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Original research

## Factors associated with post-concussion syndrome in high school student-athletes

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### ABSTRACT

**Objectives:** To identify factors associated with post-concussion syndrome (PCS) among a national sample of high school student-athletes from the 2011/12–2013/14 academic years.

**Design:** Ambispective cohort study from sports injury surveillance data.

**Methods:** Sport-related concussion data originated from the National Athletic Treatment, Injury and Outcomes Network (NATION) surveillance program, consisting of 27 sports from a convenience sample of 196 high schools across 26 states. All SRCs were reported by certified athletic trainers. The PCS and non-PCS groups consisted of concussed individuals with symptoms resolution time of >4 weeks and ≤2 weeks, respectively. Logistic regression estimated the association of athlete and concussion characteristics on the odds of PCS, and calculated adjusted odds ratios (OR) and 95% confidence intervals (CI).

**Results:** Overall, 1334 concussed high school athletes met inclusion criteria: 215 in the PCS group and 1119 in the non-PCS group. In the multivariable analysis, concussion symptoms associated with increased odds of PCS included: retrograde amnesia (OR = 3.01, 95%CI: 1.31–6.91), difficulty concentrating (OR = 2.72, 95%CI: 1.56–4.77), disorientation (OR = 1.86; 95%CI: 1.04–3.33), insomnia (OR = 2.79; 95%CI: 1.62–4.80), loss of balance (OR = 1.76; 95%CI: 1.00–3.10), sensitivity to noise (OR = 1.80; 95%CI: 1.02–3.17), and visual disturbance (OR = 2.21; 95%CI: 1.23–3.97). Sex and recurrent concussion were not associated with PCS.

**Conclusions:** As in previous research, somatic and cognitive symptoms were associated with PCS. The identification of factors associated with PCS may assist clinicians in identifying concussed athletes at greater risk of having longer symptom resolution time.

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### 1. Introduction

An estimated 1.6–3.8 million sports-related traumatic brain injuries occur annually in the United States.<sup>1</sup> While sport-related concussion (SRC) has been extensively studied in college athletics, fewer studies have included high school student-athletes even

though they outnumber collegiate student-athletes.<sup>2</sup> From a public health vantage, nearly 8 million high school student-athletes are at risk for SRC annually, and have access to fewer medical resources compared to collegiate and professional athletes. Additionally, high school sports injury surveillance has reported increases in SRC rates across time.<sup>3</sup> Further study of SRC within the high school setting is warranted, particularly as it relates to prognosis and outcomes.

Whereas 85–90% of athletes with SRC are asymptomatic by 10–14 days post-injury,<sup>4</sup> a subset experience prolonged symptoms, referred to as post-concussion syndrome (PCS).<sup>5</sup> PCS has many definitions, as described by the International Statistical Classification of Diseases and Related Health Problems 10th Revision (ICD-10)<sup>6</sup> and

**Abbreviations:** CI, Confidence interval; OR, Odds ratio; PCS, Post-concussion syndrome; SRC, Sport-related concussion.

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the Diagnostic and Statistical Manual of Mental Disorders, fourth edition (DSM-IV).<sup>7</sup> However, the most clinically-utilized definition, evidenced from a survey of over 500 physicians, is endorsement of at least 1 symptom for at least 4 weeks.<sup>8</sup>

Previously-discussed factors associated with PCS in sport populations include initial symptom severity,<sup>4</sup> loss of consciousness,<sup>9</sup> amnesia,<sup>4</sup> and female sex,<sup>10</sup> though considerable debate surrounds each factor. Very few of these studies have targeted specific playing levels (i.e. high school or collegiate student-athletes only). If associated factors can be identified in a homogeneous population, within a similar school environment, concussed athletes can be more appropriately managed to minimize risk of recurrent concussion, symptom duration, and improve quality of life.

Given the potentially debilitating effects of prolonged post-concussive symptoms in high school student-athletes, we sought to further investigate risk factors for PCS after SRC. Using data from the National Athletic Treatment, Injury and Outcomes Network (NATION) surveillance program, this study examined factors associated with PCS among high school student-athletes who sustained SRCs during the 2011/12–2013/14 academic years.

## 2. Methods

NATION was designed and implemented by the Datalys Center for Sports Injury Research and Prevention in 2011 and used a convenience sample of high schools drawn from 26 states to compile data on 27 sports. Data were collected across the 2011/12–2013/14 academic years.<sup>11</sup> Forty-seven high schools participated in year one, 68 schools in year two, and 147 schools in year three; 30 schools participated all three years. Most high schools were public (84.4%), co-educational (98.6%), set in non-urban areas (75.5%), and had enrollment under 1000 students (51.0%).<sup>11</sup> Both full-time and part-time Athletic Trainers (ATs) from these schools collected injury and exposure data, and were internally hired or contracted from nearby clinics or university graduate programs. The NATION project was reviewed by the Western Institutional Review Board (Puyallup, WA) and deemed exempt from human subject protections review. The funding organizations had no role in data collection, analysis, and interpretation, and did not have the right to approve or disapprove any resulting publications.

All reported injuries were evaluated and/or treated by ATs who attended practices and competitions during the preseason, regular season, and postseason. All athletic injuries and exposures were recorded. Using a common data element standard, data were gathered from multiple electronic medical record applications. ATs were able to document injuries as part of their clinical practice using their preferred software application.<sup>11</sup>

For each SRC, the AT completed a detailed report on the injury. Symptoms were selected from a 17-item yes/no checklist originating from the National Collegiate Athletic Association (NCAA) Injury Surveillance Program (ISP).<sup>12</sup> After initially inputting injury data, ATs could return to update the injury report as needed. Thus, delayed symptoms were reported, which consequently made our symptomatology measure an aggregate of symptoms reported at any point during recovery. We flagged concussions as recurrent when concussions were not the first sustained by athletes during their team's participation in NATION, or when their AT noted the concussion as being recurrent.

Data were exported and sent to the Datalys Center to be verified and analyzed. Prior to export, all identifying information was removed and the remaining variables were encrypted. ATs could modify injury data up to 30 days post-season. NATION data quality control staff reviewed data across the academic year for accuracy and completeness, reducing risk of memory decay. When invalid

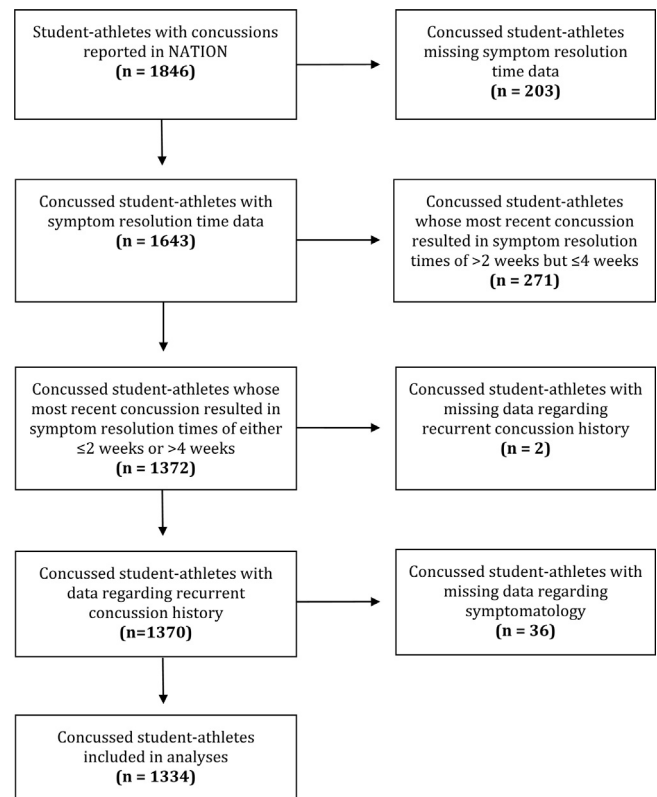


Fig. 1. Flow-chart of final cohort.

data were flagged, the quality control staff and ATs worked together to rectify the error before data entered the aggregate database.

A reportable injury in NATION was defined as an injury that: (1) occurred as a result of participation in an organized high school practice/competition, and (2) required attention from an AT or physician. A pre-determined definition of concussion was not provided as we relied on the medical expertise of the AT managing and reporting the injury. However, in lieu of local laws or guidance, ATs were encouraged to follow the international definition of concussion provided by the *Consensus Statement on Concussion in Sport*.<sup>13</sup> Previous research in the high school setting has highlighted that ATs are suitable data collectors for injury surveillance purposes.<sup>14</sup>

Cases were defined as concussed student-athletes experiencing one or more symptom related to the SRC for greater than 4 weeks, as has been characterized in previous reports of PCS.<sup>15–17</sup> Controls were defined as concussed student-athletes with symptom resolution at  $\leq 2$  weeks post-injury. Any student-athlete with symptom resolution in the intermediate area of  $>2$  weeks but  $\leq 4$  weeks was excluded from our analysis in order to sharply demarcate the control and PCS groups, similar to methodology utilized in prior research.<sup>18</sup> In addition, cases and controls with missing data were excluded.

The primary purpose of this study was to assess factors associated with prolonged SRC symptomatology. Therefore, unlike other research that utilized sports injury surveillance data,<sup>19</sup> the unit of analysis was not concussions, but each concussed individual. Thus, for each concussed individual used in the data analysis, only the most recent concussion reported in NATION was examined. Overall, 1334 concussed high school athletes met criteria for inclusion, of which 215 were in the PCS group and 1119 were in the non-PCS (control) group (Fig. 1); 271 were excluded for having symptom resolution time of  $>2$  weeks but  $\leq 4$  weeks, and 241 had missing data. Those included and excluded in the study did not differ by sex ( $p=0.07$ ) or sport ( $p=0.38$ ).

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