

# Incidents and patterns of *commotio cordis* among athletes in the USA from 1982 to 2023

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## ABSTRACT

**Introduction** *Commotio cordis* is a rare event that occurs following blunt, non-penetrating trauma to the chest, precipitating a ventricular arrhythmia. *Commotio cordis* requires immediate medical attention through cardiopulmonary resuscitation and defibrillation, often resulting in death. *Commotio cordis* is most common condition among young male athletes. The purpose of this study was to describe the incidents and patterns of *commotio cordis* among young athletes participating in organised sports in the USA from academic years 1982-1983 through 2022-2023.

**Methods** This was a retrospective, descriptive epidemiology study using surveillance data from the National Center for Catastrophic Sport Injury Research. The study included all *commotio cordis* incidents captured in the database. We calculated descriptive statistics (counts and proportions) overall and stratified by outcome and athlete sport.

**Results** Over the study period, 64 incidents of *commotio cordis* were captured. The majority occurred among males (n=60) and were caused by contact with an object/apparatus (n=39) or contact with another player (n=20). The most common sports were baseball (n=20), lacrosse (n=17) and football (n=13). Over half of these incidents resulted in death (n=34), although survival from *commotio cordis* increased over the study period. A higher proportion of fatal incidents occurred among football athletes and were caused by contact with another player.

**Conclusions** *Commotio cordis* remains most common among young male athletes who participate in organised baseball, lacrosse and football. Although survival has improved over time, greater awareness and emergency preparedness for *commotio cordis* in an organised sport are needed to facilitate prompt recognition and intervention.

## INTRODUCTION

*Commotio cordis* is a rare cardiac event that occurs after blunt, non-penetrating impact to the chest, precipitating a ventricular arrhythmia without associated structural damage to the heart.<sup>1,2</sup> *Commotio cordis* is characterised by three key mechanistic features based on juvenile swine studies.<sup>3</sup> First, the impact of the blunt trauma must occur over or near the heart; second, the speed of the impact typically ranges between 30 and 50 miles per hour; and third, the impact occurs during a 20 ms vulnerable window of cardiac repolarisation.<sup>4,5</sup>

## WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ In organised sport, *commotio cordis* typically occurs in young male athletes who are struck by a projectile object, like a baseball or lacrosse ball, and survival has historically been low. In the last decade, there have been new safety standards in lacrosse and wider access to automated external defibrillators (AEDs), so the purpose of this study was to assess trends in *commotio cordis* cases captured in the entirety of the National Center for Catastrophic Sport Injury Research's database.

## WHAT THIS STUDY ADDS

⇒ This study found that fatality was more prevalent among football athletes and when the injury mechanism was contact with another athlete. Incidents among baseball athletes increased over the entire study period as opposed to lacrosse and football athletes, which saw declines in the last 15 years.

## HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ This study highlights the importance of emergency preparedness, in particular, access to AEDs, for survival from *commotio cordis*.

Survival from *commotio cordis* depends on timely recognition and prompt treatment with cardiopulmonary resuscitation (CPR) and defibrillation.<sup>6,7</sup> This was publicly displayed in 2023 when a professional football player, Damar Hamlin, collapsed during a nationally televised game, and trained medical professionals administered CPR and defibrillation on the field.<sup>8</sup>

In the USA, prior studies have reported that *commotio cordis* most commonly occurs among children, teenagers and young adults during competitive or recreational sports where the athlete sustains a hit to the chest from a firm projectile or contact from another player.<sup>1,9,10</sup> Incidents of *commotio cordis* have been documented in multiple sports, including baseball, lacrosse, football, softball and ice hockey.<sup>1,11-13</sup> In the last decade, the National Operating Committee on Standards for Athletic Equipment enacted standards for chest protectors to prevent *commotio cordis*, which led USA Lacrosse to mandate chest protectors for youth lacrosse athletes in 2021.<sup>14</sup> However, there has not been an updated report of *commotio cordis* among



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athletes in over a decade.<sup>7 12</sup> Therefore, the purpose of this study was to describe all incidents of *commotio cordis* and survival trends captured by the National Center for Catastrophic Sport Injury Research (NCCSIR) from academic years 1982/1983 through 2022/2023.

## METHODS

### Study design

This is a retrospective, descriptive epidemiology study using national surveillance data from the NCCSIR. The NCCSIR performs active surveillance for catastrophic events in athletes

**Table 1** Athlete and injury characteristics of *commotio cordis* incidents in the USA from academic year 1982–1983 through 2022–2023 overall and stratified by fatality versus non-fatality (n=64)

| Variable                           | Total (n=64) |      | Fatalities* (n=34) |      | Non-fatalities* (n=28) |      |
|------------------------------------|--------------|------|--------------------|------|------------------------|------|
|                                    | N            | %    | N                  | %    | N                      | %    |
| Sport played at time of injury     |              |      |                    |      |                        |      |
| Baseball                           | 20           | 31.3 | 8                  | 23.5 | 12                     | 42.9 |
| Lacrosse                           | 17           | 26.6 | 7                  | 20.6 | 9                      | 32.1 |
| Football                           | 13           | 20.3 | 11                 | 32.4 | 2                      | 7.1  |
| Other†                             | 14           | 21.9 | 8                  | 23.5 | 5                      | 17.9 |
| Athlete sex                        |              |      |                    |      |                        |      |
| Female                             | 4            | 6.3  | 1                  | 2.9  | 2                      | 7.1  |
| Male                               | 60           | 93.8 | 33                 | 97.1 | 26                     | 92.9 |
| Athlete age                        |              |      |                    |      |                        |      |
| 11–15 years                        | 17           | 26.6 | 11                 | 32.4 | 5                      | 17.9 |
| 16–18 years                        | 26           | 40.6 | 15                 | 44.1 | 11                     | 39.3 |
| 19–21 years                        | 5            | 7.8  | 4                  | 11.8 | 1                      | 3.6  |
| 22+                                | 4            | 6.3  | 2                  | 5.9  | 2                      | 7.1  |
| Unknown                            | 12           | 18.8 | 2                  | 5.9  | 9                      | 32.2 |
| Sport level                        |              |      |                    |      |                        |      |
| High school                        | 34           | 53.1 | 17                 | 50.0 | 16                     | 57.1 |
| Youth league (age 11–17 years)     | 12           | 18.8 | 5                  | 14.7 | 6                      | 21.4 |
| Collegiate                         | 8            | 12.5 | 6                  | 17.7 | 2                      | 7.4  |
| Semiprofessional                   | 3            | 4.7  | 2                  | 5.9  | 1                      | 3.6  |
| Recreational league                | 2            | 3.1  | 2                  | 5.9  | 0                      | 0.0  |
| Middle school                      | 1            | 1.6  | 1                  | 2.9  | 0                      | 0.0  |
| Professional                       | 2            | 3.1  | 0                  | 0.0  | 2                      | 7.1  |
| Other                              | 2            | 3.1  | 1                  | 2.9  | 1                      | 3.6  |
| Injury mechanism                   |              |      |                    |      |                        |      |
| Contact with apparatus or object   | 39           | 60.9 | 16                 | 47.1 | 22                     | 78.6 |
| Contact with another player        | 20           | 31.3 | 14                 | 41.2 | 5                      | 17.9 |
| Contact with ground/surface        | 2            | 3.1  | 1                  | 2.9  | 1                      | 3.6  |
| Other/unknown                      | 3            | 4.7  | 3                  | 8.8  | 0                      | 0.0  |
| Event type                         |              |      |                    |      |                        |      |
| Competition/game                   | 44           | 68.8 | 24                 | 70.6 | 19                     | 67.9 |
| Practice                           | 16           | 25.0 | 9                  | 26.5 | 7                      | 25.0 |
| Other/unknown                      | 4            | 6.3  | 1                  | 2.9  | 2                      | 7.1  |
| Injury academic year               |              |      |                    |      |                        |      |
| 1982–1986                          | 4            | 6.3  | 4                  | 11.8 | 0                      | 0.0  |
| 1987–1991                          | 2            | 3.1  | 2                  | 5.9  | 0                      | 0.0  |
| 1992–1996                          | 5            | 7.8  | 4                  | 11.8 | 0                      | 0.0  |
| 1997–2001                          | 10           | 15.6 | 8                  | 23.5 | 2                      | 7.1  |
| 2002–2006                          | 7            | 10.9 | 5                  | 14.7 | 2                      | 7.1  |
| 2007–2011                          | 15           | 23.4 | 7                  | 20.6 | 7                      | 25.0 |
| 2012–2016                          | 11           | 17.2 | 4                  | 11.8 | 7                      | 25.0 |
| 2017–2022                          | 10           | 15.6 | 0                  | 0.0  | 10                     | 35.7 |
| Injury outcome                     |              |      |                    |      |                        |      |
| Fatality/sudden death              | 34           | 53.1 | –                  | –    | –                      | –    |
| Survival with temporary disability | 27           | 42.2 | –                  | –    | –                      | –    |
| Unknown                            | 2            | 3.1  | –                  | –    | –                      | –    |
| Survival with permanent disability | 1            | 1.6  | –                  | –    | –                      | –    |

\*Missing injury outcome data for two incidents.

†Other sports include cheerleading, cross-country, ice hockey, rodeo, soccer, softball, track and field.

who participate in an organised sport at the youth league, middle school, high school, collegiate, recreational league and semi-professional and professional levels.

### Data collection

The NCCSIR collects data across a range of catastrophic injuries, including incidents of sudden cardiac arrest (SCA) that occur during sanctioned organised sporting events.<sup>15</sup> Catastrophic incidents are collected through online reports submitted by athletic trainers, coaches, parents and community bystanders; by active surveillance of media and social media reports; and through direct reporting to the NCCSIR by state and national athletic associations. This study included all *commotio cordis* incidents among athletes aged 11 years or older in the NCCSIR database from academic years 1982/1983 through 2022/2023.

### Analysis

Descriptive statistics (counts and proportions) were calculated for each variable including: injury sport, athlete sex, athlete age, sport level, injury mechanism, type of event, injury academic year and outcome. We further stratified these counts and proportions by outcome (fatal vs survival with temporary or permanent disability) and sport (baseball, lacrosse, football and other). Relative risk ratios and 95% CIs quantified survival over the period (SAS V.9.4).

### Patient and public involvement

The design, analysis and writing of this manuscript did not involve patients or public.

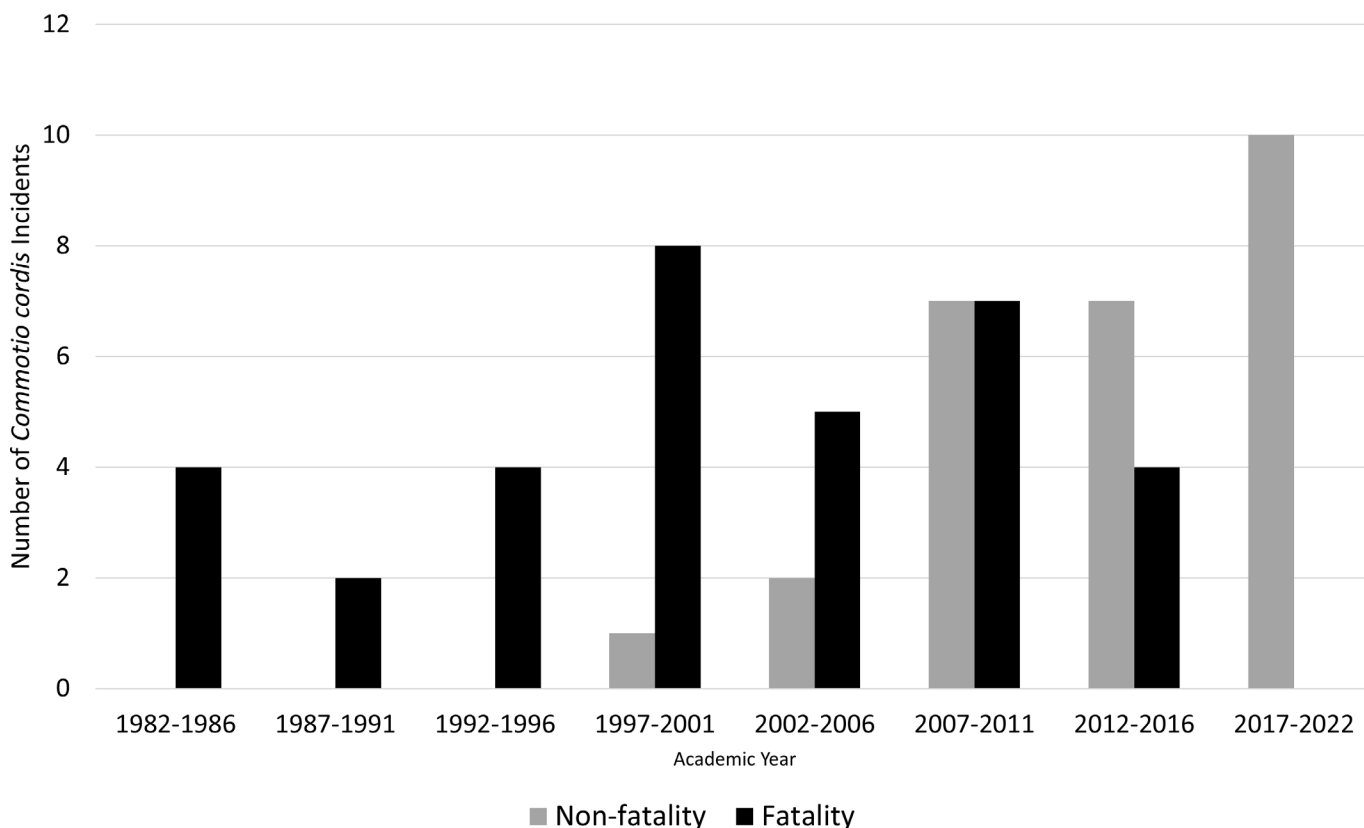
### RESULTS

Over the 41-year study period, 64 incidents of *commotio cordis* were captured by the NCCSIR during an organised sporting event. Incidents occurred most often during baseball (31%), lacrosse (27%) and football (20%) (table 1). Nearly all *commotio cordis* incidents occurred in male athletes (94%). Most athletes were 18 years or younger (67%) and injured during high school or youth league sporting events (72%). The most common mechanism of injury was contact with an apparatus or object (61%) followed by contact with another player (31%).

Over half of incidents resulted in death (53%), and 42% survived with only temporary disability (table 1). Among fatal incidents (n=34), 11 (32.4%) occurred among football athletes, 8 (23.5%) among baseball athletes, 7 (20.6%) among lacrosse athletes and 8 (23.5%) in other sports. Among non-fatal incidents (n=27), 12 (42.9%) occurred in baseball, 9 (32.1%) in lacrosse, 2 (7.1%) in football and 5 (17.9%) in other sports. The injury mechanism differed between fatalities and non-fatalities. Most non-fatal incidents (78.6%) resulted from contact with an apparatus or object, whereas 41.2% of fatal incidents resulted from contact with another player. Regardless of outcome, most *commotio cordis* incidents occurred during a competition or game (70.6% fatalities, 67.9% non-fatalities) (table 1).

*Commotio cordis* peaked between 2007 and 2011 at 15 events. Following this 5-year period, fatal incidents declined by 33%. Survival for *commotio cordis* in the first 25 years of the study period was 14.8% (4/27), compared with 66.6% survival (24/36) in the final 15 years (relative risk=3.15, 95% CI: 1.20 to 8.28) (figure 1). After 2011, there were only four fatalities, none of which occurred after 2017.

Among lacrosse, football and other sport athletes, the most common sport level was high school (58.8%, 61.5% and 64.3%,



**Figure 1** Number of *commotio cordis* incidents by year stratified by outcome.

**Table 2** Athlete and injury characteristics of *commotio cordis* incidents in the USA from academic year 1982–1983 through 2022–2023, stratified by sport (n=64)

| Variable                                 | Baseball (n=20) |       | Lacrosse (n=17) |       | Football (n=13) |       | Other sports* (n=14) |      |
|--|-----------------|-------|-----------------|-------|-----------------|-------|----------------------|------|
|  | N               | %     | N               | %     | N               | %     | N                    | %    |
| Athlete sex                              |                 |       |                 |       |                 |       |                      |      |
| Female                                   | 0               | 0.0   | 0               | 0.0   | 0               | 0.0   | 4                    | 28.6 |
| Male                                     | 20              | 100.0 | 17              | 100.0 | 13              | 100.0 | 10                   | 71.4 |
| Athlete age                              |                 |       |                 |       |                 |       |                      |      |
| 11–15 years                              | 7               | 35.0  | 4               | 23.5  | 1               | 7.7   | 5                    | 35.7 |
| 16–18 years                              | 7               | 35.0  | 6               | 35.3  | 9               | 69.2  | 4                    | 28.6 |
| 19–21 years                              | 1               | 5.0   | 2               | 11.8  | 1               | 7.7   | 1                    | 7.1  |
| 22+                                      | 0               | 0.0   | 1               | 5.9   | 2               | 15.4  | 1                    | 7.1  |
| Unknown                                  | 5               | 25.0  | 4               | 23.5  | 0               | 0.0   | 3                    | 21.4 |
| Sport level                              |                 |       |                 |       |                 |       |                      |      |
| High school sponsored                    | 7               | 35.0  | 10              | 58.8  | 8               | 61.5  | 9                    | 64.3 |
| Youth league sponsored (age 11–17 years) | 9               | 45.0  | 1               | 5.9   | 1               | 7.7   | 1                    | 7.1  |
| Collegiate                               | 2               | 10.0  | 3               | 17.7  | 1               | 7.7   | 2                    | 14.3 |
| Semiprofessional                         | 1               | 5.0   | 0               | 0.0   | 2               | 15.4  | 0                    | 0.0  |
| Middle school sponsored                  | 0               | 0.0   | 0               | 0.0   | 0               | 0.0   | 1                    | 7.1  |
| Professional                             | 0               | 0.0   | 0               | 0.0   | 1               | 7.7   | 1                    | 7.1  |
| Other                                    | 1               | 5.0   | 3               | 17.7  | 0               | 0.0   | 0                    | 0.0  |
| Injury mechanism                         |                 |       |                 |       |                 |       |                      |      |
| Contact with apparatus or object         | 16              | 80.0  | 16              | 94.1  | 0               | 0.0   | 7                    | 50.0 |
| Contact with another player              | 3               | 15.0  | 0               | 0.0   | 12              | 92.3  | 4                    | 28.6 |
| Contact with ground/surface              | 1               | 5.0   | 0               | 0.0   | 0               | 0.0   | 1                    | 7.1  |
| Other/unknown                            | 0               | 0.0   | 1               | 5.9   | 1               | 7.7   | 2                    | 14.3 |
| Event type                               |                 |       |                 |       |                 |       |                      |      |
| Competition/game                         | 15              | 75.0  | 13              | 76.5  | 8               | 61.5  | 8                    | 57.1 |
| Practice                                 | 4               | 20.0  | 4               | 23.5  | 5               | 38.5  | 3                    | 21.4 |
| Other/unknown                            | 1               | 5.0   | 0               | 0.0   | 0               | 0.0   | 3                    | 21.4 |
| Injury academic year                     |                 |       |                 |       |                 |       |                      |      |
| 1982–1986                                | 2               | 10.0  | 1               | 5.9   | 0               | 0.0   | 1                    | 7.1  |
| 1987–1991                                | 0               | 0.0   | 0               | 0.0   | 1               | 7.7   | 1                    | 7.1  |
| 1992–1996                                | 2               | 10.0  | 0               | 0.0   | 1               | 7.7   | 2                    | 14.3 |
| 1997–2001                                | 2               | 10.0  | 4               | 23.5  | 3               | 23.1  | 1                    | 7.1  |
| 2002–2006                                | 0               | 0.0   | 4               | 23.5  | 2               | 15.4  | 1                    | 7.1  |
| 2007–2011                                | 3               | 15.0  | 5               | 29.4  | 4               | 30.8  | 3                    | 21.4 |
| 2012–2016                                | 5               | 25.0  | 1               | 5.9   | 1               | 7.7   | 4                    | 28.6 |
| 2017–2022                                | 6               | 30.0  | 2               | 11.8  | 1               | 7.7   | 1                    | 7.1  |
| Injury outcome                           |                 |       |                 |       |                 |       |                      |      |
| Survival with temporary disability       | 12              | 60.0  | 8               | 47.1  | 2               | 15.4  | 4                    | 28.6 |
| Fatality/sudden death                    | 8               | 40.0  | 7               | 41.2  | 11              | 84.6  | 8                    | 57.1 |
| Survival with permanent disability       | 0               | 0.0   | 0               | 0.0   | 0               | 0.0   | 1                    | 7.1  |
| Unknown                                  | 0               | 0.0   | 2               | 11.8  | 0               | 0.0   | 1                    | 7.1  |

\*Other sports include cheerleading, cross-country, ice hockey, rodeo, soccer, softball, track and field.

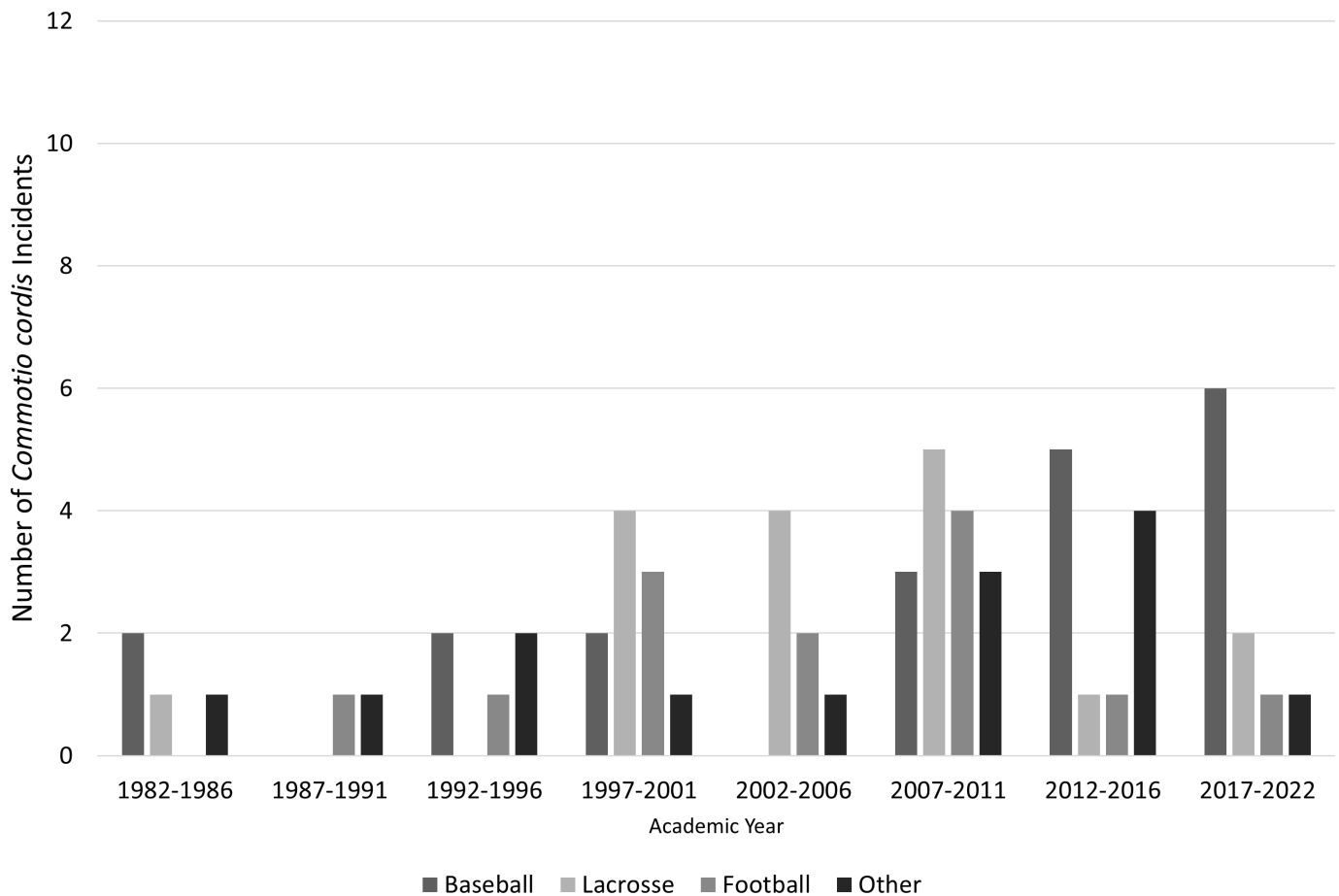
respectively), and among baseball athletes, the most common sport level was youth league (45.0%). Injury mechanism differed by sport; among lacrosse athletes, 94.1% of *commotio cordis* incidents were caused by contact with an apparatus or object; among baseball athletes, 80.0% were caused by contact with an object or apparatus; and among football athletes, 82.3% were caused by contact with another player. Fatalities were most common among football athletes (84.6%), whereas survival was most common among baseball (60%) and lacrosse athletes (47.1%) (table 2).

*Commotio cordis* in lacrosse, football and other sport athletes declined (60%, 75% and 66%, respectively) after the overall peak period from 2007 to 2011. However, among baseball

athletes, the number of incidents increased over the entire study period, peaking in 2017–2022 with six incidents (figure 2).

## DISCUSSION

This 41-year study is the longest reported surveillance of *commotio cordis* to date and provides several key findings. First, most incidents of *commotio cordis* captured by the NCCSIR occurred among male athletes aged 18 years or younger and those participating in high school or youth baseball, lacrosse or football. Second, most incidents occurred from contact with an object or apparatus, although survival was lower in football when caused by contact with another player. Third, and most



**Figure 2** Number of *commotio cordis* incidents by academic year stratified by sport.

importantly, survival from *commotio cordis* has increased over the last 15 years, likely related to improved recognition of SCA and access to automated external defibrillators (AEDs).<sup>7 16 17</sup>

### Patterns by outcome and sport

Football accounted for 32% of fatalities and 7% of non-fatalities. Furthermore, more fatalities occurred due to contact with another player compared with non-fatalities. These findings are consistent with a prior review of football fatalities that identified seven deaths due to *commotio cordis* among high school and collegiate football athletes caused by a hit to the chest while making a tackle or being tackled.<sup>13</sup> The increased complexity of resuscitating a football athlete wearing chest and shoulder pads combined with the challenge of identifying a hit to the chest that could cause *commotio cordis* in a sport with frequent collisions may account for the lower survival in football athletes and deserves more attention in contemporary emergency action plans (EAPs).

Despite an overall decline in *commotio cordis* over the past few decades, incidents among baseball players increased over the latter half of the study period. Meanwhile, incidents among lacrosse players decreased despite of increased participations, which remains to be further investigated. Prior data suggests that *commotio cordis* risk may depend on an interplay between an athlete's age, ball speed and firmness and the angle of impact.<sup>4 5</sup> More baseball incidents occurred in youth league athletes, whereas most incidents in lacrosse and football occurred among high school athletes. The increase in incidents among baseball athletes necessitates a unified, cohesive set of

safety guidelines and procedures for *commotio cordis*, which currently differ between national governing bodies of youth sport and scholastic leagues.<sup>18</sup>

### Emergency preparedness

Our results highlight the critical role of emergency preparedness for *commotio cordis*. All organised sports at risk for *commotio cordis* should have EAPs that include coach and medical staff education on *commotio cordis*, CPR training and venue-specific access to AEDs. EAPs should be reviewed and rehearsed at least annually by all potential responders to SCA in athletes.<sup>18 19</sup> SCA in young athletes, including from *commotio cordis* based on our data, is largely a survivable event with prompt recognition, early CPR and use of on-site AEDs.<sup>16 17</sup>

### Strengths and limitations

This study contains over 40 years of data from a nationally representative data source with detailed information on sport, mechanism of injury, sport level and survival outcomes. Our study is limited by the possibility of missed and under-reported *commotio cordis* incidents to the NCCSIR. We also did not have sport participation data to calculate injury rates.

### CONCLUSIONS

Over the last four decades, *commotio cordis* mostly involves young male athletes playing baseball, lacrosse and football. While being struck in the chest by an object or apparatus was the most common mechanism, more fatalities occurred among football

players secondary to contact with another player. Although the overall number of incidents and survival has improved over the past decade, the number of incidents among baseball athletes has increased. Sports organisations could help prevent sudden cardiac death by addressing *commotio cordis* in their EAPs and ensuring access to AEDs at their athletic venues.

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**Competing interests** None declared.

**Patient consent for publication** Consent obtained from next of kin.

**Ethics approval** This study was approved by the institutional review board of the University of North Carolina at Chapel Hill.

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