

# Time-to-Event Analyses: Return to Unrestricted Participation After Sport-Related Concussion in a Cohort of High School Athletes

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**Context:** Understanding time loss resulting from sport-related concussion (SRC) within individual sports allows high school athletic trainers to provide accurate and evidence-based clinical information. Currently, research regarding patterns of clinical recovery outcomes in high school student-athletes across sports is lacking.

**Objective:** To describe the time to authorized unrestricted return to participation (RTP) after SRC in a large cohort of high school student-athletes in a variety of sports using a time-to-event analysis.

**Design:** Descriptive epidemiology study.

**Setting:** Aggregate injury and player exposure data from the Michigan High School Athletic Association Head Injury Reporting System.

**Patients or Other Participants:** High school student-athletes.

**Main Outcome Measure(s):** Dates for SRC injury events and authorized unrestricted RTP were entered into the Head Injury Reporting System for each case and were used to calculate time to unrestricted RTP. Survival analysis indicated the time to authorized RTP for males and females in weekly increments across sports and academic years. Separate

Kaplan-Meier analyses adjusted for SRC cases with a history of concussion also identified the proportions of student-athletes who obtained authorized medical clearance in weekly increments.

**Results:** A total of 15 821 SRCs, 10 375 (65.6%) in males and 5446 (34.4%) in females, were reported during the 2015–2016 through 2018–2019 academic years. The median time to authorized unrestricted RTP was 11 days for all patients. Approximately 30% of concussed student-athletes were not cleared for unrestricted RTP by 14 days after their SRC diagnosis, with 13% taking longer than 21 days to return to unrestricted RTP after SRC.

**Conclusions:** The results from this multisite, state-based injury surveillance system indicated that it is not abnormal for high school student-athletes to take longer than 14 days to fully recover from an SRC. This information may be useful for educating high school student-athletes and sport stakeholders, normalizing SRC recovery trajectory perceptions, and establishing realistic RTP timeline expectations.

**Key Words:** epidemiology, injury surveillance, sports, return to play, recovery

## Key Points

- High school student-athletes missed a median of 11 days from their respective sports as a result of sport-related concussion (SRC).
- The median time to return to unrestricted play after SRC significantly increased across the 4 academic years (2015–2016 through 2018–2019).
- Nearly 30% of concussed student-athletes took longer than 14 days and 12.5% took longer than 21 days to return to unrestricted play after SRC.

Each year, 1.1 to 1.9 million concussions related to sport and recreation occur in youth and adolescent athletes (<18 years old) in the United States.<sup>1</sup> The Centers for Disease Control and Prevention<sup>2</sup> suggested that approximately 15% of high school students sustain at least 1 concussion during sport participation or physical activity annually. Over the past decade, a large number of investigations into sport-related concussion (SRC) have brought major advancements in concussion-management strategies, including return-to-learn guidelines and treatment regimens. The most recent Concussion in Sport Group consensus statement<sup>3</sup> and additional sports medicine

position statements<sup>4,5</sup> indicated that concussion symptoms, neurocognitive deficits, and balance impairments improve rapidly within the first 2 weeks after injury, and most injured high school athletes meet clinical recovery standards within 1 month.<sup>3,5</sup> Marar et al<sup>6</sup> and Rechel et al<sup>7</sup> published pioneering larger epidemiologic studies for individual sport types using the High School Reporting Information Online (RIO) database and investigating return to play from an SRC. However, these authors examined return-to-play timelines that incorporated data spanning only 2 years. Also, the studies are now a decade old and predate the changes and updates in the 2009<sup>8</sup> and 2017<sup>3</sup>

Concussion in Sport Group consensus statements and 2014 National Athletic Trainers' Association position statement.<sup>4</sup> Due to the advancements in SRC management since the completion of this foundational work, we need more up-to-date information regarding patterns of clinical recovery outcomes with a clearly defined timepoint for unrestricted return to participation (RTP) for high school athletes in various sports.

In recent years, researchers<sup>9–12</sup> found that high school-aged student-athletes could take longer to recover from an SRC than previously thought. Among adolescent patients with concussion, Henry et al<sup>9</sup> noted that recovery outcomes (ie, symptoms, neurocognitive performance, vestibular-oculomotor function) were achieved in 21 to 28 days in most patients. In another study<sup>10</sup> of student-athletes aged 13 to 19 years with concussion, 41% of females and 19% of males took >21 days to become asymptomatic after their injury. Similarly, an examination of New Zealand athletes with concussion revealed that 40% of adolescent student-athletes were asymptomatic in <2 weeks, 40% became asymptomatic within 2 to 4 weeks, and the final 20% took >4 weeks for their symptoms to resolve.<sup>11</sup> These investigations<sup>9,10,13</sup> were limited by relatively small sample sizes and varied definitions of concussion recovery. For example, Henry et al<sup>9</sup> assessed recovery in weekly increments (ie, week 1, week 2, week 3, week 4), whereas Leddy et al<sup>13</sup> classified recovery as days to being asymptomatic. Full, unrestricted RTP is not achieved simply by symptom resolution. The patient must achieve suitable recovery on the different components of a multifaceted assessment and successfully progress through an established RTP protocol. Outcomes measured in the previous literature are key indicators of recovery, but in some instances, they fail to answer the most common question posed by student-athletes with an SRC: “When will I be able to play again?” Therefore, research that accounted only for symptom resolution and singular deficits (eg, cognitive, balance, vestibular) did not consider a holistic stepwise RTP progression. These RTP progressions should take at least 7 days after a concussion for an athlete to become asymptomatic and be cleared for unrestricted sport participation.<sup>3</sup> Therefore, patterns of clinical recovery outcomes that include the full amount of time missed from sport need to be understood.

McGuine et al<sup>14</sup> described a median of 14 total days missed from sport after concussion, but only 125 Wisconsin high school student-athletes were included. In a more robust epidemiologic study, the authors<sup>12</sup> captured both the time to symptom resolution and time to return to play of 2004 high school student-athletes diagnosed with concussion from 147 high schools across the United States between 2011 and 2014. Using the National Athletic Treatment, Injury and Outcomes Network, O'Connor et al<sup>12</sup> found that 62.4% of high school student-athletes with concussion reported symptom resolution within 14 days, whereas 14.8% of girls and 10.3% of boys took >28 days.<sup>12</sup> Additionally, only 10.5% of high school athletes returned to play in ≤ 7 days concussion, and almost 1 in every 4 required >28 days to be medically cleared for participation.<sup>12</sup> Specifically, boys' baseball, basketball, and soccer had the highest percentages of athletes returning to play within 6 days of injury, and girls' lacrosse, softball, and tennis had the highest percentages of athletes returning to

play at >28 days.<sup>12</sup> Additionally, Tamura et al<sup>15</sup> demonstrated longer postconcussion recovery in a study of 726 Hawaiian high school student-athletes from 2010 to 2014; the average time lost from activity was approximately 20 days. These results<sup>12,15</sup> showed the true heterogeneity of SRC recovery, but a reassessment of these outcomes is needed as the data were collected before the most current consensus and position statements and their accompanying updated concussion-management recommendations were released.

Understanding time loss resulting from SRC within individual sports empowers high school athletic trainers to provide accurate and evidence-based clinical information to communicate RTP trajectories to key stakeholders (ie, student-athletes, parents, and coaches). To accomplish this, a large, multisite surveillance investigation to analyze current clinical practice as it relates to a clearly defined timepoint of full unrestricted RTP was warranted. In addition, a time-to-event analysis (ie, Kaplan-Meier survival curve) is an appropriate and underused method for describing the pattern of recovery after SRC. Therefore, the purpose of our study was to describe the time to authorized unrestricted RTP after SRC in a large cohort of high school student-athletes in a variety of sports using a time-to-event analysis.

## METHODS

### Research Design, Schools, and Participants

This was a descriptive epidemiologic study using the Michigan High School Athletic Association (MHSAA) online Head Injury Reporting System (HIRS). All participating high schools in the state of Michigan (ie, grades 9 through 12) were mandated by the MHSAA to enter injury data into the online HIRS. The MHSAA collects SRC data for 28 sports, and to date, a total of 16 001 SRC cases have been reported in the HIRS (Table 1). We looked at SRCs among student-athletes in grades 9 through 12. The sample consisted of 15 821 SRC cases, 10 375 (65.6%) males and 5446 (34.4%) females, reported during the 2015–2016 through 2018–2019 academic years (Table 2). Fall, winter, and spring MHSAA-sanctioned sports that took place during the 4 academic years (2015–2016, 2016–2017, 2017–2018, 2018–2019) of this study were included.

### Data Reporting and Definitions

**Operational Definition of SRC.** The MHSAA defined an SRC as an injury (1) that occurred as a result of participation during practice or competition (preseason through postseason) in MHSAA-sanctioned sports that provided a postseason tournament and (2) required the student-athlete to be withheld from activity after exhibiting signs, symptoms, or behaviors consistent with an SRC (eg, loss of consciousness, headache, dizziness, confusion, balance problems). The SRCs were recorded in the HIRS if they met the aforementioned criteria; therefore, cases that occurred outside of MHSAA-sanctioned events were not included.

**Initial Report.** For each SRC entered into the HIRS, an initial report is submitted. The initial report collects general information about the case and includes the patient's sex, level of participation (ie, freshman, junior varsity, or

**Table 1. Participating Michigan High School Athletic Association High Schools and Student-Athletes From the 2015–2016 Through 2018–2019 Academic Years**

Academic Year	Participating Schools, No.	Student-Athletes, No.		Total Reported Concussions <sup>a</sup>
		Male	Female	
2015–2016	755	165 418	118 809	4448
2016–2017	751	164 388	119 237	4150
2017–2018	750	164 318	120 589	3592
2018–2019	747	162 426	119 566	3805

<sup>a</sup> Six patients with sport-related concussion had missing or incomplete data for the academic year in which the injury occurred and were not included.

varsity), grade in school (ie, 9th, 10th, 11th, 12th), sport, and concussion history.

**Follow-Up Report.** A follow-up report is completed and linked to the initial report. The follow-up report collects general information about return to activity after the head injury. It includes the date the student received authorized written clearance to return to unrestricted activity and the number of school days missed because of the SRC.

**Time to Unrestricted Return to Participation.** The MHSAA records the date of injury and the date of authorized clearance to unrestricted RTP by a medical provider. Only a medical doctor (MD), doctor of osteopathic medicine (DO), nurse practitioner (NP), or physician assistant (PA) was allowed to authorize clearance for a student-athlete with an SRC. According to the MHSAA, the clearance obtained from the medical provider granting permission for the athlete to RTP must be in writing and must be unconditional. It was not sufficient that the MD, DO, PA, or NP approved the student-athlete to begin an RTP progression. The medical provider must approve the student-athlete's unrestricted RTP. For consistency within the HIRS, the exact date the athlete was granted permission by the medical provider for unrestricted RTP was recorded. Time to unrestricted RTP was calculated (days) as the time between injury and authorized clearance dates.

**Table 2. Characteristics of Student-Athletes With Sport-Related Concussion (N = 15821)**

Characteristic	No.	%
Sex		
Male	10 375	65.6
Female	5446	34.4
Grade <sup>a</sup>		
9	4687	29.6
10	4475	28.3
11	3483	22.0
12	3176	20.1
Previous history of concussion		
0	13 388	84.6
1+	2433	15.4
Days absent from school		
Mean ± SD	0.77 ± 2.3	
Median [interquartile range]	0 [0–1]	
0	11 430	72.3
1	1979	12.5
2	1143	7.2
3	1269	8.0

<sup>a</sup> Data from students in grade 8 were not included.

## Procedures

The institutional review board approved this study as exempt because it used de-identifiable data. Per the MHSAA concussion protocol, school personnel were required to submit an online report for each SRC. The primary data recorder was the athletic trainer; however, if the athletic trainer was not present, school administrators or coaches were required to enter all SRCs into the online HIRS. The data recorder was responsible for entering the initial SRC report and a follow-up report into the online HIRS. The initial report consisted of demographics (ie, sex, grade, level, sport), date of injury, and whether the SRC occurred during practice or competition. An athlete who sustained an SRC was assigned a unique 7-digit identification number to protect his or her identity. These identification numbers were used to complete the follow-up report. School personnel were required to enter each student-athlete's RTP and the number of missed school days into the follow-up report. School personnel only entered data into the follow-up report when a written authorization for medical clearance was provided by an MD, DO, NP, or PA or at the end of the season.

Data quality checks were monitored daily by MHSAA staff members. For example, data quality checks included monitoring initial reports for errors such as missing data or incorrect dates. If an error was found, the MHSAA staff contacted the participating school to notify them of an error and requested the correct information from the school personnel. Only MHSAA staff were allowed to edit the online HIRS; schools were not permitted to edit reports after submission. The MHSAA staff members reviewed the follow-up reports weekly. After an initial report was entered into the online HIRS, school personnel were contacted approximately 3 weeks later and then each week in the 2 to 3 weeks before the end of the season as a reminder to complete the follow-up reports. Reminders were sent to complete the follow-up report for unresolved cases. Schools reporting no SRCs for a season (ie, fall, winter, spring) were required to indicate this in the online HIRS.

## Statistical Analysis

Descriptive statistics were used to present demographics and characteristics for each SRC case. The time-to-event analysis (time measured as days to authorized unrestricted RTP) was computed using Kaplan-Meier analyses. The exposure used for Kaplan-Meier analyses was an SRC diagnosis and the outcome of interest was the time to authorized unrestricted RTP in days. Crude proportions of SRC patients for whom authorized medical clearance was

not obtained were displayed in weekly increments (eg, 7 days, 14 days, 21 days, 28 days, 35 days, 42 days) across sports and the 4 academic years (2015–2016, 2016–2017, 2017–2018, and 2018–2019), as well as by grade in school and level of competition. Separate Kaplan-Meier analyses adjusted for patients with SRC who had a history of concussion were also used to identify the proportions of student-athletes who obtained authorized medical clearance in weekly increments. The equality of the survivor function across male and female sports was evaluated using separate log-rank tests. For log-rank statistical models, sex was the exposure and authorized medical clearance was the outcome of interest. We excluded data from those patients who did not obtain authorized clearance for unrestricted RTP before their season ended. Statistical analyses were performed using Stata (version 16; College Station, TX), and a  $P$  value  $< .05$  indicated statistical significance.

## RESULTS

A total of 15821 SRC cases (males = 10375, 65.6%) were recorded in the MHSAA-sanctioned sports during the 4 academic years of this study. A history of at least 1 concussion was reported in 15.4% ( $n = 2433$ ) of patients. Most ( $n = 11430$ , 72.2%) patients missed no school days; 1979 (12.5%) missed 1 day. Analysis by grade in school yielded a significant log-rank test ( $\chi^2_3 = 8.21$ ,  $P = .014$ ) for median days to unrestricted RTP. However, clinical significance by grade was not meaningful as the median and interquartile ranges were similar among grades (9th: 11 [6–16] days, 10th: 11 [6–16] days, 11th: 11 [6–16] days, 12th: 11 [6–16] days). No difference was present among levels of competition (eg, freshman, junior varsity, varsity;  $\chi^2_2 = 4.02$ ,  $P = .134$ ). The SRC case characteristics are displayed in Table 2. Of the total patients in this sample, 79.2% ( $n = 12523$ ) had a completed follow-up report that included the date of unrestricted RTP in their competitive athletic season.

The overall median time to unrestricted RTP was 11 (interquartile range = 7–16) days. The median time to return for each academic year was different ( $\chi^2_3 = 55.95$ ;  $P \leq .001$ ) and is presented in the Figure. The median days increased from 10 days in 2015–2016 to 12 days in 2018–2019. Overall, 71.8% of patients with SRC took  $>7$  days to return, 29.6% took  $>14$  days to return, 13.1% took  $>21$  days to return, and 6.5% took  $>28$  days to return to their respective sports. More than 25% of gymnasts took  $>28$  days to full unrestricted RTP, followed by competitive cheerleaders (15.4%), male wrestlers (12.2%), male divers (12.0%), female wrestlers (11.1%), and male track and field athletes (11.1%). The time to unrestricted RTP for each sport is shown in Table 3. Differences occurred in time to unrestricted RTP between individual female sports ( $\chi^2_{10} = 90.65$ ;  $P \leq .001$ ) and individual male sports ( $\chi^2_8 = 113.82$ ;  $P \leq .001$ ). The time to unrestricted RTP for patients with SRC adjusted for a history of 1 or more previous concussions appears in Table 4.

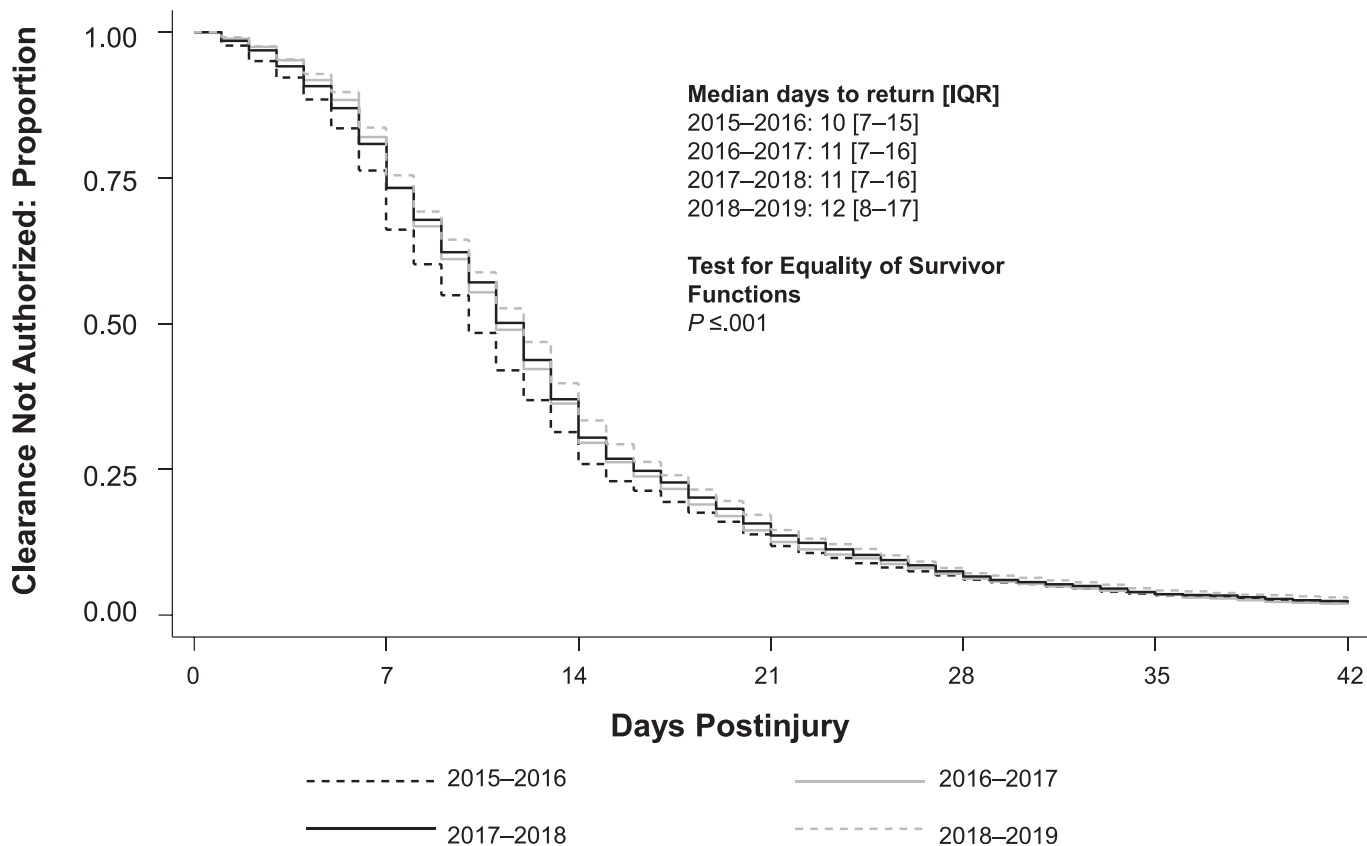
## DISCUSSION

We are among the first to examine *SRC patterns of recovery*, defined as time to unrestricted RTP, using a survival analysis across all MHSAA-sanctioned high school sports. Among all the SRC cases, the overall median time

to unrestricted RTP was 11 days; the median time to return increased by 2 days between the 2015–2016 (10 days) and 2018–2019 (12 days) academic years. Approximately 1 out of 3 patients with SRCs took  $>14$  days to return, with 6.5% of student-athletes taking  $>28$  days to return to their respective sports. The results from this multisite, state-based injury surveillance system reflect the RTP requirements mandated solely by the state of Michigan; however, they provide evidence of a more realistic timeline for recovery among a large cohort of high school student-athletes who sustained SRCs.

A recovery window has been used by sport and health care practitioners as the estimated time for patient recovery, yet evidence<sup>9,12,16</sup> has shown that the recovery timeline may vary among different athletic populations. Furthermore, *recovery timeline* has been widely defined in the literature as the days to symptom resolution, but this does not take into consideration the stepwise progression toward medical clearance for full RTP. The median number of days to athletes' unrestricted RTP in this study was 11 days, which means that 50% or more than 7500 patients took  $>11$  days to recover. Moreover, the median time to unrestricted RTP in athletes who sustained an SRC increased from 10 to 12 days over the 4-year study period. Whether this increase of 2 days is clinically meaningful is still unclear, although it could suggest an advancement in concussion management and treatment.<sup>17</sup> In addition, it could represent an increase in clinicians' knowledge of the Berlin consensus statement<sup>3</sup> related to adapting an RTP protocol and being more conservative when managing adolescent athletes. Further, this could be more meaningful to the student-athlete, as a 2-day increase could mean missing a big game or match. Other researchers have reported a median of 14 total days missed from sport<sup>16</sup> and an average of nearly 20 days to unrestricted RTP.<sup>17</sup> The slight variability in clinical recovery time between studies may be explained by diverse research designs and study settings, as described in a recent consensus systematic review.<sup>18</sup>

The strengths of our work include an up-to-date, multiyear (4 academic years) investigation of more than 15000 SRC cases based on a time-to-event analysis that incorporated standardized RTP criteria across the state. We found that approximately 1 out of 3 patients with SRC took  $>14$  days to return, with 6.5% of student-athletes taking  $>28$  days to return to their respective sports. This is congruent with the Berlin consensus statement,<sup>3</sup> which suggested that youth or pediatric athletes may take up to 4 weeks to recover. Various factors (eg, sex, concussion history) have been evaluated for their relationship with longer recovery time; however, an understudied factor is the influence of sport type. We provided auxiliary evidence, by sport, that explained the variability in time loss separated into male and female sport categories. Log-rank analyses revealed time-loss differences between individual male and female sports. For example, most baseball and men's soccer athletes with SRC returned sooner than 14 days; however, most concussed female gymnasts returned later than 21 days. Marar et al<sup>6</sup> similarly noted that gymnastics had a longer time to full RTP, yet the authors advised caution about the interpretation because they reported fewer than 10 concussions among gymnasts. Progressing a gymnast through the stepwise RTP is challenging due to the nature of the sport. For example,



**Figure.** Kaplan-Meier survival curves for time to authorized return to unrestricted activity after sport-related concussion by academic year. Abbreviation: IQR, interquartile range.

the progression includes performing sport-specific skills such as twisting and flipping. Also, every apparatus involves some type of inversion, which can exacerbate symptoms. As a result, gymnasts may have been held out longer to ensure a safe RTP. In addition, when we compared our results to the previous epidemiologic literature, similar patterns by sport were apparent in the study by O’Conner et al,<sup>12</sup> in that boys’ soccer and boys’ basketball athletes returned to participation within 6 days of an SRC. Still, a larger percentage of athletes participating in girls’ tennis, girls’ softball, and girls’ lacrosse returned to activity >28 days after their SRC.<sup>12</sup> Results from the aforementioned study<sup>12</sup> were limited by data collected during 2011–2014, when RTP was described as symptom resolution. Both studies might suggest that recovery outcomes differ by sport and may be explained by differences in mechanistic causes of injury (ie, fall from height, contact with another player, contact with ground, contact with equipment), point of care (ie, specialized concussion clinic, emergency department), or family socioeconomic status. Therefore, future researchers should continue to investigate these understudied factors.

In published studies of time loss or RTP, a significant number of authors operationalized the absence of symptoms or symptom resolution as the recovery time point. As research on recovery timelines continues to emerge, it is valuable to discuss the complex association between symptom profiles and RTP, as many clinicians benchmark a patient as being asymptomatic before returning him or her to participation or initiating a stepwise return-to-sport or

school progression protocol. At 21 days after an SRC, a longer symptom duration in adolescent patients was associated with more severe somatic and vestibular-ocular symptoms.<sup>19</sup> Further, predictors of delayed recovery, or prolonged symptoms during recovery, have been identified in youth and adolescent patients who performed poorly on the Romberg test (>10 days)<sup>20</sup> and those who scored below average on the Sport Concussion Assessment Tool2 (>28 days).<sup>21</sup> Although we did not have symptom profiles or the results from diagnostic tools to support the time-loss findings, examinations of symptoms as benchmarks and clinical predictors in high school-aged athletes could help to explain the time-loss patterns. Therefore, unrestricted RTP, as a benchmark of recovery in our study, encompassed the time to many clinical recovery outcomes, including subjective and objective measures.

These results are clinically meaningful as time loss is of significant concern to a variety of stakeholders in sport, including athletes, medical professionals, parents, and coaches. Moreover, ensuring a safe RTP after an SRC has been a focus of clinicians and scholars, as a premature RTP can be dangerous for high school-aged student-athletes.<sup>22</sup> The RTP protocols are not designed or meant to be implemented in a uniform or cookie-cutter fashion.<sup>3</sup> The time loss in this study followed the most recent recommendations and consensus statement<sup>3</sup> and included a stepwise RTP protocol leading to clearance for unrestricted RTP. With these findings, athletic trainers can reference updated RTP outcomes of individual sports to make informed decisions and communicate time loss to coaches,

**Table 3. Proportions of Student-Athletes Not Authorized to Return to Unrestricted Participation After Sport-Related Concussion (SRC) by Sport**

Sport	Sex	SRCs, No. <sup>a</sup>	Proportion Not Authorized to Return, d (%) <sup>b</sup>					
			7	14	21	28	35	42
Baseball	M	210	71.0	19.1	5.7	1.4	1.0	0.0
Softball	F	401	69.8	28.2	11.0	4.5	2.0	1.3
Basketball	M	622	71.2	27.5	11.1	5.2	3.5	2.5
	F	1231	74.7	34.9	18.3	9.4	5.1	3.2
Bowling	M	2	100.0	0.0	0.0	0.0	0.0	0.0
Competitive cheer	F	418	77.0	43.0	24.2	15.4	8.3	4.4
Sideline cheer	F	122	75.4	38.5	14.8	9.8	7.4	4.1
Cross-country	M	7	42.9	14.3	0.0	0.0	0.0	0.0
Football	F	15	80.0	46.7	26.7	13.3	13.3	13.3
	M	5238	70.6	27.2	11.7	5.5	3.2	2.0
Golf	M	2	50.0	0.0	0.0	0.0	0.0	0.0
	F	1	0.0	0.0	0.0	0.0	0.0	0.0
Gymnastics	F	30	83.3	50.0	33.3	26.7	10.0	10.0
Ice hockey	M	408	75.4	35.5	18.2	7.2	5.2	3.0
Lacrosse	F	8	100.0	50.0	50.0	25.0	12.5	0.0
	M	259	74.5	31.3	10.8	5.8	3.9	1.5
Skiing	F	148	76.4	30.4	13.5	6.1	3.4	1.4
	M	15	86.7	20.0	10.0	0.0	0.0	0.0
Soccer	F	8	75.0	0.0	0.0	0.0	0.0	0.0
	M	687	64.3	20.2	6.8	4.2	2.2	1.6
Swimming and diving	F	1065	72.2	30.0	11.2	4.8	1.9	0.7
	M	50	60.0	30.0	20.0	12.0	10.0	4.0
Tennis	F	91	74.7	34.1	17.6	11.0	6.1	4.9
	M	6	83.3	50.0	0.0	0.0	0.0	0.0
Track and field	F	17	64.7	23.5	5.9	5.9	5.9	5.9
	M	26	69.2	38.5	15.4	11.5	11.5	3.9
Volleyball	F	51	76.5	35.3	15.7	5.9	3.9	2.0
	M	630	68.1	27.3	8.8	4.3	2.0	1.3
Wrestling	M	718	79.1	39.2	21.4	12.2	6.7	4.0
	F	18	88.9	44.4	27.8	11.1	5.6	5.6
Total	M	8251	71.2	28.0	12.2	6.0	3.6	2.2
	F	4272	73.1	32.8	14.8	7.6	4.0	2.3
	Overall	12 523	71.8	29.6	13.1	6.5	3.7	2.2

Abbreviations: F, female; M, male.

<sup>a</sup> Caution should be used when interpreting the findings of sports with <30 SRC cases.

<sup>b</sup> Zero indicates 100% of patients returned to unrestricted activity.

parents, and athletes. This may also help athletic training clinicians and other health care providers explain to athletes that a longer RTP trajectory may be normal, particularly in younger athletes whose brains are still developing.<sup>23</sup> As such, this information will support conversations communicating that, due to the heterogeneity of an SRC, recovery time may vary by individual and within sport.

Our research had several limitations that must be considered when interpreting these results. First, although more than 15 000 SRCs were reported over a 4-year period, only student-athletes in the state of Michigan participating in MHSAA-sanctioned sports were included. Thus, the findings cannot be generalized to other states or high school sports not included in the analyses. Second, most SRCs were reported by a licensed athletic trainer; schools that lacked a licensed athletic trainer had school administrators or coaches enter the initial and follow-up reports. However, student-athletes with SRCs were not allowed to RTP without written clearance by an MD, DO, PA, or NP. Also, these results were limited to a clinical recovery outcome: unrestricted RTP. The total number and severity of symptoms, as well as other comorbid factors (attention-deficit/hyperactivity disorder, learning disability, history of

migraine or psychological disorders) were not explored in this study. Therefore, as the results are interpreted, those with underlying comorbidities, such as attention-deficit/hyperactivity disorder, could have been included in 5% of student-athletes. It may be that those with comorbid factors were the ones who took >35 days to recover. Nonetheless, we believed it was important to include everyone in the analyses to represent the true nature of SRC at the high school level. After adjusting for concussion history, we did not find meaningful differences in recovery. Finally, these SRC recovery patterns can only be generalized to high school student-athletes and not to collegiate or youth athletes. Future investigators should assess SRC recovery patterns in athletes younger than 13 years to determine the proportion who take longer than the typical 14 days to RTP. Future authors should also determine if treatments such as vestibular and ocular therapy, aerobic exercise, academic accommodations, or pharmacologic aids decrease recovery time for an SRC. Regarding concussion treatments, a targeted approach based on clinical profiles presented by the student-athlete with an SRC is recommended.<sup>17</sup>

In conclusion, the calculated median time loss in this study was 11 days, but a more robust finding from time-to-

**Table 4. Proportions of Student-Athletes Not Authorized to Return to Unrestricted Participation Adjusted for Previous Concussion History After Sport-Related Concussion (SRC) by Sport**

Sport	Sex	SRC, No. <sup>a</sup>	Proportion Not Authorized to Return, d (%) <sup>b</sup>					
			7	14	21	28	35	42
Baseball	M	210	70.0	17.7	4.9	1.1	0.8	—
Softball	F	401	69.3	27.3	10.3	4.1	1.8	1.1
Basketball	M	622	70.6	26.5	10.4	4.8	3.2	2.2
	F	1231	73.9	33.5	16.9	8.3	4.4	2.7
Bowling	M	2	100.0	—	—	—	—	—
Competitive cheer	F	418	76.2	41.4	22.6	14.0	7.3	3.8
Sideline cheer	F	122	74.3	36.6	13.0	8.2	6.0	3.1
Crosscountry	M	7	39.1	10.8	—	—	—	—
	F	15	80.0	46.7	26.7	13.3	13.3	13.3
Football	M	5238	70.2	26.7	11.3	5.2	3.0	1.9
	F	17	69.8	38.1	19.0	6.4	6.4	6.4
Golf	M	2	50.0	0.0	0.0	0.0	0.0	0.0
	F	1	0.0	0.0	0.0	0.0	0.0	0.0
Gymnastics	F	30	82.1	46.4	29.3	22.5	6.6	6.6
Ice hockey	M	408	74.7	34.1	16.9	6.5	4.7	2.6
	F	8	100.0	57.1	57.1	28.6	14.3	0.0
Lacrosse	M	259	73.5	29.6	9.6	4.9	3.2	1.2
	F	148	78.0	33.1	15.3	6.9	3.8	1.5
Skiing	M	15	100.0	23.1	11.5	0.0	0.0	0.0
	F	8	75.0	0.0	0.0	0.0	0.0	0.0
Soccer	M	687	63.7	19.3	6.4	3.8	20.0	1.4
	F	1065	72.2	29.9	11.2	4.8	1.9	0.1
Swimming and diving	M	50	60.6	30.8	20.5	12.3	10.3	4.1
	F	91	74.4	33.4	17.1	10.5	5.8	4.7
Tennis	M	6	89.4	56.7	0.0	0.0	0.0	0.0
	F	17	67.0	25.7	6.4	6.4	6.4	6.4
Track and field	M	26	67.1	35.8	13.0	9.3	9.3	1.7
	F	51	76.2	34.8	15.1	5.6	3.7	3.7
Volleyball	F	630	67.7	26.7	8.4	4.0	1.8	1.1
Wrestling	M	718	78.6	38.2	20.4	11.4	6.2	3.6
	F	18	89.3	46.2	29.7	12.0	6.0	6.0
Total	M	8251	70.7	27.3	11.7	5.6	3.3	2.0
	F	4272	72.6	31.9	14.0	7.1	3.6	2.0
	Overall	12523	71.3	28.9	12.5	6.1	3.4	2.0

Abbreviations: F, female; M, male.

<sup>a</sup> Caution should be used when interpreting findings of sports with less than 30 SRC cases.

<sup>b</sup> Zero indicates 100% of patients returned to unrestricted activity.

event analysis was that nearly 30% of athletes with SRC representing the majority of included sports were unable to return to unrestricted participation within 14 days of their SRC diagnosis. Much of the prior research defined the recovery window as 7 to 14 days<sup>8</sup> or operationalized time loss as days to symptom resolution; however, that narrative is quickly evolving. Many stakeholders in sports are invested in minimizing time loss from SRC, but it is of upmost importance to prioritize the health and safety of student-athletes. Recovery from SRC is highly individually variable, and discussing unrealistic recovery timelines with patients could pose serious consequences. Our more recent estimates from a large cohort of high school student-athletes suggested that high school-aged athletes were likely to endure time loss >21 days.

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