in management of concussion.

Reduction in healthcare utilization during the pandemic was a concern for many health conditions and populations and could present another challenge for the concussed pandemic cohort [28]. It is important to note that reduced utilization and delayed presentation were likely conflating factors in recovery times during the pandemic as well. While we did not assess time to initiation of care in our population, Kontos et al. [29] not only found decreases in concussion-related visits, but also delayed presentation to care following a head injury during the pandemic. Delayed access to care has implications in concussion recovery, as adolescents who presented earlier for care have shorter recovery times [30]. In our qualitative analysis of the prolonged recovery groups, we did not find system delays to be statistically different between pre-pandemic and pandemic groups though. However, the small numbers for analysis likely limited this analysis.

Receiving care and initiating the appropriate steps immediately following a concussive injury is crucial for a good recovery. Return to school, social, and physical activity should be initiated as early as can be tolerated, and is considered the predominant treatment approach for pediatric concussions. Early subthreshold aerobic activity in adolescents leads to faster recoveries, therefore increased adolescent inactivity during pandemic could impact the longer recovery times in the pandemic concussed group [22,24,31]. Return to learning can have a positive impact on

adolescent recovery from concussion, and can decrease symptom load at two weeks post-injury [20]. Benefits of early return to school include socialization, reducing stress from missing too much class, consistent scheduling, and school-associated physical activity. Many of the protective measures were disrupted during the pandemic, and therefore may not carry the same benefits for the pandemic cohort as they do under normal circumstances. During the pandemic, regular activities, such as school, sports, and socialization were dramatically altered, therefore complicating an essential aspect of pediatric concussion management protocol.

Management Considerations

During the pandemic, discerning whether increased affective moods are injury or non-injury based could be complicated by a setting of overall increased mental health issues during the pandemic [18]. Often post-injury affective states are transient, but there is evidence showing that concussions increase the risk of development of psychiatric disorders in the early years following injury, therefore adolescents who were concussed during the pandemic and experience increased affective symptoms would benefit from psychological screening in order to monitor progression [3]. Under any circumstances, concussed patients often experience emotional and physical symptoms synchronously, and care should be taken to address the full spectrum of a patient's experience. Overall, clinicians should understand the context around the injury itself and how certain factors or environmental stressors impact healing [9].

Limitations

Inherent limitations include retrospective design. We did not have access to all injured athletes as some were treated in other clinics. As an alternative, data on recovery times was pulled from athletic trainer reports from various high schools, with less detailed information on their medical history. Sample sizes were reduced due to limitations in collecting complete demographic information on users from ImPACT test data sets. Therefore if users left information on demographics blank, we could not use their subsequent data for symptom or recovery time analysis.

Conclusion

This study assessed the impacts of the COVID-19 pandemic on concussion symptoms in adolescents and is the first of our knowledge to quantify the symptom burden of the pandemic. The results show that the prevalence of concussed adolescents' affective and physical concussion symptoms increased during the pandemic. In the context of increased emotional burden, clinicians managing concussions in this population should be increasingly aware of the relationship between affective mood and physical symptoms of concussion. In clinical practice, adding an Adolescent PHQ-9 to your intake can open a discussion and improve further understanding of the scope of affective symptoms experienced by the adolescent with concussion. These results were pulled from the extenuating circumstances of the pandemic, but the implications should persist, as concussion patients benefit from a multifactorial and multidisciplinary approach.

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