Brain Injury, October 2009; 23(11): 888–898

informa
healthcare

Compliance with return to play guidelines following concussion in US high school athletes, 2005–2008

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(Received 6 January 2009; revised 26 July 2009; accepted 24 August 2009)

Abstract

Primary objective: To determine whether US concussed high school athletes complied with recommended return-to-play guidelines during the 2005–2008 school years.

Research design: Prospective cohort study in 100 nationally-representative US high schools.

Methods and procedures: Certified athletic trainers submitted injury reports for concussed athletes in five boys' (football, soccer, basketball, wrestling, baseball) and four girls' (soccer, basketball, volleyball, softball) sports via High School RIO™ (Reporting Information Online). Concussions were retrospectively graded and it was determined whether athletes followed American Academy of Neurology (AAN) or Prague return-to-play guidelines.

Main outcomes and results: There were 1308 concussions reported during 5 627 921 athlete-exposures (23.2 concussions per 100 000 athlete-exposures), reflecting an estimated 395 274 concussions sustained nationally. At least 40.5% and 15.0% of concussed athletes returned to play prematurely under AAN and Prague return-to-play guidelines, respectively. In football, 15.8% of athletes sustaining a concussion that resulted in loss-of-consciousness returned to play in <1 day. Males (12.6%) were more likely than females (5.9%) to return 1–2 days after sustaining an initial grade II concussion.

Conclusions: Too many adolescent athletes are failing to comply with recommended return-to-play guidelines. Sports medicine professionals, parents, coaches and sports administrators must work together to ensure athletes follow recommended guidelines.

Keywords: *concussion, traumatic brain injury, sports, recovery, time loss*

Introduction

High school sports, an important source of physical activity for US adolescents, drew over 7 million participants during the 2006–2007 school year [1]. Despite numerous health benefits [2], high school athletes are at risk of injury, including concussion. Annually, US high school athletes sustain over 100 000 concussions [3]. It is important to not only prevent concussions, but also to properly manage them to minimize the risk of long-lasting effects. Determining appropriate return-to-play (RTP) guidelines following concussion is a crucial component of managing this injury.

Numerous manuscripts have discussed the challenges of diagnosing and managing sports-related concussions [3–12]. As of 2001, over 25 concussion grading scales had been published [13]. These scales differ in concussion grading criteria and RTP guidelines, but most are based on symptoms and symptom resolution time and none are based on clinical evidence [14]. Of these, the Cantu [15], Colorado [9] and American Academy of Neurology (AAN) [16] guidelines have been used most frequently [17]. In 2001, concussion experts from around the world convened for the 1st International Symposium on Concussion in Sport to establish a consensus for concussion identification and management [18]. These guidelines were subsequently supported and updated in 2004 during the 2nd International Symposium on Concussion in Sport in Prague [19].

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ISSN 0269–9052 print/ISSN 1362–301X online
DOI: 10.1080/02699050903283171

Previous research has examined concussion incidence and time loss from play among concussed high school athletes [3, 4, 7]. However, despite growing awareness of the dangers of premature RTP and heightened attention on the need for universally accepted RTP guidelines, no research has focused on how often high school athletes follow recommended RTP guidelines. Athletes returning to play too soon following concussion have been shown to have slowed reaction times [8], which may result in an increased risk of re-injury [20]. Premature RTP can increase the risk of more severe post-concussive symptoms [14]. In rare cases, returning to play while still experiencing symptoms may result in diffuse brain swelling known as second-impact syndrome [9]. Previous research suggests that athletes with a history of concussions are more likely to sustain future concussions [21]. Furthermore, sustaining multiple concussions during an athletic career is a risk factor for cognitive impairment later in life [22].

The objective was to examine RTP following concussion in a nationally representative sample of US high school athletes during the 2005–2008 school years. Specifically, the aims were to: (1) determine concussion rates among US high school athletes; (2) determine the proportion of athletes who complied with RTP guidelines; and (3) examine whether compliance varied by sport or gender.

Methods

Data collection

The National High School Sports-Related Injury Surveillance Study was used, which gathers data via High School RIO^{TM} (Reporting Information Online). This surveillance study has been described previously [3, 23, 24]. In brief, high schools with at least one certified athletic trainer (AT) affiliated with the National Athletic Trainers' Association (i.e. certified by the Board of Certification (BOC)) with a valid email address were invited to participate. Willing participants were stratified based on two potential confounders: school size and US Census geographic location [25]. There were two levels of school size (<1000 and >1000 students) and four levels of geographic location (South, Midwest, West and Northeast). Thus, all schools were categorized into one of eight strata: South big (>1000 students), South small (<1000 students), Midwest big, Midwest small, West big, West small, Northeast big or Northeast small. To arrive at a study sample size of 100 schools, 12 schools were randomly selected from each of the small (i.e. <1000 students) strata and 13 schools from each of the big (i.e. >1000 students) strata. Thus, 48 schools were small and 52 were big. One hundred schools were then selected to participate by randomly choosing schools from each stratum. If a high school dropped out of the study, a replacement school was selected from the same stratum to maintain the 100-school study population.

ATs from participating high schools logged onto the High School RIO^{TM} website weekly throughout the school year to report injury incidence and athlete-exposure (AE) for five boys' (football, soccer, basketball, wrestling and baseball) and four girls' (soccer, volleyball, basketball and softball) sports. These nine sports were chosen because they had large numbers of high school participants, along with relatively high injury rates. Although not all high schools had each of the nine sports, each sport had at least 90 high schools that reported.

Definitions

This study defined AE as one athlete participating in one practice or competition. During all three study years, a reportable concussion must have (1) occurred during participation in an organized practice or competition and (2) required medical attention. During the first 2 years (2005–2007), a reportable concussion must have restricted athletic participation for $\geq$1 days. In efforts to continuously improve RIO^{TM} surveillance, during the 3rd year (2007–2008) this time loss requirement was dropped and ATs were asked to report all concussions. For each concussion, the AT submitted a detailed report on the athlete (e.g. sport, gender, etc.), concussion (e.g. symptoms, symptom resolution, RTP, etc.) and circumstances leading to concussion (e.g. mechanism, activity, etc.). For symptom resolution, ATs could chose from <15 minutes, 15–29 minutes, 30–59 minutes, 1–11 hours, 12–23 hours, 1–3 days, 4–6 days, 1 week–1 month and >1 month. For RTP, ATs could chose from <1 day (2007–2008 only), 1–2 days, 3–6 days, 7–10 days, 10–21 days and >21 days. Throughout the school year, ATs were able to view submitted information and update reports as needed.

Concussion grading and RTP

Concussions were graded and appropriate RTP was judged using two guidelines: AAN [16] and Prague [19]. The Prague guidelines were chosen because they represented the latest consensus on concussion management that ATs might have been using at the time of this study [19]. However, because the Prague guidelines were still relatively new, many high school ATs may have still been transitioning from the use of older concussion guidelines such as AAN to the Prague guidelines. Previous research suggests that the AAN guidelines were the most widely used in the

Table I. American Academy of Neurology (AAN) and Prague guidelines for concussion grading and return-to-play (RTP).

Definition	Return-to-play
AAN [16]	
Grade I	
• Transient confusion	1st occurrence: Same day
• No LOC	2nd occurrence: After 1 asymptomatic week
• Symptoms <15 min	
Grade II	
• Transient confusion	1st occurrence: After 1 asymptomatic week
• No LOC	2nd occurrence: After 2 asymptomatic weeks
• Symptoms >15 min	
Grade III	
• Any LOC	1st occurrence: Brief LOC: After 1 asymptomatic week; Prolonged LOC: After 2 weeks, following 1 asymptomatic week
	2nd occurrence: After 1 asymptomatic month
Prague [19]	
Simple	
• Symptoms resolve within 7–10 days	No RTP same day Player should not be left alone, regular monitoring for deterioration Player should be medically evaluated Follow stepwise RTP protocol. Athlete should continue to proceed to the next level if asymptomatic at the current level. If symptomatic, the athlete should drop back to the previous asymptomatic level and attempt progression after 24 hours. (1) No activity, complete rest (2) Light aerobic exercise (walking, etc.), no resistance training (3) Sport-specific exercise, progressive resistance training (4) Non-contact training drills, progressive resistance training (5) Full contact training after medical clearance (6) Game play
Complex	
• Symptoms are persistent • LOC >1 min • Prolonged cognitive impairment • Athlete has suffered multiple concussions	Rehabilitation will be more prolonged Complex cases should be managed by experienced doctors

LOC, loss-of-consciousness; PTA, post-traumatic amnesia.

years preceding the publication of the Prague guidelines [26].

AAN concussion grades were retrospectively assigned based on AT-reported presence or absence of loss of consciousness and concussion symptom resolution (Table I). For each concussion, the retrospectively-assigned AAN concussion grade, recurrence status, symptom resolution time and time till RTP were used to judge compliance with AAN RTP guidelines.

All concussions were graded as simple according to Prague guidelines because category distinctions between simple and complex are not straightforward and the authors preferred to err towards higher compliance with RTP guidelines.

For both AAN and Prague RTP guidelines, all concussions were categorized as (1) compliant; (2) non-compliant; or (3) unknown compliance. Compliance was unknown when symptom resolution and RTP categories captured by RIO^{TM} lacked adequate specificity. For example, AAN guidelines permit RTP 7 days following symptom resolution of an initial grade II concussion. If such an athlete had reported symptom resolution in 1–3 days and returned to play in 7–10 days then compliance with RTP guidelines is unknown (i.e. if symptoms resolved in 1 day and RTP was 8 days, the athlete would have been compliant; if symptoms resolved in 3 days and RTP was 8 days, the athlete would have been non-compliant).

Statistical analysis

This study analysed data using SAS, version 9.0. Concussion rates were the number of concussions per 100 000 AE. Concussion rate ratios (RR) and injury proportion ratios (IPR) were calculated with 95% confidence intervals (CI), with 95% CI not including 1.00 considered statistically significant. As an example of RR calculation, the following compares competition and practice concussion rates:

$$RR = \frac{(\#\text{ competition concussions}/\#\text{ competition AE})}{(\#\text{ practice concussions}/\#\text{ practice AE})}$$

Table II. Concussion rates per 100 000 athlete-exposures by sport and school year, National High School Sports-Related Injury Surveillance Study, US 2005–2008 school years*.

	2005–2007				2007–2008				Overall			
	Total	Grade I	Grade II	Grade III	Total	Grade I	Grade II	Grade III	Total	Grade I	Grade II	Grade III
Overall	22.7	1.32	19.8	0.82	24.1	2.07	19.8	1.59	23.2	1.60	19.8	1.10
Boys' sports	25.8	1.49	22.5	0.81	28.2	2.52	22.7	2.09	26.7	1.87	22.6	1.28
Football	47.2	2.79	42.0	0.75	52.7	4.19	43.3	3.32	49.3	3.32	42.5	1.73
Soccer	21.0	0.30	18.3	0.90	19.2	1.97	15.8	1.48	20.4	0.93	17.4	1.12
Basketball	7.09	0.47	6.38	0.00	8.41	1.60	6.00	0.40	7.58	0.89	6.24	0.15
Wrestling	16.4	1.55	12.4	1.86	14.5	1.11	10.6	2.79	15.7	1.39	11.8	2.19
Baseball	4.09	0.29	2.92	0.88	2.15	0.54	1.07	0.54	3.41	0.38	2.27	0.76
Girls' sports	16.6	1.00	14.5	0.84	15.9	1.16	14.0	0.58	16.4	1.06	14.3	0.74
Soccer	28.9	1.31	26.3	0.99	26.5	1.73	24.2	0.58	28.0	1.46	25.5	0.84
Basketball	21.3	1.40	18.5	1.12	18.1	0.50	16.6	0.50	16.6	1.08	14.7	0.74
Volleyball	6.07	0.00	5.00	0.71	10.0	1.18	8.24	0.59	7.56	0.44	6.23	0.67
Softball	7.07	1.18	5.50	0.39	6.90	1.38	4.83	0.69	7.01	1.25	5.26	0.50

*Concussions were graded retrospectively following AAN guidelines based on presence or absence of loss-of-consciousness and concussion symptom resolution time.

As an example of IPR calculation, the following shows the IPR comparing the proportion of females and males complying with AAN RTP guidelines:

$$\text{IPR} = \frac{\left(\frac{\#\text{ females with AAN RTP compliance}}{\#\text{ females sustaining a concussion}}\right)}{\left(\frac{\#\text{ males with AAN RTP compliance}}{\#\text{ males sustaining a concussion}}\right)}$$

Unless otherwise specified, all analyses used unweighted data. National concussion incidence was estimated using weights provided by the High School RIO^{TM} sampling plan. This study was approved by the Institutional Review Board at Nationwide Children's Hospital.

Results

Concussion rates and incidence

During 2005–2008, 1308 concussions were captured during 5 627 921 AE (23.2 concussions per 100 000 AE). This reflects an estimated 395 274 concussions sustained nationally by US high school athletes participating in the nine sports studied. Despite a slightly more inclusive concussion definition in 2007–2008, the overall concussion rate was similar between 2007–2008 and 2005–2007 (24.1 and 22.7 per 100 000 AE, respectively) (RR = 1.06, 95% CI: 0.95–1.19) (Table II). Specifically, grade I (RR = 1.56, 95% CI: 1.03–2.36) and grade III (RR = 1.94, 95% CI: 1.18–3.20) concussion rates were higher in 2007–2008 compared to 2005–2007, while grade II concussion rates remained the same from 2007–2008 to 2005–2007 (RR = 1.00, 95% CI: 0.89–1.13). Thus, this suggests that a small number of grade I and grade III concussions may have been missed during the first 2 study years. Concussion rates per 100,000 AE were highest in football (49.3), girls' soccer (28.0), boys' soccer (20.4), girls' basketball (16.6) and wrestling (15.7) (Table II) and were higher in competition (55.0) than practice (10.4) (RR = 5.31, 95% CI: 4.73–5.97).

Most athletes returned to play 3–6 (24.4%), 7–9 (28.9%) or 10–21 (24.4%) days following concussion. One tenth (10.1%) missed >21 days or were unable to return (1.5% had unknown time loss). When restricting to 2007–2008, the only year that captured non-time loss concussions, 14.0% of athletes sustaining grade I concussions, 6.3% of athletes sustaining grade II concussions and 9.1% of athletes sustaining grade III concussions (i.e. losing consciousness) returned to play in <1 day. In football, 15.8% of players with a grade III concussion returned to play in <1 day.

AAN

The majority of concussions were retrospectively categorized as AAN grade II ($n = 1116$, 85.3%), with fewer grade I ($n = 90$, 6.9%) and grade III ($n = 62$, 4.7%) concussions. There were 40 (3.1%) concussions for which AAN grade could not be determined due to missing data. Almost half (40.5%) of concussed athletes were non-compliant with recommended AAN RTP guidelines, 28.3% were compliant and 31.2% had unknown compliance. AAN non-compliance was highest in baseball (55.6%), followed by volleyball (53.1%), boys' basketball (51.0%), girls' basketball (46.0%) and girls' soccer (44.9%) (Figure 1(a)).

Grade I concussions. Athletes sustaining grade I concussions most frequently reported headache (95.7%), dizziness/unsteadiness (71.4%),

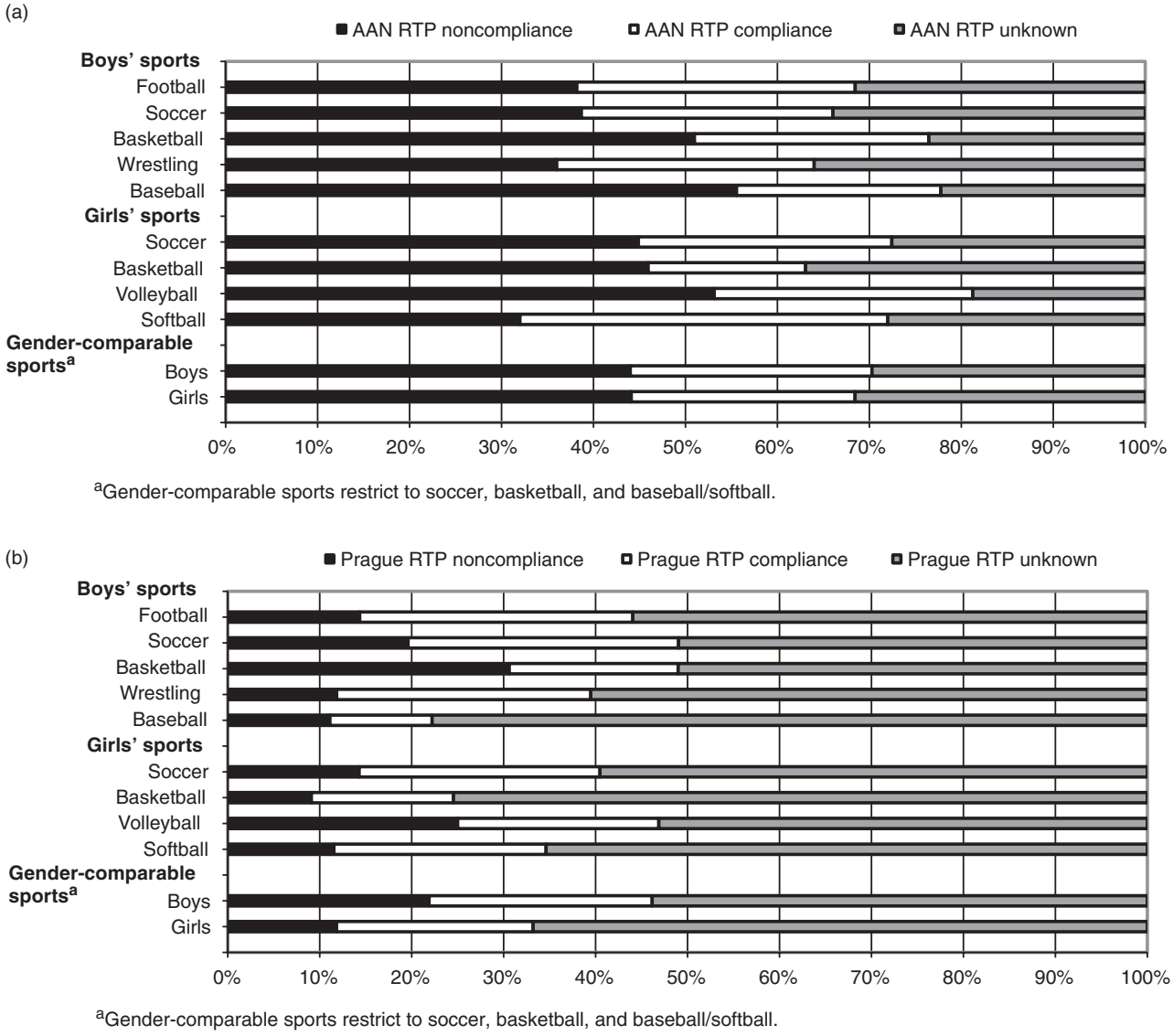


Figure 1. (a) Compliance with AAN return-to-play guidelines following concussion by sport and gender, National High School Sports-Related Injury Surveillance Study, US 2005–08 school years. (b) Compliance with Prague return-to-play guidelines following concussion by sport and gender, National High School Sports-Related Injury Surveillance Study, US 2005–08 school years.

confusion/disorientation (45.7%) and concentration difficulty (38.6%). By definition (Table I), athletes sustaining grade I concussions had symptom resolution in <15 minutes. Athletes sustaining an initial grade I concussion often returned to play in 1–2 days (21.8%), 3–6 days (34.5%) or 7–9 days (25.3%) (Table III). There were two recurrent grade I concussions, both in football. Both of these athletes had RTP >1 week. Because AAN guidelines permit same day RTP following an initial grade I concussion and RTP in 1 week following a recurrent grade I concussion (Table I), all athletes sustaining grade I concussions were compliant.

Grade II concussions. Athletes sustaining grade II concussions most frequently reported headache (94.9%), dizziness/unsteadiness (81.1%), concentration difficulty (56.6%) and confusion/disorientation (49.0%). Symptoms often resolved in 1–3 days (35.4%), 4–6 days (18.9%) or 1 week–1 month (12.8%).

Following symptom resolution, AAN RTP guidelines recommend players sustaining grade II concussions remain out of play ≥1 week following an initial concussion and ≥2 weeks following a recurrent concussion (Table II). Almost half (44.2%) of all athletes sustaining an initial grade II concussion were non-compliant with recommended AAN RTP guidelines (Figure 2(a)). Non-compliance was highest in boys' basketball (61.5%), volleyball (58.3%), baseball (50.0%) and girls' soccer (47.5%). Similarly, almost half (47.5%) of all athletes sustaining a recurrent grade II concussion ($n = 143$) were non-

Table III. Time loss by AAN concussion grade, National High School Sports-Related Injury Surveillance Study, US 2005–2008 school years.[a]

	Grade I		Grade II		Grade III	
	1st occurrence[b], $n=87$ (97.8%)	Recurrent, $n=2$ (2.2%)	1st occurrence, $n=952$ (86.9%)	Recurrent, $n=143$ (13.1%)	1st occurrence, $n=51$ (83.6%)	Recurrent, $n=10$ (16.4%)
<1 day[c]	6.9%	0.0%	2.5%	1.4%	5.9%	0.0%
1–2 days	21.8%	0.0%	6.8%	6.3%	2.0%	0.0%
3–6 days	34.5%	0.0%	26.1%	14.0%	15.7%	20.0%
7–9 days	25.3%	0.0%	30.5%	24.5%	25.5%	30.0%
10–21 days	9.2%	50.0%	25.2%	25.9%	23.5%	50.0%
>21 days[d]	2.3%	50.0%	7.2%	26.6%	25.5%	0.0%
Other	0.0%	0.0%	1.7%	1.4%	2.0%	0.0%
Total	100%	100%	100%	100%	100%	100%

[a]Concussions were graded retrospectively following AAN guidelines based on presence or absence of loss of consciousness and symptom resolution time.
[b]Sixty-three concussions did not contain a response for time loss or recurrence status.
[c]The 2007–2008 school year was the first to capture non-time loss concussions. Thus, <1 day time loss was only an answer choice in 2007–2008. When restricting to 2007–2008, 14.0% of athletes sustaining grade I concussions, 6.3% of athletes sustaining grade II concussions and 9.1% of athletes sustaining grade III concussions returned to play in <1 day.
[d]Includes athletes who returned to play in >21 days, athletes with a season or career medical disqualification and athletes who chose to discontinue their season.

compliant (Figure 2(b)). Non-compliance was highest in boys' basketball (66.7%), volleyball (66.7%) and girls' basketball (63.2%).

Grade III concussions. By AAN definition, all players sustaining grade III concussions experienced loss of consciousness (Table I). Athletes also reported headache (98.0%), dizziness/unsteadiness (88.0%), confusion/disorientation (72.0%) and concentration difficulty (60.0%). Symptoms commonly resolved 1–3 days (30.0%), 4–6 days (16.7%) or 1 week–1 month (25.0%) following concussion, with 3.3% lingering after 1 month.

Because LOC duration was not captured, it was assumed that all LOC were brief in order to present a best picture scenario. Following symptom resolution, AAN RTP guidelines recommend players sustaining grade III concussions remain out of play ≥1 week following an initial concussion with brief LOC and ≥1 month following a recurrent concussion (Table I). Under these criteria, almost half (44.4%) of athletes sustaining initial grade III concussions were non-compliant (Figure 2(c)), 19.4% were compliant and 36.1% had unknown compliance. Non-compliance was highest in baseball (100%).

All athletes (100%) sustaining a recurrent grade III concussion ($n=10$) were non-compliant with AAN guidelines. Specifically, players with <1 hour symptom resolution ($n=2$) returned to play in 3–6 days (50%) and 10–21 days (50%). Players with 1–3 days symptom resolution ($n=5$) returned to play in 1–2 days (20%), 7–9 days (40%), and 10–21 days (40%). One player with 4–6 days symptom resolution returned to play in 10–21 days and players with 1 week–1 month symptom resolution ($n=2$) returned to play in 7–9 days (50%) and 10–21 days (50%).

Prague

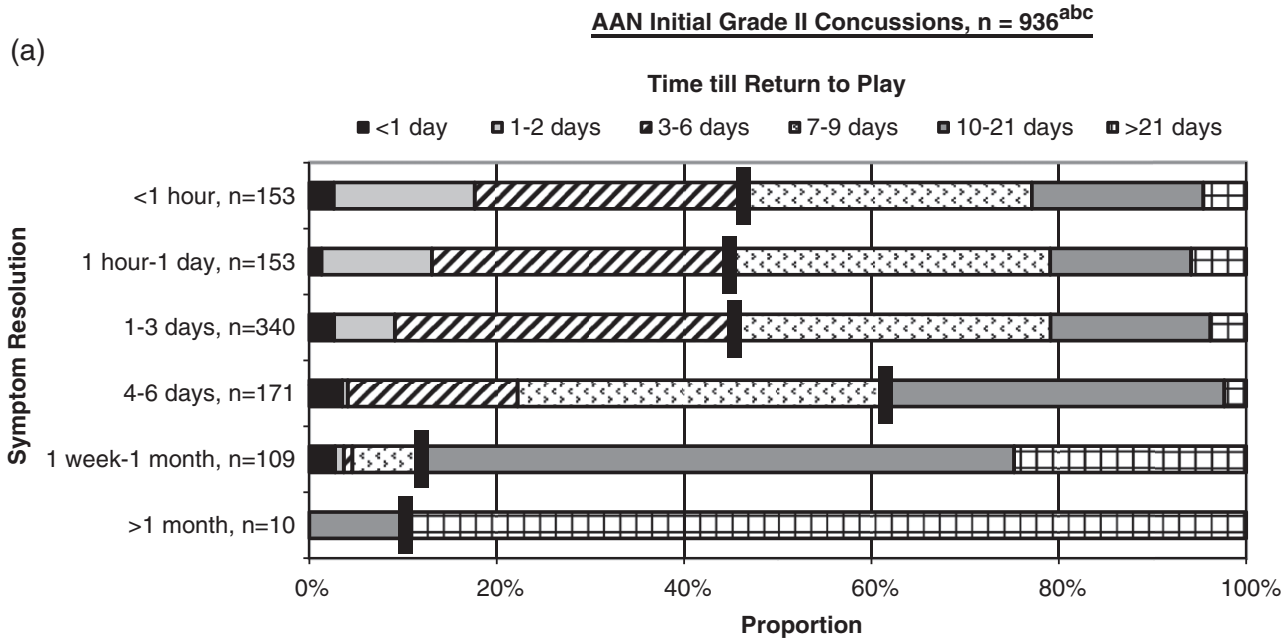
Prague RTP guidelines recommend a stepwise recovery from concussion that begins with complete rest until asymptomatic (Table I). Permitted exertion increases gradually until the athlete returns to full asymptomatic play. Athletes progress through the steps daily if they remain asymptomatic at the previous step. Thus, athletes who do not experience symptom recurrence can return to play 5 days following symptom resolution. Because one could not ascertain whether concussed athletes experienced symptom recurrence during the stepwise progression, in order to present a best picture scenario it was assumed that athletes experienced no symptom recurrence.

Applying these criteria, 15.0% of concussed athletes were non-compliant with Prague RTP guidelines (Figure 2(d)). One quarter (26.9%) were compliant and 58.2% had unknown compliance. Non-compliance with Prague RTP guidelines was highest in boys' basketball (30.6%), volleyball (25.0%) and boys' soccer (19.6%).

Gender comparisons

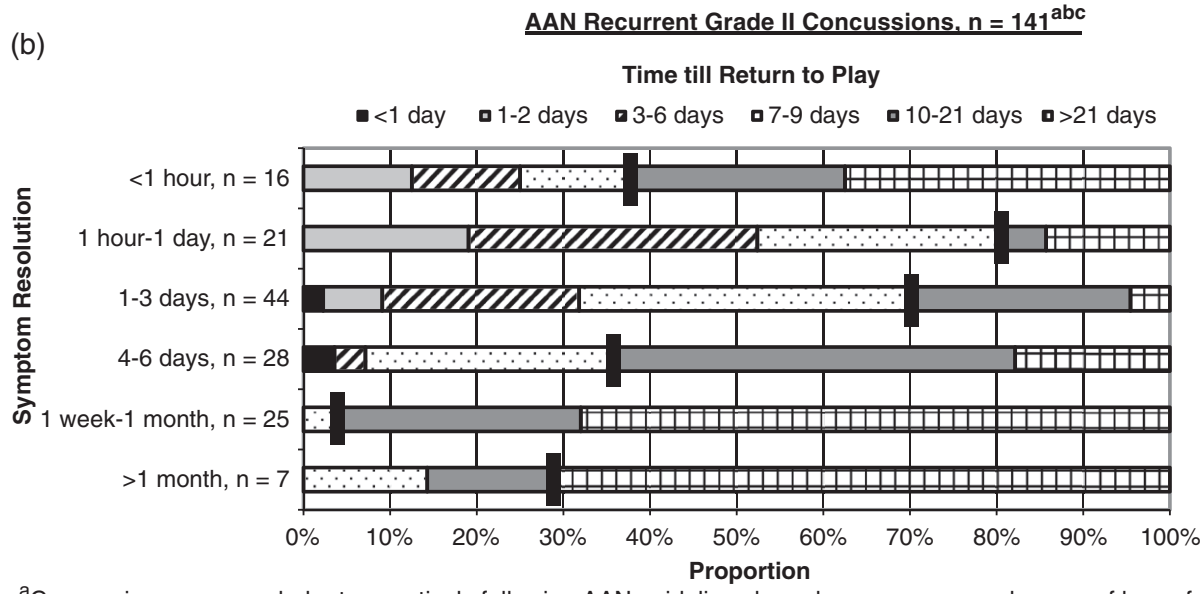
In gender-comparable sports (i.e. soccer, basketball and baseball/softball), 2005–2008 overall concussion rates were higher among girls (19.1) than boys (10.3) (RR = 1.87, 95% CI: 1.54–2.25). This reflects a higher grade II concussion rate among

(a)



[a]Concussions were graded retrospectively following AAN guidelines based on presence or absence of loss of consciousness and symptom resolution time.
[b]Horizontal lines represent the division between noncompliance and compliance/unknown compliance with AAN guidelines. Athletes with noncompliance are on the left, athletes with compliance/unknown compliance are on the right.
[c]Sixteen initial grade II concussions did not contain a response for time loss.

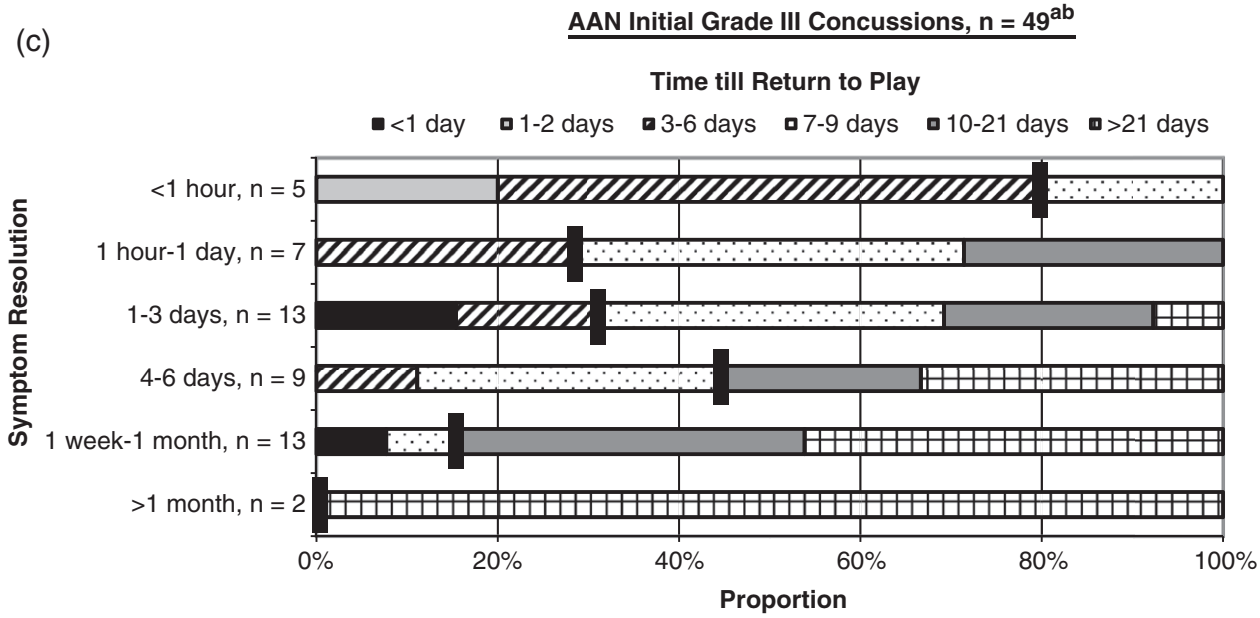
(b)



[a]Concussions were graded retrospectively following AAN guidelines based on presence or absence of loss of consciousness and symptom resolution time.
[b]Horizontal lines represent the division between noncompliance and compliance/unknown compliance with AAN guidelines. Athletes with noncompliance are on the left, athletes with compliance/unknown compliance are on the right.
[c]Two recurrent grade II concussions did not contain a response for time loss.

Figure 2. (a) Return to play compliance under AAN and Prague guidelines by symptom resolution, National High School Sports-Related Injury Surveillance Study, US 2005–08 school years. (b) Return to play compliance under AAN and Prague guidelines by symptom resolution, National High School Sports-Related Injury Surveillance Study, US 2005–08 school years. (c) Return to play compliance under AAN and Prague guidelines by symptom resolution, National High School Sports-Related Injury Surveillance Study, US 2005–08 school years. (d) Return to play compliance under AAN and Prague guidelines by symptom resolution, National High School Sports-Related Injury Surveillance Study, US 2005–08 school years.

(c)

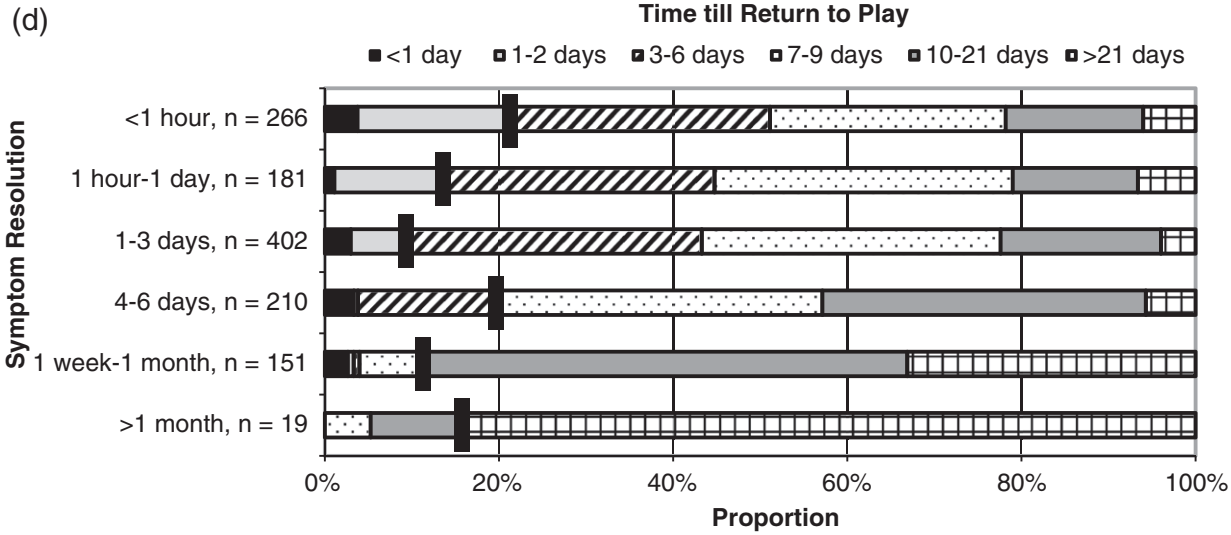


[a]Concussions were graded retrospectively following AAN guidelines based on presence or absence of loss of consciousness and symptom resolution time.

[b]Horizontal lines represent the division between noncompliance and compliance/unknown compliance with AAN guidelines. Athletes with noncompliance are on the left, athletes with compliance/unknown compliance are on the right.

[c]Two initial grade III concussions did not contain a response for time loss.

(d)



[a]Horizontal lines represent the division between noncompliance and compliance/unknown compliance with Prague guidelines. Athletes with noncompliance are on the left, athletes with compliance/unknown compliance are on the right.

[b]Seventy-nine concussions did not contain a response for time loss or symptom resolution.

Figure 2. Continued.

girls (RR = 1.99, 95% CI: 1.62–2.45). Although grade I (RR = 1.68, 95% CI: 0.82–3.42) and grade III (RR = 1.21, 95% CI: 0.53–2.79) concussion rates were also higher among females, these differences were statistically insignificant. When restricting to 2007–2008, 22.2% of males with a grade I concussion returned to play in <1 day, compared to 0% of females. Males were also more likely than females to return 1–2 days after sustaining an initial grade II concussion (12.6% and 5.9%, respectively) (IPR = 2.13, 95% CI: 1.05–4.32).

Similar proportions of males (44.0%) and females (44.1%) in gender-comparable sports were non-compliant with AAN RTP guidelines. Although males appeared to have higher non-compliance following initial grade III concussions (IPR = 1.54, 95% CI: 0.80–2.98), this difference was statistically insignificant. Males were more likely than females to be non-compliant with Prague RTP guidelines (21.9% and 11.8%, respectively) (IPR = 1.85, 95% CI: 1.20–2.86).

Discussion

This research, the first nationally-representative study to evaluate whether concussed high school athletes follow commonly-accepted RTP guidelines, found that almost half of all high school athletes failed to comply with AAN RTP guidelines. Although compliance appeared higher when assessed using the newer Prague RTP guidelines [19], at least one in six athletes still returned to play prematurely and this proportion is likely much higher. Given the potentially catastrophic consequences of returning to play before being fully recovered following concussion, these findings stress the need to improve education on appropriate RTP guidelines and to find ways to ensure these guidelines are being followed.

These overall epidemiologic patterns reconfirm prior research on high school athletes [4], with concussion rates highest in football and higher in competition than practice. As previously reported [7, 21], common concussion symptoms were headache and dizziness/unsteadiness. Although previous research [7, 11] found the majority of concussions were grade I, this study retrospectively graded 85.3% of concussions as AAN grade II. One potential explanation for the increase in grade II concussion may be increased follow-up attention of concussed athletes. Recent research found high school athletes with initial symptom resolution <15 minutes often experienced symptom recurrence after 36 hours [10]. Increased follow-up attention may result in these prolonged resolution times getting noticed, resulting in more grade II concussions.

Like previous research, higher concussion rates were found among females compared to males [4, 27]. Two reasons potentially explain this difference: either males and females are truly different physiologically in terms of concussion susceptibility or concussions are simply more likely to be reported or diagnosed among females. The data indicate that males returned to play sooner after sustaining the same severity concussion as females, with 22% of males returning the same day following a grade II concussion compared to 0% of females. Males were almost twice as likely to be non-compliant with Prague RTP guidelines. This confirms the possibility that at least part of the increased concussion rate among females stems from a socio-cultural structure in which the athletic community is more protective of concussed female athletes. Coaches and athletic trainers may be more likely to diagnose concussions among females, either because females are more likely to report concussion symptoms or because coaches and athletic trainers are more concerned when females report these symptoms. In addition, males likely feel more pressure to continue playing through concussion. The finding that females and males had similar grade III concussion rates reaffirms the significance of socio-cultural differences. Because grade III concussions result in a loss-of-consciousness, they are the only grade where nearly 100% are likely to be reported. If this theory is correct, gender differences in concussion rates may be much smaller than previously reported.

Using the most constrictive calculations, it was found that four in 10 concussed high school athletes returned prematurely under AAN RTP guidelines and one in six returned prematurely under Prague RTP guidelines. At least some athletes categorized with unknown compliance were likely non-compliant. Also, it is possible that some athletes in this study cohort either failed to report a concussion or under-reported concussion symptoms [12]. There are several potential reasons for the high level of premature RTP among high school athletes. Some ATs may not refer to established guidelines when making RTP decisions. ATs who utilize guidelines such as AAN or Prague may not have the authority to keep athletes out of play. Because there is still a sense among the general public that 'minor' concussions are relatively benign [28], ATs may feel pressure by coaches, parents or athletes to disregard clinically-accepted RTP recommendations [29].

These findings are troubling given recent research showing high school and collegiate athletes often demonstrate cognitive impairment after they report being symptom free [11, 20]. One study found that most high school and collegiate athletes exhibited neurocognitive deficits ≥14 days following concussion [11]. If the findings of this previous study are

generalizable to all concussed high school and collegiate athletes, then this would suggest that the two-thirds of the athletes in this study who returned to play in <10 days may have still been experiencing neurocognitive deficits. This is worrisome because premature RTP can have serious adverse consequences. Concussed athletes can have slowed reaction times, putting them at increased risk of subsequent injury [8, 20]. Athletes also risk sustaining a catastrophic event such as second impact syndrome if they sustain a second hit before being fully recovered from the previous concussion [30].

Neurocognitive testing through programmes such as ImPACT, CogState, Headminders and ANAM can offer an individualized approach to grading concussion severity and guiding RTP decisions [11, 17, 20]. However, limited data are available to show their efficacy in the high school population and many high schools lack the financial or clinical resources to access and interpret such programmes [26]. Thus, the vast majority of high school coaches and athletic trainers will continue to rely on clinical examination and RTP guidelines to assess and manage their concussed athletes [26]. Furthermore, neuropsychological test results often suggest a lengthier RTP protocol compared to traditional guidelines such as AAN or Prague [11, 20]. If, as indicated by these findings, the high school athletic community is currently experiencing difficulties ensuring that athletes follow traditional RTP guidelines, it will likely also be difficult to achieve compliance with neuropsychological test results.

This study demonstrates the importance of making sure that knowledge gained from concussion management research is translated to the high school playing field. Future research should focus on findings ways to decrease concussion incidence and increase RTP compliance among all youth and high school athletes. Efforts to educate coaches, parents, athletes, policy-makers, etc. on the dangers of premature RTP must be improved and increased [26, 29, 31]. Implementing a community-wide approach may help alleviate pressures on ATs and coaches by parents and fans. Although policy changes that make it illegal to play until being fully recovered could be effective, such rule changes would have to be implemented in such a way as to be enforceable with care taken to ensure athletes continue to be encouraged to report concussion symptoms. Although ATs and coaches in all sports need to work together to help protect concussed high school athletes from further injury, these results suggest this need is particularly great in football, where an alarming number of athletes returned to play the same day following concussion.

Like all research, this study has limitations. The study sample was limited to high schools with an NATA-affiliated AT. This restriction was necessary to ensure high quality data were reported by medically trained professionals. Athletes at schools without access to ATs may be less likely to comply with concussion RTP guidelines [32], thus these findings likely err toward higher RTP compliance. Answer choices to concussion symptom resolution and RTP were not always precise enough to definitively determine compliance. However, these broader categories decreased reporting burden on ATs. Finally, the concussion definition was made more inclusive during the 2007–2008 school year in order to respond to the changing needs of surveillance. However, this change had no significant effect on concussion rates.

Despite these limitations, this study is the first to examine RTP among a nationally representative sample of concussed high school athletes. Furthermore, by using data from the National High School Sports-Related Injury Surveillance Study, the authors were able to examine this phenomenon using the best, most nationally representative data collected to date. Adolescent athletes returning to play before fully recovering from concussion are at risk of negative outcomes including serious lifelong physical and mental health problems or even death. This complex issue should be a high priority for sports medicine professionals, parents, coaches and sports administrators, who must work together to improve concussion management.

Acknowledgements

The content of this report was funded in part by the Centers for Disease Control and Prevention (CDC) grant #R49/CE000674-01. The content of this report is solely the responsibility of the authors and does not necessarily reflect the official view of the CDC. We would also like to acknowledge the generous research funding contributions of DonJoy Orthotics, the National Federation of State High School Associations, and EyeBlack.

Declaration of Interest: The authors report no conflicts of interest. The authors alone are responsible for the content and writing of this paper.

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