

A technology-enabled electronic incident report to document and facilitate management of sport concussion

A cohort study of youth and young adults

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Abstract

Despite the widespread awareness of concussion across all levels of sport, the management of concussion from youth to college is inconsistent and fragmented. A fundamental gap contributing to inconsistent care is the lack of a scalable, systematic approach to document initial injury characteristics following concussion. The purpose of this study was to determine differences in injury profiles and management of youth, high school, and college athletes using a mobile application for incident report documentation.

A cohort study was conducted in which concussion electronic incident report data from 46 high schools and colleges, and Cleveland Clinic ambulatory concussion clinics were gathered and analyzed.

In sum, 1421 (N=88 youth, N=1171 high school and N=162 college) athletes with sport-related concussions were included.

Despite the relative absence of red flags, youth athletes had a greater probability of being sent to the emergency department than high school and collegiate athletes. Over 60% of athletes were removed from play immediately post-injury. Injury recognition was delayed in 25% of athletes due to delayed symptom reporting (20% of males, 16% of females) or delayed symptom onset (5% of males, 9% of females). A significantly greater incidence of red flags was evident in males, and in high school and collegiate athletes compared to youth athletes.

The high frequency of youth athletes sent to the emergency department, despite the absence of red flags, may be a reflection of inadequate medical coverage at youth events, ultimately resulting in unnecessary utilization of emergency medicine services. The relatively high incidence of delayed injury reporting implies that additional educational efforts targeting student-athletes and the utilization of resources to improve injury detection are warranted. The systematic collection of injury-related demographics through the electronic mobile application facilitated interdisciplinary communication and improved the efficiency of managing athletes with concussion.

Abbreviations: AT = athletic trainer, C3 app = cleveland clinic concussion application, ED = emergency department, EHR = electronic health record, HIPAA = health insurance portability and accountability act, IR = incident report.

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Jay Alberts and Susan Linder have filed intellectual property related to the incident report mobile application used in this study.

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1. Introduction

The incidence of sports- and recreation concussion has been estimated between 1.1 and 1.9 million annually among youth in the United States.^[1] The identification and management of concussive injuries by athletes, parents, coaches, and medical providers is complicated by inconsistent approaches to injury detection, delayed symptom onset, misconceptions related to injury management, and the dynamic environment in which injuries occur (practice, competition or recreational settings).^[2,3] Regardless of injury severity, it is common that medical providers from multiple disciplines participate in the care of athletes with concussion along the continuum of care, from detection and diagnosis to return to school and play. Health care systems often lack continuity of care across providers who may be administratively or physically located in different departments or locations. These logistical challenges coupled with the lack of interoperability within and between traditional electronic health record (EHR) systems further complicate a team approach to the management of concussion.^[4]

In youth athletics, coaches, parents, and other non-medical personnel often provide oversight of all aspects of event safety and injury. For high school athletes, athletic trainers (AT) are often the first medically licensed practitioners to identify,

evaluate, and manage an injured athlete.^[5,6] However, even for the ~50% of high schools with an AT,^[7] the dynamic environment of competition and covering multiple practices makes it difficult to systematically standardize the triage process and injury management.^[8] The inconsistent or lack of documentation of the injury by those providers who first encounter the injured athlete creates the initial barrier to effective multidisciplinary care of concussion as subsequent hand-offs across providers becomes challenging and time-consuming.^[9,10]

In the evaluation of the clinical practice behaviors of providers within the Cleveland Clinic Health System between 2011 and 2012, gaps in consistent documentation of the concussive injury demographics were identified. These gaps in documentation resulted in inefficient hand-offs between ATs, physicians and other providers. Recognizing the diversity of the providers, their disparate locations and departments and the lack of convenient and rapid access to the EHR, a mobile application was developed to aid in the clinical management of concussion and communication between providers. The iPad-based Cleveland Clinic Concussion Application (C3 app)^[4,11,12] was designed as a concussion management platform for use by providers within the Cleveland Clinic Health System. While the initial platform only consisted of evaluation modules, an incident report (IR) module was developed based on evaluation of practice patterns. The IR module was designed to standardize and systematize the characterization of injury severity through the evaluation of red flags, and document injury-related demographics and athlete disposition. Red flags were operationally defined as any clinical sign or symptom that may be indicative of a more severe injury warranting medical monitoring, additional diagnostic testing, or a higher level of management. Data from the IR module were uploaded to a secure,

HIPAA-compliant cloud-based server accessible to Cleveland Clinic providers via a link within the EHR system. The objectives of this study were to characterize the implementation of the technology-enabled incident report and to determine the impact of age and gender on injury presentation and management of student athletes. We hypothesized that youth athletes would be managed differently from high school and college student-athletes, due in part to lack of formal medical coverage.

2. Methods and materials

2.1. Study design and participants

A cohort study was conducted consisting of a retrospective analysis of prospectively collected data from the IR module. The study was approved by the Cleveland Clinic Institutional Review Board. Of the 1613 IR's completed, 192 were classified as non-sport related injuries, occurring as a result of motor vehicle accidents, recreational activities, altercations, etc. Sport-related injuries were defined as any injury occurring during an athletic exposure (practice or competition) in an organized or sanctioned athletic event. The remaining 1421 unique incidences with documented sport-related concussions were included in this sample for analysis. Age cohorts were categorized to correspond roughly with academic age levels as follows: youth (ages 5–13), high school (ages 14–18), and collegiate (ages 19–24).

2.2. Materials and data collection

Incident report data were collected from July, 2014 to March, 2016 from 46 ATs employed by the Cleveland Clinic in high schools and colleges across Northeast Ohio and from Cleveland

Table 1

Participant and injury demographics by age and gender.

	Youth (Ages 5–13) n=88		High School (Ages 14–18) n=1171		College (Ages 19–23) n=162	
	Male	Female	Male	Female	Male	Female
n (%)	63 (72%)	25 (28%)	771 (66%)	400 (34%)	122 (75%)	40 (25%)
Injured in Game (vs Practice)	38 (60%)	14 (56%)	447 (58%)	279 (70%)	55 (45%)	21 (52%)
Mechanism of Injury						
Collision with another player	41 (65%)	11 (44%)	504 (65%)	127 (32%)	92 (75%)	18 (45%)
Impact with Surface	23 (37%)	9 (36%)	180 (23%)	120 (30%)	10 (8%)	6 (15%)
Impact with Implement	6 (10%)	6 (24%)	72 (9%)	148 (37%)	13 (11%)	14 (35%)
Athlete Disposition						
Removed from play	27 (43%)	19 (76%)	489 (63%)	254 (64%)	73 (60%)	18 (45%)
Continued to play - delayed symptom onset	0 (0%)	0 (0%)	42 (5%)	38 (10%)	8 (7%)	6 (15%)
Continued to play - delayed report of injury	12 (19%)	2 (8%)	153 (20%)	64 (16%)	31 (25%)	11 (28%)
Sent to ED	20 (32%)	3 (12%)	64 (8%)	22 (6%)	7 (6%)	3 (8%)
Returned to play	1 (2%)	1 (4%)	8 (1%)	3 (1%)	0 (0%)	0 (0%)
Return to Play - Cleared	0 (0%)	0 (0%)	3 (0.4%)	3 (1%)	3 (2%)	1 (3%)
Returned to play - No AT	3 (5%)	0 (0%)	12 (2%)	16 (4%)	0 (0%)	1 (3%)
Red Flags						
Worsening Headache	0 (0%)	0 (0%)	44 (6%)	9 (2%)	12 (10%)	5 (13%)
Facial Injury/Fracture	0 (0%)	0 (0%)	0 (0%)	1 (0.3%)	1 (1%)	0 (0%)
Spine injury	0 (0%)	0 (0%)	35 (5%)	6 (2%)	6 (5%)	3 (8%)
Somnolence	0 (0%)	0 (0%)	25 (3%)	3 (1%)	6 (5%)	1 (3%)
Severe amnesia	0 (0%)	0 (0%)	26 (3%)	3 (1%)	4 (3%)	0 (0%)
Weakness/Tingling	0 (0%)	1 (4%)	16 (2%)	1 (0.3%)	1 (1%)	0 (0%)
Agitation	0 (0%)	0 (0%)	19 (2%)	4 (1%)	2 (2%)	0 (0%)
Severe imbalance	0 (0%)	0 (0%)	15 (2%)	0 (0%)	4 (3%)	0 (0%)
Repeated Emesis	0 (0%)	0 (0%)	4 (1%)	2 (1%)	1 (1%)	0 (0%)
Altered Mental Status	0 (0%)	0 (0%)	11 (1%)	1 (0.3%)	1 (1%)	0 (0%)
Pupillary reaction	0 (0%)	0 (0%)	5 (1%)	0 (0%)	1 (1%)	0 (0%)

AT=athletic trainer, ED=emergency department.

Clinic ambulatory concussion clinics. The content of the IR module, which is included within the C3 App, was derived from best practices identified in concussion management guidelines and clinical consensus within the Cleveland Clinic concussion management staff. Three components of the IR were:

1. evaluation of red flags for triage purposes,^[5,6]
2. Injury demographics (e.g., mechanism of injury, primary symptoms, etc) and
3. Athlete disposition (e.g., the action that occurred directly following the injury: sent to emergency department, removed from play, etc).

Specific questions within the IR are provided in Appendix 1, <http://links.lww.com/MD/C894>. Athletic trainers completed an IR for any athlete in which a concussion was suspected. Once completed, all information was uploaded to a secure, cloud-based database using an industry standard Secure Sockets Layer (SSL) communication protocol. The C3 app and database are in compliance with HIPAA guidelines and Cleveland Clinic Health System ITD policies.

2.3. Outcomes

The primary variables summarized were:

1. clinical manifestation including initial symptoms and incidence of red flags;
2. injury-related demographics including sport, venue, and mechanism of injury;
3. athlete disposition.

2.4. Statistical analysis

The incidence of injury-related demographic, clinical presentation, and athlete management variables were summarized by age and gender. The associations between age cohort and gender with injury venue were assessed using a multivariable logistic regression model adjusting for age and gender. Relevant odds ratios were estimated from this model with 95% confidence intervals (e.g., ratio of odds of female injury during game to odds of male injury during games).

Since each student-athlete can have multiple initial symptoms, a multivariate analysis was performed to assess associations between age and gender with the top 6 most frequent initial symptoms. Specifically, separate generalized estimating equation models with logit links and an exchangeable correlation structures^[13] were fitted for age and gender. The age-by-symptom and gender-by-symptom interactions were estimated to determine whether age and gender associations were consistent across symptoms. Given observed significant interactions suggested heterogeneity, separate multivariate logistic regression models were fit for each of the top 6 symptoms, adjusting for age and gender. Given that each athlete could have multiple mechanisms of injury (e.g., head to head collision resulting in a fall and subsequent collision against the playing surface), the associations between mechanism of injury with age and gender were also estimated using this approach.

A logistic regression model including a term for gender was used to assess the association between gender and the incidence of any red flag symptoms. The independence of age cohort with red flag symptoms was assessed using Fisher exact test. Odds ratios

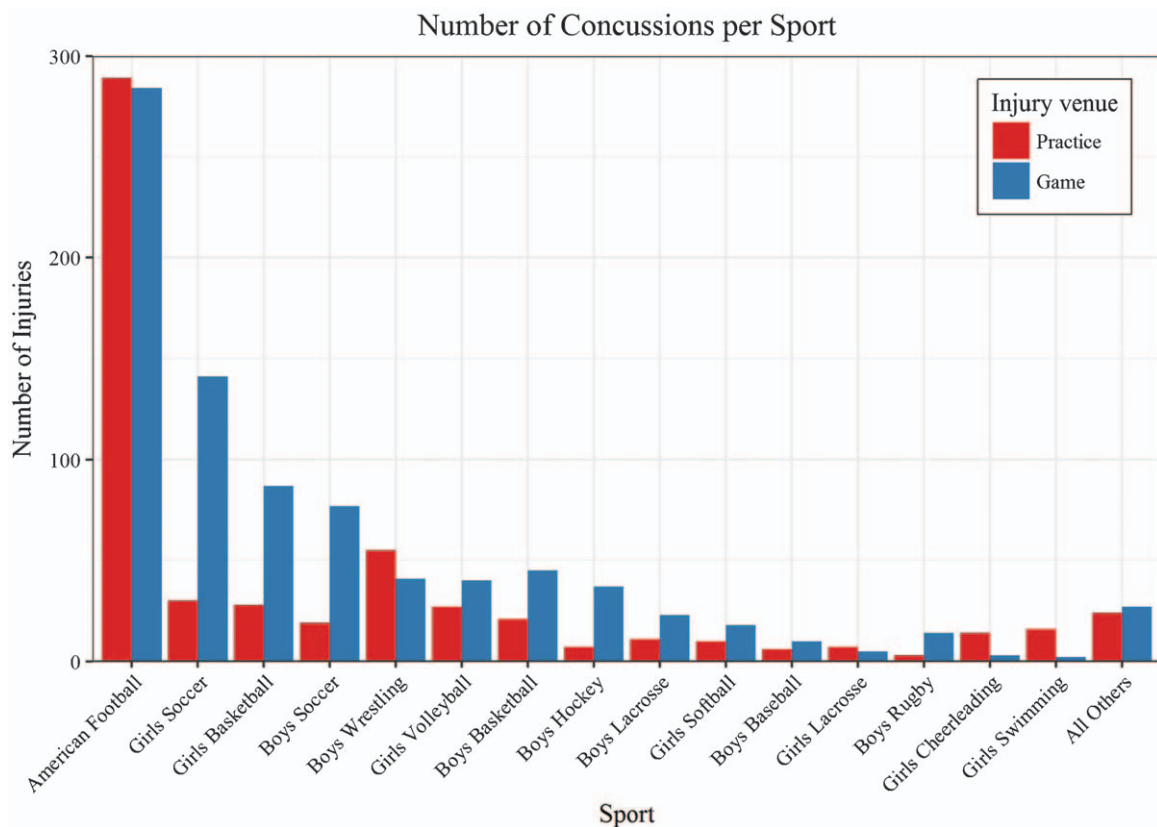


Figure 1. Number of concussions as a function of sport is stratified according to venue, with those occurring during game or competition depicted in blue, and those occurring during practice shown in red. Overall, an increased number of concussions occurred during game situations except in American football, boys wrestling, girls cheerleading, and girls swimming.

could not be estimated from a logistic regression due to poor model stability given few youth had red flag symptoms.

Four athlete dispositions were established: continued to play due to delayed athlete reporting or delayed symptom onset, returned to play, sent to emergency department (ED), and removed from play. The extent to which athlete disposition differed by age cohort, gender, or incidence of at least 1 red flag symptom was assessed from a multinomial regression model with the athlete disposition category as a function of age cohort, gender, and red flag incidence. The reference category was defined as “continued to play.” The consistency of disposition among athletes with and without red flags across gender and age was assessed by testing interactions between age and gender with red flags.

Analyses were completed using R version 3.4.1 (R Project for Statistical Computing, Vienna, Austria). Each analysis was conducted at the 0.05 significance level unless otherwise stated. Type I error was preserved for each model using the single-step procedure by Hothorn et al.^{114]}

3. Results

3.1. Sample and Injury demographics

Details of the sample and injury-related demographics stratified by age and gender are provided in Table 1. Of the 1421 athletes included, 956 were male (67%) and 465 were female (33%). The majority of injured males participated in American football (60%), soccer (10%) and wrestling (10%), while most injured females participated in soccer (37%), basketball (25%), or volleyball (14%). Figure 1 illustrates injury frequency as a function of sport and venue. Of all sport-related injuries, 60% occurred during game situations and 40% occurred during practice. The distribution of venue (game vs practice) significantly differed across age cohorts ($P = .001$) and gender ($P < .001$): high school students were more likely to get injured in games than college students, while male athletes were more likely to get injured in games compared to female athletes (Table 2).

3.2. Clinical presentation

The self-reported symptoms at the time of injury were stratified according to age and gender (Fig. 2). Headache and dizziness were the 2 most commonly reported initial symptom across all age cohorts and genders. However, the top 6 initial symptoms significantly differed across age categories ($P < .001$; Table 3). Headaches were significantly more common in youth ($P = .02$) and high school ($P < .001$) than college athletes, dizziness was more commonly reported among high school than college athletes ($P = .01$), and not feeling right was more common among college athletes than youth ($P = .01$). Similarly, the top 6 initial symptoms significantly differed by gender ($P = .04$), with male athletes were significantly more likely to report that they do not feel right than females ($P = .01$). There was no age-by-gender interaction for any of the top 6 initial symptoms (all interaction $P > .05$).

3.3. The incidence of red flags

Red flag symptoms were reported in 114 (8%) of student-athletes, including 1 youth athlete (1%), 95 high school athletes (8%), and 18 college athletes (11%). Incidence of red flag symptoms significantly differed by age cohort ($P = .01$). Red flag symptoms occurred in 19 female athletes (4%) and 95 male

Table 2
Association between age and gender with outcomes.

Analysis	Odds ratio (95% CI)	P value
Venue distribution (game vs practice)		
Female vs male	1.57 (1.24, 1.98)	<.001
Age		
High school vs youth	1.10 (0.65, 1.86)	.97
College vs high school	0.56 (0.38, 0.83)	.003
College vs youth	0.62 (0.33, 1.16)	.23
Red flags		
Female vs male	0.39 (0.23, 0.64)	<.001
Age	NA*	.04
Disposition – Sent to ED (vs CTP)		
Female vs male	0.69 (0.34, 1.42)	.81
Age		
High school vs youth	0.15 (0.05, 0.44)	<.001
College vs high school	0.55 (0.19, 1.61)	.74
College vs youth	0.09 (0.02, 0.35)	<.001
Red flag (vs none)	7.54 (2.26, 25.1)	<.001
Disposition – RFP (vs CTP)		
Female vs male	1.04 (0.71, 1.53)	>.99
Age		
High school vs youth	0.71 (0.29, 1.76)	.97
College vs high school	0.63 (0.37, 1.07)	.14
College vs youth	0.45 (0.16, 1.23)	.24
Red flag (vs none)	3.97 (1.48, 10.7)	<.001
Disposition – RTP (vs CTP)		
Female vs male	1.70 (0.72, 3.97)	.59
Age		
High school vs youth	0.40 (0.08, 1.96)	.70
College vs high school	0.62 (0.15, 2.58)	.99
College vs youth	0.25 (0.03, 1.90)	.45
Red flag (vs none)	1.62 (0.16, 16.0)	>.99

Odds ratios estimated from separate multivariable logistic regression models with the outcome a function of age, gender, and red flag (if applicable). For each model, family-wise error rate was controlled for using the single step procedure.

CTP = continued to play, ED = emergency department, RFP = removed from play, RTP = returned to play. *The odds ratio between age and red flags could not be assessed because of a low number of red flags in the youth cohort. P value estimated from Fisher exact test.

athletes (10%). Male athletes had a significantly higher incidence of red flags than female athletes ($P < .001$, Table 2).

3.4. Athlete disposition

The athlete's initial disposition is illustrated by age and gender in Figure 3. Over half of athletes in each age cohort were removed from play. About 35% of college, 25% of high school, and 16% of youth athletes did not report the injury or experienced delayed symptom onset and continued to play. Youth athletes were significantly more likely to be sent to the emergency department (vs continuing to play) than high school or college athletes ($P < .001$, Table 2). Athletes with red flag symptoms had significantly higher odds of being sent to the emergency department ($P < .001$) or removed from play ($P < .001$) rather than continuing to play. Gender was not associated with athlete disposition. A forest plot depicting odds ratios of athlete disposition by age, sex, and presence of red flags is presented in Figure 4.

3.5. Mechanism of injury across sport, age, and gender

Collision with another player was the most common mechanism of injury, accounting for 56% of injuries, followed by impact against playing surface (25%) and impact with an implement

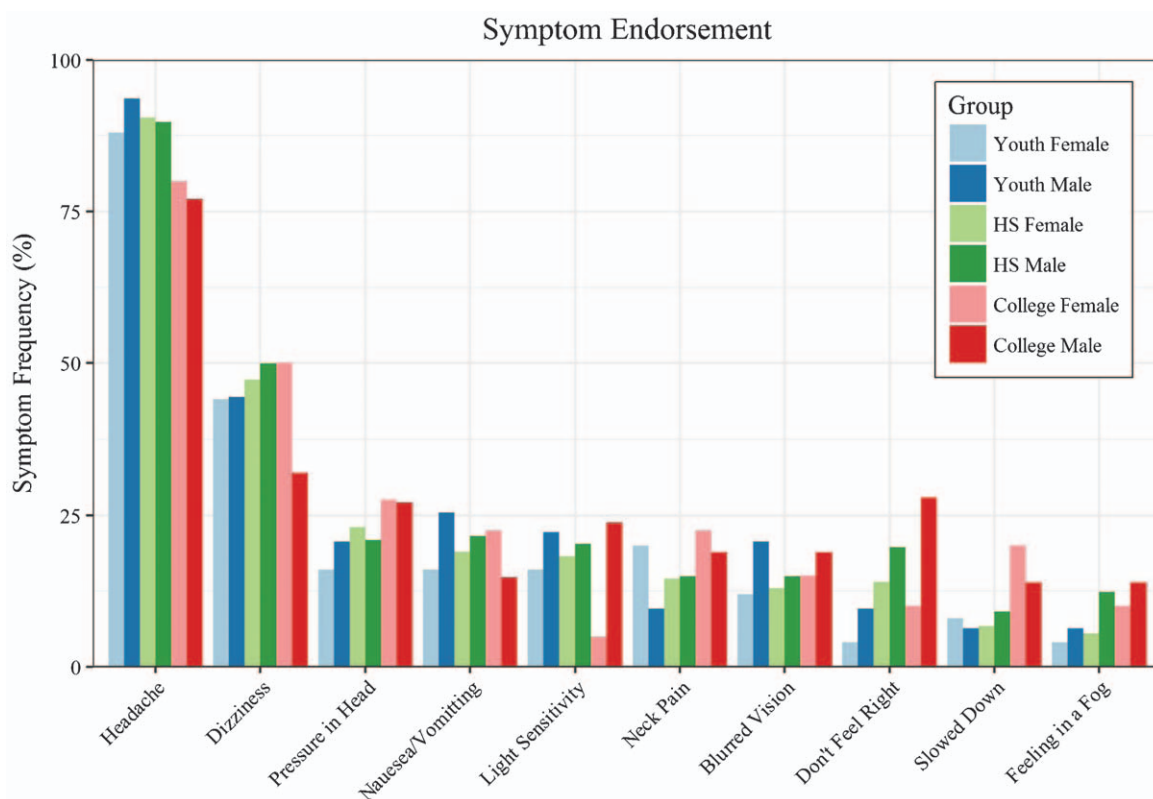


Figure 2. The 10 most frequently reported symptoms stratified according to age and gender cohorts are depicted. The 2 most frequently reported symptoms, headache and dizziness, were similar across all cohorts, with subtle variations in the remainder of the 8 symptoms.

(ball, puck, etc.) (18%); Table 1. Injury mechanisms differed significantly across age cohorts and gender (both $P < .001$). College athletes were injured significantly more often via collision than high school students ($P = .007$) and injured less often due to impact with the playing surface than youth ($P < .001$) or high school athletes ($P < .001$); Table 4. Female athletes were injured more frequently from implements ($P < .001$) and playing surfaces ($P = .02$) than males, but males were injured more frequently from collisions ($P < .001$).

4. Discussion

Numerous barriers exist that prevent the accurate detection, effective management, and appropriate documentation of concussive injuries in student-athletes.^[9,10,15,16] Given that athletes with concussion are most optimally managed by an interdisciplinary team of clinicians,^[17] effective communication and handoffs between providers is critical, yet hindered by paper documentation or EHR systems that lack full integration.^[9] The purpose of this study was to document the implementation of an electronic incident report and to investigate whether clinical presentation or injury management varied among youth, high school, and collegiate student-athletes. The IR module embedded within the C3 app provided a secure, HIPAA-compliant platform conducive for field use to efficiently document concussive injuries, served to define injury characteristics, and allowed for the secure sharing of injury demographics across the multi-disciplinary clinical team.

A critical feature of the IR was the ability to programmatically guide clinicians along the clinical algorithms developed as part of the Cleveland Clinic concussion care path, an evidence-informed

guideline created to standardize concussion management according to current best practices.^[11] Diagnosis-specific clinical guidelines as such are designed to reduce the ambiguity associated with clinical decision-making, streamline care, improve outcomes, and improve the cost-effectiveness and value associated with the delivery of medical care.^[18] While licensed medical personnel are trained to examine the injured athlete to determine clinical status and the appropriate action to be taken, it is acknowledged that varying levels of experience and clinical expertise abound in clinicians managing concussive injuries in youth sports. Mismanagement during this acute stage of injury may result in unnecessary transfer to the emergency department setting or inappropriate recommendations for imaging based on the clinical misinterpretation of common concussion symptoms.^[19–21] Conversely, insufficient monitoring or not observing critical signs/symptoms indicative of a more serious injury may also occur with unsuspecting or inexperienced clinicians. Therefore, providing evidence-based criteria such as red flags to guide clinical decision-making may improve the efficacy and cost-effectiveness of medical care in this population. Our data indicate a disproportionate percentage (26%) of youth athletes (<14 years of age) were sent to the emergency department at a rate significantly higher than high school- and college-age athletes, despite the absence of red flags that would warrant transfer to a higher level of care. While the high school and collegiate athletes in our study had direct access to formal medical coverage, youth events typically did not have formal medical coverage onsite. This lack of medical triage by experienced field clinicians may have led to the higher propensity for ED visits for the youth cohort. While our study did not include youth younger than 5 years of age, our findings that younger children were more

Table 3
Associations between age cohorts and gender with the top 6 initial symptoms.

Initial symptom	Odds ratio (95% CI)	P value
Headache		
Female vs male	1.06 (0.68, 1.66)	.98
Age		
High school vs youth	0.78 (0.29, 2.09)	.91
College vs high school	0.39 (0.23, 0.66)	<.001
College vs youth	0.30 (0.10, 0.88)	.02
Dizziness		
Female vs male	0.98 (0.74, 1.29)	>.99
Age		
High school vs youth	1.21 (0.70, 2.09)	.79
College vs high school	0.59 (0.39, 0.91)	.01
College vs youth	0.72 (0.37, 1.39)	.55
Head pressure		
Female vs male	1.10 (0.79, 1.53)	.89
Age		
High school vs youth	1.15 (0.58, 2.27)	.95
College vs high school	1.36 (0.86, 2.18)	.30
College vs youth	1.56 (0.71, 3.44)	.45
Nausea/Vomiting		
Female vs male	0.89 (0.63, 1.26)	.80
Age		
High school vs youth	0.89 (0.47, 1.70)	.97
College vs high school	0.76 (0.44, 1.31)	.55
College vs youth	0.68 (0.30, 1.52)	.58
Light sensitivity		
Female vs male	0.78 (0.54, 1.11)	.26
Age		
High school vs youth	0.96 (0.49, 1.88)	>.99
College vs high school	0.95 (0.56, 1.60)	.99
College vs youth	0.91 (0.40, 2.05)	.99
Do not feel right		
Female vs male	0.60 (0.41, 0.89)	.01
Age		
High school vs youth	2.58 (0.97, 6.87)	.06
College vs high school	1.36 (0.83, 2.22)	.36
College vs youth	3.51 (1.21, 10.2)	.01

Odds ratios estimated from post hoc analyses of age and gender based on separate logistic regression models with the symptom as a function of age and gender. For each model, family-wise error rate was controlled for using the single step procedure.

likely to seek care in the ED setting are similar to those reported by Arbogast and colleagues, who found that the highest incidence of ED utilization occurred in 0 to 4 year olds (51.9% rate), followed by 5 to 11 year olds (14.9% rate), 12 to 14 year olds (7.9% rate), and finally, 15 to 17 year olds (6.8% rate).^[22] Future analysis is aimed at understanding both the clinical efficacy and financial ramifications of ED utilization in the concussion domain, as tests including computerized tomography are often completed without rigorous adherence to guidelines directing their indication of use.^[21]

Despite increased awareness and education surrounding concussion, 367 (25.8%) student-athletes continued to play after incurring their concussive injury. These injuries went undetected by onsite personnel, and 273 of the occurrences were as a result of the athlete not reporting his/her symptoms, while in the remaining 94 cases, a delay in symptom onset occurred. Understanding the behaviors of student-athletes including gender- or age-related tendencies,^[23] and the clinical presentation and immediate management of injured student-athletes are critical to inform the clinical and athletic staff in analyzing gaps in concussion management. Identifying gaps can lead to the

development of strategies to improve processes, and evaluating the outcomes of process improvement strategies. For example, while one-quarter of our sample did not report or recognize their concussive injury, previous reports indicated that concussions went unreported in 70% of collegiate athletes^[24] and more than 50% of high school athletes.^[25] A recent study of female middle school soccer players reported a 58.6% rate of continuing to play despite being symptomatic.^[3] It is plausible that in the 5 to 10 years since the latter data were collected, efforts to educate athletes, parents, coaches, and medical providers in concussion symptoms and management have reduced the incidence of the underreporting and/or under-recognition of concussive injuries. Legislative efforts mandating concussion education for athletes, parents, coaches and athletic directors/administrators may have also contributed to improved injury detection and management and lower rates of athletes continuing to play with concussive symptoms.^[26] The systematic collection of longitudinal data through a mechanism such as the IR and the creation of a data repository would be valuable in determining the effectiveness of various initiatives (education,^[27] legislative, rule changes, etc) in improving the detection and management of student-athletes with concussion.^[26]

The IR data supported the value of trained medical professional on the sideline, as of the 55 student-athletes (3.9% of the total sample) who were returned to play, 32 did not have an AT onsite. In 13 additional occurrences (.9% of the total sample), supplemental documentation revealed that overt concussive symptoms were not present at the time of the exam; thus, a concussion was ultimately ruled out. This, combined with data presented above in which athletes continued to play due to delayed symptom onset, highlights the challenges associated with injury detection when symptom onset is delayed, and supports legislation mandating that student-athletes not be permitted to return to play on the same day if a concussive injury was suspected. Furthermore, these data underscore the value AT's provide in ensuring the safety of student-athletes, and support recent evidence demonstrating that concussive injury detection is higher when athletic trainers are onsite.^[16,28] Lastly, these data justify increasing onsite coverage by AT's to improve the safety and management of injured student-athletes, given that only an estimated 50% of high schools in the United States employ dedicated athletic trainers, and that the presence of AT's or those with formal medical training at middle school, recreational/club sporting events, and in socioeconomically disadvantaged communities^[15] is even more sparse.

Using best practice standards to guide clinical decision making coupled with immediate electronic documentation outlining injury management and decision-making not only facilitates optimal medical management, but also aids in controlling an institution's liability risk.^[5,29] Decreasing overall risk to the athlete, school, and medical personnel is paramount, as scrutiny over the management of concussive injuries is increasingly prevalent in the United States and abroad.^[5,26,30] Furthermore, given that an estimated 50% of high schools and a far greater percentage of middle school and recreation/travel league teams do not have personnel on hand with formal medical/first responder training, the clinical algorithm may facilitate the safe management of youth athletes, thus bridging the gap between environments with disparate medical coverage and those with expert care.^[15]

A comprehensive understanding of injury mechanism and demographics is also critical from an epidemiological standpoint in implementing primary prevention interventions. Sport-specific policy and rule changes aimed at decreasing the incidence of

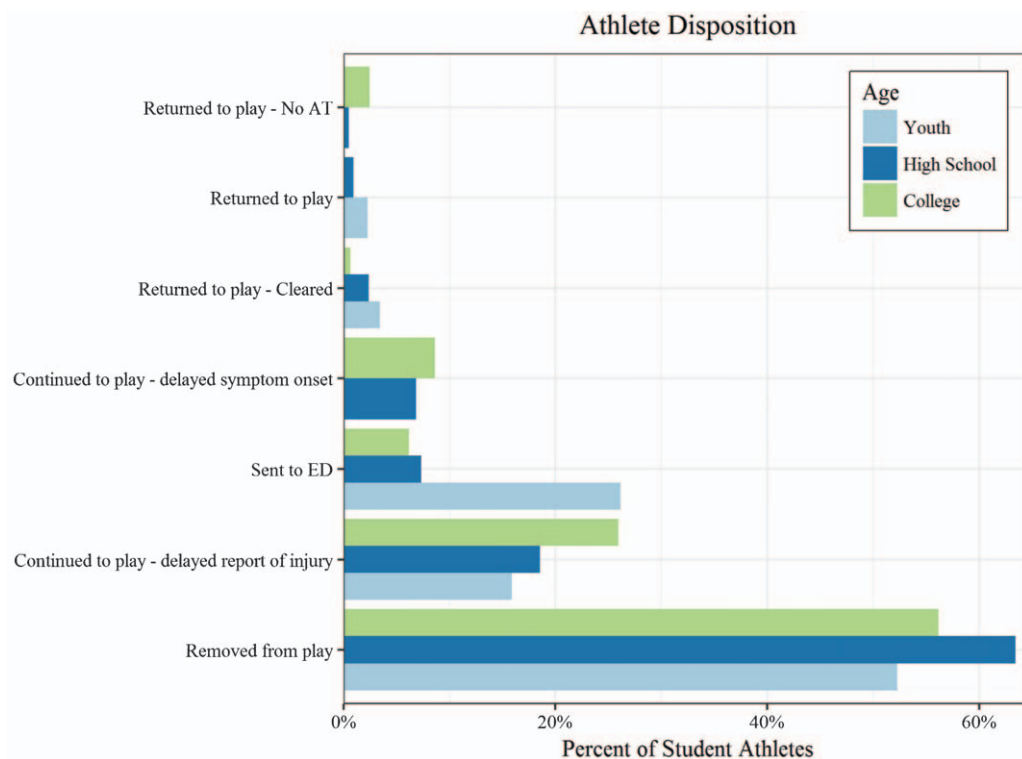


Figure 3. The disposition of the athletes was documented following initial examination by onsite personnel, and stratified according to youth, high school, and collegiate age cohorts. A significant interaction effect was found, indicating that athletes in the youth cohort were sent to the emergency department at significantly higher frequencies compared to high school and collegiate student-athletes.

concussion are directly related to understanding the circumstances surrounding the injury. In youth ice hockey leagues, a significant reduction in overall injury and concussion rates was recently reported after policy eliminating body checking was enacted.^[31] Additionally, the United States Youth Soccer Associations recently enacted rule changes eliminating heading for athletes under the age of 10, and limiting heading in ages 11 to 13.^[32] While this initiative was driven by a class-action lawsuit alleging negligence in treating and monitoring head injuries on part of several US and International soccer organizations which were named as defendants, the rule changes were based on a large retrospective analysis of injury data which indicated that heading resulted in the greatest number of concussions in high school soccer.^[33] Interestingly, athlete-to-athlete contact during heading was the mechanism which resulted in the greatest incidence of concussions, not ball to head contact, as one might have presumed.^[33] These data highlight the importance of detailed injury reporting, as the athlete-to-athlete contact associated with heading may not have been considered as a culprit of injury, and limiting aggressive play in certain age groups may be another appropriate consideration in risk reduction.

With patient-centered care in mind, a critical goal of the electronic IR was to ensure the continuity of care across members of the interdisciplinary concussion team. While AT's are often the first providers to evaluate and manage the injured student-athlete, physicians, physical therapists, speech therapists, neuropsychologists, and psychologists, among others, often participate to varying degrees, in the individual's care. Documentation in EMR's have been shown to facilitate communication among members of multi-disciplinary clinical teams;^[34] however, EMR systems are often not accessible to AT's in the field. Therefore,

paper charts stored onsite remain the most commonly used documentation method by AT's working in the field, serving as a barrier for effective communication across providers. The electronic IR eliminates this barrier by allowing for uploaded information to be accessed securely by all members of the concussion management team. The IR also allows for systematic quality assurance analysis by allowing administrators to review the clinical practice patterns of staff and clinical outcomes, thereby facilitating continuous refinement of the care path guideline.^[35] Process improvements embarked upon following implementation of the app included internal audits to track the quality and completeness of documentation related to the IR, post-injury rehabilitation, and the return to school/play process.

5. Limitations

While we have reported the details associated with and initial clinical presentation of 1421 documented incidences of sport concussion injuries, a seasonal bias may exist as the data were obtained over the course of 2 fall seasons, 2 winter seasons, and 1 spring season. Additionally, although use of the electronic incident report was a documentation requirement for all Cleveland Clinic athletic trainers, it is plausible that not all sport-related injuries were documented. Despite widespread use across ATs, the existing IR data may be reflective of injuries managed by the most compliant ATs. Data on youth athletes who did not have an AT onsite at the time of injury were obtained in the clinical environment following the injury. Exact recall of specific symptom manifestation may be compromised over the course of time. In the absence of medical personnel, parents or guardians often decide on how, when, or where to seek care for

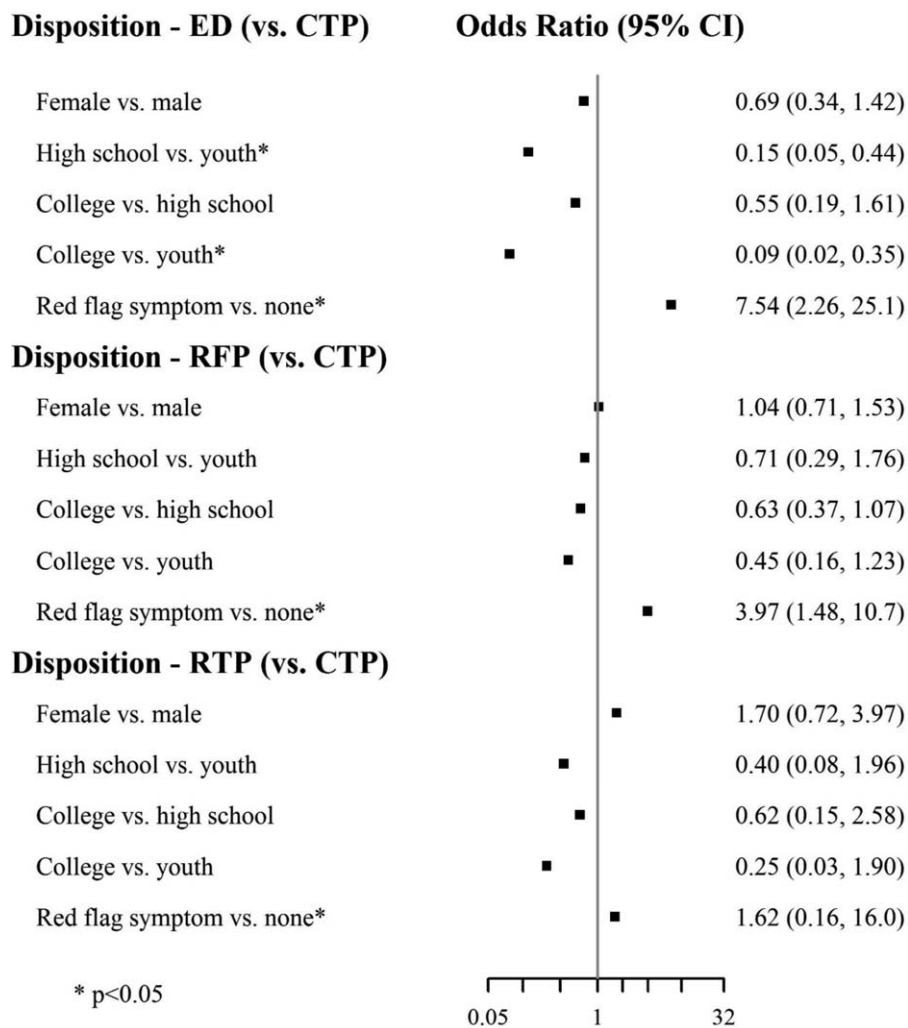


Figure 4. Odds ratios of disposition (vs continuing to play) by gender, age, and red flag symptoms. The boxes represent the odds ratios while the lines represent the confidence intervals. For each outcome, confidence intervals are adjusted using the single-step procedure by Hothorn et al to control for multiple comparisons. The gray line at OR=1 indicates no difference between groups. If the confidence interval overlaps this line, there is no significant difference between groups.

their injured child. Thus, the increased utilization of ED for youth athletes in the absence of red flags may be a reflection of conservative parental decision-making. Substantial effort has been made to educate practitioners and standardize care according to best practice guidelines; thus, data regarding clinical management reported in this study may be influenced by these educational efforts and may not reflect practices outside the Cleveland Clinic Health System.

Numerous factors associated with concussion and injury detection/management may present as confounders that influence the data and outcomes. These include but are not limited to the following:

1. the influence of game time competition compared to practice;
2. self-reporting of symptoms and its influence on factors such as playing time, removal from play;
3. the knowledge/expertise of onsite personnel including coaching staff, parents, officials, and spectators; and
4. changes in rules, laws, or standards of care.

It is difficult to quantify the influence of these potential confounders, but all should be considered when interpreting the results of our study.

6. Conclusion

The electronic IR filled numerous gaps identified by the concussion management team at the Cleveland Clinic by guiding clinical management outlined in the evidence-informed care path, providing a platform for the systematic documentation of the injury, and allowing for analysis of injury-related demographics. A thorough understanding of the clinical course of each injury and use of predictive modeling to analyze relationships between injury demographics and clinical outcome are underway and may enhance the clinical relevance of our findings. Nonetheless, the approach to injury reporting described through the electronic IR within the Cleveland Clinic Healthcare System may serve as a model in the systematic collection and analysis of concussive injury demographics^[22] to inform the medical and sports communities in optimal management practices and enact directives or rule changes to improve the safety of youth sports.

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Table 4**Associations between age cohorts and gender with mechanism of injury.**

Mechanism of injury	Odds ratio (95% CI)	P value
Collision with another player		
Female vs male	0.26 (0.19, 0.34)	<.001
Age		
High school vs youth	0.86 (0.48, 1.53)	.90
College vs high school	1.67 (1.06, 2.63)	.02
College vs youth	1.44 (0.71, 2.90)	.53
Impact against playing surface		
Female vs male	1.40 (1.02, 1.92)	.04
Age		
High school vs youth	0.59 (0.33, 1.04)	.08
College vs high school	0.33 (0.17, 0.64)	<.001
College vs youth	0.19 (0.08, 0.45)	<.001
Impact with an implement		
Female vs male	5.37 (3.75, 7.70)	<.001
Age		
High school vs youth	1.36 (0.60, 3.08)	.76
College vs high school	1.03 (0.58, 1.84)	>.99
College vs youth	1.41 (0.54, 3.68)	.79

Odds ratios estimated from post hoc analyses of age and gender based on separate logistic regression models with the mechanism as a function of age and gender. For each model, family-wise error rate was controlled for using the single step procedure.

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