

# BMJ Open

BMJ Open is committed to open peer review. As part of this commitment we make the peer review history of every article we publish publicly available.

When an article is published we post the peer reviewers' comments and the authors' responses online. We also post the versions of the paper that were used during peer review. These are the versions that the peer review comments apply to.

The versions of the paper that follow are the versions that were submitted during the peer review process. They are not the versions of record or the final published versions. They should not be cited or distributed as the published version of this manuscript.

BMJ Open is an open access journal and the full, final, typeset and author-corrected version of record of the manuscript is available on our site with no access controls, subscription charges or pay-per-view fees (<http://bmjopen.bmj.com>).

If you have any questions on BMJ Open's open peer review process please email [info.bmjopen@bmj.com](mailto:info.bmjopen@bmj.com)

# BMJ Open

## Medical Assessment of Potential Concussion in Elite Football

Journal:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2018-024607
Article Type:	Research
Date Submitted by the Author:	11-Jun-2018
Complete List of Authors:	Abraham, Karan ; St. Michael's Hospital, Neurosurgery Casey, Julia; St. Michael's Hospital, Neurosurgery Subotic , Arsenije; St. Michael's Hospital, Neurosurgery Chris, Tarzi; St. Michael's Hospital, Neurosurgery Zhu, Alice; St. Michael's Hospital, Neurosurgery Cusimano, Michael; St. Michael's Hospital, Neurosurgery; University of Toronto Dalla Lana School of Public Health, Public Health
Keywords:	Concussion, Head injury, Traumatic brain injury, Football, Sport, Injury prevention

SCHOLARONE™  
Manuscripts

Peer Review Only

Abraham. *et al.* (2018)

## Medical Assessment of Potential Concussion in Elite Football

Karan Joshua Abraham MSc<sup>1</sup>, Julia Casey BSc<sup>1</sup>, Arsenije Subotic BSc<sup>1</sup>, Christopher Tarzi<sup>1</sup>,  
Alice Zhu BSc<sup>1</sup>, and Michael D. Cusimano MD PhD<sup>1,2\*</sup>

<sup>1</sup>*Injury Prevention Research Office, Division of Neurosurgery, St. Michael's Hospital,  
Toronto, Ontario, M5B 1W8, Canada*

<sup>2</sup>*Department of Surgery, University of Toronto, Toronto, Ontario, M5G 1M1, Canada*

\*Lead contact: Dr. Michael D. Cusimano, MD, MHPE, FRCSC, PhD, FACS  
Division of Neurosurgery, St. Michael's Hospital  
Professor of Neurosurgery, Education and Public Health  
University of Toronto

### Postal/Mailing address:

30 Bond Street  
Toronto, ON, Canada  
M5B 1W8

### Phone:

(416) 864 6048 (Clinical Office)  
(418) 864 5312 (Research Office)

**Email:** [injuryprevention@smh.ca](mailto:injuryprevention@smh.ca)

**Word count: 2668**

### KEYWORDS

Concussion, Head injury, Traumatic brain injury, Soccer, Football, Sport, Injury prevention, FIFA; Fédération Internationale de Football Association, UEFA; Union of European Football Associations.

1 Abraham. *et al.* (2018)

2  
3 **ABSTRACT**

4  
5 **Objective:** The objective is to determine if suspected concussions in elite football are medically  
6 assessed according to the International Conferences on Concussion in Sport consensus statement  
7 recommendations.  
8  
9

10  
11  
12 **Setting:** Men's Union of European Football Association (UEFA) Football Championship

13  
14  
15 **Participants:** All professional football players in the UEFA 2016 Championship Tournament.

16  
17 **Design:** Observational study.

18  
19 **Outcome Measures:** Potential concussive events (PCEs) were defined as direct head collision  
20 incidents resulting in the athlete being unable to immediately resume play following impact.  
21  
22 PCEs identified and description of PCE assessment and outcome were accomplished through  
23  
24 direct standardized observation of video footage by trained observers in 51 games played in the  
25  
26 Men's UEFA European Championship (10 June – 10 July 2016).  
27  
28

29  
30  
31 **Results:** Sixty-nine total PCEs (1.35 per match) were identified in 51 games played during the  
32  
33 2016 Men's UEFA European Championship. Forty-eight PCEs (69.6%) resulted in two  
34  
35 observable signs of concussion, 13 (18.8%) resulted in three signs, and 1 (1.4%) resulted in four  
36  
37 signs in the injured athletes. Nineteen (27.5%) PCEs were medically assessed by sideline  
38  
39 healthcare personnel while 50 (72.5%) were not. Of the 50 PCEs that were not medically  
40  
41 assessed, 44 (88%) PCEs resulted in two or more signs of concussion among injured athletes. Of  
42  
43 the 19 medically assessed PCEs, 8 resulted in 3 signs of concussion, and 1 resulted in 4 signs; all  
44  
45 assessments concluded in same-game return for the injured athletes.  
46  
47

48  
49 **Conclusions:** PCEs were frequent events in the 2016 UEFA Euro championship, but were rarely  
50  
51 assessed concordant with the International Conferences on Concussion in Sport consensus  
52  
53

1 Abraham. *et al.* (2018)

2  
3 statement recommendations. There is an imperative need to improve the assessment and  
4 management of players suspected of concussion in elite football.  
5  
6  
7  
8  
9

10 **Trial Registration:** Not applicable

11  
12 **Patient and Public Involvement:** Patients and or public were not involved.  
13  
14

### 15 16 17 **Strengths and limitations of this study**

- 18  
19 • In this study, we sought to determine if suspected concussions in elite football are medically  
20 assessed according to the International Conferences on Concussion in Sport consensus statement  
21 recommendations to improve concussion awareness and safety measures in football-dominant  
22 nations.  
23  
24  
25  
26  
27
- 28 • This study shows that there is an urgent need to improve the assessment and management of  
29 players suspected of concussion in the realm of elite football  
30  
31
- 32 • The major weakness of this study is that video analysis provides limited information on the  
33 details of medical evaluation for PCEs and thus cannot always provide information on whether  
34 or not an appropriate medical decision is made.  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

Abraham. *et al.* (2018)

## INTRODUCTION

Sport-related concussion (SRC) is a frequent type of mild traumatic brain injury (mTBI) that has emerged as a major public health concern. In children, adolescents, and young adults, sports participation is recognized as one of the leading causes of concussion<sup>1</sup>. The United States (US) national Centers for Disease Control and Prevention (CDC) reported that sports- and recreation-related TBI was responsible for 3.4 million visits to Emergency Departments between 2001-2012; approximately 70% of reported cases involved persons 19 or younger<sup>2</sup>. Accounting for unreported, unrecognized, and untreated injuries, the total number of sports-related mTBI per year was estimated to be as high as 1.8-3.8 million in the US<sup>3</sup>. Although most individuals experiencing mTBI are likely to recover within 1-3 weeks, a sizeable minority (up to 30% in some studies) may suffer from persistent concussion symptoms (i.e. post-concussion syndrome)<sup>4</sup><sup>5</sup>. Furthermore, 15-25% of mTBI cases are associated with adverse long-term physical, cognitive, and emotional sequelae<sup>1</sup>. The high incidence and economic costs of SRC, preferential risk among vulnerable youth, and potential for adverse long-term consequences underscore the need to better prevent, identify, and manage such injuries.

Athletes involved in football, also called ‘soccer’ in North America, consistently experience among the highest rates of concussion<sup>6 7</sup>. Football is the world’s most popular and

Abraham. *et al.* (2018)

1  
2  
3 fastest growing sport; an estimated 270 million people play the sport in various professional,  
4 semi-professional, and/or organized formal recreational capacities<sup>8</sup>. By virtue of its widespread  
5 popularity, football's cumulative contribution to total SRC is likely to significantly overshadow  
6 other sports. Moreover, concussion awareness and safety measures remain relatively  
7 underdeveloped in many football-dominant nations<sup>9</sup>. Such conditions are conducive to large  
8 numbers of undiagnosed concussions, inappropriate management, and increased risk of  
9 potentially severe neurological consequences among vulnerable and/or improperly rehabilitated  
10 football athletes.  
11  
12  
13  
14  
15  
16  
17  
18  
19  
20

21 The proper assessment of suspected concussions immediately following injury is an  
22 important practice needed for early diagnosis and safe rehabilitation of athletes with brain  
23 injuries. Consensus statement recommendations published by 4<sup>th</sup> and 5<sup>th</sup> International  
24 Conferences on Concussion in Sport in 2012 and 2016, respectively, provide clear  
25 recommendations for assessment of athletes sustaining a potential concussive event (PCE)  
26 during a competitive event<sup>10 11</sup>. These statements were previously accepted and endorsed by  
27 football's major international governing body the Fédération Internationale de Football  
28 Association (FIFA). However, our previous analysis of 2014 Men's FIFA world cup (WC) found  
29 that the majority of PCEs (63%) were not medically assessed, indicating a lack of congruence  
30 between recommendations and current practices at the elite level<sup>12</sup>. In this study, we used video  
31 analysis to characterize PCEs and their assessment in the 2016 Men's UEFA European  
32 Championship to determine if improvements had been made over the two-year gap between  
33 tournaments.  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50

## 51 52 **METHODS**

### 53 ***Video Analysis by trained observers***

54  
55  
56  
57  
58  
59  
60

1  
2  
3  
4  
5  
6  
7  
8  
9  
10  
11  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21  
22  
23  
24  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

Abraham. *et al.* (2018)

Video analysis has emerged as a reliable and valid tool to assess concussion in a variety of sports including American football, mixed martial arts, ice hockey, and lacrosse<sup>12-15</sup>. Furthermore, information content in digital videos can be analysed systematically to yield key insights into situational factors and injury-prone patterns of play leading to an injury. We analysed footage of the 51 games that took place during the 2016 UEFA European Championship from 10 June to 10 July. Four observers were trained using video footage of 4 Premier League football matches in order to correctly identify PCEs and collect information pertaining to several variables on a standardized form used in a previous study on concussion<sup>15</sup>. PCEs were classified as any event in which one or more athletes experienced a head impact injury (through direct contact with another athlete, ball, or object in the environment) and were unable to immediately resume play following impact. Athletes involved in PCEs were observed for 6 established observable physical signs of concussion: slow to get up (defined as a duration of 5 or more seconds following impact), clutching of the head, disorientation, loss of consciousness, seizure-like behavior, and signs of obvious disequilibrium<sup>12 16</sup>. Information pertaining to the assessment of athletes sustaining a PCE, including the personnel assessing the players (medical personnel, other players, the referee, no one) was recorded. Trained observers also collected information on PCE outcomes: return-to-play (RTP) after assessment on pitch, RTP after assessment on sidelines, removed for remainder of match, removed from tournament. Three observers watched all 51 games of Men's UEFA Euro 2016 tournament, identified PCEs, and collected data on aforementioned variables. Following this analysis, discrepancies in data were resolved through consultation with a fourth independent observer. Descriptive statistics were reported as counts or frequencies and their associated percentages.

## RESULTS



Abraham. *et al.* (2018)

### ***PCE incidence at Euro 2016***

Sixty-nine PCEs involving 61 different athletes were identified over the course of 51 games played during the 2016 UEFA European Championship (1.35 per match). Seven incidents involved direct head collisions between 2 athletes, which were scored as individual PCEs for each athlete. Of the 61 athletes who experienced a PCE, 4 (6.6%) sustained 2 separate PCEs, and 2 (3.3%) sustained 3 separate PCEs over the course of the tournament. Of the 69 PCEs recorded, 2 (2.9%) resulted in no observable physical signs of concussion, 5 (7.2%) resulted in 1 sign, 48 (69.6%) resulted in 2 signs, 13 (18.8%) resulted in 3 signs, and 1 resulted in 4 signs (1.4%) (table 1).

Table 1 PCE Assessment and Outcome at Euro 2016

No. of concussion signs	No. of PCE (% total)	PCE assessment (n)		RTP Outcome when medically assessed (n)	
		No assessment	Medical assessment	Same-game RTP	Removed from game or tournament
0	2 (2.9)	1	1	1	0
1	5 (7.2)	5	0	0	0
2	48 (69.6)	39	9	9	0
3	13 (18.8)	5	8	8	0
4	1 (1.4)	0	1	1	0
Total (%)	69 (100)	50 (72.5)	19 (27.5)	19 (100)	0 (0)

### ***Medical assessment of PCEs at Euro 2016***

As illustrated in table 1, of the 69 PCE incidents, 19 (27.5%) were medically assessed by sideline healthcare personnel while 50 (72.4%) were not. Of the 50 PCEs that were not medically assessed, 9 (18%) received some attention from the referee and/or another player, while 41 (82%) did not; all athletes involved in these incidents remained on the field following the incident. Among the 50 PCE incidents that did not receive medical assessment, 1 (2%) showed

Abraham. *et al.* (2018)

no physical signs of concussion, 5 (10%) showed one sign, 39 (78%) showed two signs, and 5 (6.4%) showed three signs of concussions. Therefore, 44 out of the 50 (88%) non-assessed PCEs, involved athletes who exhibited 2 or more signs of concussion.

Among the 19 PCE incidents that were medically assessed by healthcare professionals, 1 (5.3%) showed no physical signs of concussion, 9 (47.3%) showed two signs, 8 (42.1%) showed three signs, and 1 (5.3%) showed 4. All 19 (100%) medically assessed PCEs concluded with the athlete returning to play following a brief assessment; no athletes were removed from the game or for the remainder of the tournament.

### ***Medical assessment of concussion: FIFA WC 2014 versus UEFA Euros 2016***

Table 2 compares PCE assessment and outcome in Euros 2016 versus our data from our previously published PCE analysis of WC 2014<sup>12</sup>. PCE incidence was higher in the Euros (1.35 per match) compared to FIFA WC 2014 (1.13 per match). In Euro 2016, 89.8% of PCEs involved athletes with 2 or more signs of concussion compared to 82.7% for WC 2014. Medical assessment of PCE at Euro 2016 (27.5% assessed, 72.5% not assessed) was worse in relation to FIFA WC 2014 (37% assessed, 63% not assessed). In WC 2014, of the 29 PCEs that were medically assessed and involved athletes with 2 or more signs of concussion, 27 (93.1%) returned to the same game, while 2 (6.9%) were removed from the game and/or tournament. In Euro 2016, of the 18 medically-assessed PCEs involving athletes with 2 or more signs of concussion, 18 (100%) resulted in same-game RTP.

Table 2 Comparison of PCE assessment and outcome: UEFA Euro 2016 versus FIFA World

No. of	No. of PCE (% of total)		PCEs medically assessed (n)		PCEs NOT medically assessed (n)		Medically assessed PCEs with same-game RTP (n)	
	WC	Euro	WC	Euro	WC	Euro	WC	Euro

Abraham. *et al.* (2018)

concussion signs	2014	2016	2014	2016	2014	2016	2014	2016
0	3 (4)	2 (2.9)	0	1	3	1	0	1
1	11 (14)	5 (7.2)	1	0	10	5	1	0
2 or more	67 (82.7)	62 (89.8)	29	18	38	44	27	18
Total (%)	81 (100)	69 (100)	30 (37)	19 (27.5)	51 (63)	50 (72.5)	28 (93)	19 (100)

## DISCUSSION

### *Concussion in football – an important public health concern*

Concussion is an inherent risk associated with sports participation and SRC is now recognized as a major public health concern<sup>1 17</sup>. Yet, participation in sports is a meaningful part of millions of people's lives, and provides numerous physical and emotional health benefits. Maximizing these benefits, while simultaneously minimizing the risks of adverse events such as concussion and its long-term sequelae represents an important public health imperative. Athletes involved in contact and/or collision sports are at higher risk for SRC. Football is a sport with an under-appreciated high rate and burden of concussion<sup>1 67</sup>. By virtue of football's global dimension and contribution to worldwide sport-related mTBI, sustained efforts at improving concussion awareness and assessment at all levels of the sport will have a substantial impact on reducing disability from and/or risk of injury.

### *Inadequate implementation of consensus statement recommendations*

Medical assessment of a PCE is an important practice needed for early concussion diagnosis, proper management, and safe return to play for injured athletes. Successful implementation of medical assessment protocols in sport is imperative to the larger effort to reduce SRC morbidity and its potentially serious long-term consequences. To aid this effort, clear protocols for on-field

1  
2  
3  
4  
5  
6  
7  
8  
9  
10  
11  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21  
22  
23  
24  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

Abraham. *et al.* (2018)

assessment of an athlete with a suspected concussion were published and reiterated in consensus statements following the 4<sup>th</sup> and 5<sup>th</sup> International Conferences on Concussion in Sport held in 2012 and 2016, respectively<sup>10 11</sup>. These endeavors have been supported and endorsed by football's major international governing body FIFA<sup>10 11</sup>. The 2012 and 2016 consensus statements assert that when an athlete shows ANY features of a concussion, the athlete should be 1) evaluated by a physician or another licensed healthcare provider onsite, 2) assessed using SCAT3/SCAT5 or other sideline concussion assessment tools, and 3) prevented from return-to-play in the event of a positive diagnosis<sup>10 11</sup>. In a previous study on the Men's 2014 FIFA WC, we found that 63% of elite-level football athletes who sustained PCEs were not medically assessed, thereby underscoring the need for better implementation of concussion assessment protocols in elite football. Our current analysis of the 2016 UEFA European Championship reinforces this notion since only 27.5% of PCEs were medically assessed while 72.5% were not. Furthermore, all PCEs that were medically assessed culminated in same game RTP despite the majority of these incidents resulting in 2 or more physical signs among injured athletes. Notably, the only athlete who experienced 4 physical signs of concussion was allowed to return to game following assessment, while another athlete who suffered a PCE incident that resulted in a head laceration, heavy bleeding, and 2 physical signs of concussion was allowed to return to the game and sustained a second PCE shortly after returning. Thus, our data also indicates that the quality and accuracy of assessment received by athletes suffering PCEs is in need of careful scrutiny. Injury reporting and analysis by UEFA and FIFA should include more detail on PCEs and PCE evaluation in order to identify opportunities to improve athlete safety<sup>18</sup>. Overall, our data highlights an obvious need to improve concussion assessment in the realm of elite football, and

1 Abraham. *et al.* (2018)

2  
3 suggest that significant and persistent knowledge uptake and/or attitudinal barriers to  
4  
5 implementation may exist.  
6

### 7 ***Barriers to Implementation***

8  
9  
10 Several factors may contribute to weak implementation of SRC assessment protocols in elite  
11  
12 football. First, a misperception and/or lack of awareness of SRC risk among football athletes,  
13  
14 coaches, franchises, and related organizations may limit enforcement. Advances in the  
15  
16 prevention and proper management of SRC require that sporting associations attend to  
17  
18 concussion with the same diligence typically applied to doping and other serious breaches.  
19  
20 Second, the high stakes of competitive sport may pressure team medical staff to ignore PCEs, or  
21  
22 inappropriately shorten examination and encourage RTP, particularly in situations when the team  
23  
24 needs a result. In a widely-publicized and recent example illustrating the pressures that team  
25  
26 doctors may experience, a long-serving female team doctor from Chelsea Football Club was  
27  
28 publically criticized, demoted, and eventually forced out of the club for fulfilling her medical  
29  
30 obligation to assess an injured player in stoppage time of a Premier League game. Third, factors  
31  
32 that normally contribute to under-reporting in other sports may be relevant as implementation  
33  
34 barriers in football<sup>19</sup>. For instance, a culture of toughness and loyalty to the team may either  
35  
36 openly or subtly encourage athletes to downplay concussion or inappropriately accelerate RTP  
37  
38 following injury<sup>19 20</sup>. Furthermore, athletes are influenced by a strong desire to win, and fear of  
39  
40 letting their teams or nations down, which may also encourage underreporting of SRC  
41  
42 symptoms. Fourth our data suggest that significant gaps in knowledge translation exist, and  
43  
44 highlight the need for improved knowledge dissemination and uptake at multiple levels including  
45  
46 international football associations such as FIFA and UEFA, individual franchises, as well as  
47  
48 associated staff, coaches, athletes and the wider spectrum of stakeholders in the sport. Research  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

1 Abraham. *et al.* (2018)

2  
3 identifying barriers to implementation such as knowledge translation bottlenecks, followed by  
4  
5 strategic targeting of such impediments will be imperative to improved implementation of risk-  
6  
7 reducing practices (including but not limited to medical assessment) that ultimately safeguard the  
8  
9 long-term brain health of football athletes. Reaching out directly to stakeholders, including  
10  
11 FIFA, national team coaches and their staff physicians, as well as the intended beneficiaries of  
12  
13 this work (athletes) will be imperative to widespread knowledge dissemination and uptake  
14  
15 efforts.  
16  
17

### 18 ***Limitations***

19  
20 Video analysis provides limited information on the details of medical evaluation for PCEs and  
21  
22 thus cannot always provide information on whether or not an appropriate medical decision is  
23  
24 made. In some PCEs, full description of variables may be limited by the camera angles available  
25  
26 for the video clip. Some game events may be misidentified as PCEs if players simulate or feign  
27  
28 injury. Finally, it is possible, though unlikely, that some PCEs do not result in stoppage of play  
29  
30 and the athlete continues to play resulting in a PCE being erroneously excluded from analysis.  
31  
32  
33

### 34 ***Future directions***

35  
36  
37 Overall, our data indicate that PCEs occur relatively frequently (at least one per game) in elite  
38  
39 level football matches, but are rarely assessed in a manner concordant with the 2012 or 2016  
40  
41 International Conferences on Concussion in Sport consensus recommendations. Major  
42  
43 international tournaments such as the FIFA World cup and UEFA European Championships  
44  
45 feature elite-level athletes and are among the most widely broadcasted and followed sporting  
46  
47 events on the planet<sup>21</sup>. The norms that persist on such a stage are likely to influence attitudes  
48  
49 towards concussion on a global scale. The upcoming 2018 FIFA men's World Cup offers the  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59

1 Abraham. *et al.* (2018)

2  
3 opportunity to set a new precedent for excellence in enforcement of concussion assessment, and  
4  
5 initiate beneficial improvements in concussion awareness and the implementation of proper  
6  
7 assessment protocols in the sport.  
8  
9

### 10 11 **Funding Statement**

12  
13 This work is supported by the Canadian Institutes of Health Research Strategic Team Grant in  
14  
15 Applied Injury Research #TIR-103946 and the Ontario Neurotrauma Foundation.  
16  
17

### 18 19 20 **Author Contributorship**

21  
22 Research concept and design by M.D.C; data collection and analysis by K.J.A, J.C., A.S., C.T.,  
23  
24 and A.Z.; manuscript writing by K.J.A and M.D.C. Guarantor: K.J.A. Dr. Michael Cusimano is a  
25  
26 non-paid volunteer on the expert advisory committee and the concussion committee of Parachute  
27  
28 Canada a not-for-profit injury prevention organization. He is a neurosurgeon at St. Michael's  
29  
30 hospital who wishes he would never see one more brain injured person and that we can prevent  
31  
32 every brain injury in the future.  
33  
34  
35  
36  
37  
38

### 39 **Competing Interest**

40  
41 None declared.  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

Abraham. *et al.* (2018)

## REFERENCES

1. Mannix R, Meehan WP, Pascual-Leone A. OPINION Sports-related concussions - media, science and policy. *Nat Rev Neurol* 2016;12(8):486-90. doi: 10.1038/nrneurol.2016.99
2. Coronado VG, Haileyesus T, Cheng TA, et al. Trends in Sports- and Recreation-Related Traumatic Brain Injuries Treated in US Emergency Departments: The National Electronic Injury Surveillance System-All Injury Program (NEISS-AIP) 2001-2012. *J Head Trauma Rehab* 2015;30(3):185-97. doi: 10.1097/Htr.000000000000156
3. Langlois JA, Rutland-Brown W, Wald MM. The epidemiology and impact of traumatic brain injury - A brief overview. *J Head Trauma Rehab* 2006;21(5):375-78. doi: Doi 10.1097/00001199-200609000-00001
4. Zemek R, Barrowman N, Freedman SB. Clinical risk score for persistent postconcussion symptoms among children with acute concussion in the ED (vol 315, pg 1014, 2016). *Jama-J Am Med Assoc* 2016;315(23):2624-24. doi: 10.1001/jama.2016.7407
5. Guskiewicz KM, Marshall SW, Bailes J, et al. Recurrent concussion and risk of depression in retired professional football players. *Med Sci Sport Exer* 2007;39(6):903-09. doi: 10.1249/mss.0b013e3180383da5
6. Covassin T, Swanik CB, Sachs ML. Sex differences and the incidence of concussions among collegiate athletes. *J Athl Training* 2003;38(3):238-44.
7. Agel J, Evans TA, Dick R, et al. Descriptive epidemiology of collegiate men's soccer injuries: National Collegiate Athletic Association Injury Surveillance System, 1988-1989 through 2002-2003. *J Athl Train* 2007;42(2):270-7. [published Online First: 2007/08/22]
8. Kunz M. 265 million playing football. *FIFA magazine*, 2007:10-15.
9. Broglio SP, Vagnozzi R, Sabin M, et al. Concussion occurrence and knowledge in Italian football (soccer). *J Sport Sci Med* 2010;9(3):418-30.
10. McCrory P, Meeuwisse WH, Aubry M, et al. Consensus statement on concussion in sport: the 4th International Conference on Concussion in Sport held in Zurich, November 2012. *Brit J Sport Med* 2013;47(5):250-58. doi: 10.1136/bjsports-2013-092313
11. McCrory P, Meeuwisse WH, Dvorak J, et al. 5th International Conference on Concussion in Sport (Berlin). *Brit J Sport Med* 2017;51(11):837-37. doi: 10.1136/bjsports-2017-097878



Abraham. *et al.* (2018)

12. Cusimano MD, Casey J, Jing RW, et al. Assessment of Head Collision Events During the 2014 FIFA World Cup Tournament. *Jama-J Am Med Assoc* 2017;317(24):2548-49. doi: 10.1001/jama.2017.6204
13. Makdissi M, Davis G. Using video analysis for concussion surveillance in Australian football. *J Sci Med Sport* 2016;19(12):958-63. doi: 10.1016/j.jsams.2016.02.014
14. McCrea M, Guskiewicz KM, Marshall SW, et al. Acute effects and recovery time following concussion in collegiate football players - The NCAA Concussion Study. *Jama-J Am Med Assoc* 2003;290(19):2556-63. doi: DOI 10.1001/jama.290.19.2556
15. Lawrence DW, Hutchison MG, Cusimano MD, et al. Interrater Agreement of an Observational Tool to Code Knockouts and Technical Knockouts in Mixed Martial Arts. *Clin J Sport Med* 2014;24(5):397-402. doi: Doi 10.1097/Jsm.0000000000000047
16. Makdissi M, Davis G. The reliability and validity of video analysis for the assessment of the clinical signs of concussion in Australian football. *J Sci Med Sport* 2016;19(10):859-63. doi: 10.1016/j.jsams.2016.02.015
17. Jordan BD. The clinical spectrum of sport-related traumatic brain injury. *Nat Rev Neurol* 2013;9(4):222-30. doi: 10.1038/nrneurol.2013.33
18. Group IS. UEFA Injury Study Report, 2016:15.
19. Cusimano MD, Topolovec-Vranic J, Zhang S, et al. Factors Influencing the Underreporting of Concussion in Sports: A Qualitative Study of Minor Hockey Participants. *Clin J Sport Med* 2017;27(4):375-80. doi: Doi 10.1097/Jsm.0000000000000372
20. Cusimano MD, Cho N, Amin K, et al. Mechanisms of Team-Sport-Related Brain Injuries in Children 5 to 19 Years Old: Opportunities for Prevention. *Plos One* 2013;8(3) doi: ARTN e5886810.1371/journal.pone.0058868
21. FIFA. 2014 FIFA World Cup breaks online streaming records, 2014.

**STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies***

Section/Topic	Item #	Recommendation	Reported on page #
<b>Title and abstract</b>	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	3
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	3
<b>Introduction</b>			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	5,6
Objectives	3	State specific objectives, including any prespecified hypotheses	6
<b>Methods</b>			
Study design	4	Present key elements of study design early in the paper	6,7
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6,7
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants	6,7
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6,7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6,7
Bias	9	Describe any efforts to address potential sources of bias	7
Study size	10	Explain how the study size was arrived at	7
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	7
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	7
		(b) Describe any methods used to examine subgroups and interactions	7
		(c) Explain how missing data were addressed	7
		(d) If applicable, describe analytical methods taking account of sampling strategy	7
		(e) Describe any sensitivity analyses	N/A
<b>Results</b>			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	7,8,9
		(b) Give reasons for non-participation at each stage	N/A
		(c) Consider use of a flow diagram	N/A
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	7,8,9
		(b) Indicate number of participants with missing data for each variable of interest	0
Outcome data	15*	Report numbers of outcome events or summary measures	7,8,9
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	N/A
		(b) Report category boundaries when continuous variables were categorized	N/A
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	N/A
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	7,8,9
<b>Discussion</b>			
Key results	18	Summarise key results with reference to study objectives	10,11,12
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	12
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	11,12
Generalisability	21	Discuss the generalisability (external validity) of the study results	10,11,12
<b>Other information</b>			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	13

\*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

**Note:** An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at [www.strobe-statement.org](http://www.strobe-statement.org).

# BMJ Open

## Medical Assessment of Potential Concussion in Elite Football: A Video Analysis of the 2016 UEFA European Championship

Journal:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2018-024607.R1
Article Type:	Research
Date Submitted by the Author:	26-Oct-2018
Complete List of Authors:	Abraham, Karan; St. Michael's Hospital, Neurosurgery Casey, Julia; St. Michael's Hospital, Neurosurgery Subotic, Arsenije; St. Michael's Hospital, Neurosurgery Christopher, Tarzi; St. Michael's Hospital, Zhu, Alice; St. Michael's Hospital, Neurosurgery Cusimano, Michael; St. Michael's Hospital, Neurosurgery; University of Toronto Dalla Lana School of Public Health, Public Health
<b>Primary Subject Heading</b>:	Sports and exercise medicine
Secondary Subject Heading:	Public health
Keywords:	Concussion, Head injury, Traumatic brain injury, Football, Sport, Injury prevention

SCHOLARONE™  
Manuscripts

1 Abraham. *et al.* (2018)  
2  
3  
4  
5

6 **Medical Assessment of Potential Concussion in Elite Football: A Video Analysis of the 2016**  
7 **UEFA European Championship**  
8  
9

10 Karan J. Abraham MSc<sup>1</sup>, Julia Casey BSc<sup>1</sup>, Arsenije Subotic BSc<sup>1</sup>, Christopher Tarzi<sup>1</sup>, Alice Zhu  
11 BSc<sup>1</sup>, and Michael D. Cusimano MD PhD<sup>1,2\*</sup>  
12  
13

14  
15  
16 <sup>1</sup>*Injury Prevention Research Office, Division of Neurosurgery, St. Michael's Hospital,*  
17 *Toronto, Ontario, M5B 1W8, Canada*

18 <sup>2</sup>*Department of Surgery, University of Toronto, Toronto, Ontario, M5G 1M1, Canada*  
19  
20  
21  
22  
23  
24  
25

26 \*Lead contact: Dr. Michael D. Cusimano, MD, MHPE, FRCSC, PhD, FACS  
27 Division of Neurosurgery, St. Michael's Hospital  
28 Professor of Neurosurgery, Education and Public Health  
29 University of Toronto  
30  
31

32 **Postal/Mailing address:**

33 30 Bond Street  
34 Toronto, ON, Canada  
35 M5B 1W8  
36  
37

38 **Phone:**

39 (416) 864 6048 (Clinical Office)  
40 (418) 864 5312 (Research Office)  
41  
42

43 **Email:** [injuryprevention@smh.ca](mailto:injuryprevention@smh.ca)  
44  
45  
46  
47

48 **Word count: 2668**  
49  
50

51 **KEYWORDS**

52 Concussion, Head injury, Traumatic brain injury, Soccer, Football, Sport, Injury prevention, FIFA;  
53 Fédération Internationale de Football Association, UEFA; Union of European Football  
54 Associations.  
55  
56  
57  
58  
59

1 Abraham. *et al.* (2018)

2  
3  
4 **ABSTRACT**

5  
6  
7 **Objective:** The objective is to determine if suspected concussions in elite football  
8  
9  
10 are medically assessed according to the International Conferences on Concussion in  
11  
12  
13 Sport consensus statement recommendations.  
14

15  
16  
17 **Setting:** Men's Union of European Football Association (UEFA) Football  
18  
19  
20 Championship  
21

22  
23  
24 **Participants:** All professional football players in the UEFA 2016 Championship  
25  
26  
27 Tournament.  
28

29  
30 **Design:** Observational study.  
31

32  
33  
34 **Outcome Measures:** Potential concussive events (PCEs) were defined as direct  
35  
36  
37 head collision incidents resulting in the athlete being unable to immediately  
38  
39  
40 resume play following impact. PCEs identified and description of PCE assessment  
41  
42  
43 and outcome were accomplished through direct standardized observation of video  
44  
45  
46  
47 footage by trained observers in 51 games played in the Men's UEFA European  
48  
49  
50 Championship (10 June - 10 July 2016).  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

1 Abraham. *et al.* (2018)

2  
3 **Results:** Sixty-nine total PCEs (1.35 per match) were identified in 51 games  
4  
5  
6 played during the 2016 Men's UEFA European Championship. Forty-eight PCEs  
7  
8  
9  
10 (69.6%) resulted in two observable signs of concussion, 13 (18.8%) resulted in three signs, and 1  
11  
12 (1.4%) resulted in four signs in the injured athletes. Nineteen (27.5%) PCEs were medically  
13  
14 assessed by sideline healthcare personnel while 50 (72.5%) were not. Of the 50 PCEs that were  
15  
16 not medically assessed, 44 (88%) PCEs resulted in two or more signs of concussion among injured  
17  
18 athletes. Of the 19 medically assessed PCEs, 8 resulted in 3 signs of concussion, and 1 resulted in  
19  
20 4 signs; all assessments concluded in same-game return for the injured athletes.  
21  
22

23  
24 **Conclusions:** PCEs were frequent events in the 2016 UEFA Euro championship, but were rarely  
25  
26 assessed concordant with the International Conferences on Concussion in Sport consensus  
27  
28 statement recommendations. There is an imperative need to improve the assessment  
29  
30 and management of players suspected of concussion in elite football.  
31  
32  
33  
34  
35  
36  
37  
38  
39

40 **Trial Registration:** Not applicable  
41  
42  
43  
44  
45

#### 46 **Strengths and limitations of this study**

47  
48  
49

- 50 • In this study, we sought to determine if suspected concussions in elite  
51  
52  
53 football are medically assessed according to the International Conferences on  
54  
55  
56  
57  
58  
59  
60

1 Abraham. *et al.* (2018)

2  
3 Concussion in Sport consensus statement recommendations to improve  
4  
5  
6  
7 concussion awareness and safety measures in football-dominant nations.  
8  
9

- 10 • This study shows that there is an urgent need to improve the assessment  
11  
12  
13 and management of players suspected of concussion in the realm of elite football  
14  
15  
16
- 17 • The major weakness of this study is that video analysis provides limited  
18  
19  
20 information on the details of medical evaluation for PCEs and thus cannot always  
21  
22  
23 provide information on whether or not an appropriate medical decision is made.  
24  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49

## 50 **INTRODUCTION**

51  
52  
53 Sport-related concussion (SRC) is a frequent type of mild traumatic brain injury (mTBI)  
54  
55  
56 that has emerged as a major public health concern. In children, adolescents, and young adults,  
57  
58  
59



1 Abraham. *et al.* (2018)

2  
3 sports participation is recognized as one of the leading causes of concussion<sup>1</sup>. The United States  
4 (US) national Centers for Disease Control and Prevention (CDC) reported that sports- and  
5 recreation-related TBI was responsible for 3.4 million visits to Emergency Departments between  
6 2001-2012; approximately 70% of reported cases involved persons 19 or younger<sup>2</sup>. Accounting  
7 for unreported, unrecognized, and untreated injuries, the total number of sports-related TBI per  
8 year was estimated to be as high as 1.8-3.8 million in the US, the majority of them being mTBI<sup>3</sup>.  
9  
10 Although most individuals experiencing mTBI are likely to recover within 1-3 weeks, a sizeable  
11 minority (up to 30% in some studies) may suffer from persistent concussion symptoms (i.e. post-  
12 concussion syndrome)<sup>4 5</sup>. Furthermore, 15-25% of mTBI cases are associated with adverse long-  
13 term physical, cognitive, and emotional sequelae<sup>1</sup>. The high incidence and economic costs of SRC,  
14 preferential risk among vulnerable youth, and potential for adverse long-term consequences  
15 underscore the need to better prevent, identify, and manage such injuries.  
16  
17  
18  
19  
20  
21  
22  
23  
24  
25  
26  
27  
28  
29

30  
31 Athletes involved in football, also called ‘soccer’ in North America, consistently  
32 experience among the highest rates of concussion<sup>6 7</sup>. Football is the world’s most popular and  
33 fastest growing sport; an estimated 270 million people play the sport in various professional, semi-  
34 professional, and/or organized formal recreational capacities<sup>8</sup>. By virtue of its widespread  
35 popularity, football’s cumulative contribution to total SRC is likely to significantly overshadow  
36 other sports. Moreover, concussion awareness and safety measures remain relatively  
37 underdeveloped in many football-dominant nations<sup>9</sup>. Such conditions are conducive to large  
38 numbers of undiagnosed concussions, inappropriate management, and increased risk of potentially  
39 severe neurological consequences among vulnerable and/or improperly rehabilitated football  
40 athletes.  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

1  
2  
3  
4  
5  
6  
7  
8  
9  
10  
11  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21  
22  
23  
24  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

Abraham. *et al.* (2018)

The proper assessment of suspected concussions immediately following injury is an important practice needed for early diagnosis and safe rehabilitation of athletes with brain injuries. Consensus statement recommendations published by 4<sup>th</sup> and 5<sup>th</sup> International Conferences on Concussion in Sport in 2012 and 2016, respectively, provide clear recommendations for assessment of suspected concussions during a competitive event<sup>10 11</sup>. The Concussion in Sport Group (CISG) 2012 and 2016 consensus statements assert that when an athlete shows ANY features of a concussion, the athlete should be 1) evaluated by a physician or another licensed healthcare provider onsite, 2) assessed using SCAT3/SCAT5 or other sideline concussion assessment tools, and 3) prevented from return-to-play in the event of a positive diagnosis<sup>10</sup>

<sup>11</sup>These statements were previously accepted and endorsed by football's major international governing body the Fédération Internationale de Football Association (FIFA). However, our previous analysis of 2014 Men's FIFA world cup (WC) found that the majority of PCEs (63%) were not medically assessed, indicating a lack of congruence between recommendations and current practices at the elite level<sup>12</sup>. In this study, we used video analysis to characterize PCEs and their assessment in the 2016 Men's UEFA European Championship. Additionally, we compared our findings against our previous analysis of the 2014 FIFA WC to determine if compliance with CISG recommendations had improved over the two-year gap between tournaments.

## METHODS

Video analysis has emerged as a reliable and valid tool to assess concussion in a variety of sports including American football, mixed martial arts, ice hockey, and lacrosse <sup>12-15</sup>. Furthermore, information content in digital videos can be analysed systematically to yield key insights into situational factors and injury-prone patterns of play leading to an injury.

### *Coding of Events*

1 Abraham. *et al.* (2018)

2  
3 PCEs were defined as any event in which one or more athletes experienced a head impact injury  
4 (through direct contact with another athlete, ball, or object in the environment) and were unable to  
5 immediately resume play following impact. Athletes involved in PCEs were observed for 6  
6 established observable physical signs of concussion: slow to get up (defined as a duration of 5 or  
7 more seconds following impact), clutching of the head, disorientation, loss of consciousness,  
8 seizure-like behavior, and signs of obvious disequilibrium<sup>12 16</sup>. The term PCE is not used  
9 synonymously with SRC. Instead, it captures the broad range of in-game scenarios involving head  
10 collisions; recognizing that the higher the number of concussion signs associated with a PCE, the  
11 greater the index for suspicion that it may represent a *bona fide* concussion. Information pertaining  
12 to the assessment of athletes sustaining a PCE, including the personnel assessing the players  
13 (medical personnel, other players, the referee, no one) was recorded. Trained observers also  
14 collected information on PCE outcomes: return-to-play (RTP) after assessment on pitch, RTP after  
15 assessment on sidelines, removed for remainder of match, removed from tournament.  
16  
17  
18  
19  
20  
21  
22  
23  
24  
25  
26  
27  
28  
29  
30  
31

### 32 ***Training of Reviewers***

33  
34 Four observers were trained using video footage of 4 Premier League football matches in order to  
35 correctly identify PCEs and collect information pertaining to several variables on a standardized  
36 form used in a previous study on concussion<sup>15</sup>. The standardized data collection form was used to  
37 provide a person viewing digital video images with a consistent way of coding and accounting for  
38 the majority of circumstances and mechanisms leading to concussion. The standardized data form  
39 was adapted from a validated form used in a prior study on concussion<sup>15</sup>. The form was  
40 accompanied by a detailed data dictionary outlining the codes associated with each variable.  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50

### 51 ***Video Analysis***

1 Abraham. *et al.* (2018)

2  
3 The observers analysed footage of the 51 games that took place during the 2016 UEFA European  
4  
5 Championship from 10 June to 10 July. Observers independently reviewed the video footage to  
6  
7 complete the standardized form. Three observers watched all 51 games of Men's UEFA Euro 2016  
8  
9 tournament, identified PCEs, and collected data on aforementioned variables. All variables yielded  
10  
11 a Cohen's kappa value of 0.90 or greater between all reviewers. Following this analysis,  
12  
13 discrepancies in data were resolved through consultation with a fourth independent observer.  
14  
15

### 16 *Statistical Analysis*

17  
18 Descriptive statistics were reported as counts or frequencies and their associated percentages. All  
19  
20 statistical analysis was done in STATA 13 (StataCorp, Texas, USA).  
21  
22

### 23 **Patient and Public Involvement:**

24  
25 Patients and or public were not involved.  
26  
27  
28  
29  
30

## 31 **RESULTS**

### 32 *PCE incidence at Euro 2016*

33  
34 Sixty-nine PCEs involving 61 different athletes were identified over the course of 51 games played  
35  
36 during the 2016 UEFA European Championship (1.35 per match). Seven incidents involved  
37  
38 direct head collisions between 2 athletes, which were scored as individual PCEs for each athlete.  
39  
40 Of the 61 athletes who experienced a PCE, 4 (6.6%) sustained 2 separate PCEs, and 2 (3.3%)  
41  
42 sustained 3 separate PCEs over the course of the tournament. Of the 69 PCEs recorded, 2 (2.9%)  
43  
44 resulted in no observable physical signs of concussion, 5 (7.2%) resulted in 1 sign, 48 (69.6%)  
45  
46 resulted in 2 signs, 13 (18.8%) resulted in 3 signs, and 1 resulted in 4 signs (1.4%) (table 1).  
47  
48  
49  
50  
51  
52

53 Table 1 PCE Assessment and Outcome at Euro 2016  
54  
55  
56  
57  
58  
59

Abraham. *et al.* (2018)

No. of concussion signs	No. of PCE (% total)	PCE assessment (n)		RTP Outcome when medically assessed (n)	
		No assessment	Medical assessment	Same-game RTP	Removed from game or tournament
0	2 (2.9)	1	1	1	0
1	5 (7.2)	5	0	0	0
2	48 (69.6)	39	9	9	0
3	13 (18.8)	5	8	8	0
4	1 (1.4)	0	1	1	0
Total (%)	69 (100)	50 (72.5)	19 (27.5)	19 (100)	0 (0)

### ***Medical assessment of PCEs at Euro 2016***

As illustrated in table 1, of the 69 PCE incidents, 19 (27.5%) were medically assessed by sideline healthcare personnel while 50 (72.4%) were not. Of the 50 PCEs that were not medically assessed, 9 (18%) received some attention from the referee and/or another player, while 41 (82%) did not; all athletes involved in these incidents remained on the field following the incident. Among the 50 PCE incidents that did not receive medical assessment, 1 (2%) showed no physical signs of concussion, 5 (10%) showed one sign, 39 (78%) showed two signs, and 5 (6.4%) showed three signs of concussions. Therefore, 44 out of the 50 (88%) non-assessed PCEs, involved athletes who exhibited 2 or more signs of concussion.

Among the 19 PCE incidents that were medically assessed by healthcare professionals, 1 (5.3%) showed no physical signs of concussion, 9 (47.3%) showed two signs, 8 (42.1%) showed three signs, and 1 (5.3%) showed 4. All 19 (100%) medically assessed PCEs concluded with the athlete returning to play following a brief assessment; no athletes were removed from the game or for the remainder of the tournament.

### ***Medical assessment of concussion: FIFA WC 2014 versus UEFA Euros 2016***

Abraham. *et al.* (2018)

Table 2 compares PCE assessment and outcome in Euros 2016 versus our data from our previously published PCE analysis of WC 2014<sup>12</sup>. PCE incidence was higher in the Euros (1.35 per match) compared to FIFA WC 2014 (1.13 per match). In Euro 2016, 89.8% of PCEs involved athletes with 2 or more signs of concussion compared to 82.7% for WC 2014. Medical assessment of PCE at Euro 2016 (27.5% assessed, 72.5% not assessed) was worse in relation to FIFA WC 2014 (37% assessed, 63% not assessed). In WC 2014, of the 29 PCEs that were medically assessed and involved athletes with 2 or more signs of concussion, 27 (93.1%) returned to the same game, while 2 (6.9%) were removed from the game and/or tournament. In Euro 2016, of the 18 medically-assessed PCEs involving athletes with 2 or more signs of concussion, 18 (100%) resulted in same-game RTP.

Table 2 Comparison of PCE assessment and outcome: UEFA Euro 2016 versus FIFA World

No. of concussion signs	No. of PCE (% of total)		PCEs medically assessed (n)		PCEs NOT medically assessed (n)		Medically assessed PCEs with same-game RTP (n)	
	WC 2014	Euro 2016	WC 2014	Euro 2016	WC 2014	Euro 2016	WC 2014	Euro 2016
0	3 (4)	2 (2.9)	0	1	3	1	0	1
1	11 (14)	5 (7.2)	1	0	10	5	1	0
2 or more	67 (82.7)	62 (89.8)	29	18	38	44	27	18
Total (%)	81 (100)	69 (100)	30 (37)	19 (27.5)	51 (63)	50 (72.5)	28 (93)	19 (100)

## DISCUSSION

### *Concussion in football – an important public health concern*

1 Abraham. *et al.* (2018)

2  
3 Concussion is an inherent risk associated with sports participation and SRC is now recognized as  
4 a major public health concern<sup>1 17</sup>. Yet, participation in sports is a meaningful part of millions of  
5 people's lives, and provides numerous physical and emotional health benefits. Maximizing these  
6 benefits, while simultaneously minimizing the risks of adverse events such as concussion and its  
7 long-term sequelae represents an important public health imperative. Athletes involved in contact  
8 and/or collision sports are at higher risk for SRC. Football is a sport with an under-appreciated  
9 high rate and burden of concussion<sup>1 6 7</sup>. By virtue of football's global dimension and contribution  
10 to worldwide sport-related mTBI, sustained efforts at improving concussion awareness and  
11 assessment at all levels of the sport will have a substantial impact on reducing disability from  
12 and/or risk of injury.  
13  
14  
15  
16  
17  
18  
19  
20  
21  
22  
23  
24  
25  
26

### 27 ***Inadequate implementation of consensus statement recommendations***

28  
29 Medical assessment of a PCE is an important practice needed for early concussion diagnosis,  
30 proper management, and safe return to play for injured athletes. Successful implementation of  
31 medical assessment protocols in sport is imperative to the larger effort to reduce SRC morbidity  
32 and its potentially serious long-term consequences. To aid this effort, clear protocols for on-field  
33 assessment of an athlete with a suspected concussion were published and reiterated in consensus  
34 statements following the 4<sup>th</sup> and 5<sup>th</sup> International Conferences on Concussion in Sport held in 2012  
35 and 2016, respectively<sup>10 11</sup>. These endeavors have been supported and endorsed by football's major  
36 international governing body FIFA<sup>10 11</sup>. The CISG recommendations assert that when an athlete  
37 shows ANY features of a concussion, the athlete should be 1) evaluated by a physician or another  
38 licensed healthcare provider onsite, 2) assessed using SCAT3/SCAT5 or other sideline concussion  
39 assessment tools, and 3) prevented from return-to-play in the event of a positive diagnosis<sup>10 11</sup>. In  
40 a previous study on the Men's 2014 FIFA WC, we found that 63% of elite-level football athletes  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

1  
2  
3  
4  
5  
6  
7  
8  
9  
10  
11  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21  
22  
23  
24  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

Abraham. *et al.* (2018)

who sustained PCEs were not medically assessed, thereby underscoring the need for better implementation of concussion assessment protocols in elite football. Our current analysis of the 2016 UEFA European Championship reinforces this notion since only 27.5% of PCEs were medically assessed while 72.5% were not. While many PCEs are unlikely to result in *bona fide* concussions, it is clear that CISG recommendations apply to PCEs in which the index of suspicion for concussion is high (e.g. PCEs with multiple signs of concussion). Notably, 44 out of the 50 (88%) non-assessed PCEs in the 2016 UEFA European Championship involved athletes who exhibited 2 or more signs of concussion. A proper assessment for concussion is warranted in such situations and a failure to assess raises legitimate concerns that some concussions may be missed. Furthermore, all PCEs that were medically assessed culminated in same game RTP despite the majority of these incidents resulting in 2 or more physical signs among injured athletes. Notably, the only athlete who experienced 4 physical signs of concussion was allowed to return to game following assessment, while another athlete who suffered a PCE incident that resulted in a head laceration, heavy bleeding, and 2 physical signs of concussion was allowed to return to the game and sustained a second PCE shortly after returning. Thus, our data also indicates that the quality and accuracy of assessment received by athletes suffering PCEs is in need of careful scrutiny. Injury reporting and analysis by UEFA and FIFA should include more detail on PCEs and PCE evaluation in order to identify opportunities to improve athlete safety<sup>18</sup>. Overall, our data highlights an obvious need to improve concussion assessment in the realm of elite football, and suggest that significant and persistent knowledge uptake and/or attitudinal barriers to implementation may exist.

### ***Barriers to Implementation***



1 Abraham. *et al.* (2018)

2  
3 Several factors may contribute to weak implementation of SRC assessment protocols in elite  
4 football. First, the high stakes of competitive sport and rules of the games may pressure team  
5 medical staff to ignore PCEs, or inappropriately shorten examination and encourage RTP,  
6 particularly in situations when the team needs a result. In a widely-publicized and recent example  
7 illustrating the pressures that team doctors may experience, a long-serving female team doctor  
8 from Chelsea Football Club was publically criticized, demoted, and eventually forced out of the  
9 club for fulfilling her medical obligation to assess an injured player in stoppage time of a Premier  
10 League game. The current rules of the game, including running time and limited substitutions,  
11 further discourage pulling player for medical assessment. For the recent 2018 WC competition,  
12 FIFA implemented a new protocol for head injuries and concussions. This includes giving the  
13 referee the ability to stop the match for 3 minutes if a head injury is suspected for an on-pitch  
14 assessment. 3 minutes is not sufficient time to complete a SCAT3/5. The SCAT5 explicitly states  
15 on the form “The SCAT5 cannot be performed correctly in less than 10 minutes”<sup>19</sup>. Second, factors  
16 that normally contribute to under-reporting in other sports may be relevant as implementation  
17 barriers in football<sup>20</sup>. For instance, a culture of toughness and loyalty to the team may either openly  
18 or subtly encourage athletes to downplay concussion or inappropriately accelerate RTP following  
19 injury<sup>20 21</sup>. Furthermore, athletes are influenced by a strong desire to win, and fear of letting their  
20 teams or nations down, which may also encourage underreporting of SRC symptoms. Third, our  
21 data suggest that significant gaps in knowledge translation exist, and highlight the need for  
22 improved knowledge dissemination and uptake at multiple levels including international football  
23 associations such as FIFA and UEFA, individual franchises, as well as associated staff, coaches,  
24 athletes and the wider spectrum of stakeholders in the sport. Research identifying barriers to  
25 implementation such as knowledge translation bottlenecks, followed by strategic targeting of such  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59

1 Abraham. *et al.* (2018)

2  
3 impediments will be imperative to improved implementation of risk-reducing practices (including  
4 but not limited to medical assessment) that ultimately safeguard the long-term brain health of  
5 football athletes. Fourth, there may be a misperception and/or lack of awareness of SRC risk  
6 among football athletes, coaches, franchises, and related organizations, which could limit  
7 enforcement. Advances in the prevention and proper management of SRC require that sporting  
8 associations attend to concussion with the same diligence typically applied to doping and other  
9 serious breaches. Reaching out directly to stakeholders, including FIFA, national team coaches  
10 and their staff physicians, as well as the intended beneficiaries of this work (athletes) will be  
11 imperative to widespread knowledge dissemination and uptake efforts.  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21  
22

### 23 ***Limitations***

24  
25  
26 Video analysis provides limited information on the details of medical evaluation for PCEs and thus  
27 cannot always provide information on whether or not an appropriate medical decision is made. In  
28 some PCEs, full description of variables may be limited by the camera angles available for the  
29 video clip. Some game events may be misidentified as PCEs if players simulate or feign injury.  
30  
31 Finally, it is possible, though unlikely, that some PCEs do not result in stoppage of play and the  
32 athlete continues to play resulting in a PCE being erroneously excluded from analysis.  
33  
34  
35  
36  
37  
38  
39  
40  
41

### 42 ***Future directions***

43  
44  
45 Overall, our data indicate that PCEs occur relatively frequently (at least one per game) in elite  
46 level football matches, but are rarely assessed in a manner concordant with the 2012 and 2016  
47 CISG recommendations. Major international tournaments such as the FIFA World cup and UEFA  
48 European Championships feature elite-level athletes and are among the most widely broadcasted  
49 and followed sporting events on the planet<sup>22</sup>. The norms that persist on such a stage are likely to  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

1 Abraham. *et al.* (2018)

2  
3 influence attitudes towards concussion on a global scale. Future major international tournaments  
4 offer the opportunity to set a new precedent for excellence in enforcement of concussion  
5 assessment, and initiate beneficial improvements in concussion awareness and the implementation  
6 of proper assessment protocols in the sport.  
7  
8  
9  
10  
11  
12

### 13 **Funding Statement**

14 This work is supported by the Canadian Institutes of Health Research Strategic Team Grant in  
15 Applied Injury Research #TIR-103946 and the Ontario Neurotrauma Foundation.  
16  
17  
18  
19  
20  
21  
22

### 23 **Author Contributorship**

24 Research concept and design by M.D.C; data collection and analysis by K.J.A, J.C., A.S., C.T.,  
25 and A.Z.; manuscript writing by K.J.A, J.C., and M.D.C. Guarantor: K.J.A. Dr. Michael Cusimano  
26 is a non-paid volunteer on the expert advisory committee and the concussion committee of  
27 Parachute Canada a not-for-profit injury prevention organization. He is a neurosurgeon at St.  
28 Michael's hospital who wishes he would never see one more brain injured person and that we can  
29 prevent every brain injury in the future.  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40

### 41 **Data Sharing Statement**

42 We are happy to share data published in this study but most if not all data is already included in  
43 the manuscript and/or in the public domain.  
44  
45  
46  
47  
48  
49

### 50 **Competing Interest**

51 None declared.  
52  
53  
54  
55  
56  
57  
58  
59  
60

1  
2  
3  
4  
5  
6  
7  
8  
9  
Abraham. *et al.* (2018)

## 10 REFERENCES

- 11 1. Mannix R, Meehan WP, Pascual-Leone A. OPINION Sports-related concussions - media,  
12 science and policy. *Nat Rev Neurol* 2016;12(8):486-90. doi:  
13 10.1038/nrneurol.2016.99
- 14 2. Coronado VG, Haileyesus T, Cheng TA, et al. Trends in Sports- and Recreation-Related  
15 Traumatic Brain Injuries Treated in US Emergency Departments: The National  
16 Electronic Injury Surveillance System-All Injury Program (NEISS-AIP) 2001-2012. *J*  
17 *Head Trauma Rehab* 2015;30(3):185-97. doi: 10.1097/Htr.000000000000156
- 18 3. Langlois JA, Rutland-Brown W, Wald MM. The epidemiology and impact of traumatic  
19 brain injury - A brief overview. *J Head Trauma Rehab* 2006;21(5):375-78. doi: Doi  
20 10.1097/00001199-200609000-00001
- 21 4. Zemek R, Barrowman N, Freedman SB. Clinical risk score for persistent postconcussion  
22 symptoms among children with acute concussion in the ED (vol 315, pg 1014, 2016).  
23 *Jama-J Am Med Assoc* 2016;315(23):2624-24. doi: 10.1001/jama.2016.7407
- 24 5. Guskiewicz KM, Marshall SW, Bailes J, et al. Recurrent concussion and risk of depression  
25 in retired professional football players. *Med Sci Sport Exer* 2007;39(6):903-09. doi:  
26 10.1249/mss.0b013e3180383da5
- 27 6. Covassin T, Swanik CB, Sachs ML. Sex differences and the incidence of concussions  
28 among collegiate athletes. *J Athl Training* 2003;38(3):238-44.
- 29 7. Agel J, Evans TA, Dick R, et al. Descriptive epidemiology of collegiate men's soccer  
30 injuries: National Collegiate Athletic Association Injury Surveillance System, 1988-  
31 1989 through 2002-2003. *J Athl Train* 2007;42(2):270-7. [published Online First:  
32 2007/08/22]
- 33 8. Kunz M. 265 million playing football. *FIFA magazine*, 2007:10-15.
- 34 9. Broglio SP, Vagnozzi R, Sabin M, et al. Concussion occurrence and knowledge in Italian  
35 football (soccer). *J Sport Sci Med* 2010;9(3):418-30.
- 36 10. McCrory P, Meeuwisse WH, Aubry M, et al. Consensus statement on concussion in sport:  
37 the 4th International Conference on Concussion in Sport held in Zurich, November  
38 2012. *Brit J Sport Med* 2013;47(5):250-58. doi: 10.1136/bjsports-2013-092313
- 39 11. McCrory P, Meeuwisse WH, Dvorak J, et al. 5th International Conference on Concussion  
40 in Sport (Berlin). *Brit J Sport Med* 2017;51(11):837-37. doi: 10.1136/bjsports-2017-  
41 097878
- 42 12. Cusimano MD, Casey J, Jing RW, et al. Assessment of Head Collision Events During the  
43 2014 FIFA World Cup Tournament. *Jama-J Am Med Assoc* 2017;317(24):2548-49.  
44 doi: 10.1001/jama.2017.6204
- 45 13. Makdissi M, Davis G. Using video analysis for concussion surveillance in Australian  
46 football. *J Sci Med Sport* 2016;19(12):958-63. doi: 10.1016/j.jsams.2016.02.014  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

1 Abraham. *et al.* (2018)

- 2
- 3 14. McCrea M, Guskiewicz KM, Marshall SW, et al. Acute effects and recovery time following
- 4 concussion in collegiate football players - The NCAA Concussion Study. *Jama-J Am*
- 5 *Med Assoc* 2003;290(19):2556-63. doi: DOI 10.1001/jama.290.19.2556
- 6
- 7 15. Lawrence DW, Hutchison MG, Cusimano MD, et al. Interrater Agreement of an
- 8 Observational Tool to Code Knockouts and Technical Knockouts in Mixed Martial
- 9 Arts. *Clin J Sport Med* 2014;24(5):397-402. doi: Doi
- 10 10.1097/Jsm.0000000000000047
- 11
- 12 16. Makdissi M, Davis G. The reliability and validity of video analysis for the assessment of
- 13 the clinical signs of concussion in Australian football. *J Sci Med Sport*
- 14 2016;19(10):859-63. doi: 10.1016/j.jsams.2016.02.015
- 15
- 16 17. Jordan BD. The clinical spectrum of sport-related traumatic brain injury. *Nat Rev Neurol*
- 17 2013;9(4):222-30. doi: 10.1038/nrneurol.2013.33
- 18
- 19 18. Group IS. UEFA Injury Study Report, 2016:15.
- 20
- 21 19. Sport concussion assessment tool - 5th edition. *Br J Sports Med* 2017;51(11):851-58.
- 22 doi: 10.1136/bjsports-2017-097506SCAT5 [published Online First: 2017/04/28]
- 23
- 24 20. Cusimano MD, Topolovec-Vranic J, Zhang S, et al. Factors Influencing the
- 25 Underreporting of Concussion in Sports: A Qualitative Study of Minor Hockey
- 26 Participants. *Clin J Sport Med* 2017;27(4):375-80. doi: Doi
- 27 10.1097/Jsm.0000000000000372
- 28
- 29 21. Cusimano MD, Cho N, Amin K, et al. Mechanisms of Team-Sport-Related Brain Injuries
- 30 in Children 5 to 19 Years Old: Opportunities for Prevention. *Plos One* 2013;8(3) doi:
- 31 ARTN e58868
- 32 10.1371/journal.pone.0058868
- 33
- 34 22. FIFA. 2014 FIFA World Cup breaks online streaming records, 2014.
- 35
- 36
- 37
- 38
- 39
- 40
- 41
- 42
- 43
- 44
- 45
- 46
- 47
- 48
- 49
- 50
- 51
- 52
- 53
- 54
- 55
- 56
- 57
- 58
- 59
- 60

**STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies***

Section/Topic	Item #	Recommendation	Reported on page #
<b>Title and abstract</b>	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	3
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	3
<b>Introduction</b>			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	5,6
Objectives	3	State specific objectives, including any prespecified hypotheses	6
<b>Methods</b>			
Study design	4	Present key elements of study design early in the paper	6,7
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6,7
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants	6,7
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6,7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6,7
Bias	9	Describe any efforts to address potential sources of bias	7
Study size	10	Explain how the study size was arrived at	7
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	7
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	7
		(b) Describe any methods used to examine subgroups and interactions	7
		(c) Explain how missing data were addressed	7
		(d) If applicable, describe analytical methods taking account of sampling strategy	7
		(e) Describe any sensitivity analyses	N/A
<b>Results</b>			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	7,8,9
		(b) Give reasons for non-participation at each stage	N/A
		(c) Consider use of a flow diagram	N/A
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	7,8,9
		(b) Indicate number of participants with missing data for each variable of interest	0
Outcome data	15*	Report numbers of outcome events or summary measures	7,8,9
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	N/A
		(b) Report category boundaries when continuous variables were categorized	N/A
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	N/A
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	7,8,9
<b>Discussion</b>			
Key results	18	Summarise key results with reference to study objectives	10,11,12
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	12
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	11,12
Generalisability	21	Discuss the generalisability (external validity) of the study results	10,11,12
<b>Other information</b>			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	13

\*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

**Note:** An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at [www.strobe-statement.org](http://www.strobe-statement.org).

# BMJ Open

## Medical Assessment of Potential Concussion in Elite Football: A Video Analysis of the 2016 UEFA European Championship

Journal:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2018-024607.R2
Article Type:	Research
Date Submitted by the Author:	23-Mar-2019
Complete List of Authors:	Abraham, Karan; St. Michael's Hospital, Neurosurgery Casey, Julia; St. Michael's Hospital, Neurosurgery Subotic, Arsenije; St. Michael's Hospital, Neurosurgery Christopher, Tarzi; St. Michael's Hospital, Zhu, Alice; St. Michael's Hospital, Neurosurgery Cusimano, Michael; St. Michael's Hospital, Neurosurgery; University of Toronto Dalla Lana School of Public Health, Public Health
<b>Primary Subject Heading</b>:	Sports and exercise medicine
Secondary Subject Heading:	Public health
Keywords:	Concussion, Head injury, Traumatic brain injury, Football, Sport, Injury prevention

SCHOLARONE™  
Manuscripts



1 Abraham. *et al.* (2018)  
2  
3  
4  
5  
6

7 **Medical Assessment of Potential Concussion in Elite Football: A Video Analysis of the 2016**  
8 **UEFA European Championship**  
9

10 Karan J. Abraham MSc<sup>1</sup>, Julia Casey BSc<sup>1</sup>, Arsenije Subotic BSc<sup>1</sup>, Christopher Tarzi<sup>1</sup>, Alice Zhu  
11 BSc<sup>1</sup>, and Michael D. Cusimano MD PhD<sup>1,2\*</sup>  
12  
13

14  
15  
16 <sup>1</sup>*Injury Prevention Research Office, Division of Neurosurgery, St. Michael's Hospital,*  
17 *Toronto, Ontario, M5B 1W8, Canada*

18 <sup>2</sup>*Department of Surgery, University of Toronto, Toronto, Ontario, M5G 1M1, Canada*  
19  
20  
21  
22  
23  
24  
25

26 \*Lead contact: Dr. Michael D. Cusimano, MD, MHPE, FRCSC, PhD, FACS  
27 Division of Neurosurgery, St. Michael's Hospital  
28 Professor of Neurosurgery, Education and Public Health  
29 University of Toronto  
30  
31

32 **Postal/Mailing address:**

33 30 Bond Street  
34 Toronto, ON, Canada  
35 M5B 1W8  
36  
37

38 **Phone:**

39 (416) 864 6048 (Clinical Office)  
40 (418) 864 5312 (Research Office)  
41  
42

43 **Email:** [injuryprevention@smh.ca](mailto:injuryprevention@smh.ca)  
44  
45  
46  
47

48 **Word count: 2668**  
49  
50

51 **KEYWORDS**

52 Concussion, Head injury, Traumatic brain injury, Soccer, Football, Sport, Injury prevention, FIFA;  
53 Fédération Internationale de Football Association, UEFA; Union of European Football  
54 Associations.  
55  
56  
57  
58  
59  
60

1 Abraham. *et al.* (2018)

2  
3  
4 **ABSTRACT**

5  
6 **Objective:** The objective is to determine if suspected concussions in elite football are  
7 medically assessed according to the International Conferences on Concussion in Sport  
8  
9  
10  
11  
12  
13  
14 consensus statement recommendations.

15 **Setting:** Men's Union of European Football Association (UEFA) Football Championship

16  
17 **Participants:** All professional football players in the UEFA 2016 Championship  
18  
19  
20  
21  
22  
23  
24  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60  
Tournament.

**Design:** Observational study.

**Outcome Measures:** Potential concussive events (PCEs) were defined as direct head  
collision incidents resulting in the athlete being unable to immediately resume play  
following impact. PCEs identified and description of PCE assessment and outcome were  
accomplished through direct standardized observation of video footage by trained  
observers in 51 games played in the Men's UEFA European Championship (10 June – 10  
July 2016).

**Results:** Sixty-nine total PCEs (1.35 per match) were identified in 51 games played during  
the 2016 Men's UEFA European Championship. Forty-eight PCEs (69.6%) resulted in two  
observable signs of concussion, 13 (18.8%) resulted in three signs, and 1 (1.4%) resulted in four  
signs in the injured athletes. Nineteen (27.5%) PCEs were medically assessed by sideline  
healthcare personnel while 50 (72.5%) were not. Of the 50 PCEs that were not medically assessed,  
44 (88%) PCEs resulted in two or more signs of concussion among injured athletes. Of the 19

1 Abraham. *et al.* (2018)

2  
3 medically assessed PCEs, 8 resulted in 3 signs of concussion, and 1 resulted in 4 signs; all  
4  
5 assessments concluded in same-game return for the injured athletes.  
6

7  
8 **Conclusions:** PCEs were frequent events in the 2016 UEFA Euro championship, but were rarely  
9  
10 assessed concordant with the International Conferences on Concussion in Sport consensus  
11  
12 statement recommendations. There is an imperative need to improve the assessment and  
13  
14 management of players suspected of concussion in elite football.  
15  
16  
17

18  
19  
20  
21 **Trial Registration:** Not applicable  
22

### 23 24 25 26 **Strengths and limitations of this study** 27

- 28  
29 • In this study, we sought to determine if suspected concussions in elite football are  
30  
31 medically assessed according to the International Conferences on Concussion in Sport  
32  
33 consensus statement recommendations to improve concussion awareness and safety  
34  
35 measures in football-dominant nations.  
36  
37
- 38  
39 • This study shows that there is an urgent need to improve the assessment and  
40  
41 management of players suspected of concussion in the realm of elite football  
42  
43
- 44  
45 • The major weakness of this study is that video analysis provides limited information  
46  
47 on the details of medical evaluation for PCEs and thus cannot always provide  
48  
49 information on whether or not an appropriate medical decision is made.  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

Abraham. *et al.* (2018)

## INTRODUCTION

Sport-related concussion (SRC) is a frequent type of mild traumatic brain injury (mTBI) that has emerged as a major public health concern. In children, adolescents, and young adults, sports participation is recognized as one of the leading causes of concussion<sup>1</sup>. The United States (US) national Centers for Disease Control and Prevention (CDC) reported that sports- and recreation-related TBI was responsible for 3.4 million visits to Emergency Departments between 2001-2012; approximately 70% of reported cases involved persons 19 or younger<sup>2</sup>. Accounting for unreported, unrecognized, and untreated injuries, the total number of sports-related TBI per year was estimated to be as high as 1.8-3.8 million in the US, the majority of them being mTBI<sup>3</sup>. Although most individuals experiencing mTBI are likely to recover within 1-3 weeks, a sizeable minority (up to 30% in some studies) may suffer from persistent concussion symptoms (i.e. post-concussion syndrome)<sup>4 5</sup>. Furthermore, 15-25% of mTBI cases are associated with adverse long-term physical, cognitive, and emotional sequelae<sup>1</sup>. The high incidence and economic costs of SRC, preferential risk among vulnerable youth, and potential for adverse long-term consequences underscore the need to better prevent, identify, and manage such injuries.

1 Abraham. *et al.* (2018)

2  
3 Athletes involved in football, also called ‘soccer’ in North America, consistently  
4 experience among the highest rates of concussion<sup>6 7</sup>. Football is the world’s most popular and  
5 fastest growing sport; an estimated 270 million people play the sport in various professional, semi-  
6 professional, and/or organized formal recreational capacities<sup>8</sup>. By virtue of its widespread  
7 popularity, football’s cumulative contribution to total SRC is likely to significantly overshadow  
8 other sports. Moreover, concussion awareness and safety measures remain relatively  
9 underdeveloped in many football-dominant nations<sup>9</sup>. Such conditions are conducive to large  
10 numbers of undiagnosed concussions, inappropriate management, and increased risk of potentially  
11 severe neurological consequences among vulnerable and/or improperly rehabilitated football  
12 athletes.  
13  
14  
15  
16  
17  
18  
19  
20  
21  
22  
23  
24  
25

26 The proper assessment of suspected concussions immediately following injury is an  
27 important practice needed for early diagnosis and safe rehabilitation of athletes with brain injuries.  
28 Consensus statement recommendations published by 4<sup>th</sup> and 5<sup>th</sup> International Conferences on  
29 Concussion in Sport in 2012 and 2016, respectively, provide clear recommendations for  
30 assessment of suspected concussions during a competitive event<sup>10 11</sup>. The Concussion in Sport  
31 Group (CISG) 2012 and 2016 consensus statements assert that when an athlete shows ANY  
32 features of a concussion, the athlete should be 1) evaluated by a physician or another licensed  
33 healthcare provider onsite, 2) assessed using SCAT3/SCAT5 or other sideline concussion  
34 assessment tools, and 3) prevented from return-to-play in the event of a positive diagnosis<sup>10</sup>  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46

47 <sup>11</sup>These statements were previously accepted and endorsed by football’s major international  
48 governing body the Fédération Internationale de Football Association (FIFA). However, our  
49 previous analysis of 2014 Men’s FIFA world cup (WC) found that the majority of PCEs (63%)  
50 were not medically assessed, indicating a lack of congruence between recommendations and  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

1 Abraham. *et al.* (2018)

2  
3 current practices at the elite level<sup>12</sup>. In this study, we used video analysis to characterize PCEs and  
4 their assessment in the 2016 Men's UEFA European Championship. Additionally, we compared  
5 our findings against our previous analysis of the 2014 FIFA WC to determine if compliance with  
6 CISC recommendations had improved over the two-year gap between tournaments.  
7  
8  
9  
10  
11  
12

## 13 **METHODS**

14  
15 Video analysis has emerged as a reliable and valid tool to assess concussion in a variety of sports  
16 including American football, mixed martial arts, ice hockey, and lacrosse <sup>12-15</sup>. Furthermore,  
17 information content in digital videos can be analysed systematically to yield key insights into  
18 situational factors and injury-prone patterns of play leading to an injury.  
19  
20  
21  
22  
23  
24

### 25 ***Coding of Events***

26  
27 PCEs were defined as any event in which one or more athletes experienced a head impact injury  
28 (through direct contact with another athlete, ball, or object in the environment) and were unable to  
29 immediately resume play following impact. Athletes involved in PCEs were observed for 6  
30 established observable physical signs of concussion: slow to get up (defined as a duration of 5 or  
31 more seconds following impact), clutching of the head, disorientation, loss of consciousness,  
32 seizure-like behavior, and signs of obvious disequilibrium<sup>12 16</sup>. The term PCE is not used  
33 synonymously with SRC. Instead, it captures the broad range of in-game scenarios involving head  
34 collisions; recognizing that the higher the number of concussion signs associated with a PCE, the  
35 greater the index for suspicion that it may represent a *bona fide* concussion. Information pertaining  
36 to the assessment of athletes sustaining a PCE, including the personnel assessing the players  
37 (medical personnel, other players, the referee, no one) was recorded. Trained observers also  
38 collected information on PCE outcomes: return-to-play (RTP) after assessment on pitch, RTP after  
39 assessment on sidelines, removed for remainder of match, removed from tournament.  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

1 Abraham. *et al.* (2018)

2  
3 ***Training of Reviewers***

4  
5 Four observers were trained using video footage of 4 Premier League football matches in order to  
6 correctly identify PCEs and collect information pertaining to several variables on a standardized  
7 form used in a previous study on concussion<sup>15</sup>. The standardized data collection form was used to  
8 provide a person viewing digital video images with a consistent way of coding and accounting for  
9 the majority of circumstances and mechanisms leading to concussion. The standardized data form  
10 was adapted from a validated form used in a prior study on concussion<sup>15</sup>. The form was  
11 accompanied by a detailed data dictionary outlining the codes associated with each variable.  
12  
13  
14  
15  
16  
17  
18  
19  
20

21 ***Video Analysis***

22  
23 The observers analysed footage of the 51 games that took place during the 2016 UEFA European  
24 Championship from 10 June to 10 July. Observers independently reviewed the video footage to  
25 complete the standardized form. Three observers watched all 51 games of Men's UEFA Euro 2016  
26 tournament, identified PCEs, and collected data on aforementioned variables. All variables yielded  
27 a Cohen's kappa value of 0.90 or greater between all reviewers. Following this analysis,  
28 discrepancies in data were resolved through consultation with a fourth independent observer.  
29  
30  
31  
32  
33  
34  
35  
36  
37

38 ***Statistical Analysis***

39  
40 Descriptive statistics were reported as counts or frequencies and their associated percentages. All  
41 statistical analysis was done in STATA 13 (StataCorp, Texas, USA).  
42  
43

44 **Patient and Public Involvement:**

45  
46 Patients and or public were not involved.  
47  
48  
49  
50

51 **RESULTS**

52 ***PCE incidence at Euro 2016***

Abraham. *et al.* (2018)

Sixty-nine PCEs involving 61 different athletes were identified over the course of 51 games played during the 2016 UEFA European Championship (1.35 per match). Seven incidents involved direct head collisions between 2 athletes, which were scored as individual PCEs for each athlete. Of the 61 athletes who experienced a PCE, 4 (6.6%) sustained 2 separate PCEs, and 2 (3.3%) sustained 3 separate PCEs over the course of the tournament. Of the 69 PCEs recorded, 2 (2.9%) resulted in no observable physical signs of concussion, 5 (7.2%) resulted in 1 sign, 48 (69.6%) resulted in 2 signs, 13 (18.8%) resulted in 3 signs, and 1 resulted in 4 signs (1.4%) (table 1).

Table 1 PCE Assessment and Outcome at Euro 2016

No. of concussion signs	No. of PCE (% total)	PCE assessment (n)		RTP Outcome when medically assessed (n)	
		No assessment	Medical assessment	Same-game RTP	Removed from game or tournament
0	2 (2.9)	1	1	1	0
1	5 (7.2)	5	0	0	0
2	48 (69.6)	39	9	9	0
3	13 (18.8)	5	8	8	0
4	1 (1.4)	0	1	1	0
Total (%)	69 (100)	50 (72.5)	19 (27.5)	19 (100)	0 (0)

### ***Medical assessment of PCEs at Euro 2016***

As illustrated in table 1, of the 69 PCE incidents, 19 (27.5%) were medically assessed by sideline healthcare personnel while 50 (72.4%) were not. Of the 50 PCEs that were not medically assessed, 9 (18%) received some attention from the referee and/or another player, while 41 (82%) did not; all athletes involved in these incidents remained on the field following the incident. Among the 50 PCE incidents that did not receive medical assessment, 1 (2%) showed no physical signs of concussion, 5 (10%) showed one sign, 39 (78%) showed two signs, and 5 (6.4%) showed three



Abraham. *et al.* (2018)

signs of concussions. Therefore, 44 out of the 50 (88%) non-assessed PCEs, involved athletes who exhibited 2 or more signs of concussion.

Among the 19 PCE incidents that were medically assessed by healthcare professionals, 1 (5.3%) showed no physical signs of concussion, 9 (47.3%) showed two signs, 8 (42.1%) showed three signs, and 1 (5.3%) showed 4. All 19 (100%) medically assessed PCEs concluded with the athlete returning to play following a brief assessment; no athletes were removed from the game or for the remainder of the tournament.

### ***Medical assessment of concussion: FIFA WC 2014 versus UEFA Euros 2016***

Table 2 compares PCE assessment and outcome in Euros 2016 versus our data from our previously published PCE analysis of WC 2014<sup>12</sup>. PCE incidence was higher in the Euros (1.35 per match) compared to FIFA WC 2014 (1.13 per match). In Euro 2016, 89.8% of PCEs involved athletes with 2 or more signs of concussion compared to 82.7% for WC 2014. Medical assessment of PCE at Euro 2016 (27.5% assessed, 72.5% not assessed) was worse in relation to FIFA WC 2014 (37% assessed, 63% not assessed). In WC 2014, of the 29 PCEs that were medically assessed and involved athletes with 2 or more signs of concussion, 27 (93.1%) returned to the same game, while 2 (6.9%) were removed from the game and/or tournament. In Euro 2016, of the 18 medically-assessed PCEs involving athletes with 2 or more signs of concussion, 18 (100%) resulted in same-game RTP.

Table 2 Comparison of PCE assessment and outcome: UEFA Euro 2016 versus FIFA World

No. of PCE (% of total)	PCEs medically assessed (n)	PCEs NOT medically assessed (n)	Medically assessed PCEs with same-game RTP (n)
----------------------------	--------------------------------	---------------------------------------	---

Abraham. *et al.* (2018)

No. of concussion signs	WC 2014	Euro 2016	WC 2014	Euro 2016	WC 2014	Euro 2016	WC 2014	Euro 2016
0	3 (4)	2 (2.9)	0	1	3	1	0	1
1	11 (14)	5 (7.2)	1	0	10	5	1	0
2 or more	67 (82.7)	62 (89.8)	29	18	38	44	27	18
Total (%)	81 (100)	69 (100)	30 (37)	19 (27.5)	51 (63)	50 (72.5)	28 (93)	19 (100)

## DISCUSSION

### *Concussion in football – an important public health concern*

Concussion is an inherent risk associated with sports participation and SRC is now recognized as a major public health concern<sup>1 17</sup>. Yet, participation in sports is a meaningful part of millions of people's lives, and provides numerous physical and emotional health benefits. Maximizing these benefits, while simultaneously minimizing the risks of adverse events such as concussion and its long-term sequelae represents an important public health imperative. Athletes involved in contact and/or collision sports are at higher risk for SRC. Football is a sport with an under-appreciated high rate and burden of concussion<sup>1 6 7</sup>. By virtue of football's global dimension and contribution to worldwide sport-related mTBI, sustained efforts at improving concussion awareness and assessment at all levels of the sport will have a substantial impact on reducing disability from and/or risk of injury.

### *Inadequate implementation of consensus statement recommendations*

Medical assessment of a PCE is an important practice needed for early concussion diagnosis, proper management, and safe return to play for injured athletes. Successful implementation of medical assessment protocols in sport is imperative to the larger effort to reduce SRC morbidity

1 Abraham. *et al.* (2018)

2  
3 and its potentially serious long-term consequences. To aid this effort, clear protocols for on-field  
4 assessment of an athlete with a suspected concussion were published and reiterated in consensus  
5 statements following the 4<sup>th</sup> and 5<sup>th</sup> International Conferences on Concussion in Sport held in 2012  
6 and 2016, respectively<sup>10 11</sup>. These endeavors have been supported and endorsed by football's major  
7 international governing body FIFA<sup>10 11</sup>. The CISG recommendations assert that when an athlete  
8 shows ANY features of a concussion, the athlete should be 1) evaluated by a physician or another  
9 licensed healthcare provider onsite, 2) assessed using SCAT3/SCAT5 or other sideline concussion  
10 assessment tools, and 3) prevented from return-to-play in the event of a positive diagnosis<sup>10 11</sup>. In  
11 a previous study on the Men's 2014 FIFA WC, we found that 63% of elite-level football athletes  
12 who sustained PCEs were not medically assessed, thereby underscoring the need for better  
13 implementation of concussion assessment protocols in elite football. Our current analysis of the  
14 2016 UEFA European Championship reinforces this notion since only 27.5% of PCEs were  
15 medically assessed while 72.5% were not. While many PCEs are unlikely to result in *bona fide*  
16 concussions, it is clear that CISG recommendations apply to PCEs in which the index of suspicion  
17 for concussion is high (e.g. PCEs with multiple signs of concussion). Notably, 44 out of the 50  
18 (88%) non-assessed PCEs in the 2016 UEFA European Championship involved athletes who  
19 exhibited 2 or more signs of concussion. A proper assessment for concussion is warranted in such  
20 situations and a failure to assess raises legitimate concerns that some concussions may be missed.  
21 Furthermore, all PCEs that were medically assessed culminated in same game RTP despite the  
22 majority of these incidents resulting in 2 or more physical signs among injured athletes. Notably,  
23 the only athlete who experienced 4 physical signs of concussion was allowed to return to game  
24 following assessment, while another athlete who suffered a PCE incident that resulted in a head  
25 laceration, heavy bleeding, and 2 physical signs of concussion was allowed to return to the game  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59

1 Abraham. *et al.* (2018)

2  
3 and sustained a second PCE shortly after returning. Thus, our data also indicates that the quality  
4 and accuracy of assessment received by athletes suffering PCEs is in need of careful scrutiny.  
5  
6 Injury reporting and analysis by UEFA and FIFA should include more detail on PCEs and PCE  
7  
8 evaluation in order to identify opportunities to improve athlete safety<sup>18</sup>. Overall, our data highlights  
9  
10 an obvious need to improve concussion assessment in the realm of elite football, and suggest that  
11  
12 significant and persistent knowledge uptake and/or attitudinal barriers to implementation may  
13  
14 exist.  
15  
16  
17

### 18 ***Barriers to Implementation***

19  
20 Several factors may contribute to weak implementation of SRC assessment protocols in elite  
21  
22 football. First, the high stakes of competitive sport and rules of the games may pressure team  
23  
24 medical staff to ignore PCEs, or inappropriately shorten examination and encourage RTP,  
25  
26 particularly in situations when the team needs a result. In a widely-publicized and recent example  
27  
28 illustrating the pressures that team doctors may experience, a long-serving female team doctor  
29  
30 from Chelsea Football Club was publically criticized, demoted, and eventually forced out of the  
31  
32 club for fulfilling her medical obligation to assess an injured player in stoppage time of a Premier  
33  
34 League game. The current rules of the game, including running time and limited substitutions,  
35  
36 further discourage pulling player for medical assessment. For the recent 2018 WC competition,  
37  
38 FIFA implemented a new protocol for head injuries and concussions. This includes giving the  
39  
40 referee the ability to stop the match for 3 minutes if a head injury is suspected for an on-pitch  
41  
42 assessment. 3 minutes is not sufficient time to complete a SCAT3/5. The SCAT5 explicitly states  
43  
44 on the form “The SCAT5 cannot be performed correctly in less than 10 minutes”<sup>19</sup>. Second, factors  
45  
46 that normally contribute to under-reporting in other sports may be relevant as implementation  
47  
48 barriers in football<sup>20</sup>. For instance, a culture of toughness and loyalty to the team may either openly  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59

1 Abraham. *et al.* (2018)

2  
3 or subtly encourage athletes to downplay concussion or inappropriately accelerate RTP following  
4 injury<sup>20 21</sup>. Furthermore, athletes are influenced<sup>20</sup> by a strong desire to win, and fear of letting their  
5 teams or nations down, which may also encourage underreporting of SRC symptoms. Third, our  
6 data suggest that significant gaps in knowledge translation exist, and highlight the need for  
7 improved knowledge dissemination and uptake at multiple levels including international football  
8 associations such as FIFA and UEFA, individual franchises, as well as associated staff, coaches,  
9 athletes and the wider spectrum of stakeholders in the sport. Research identifying barriers to  
10 implementation such as knowledge translation bottlenecks, followed by strategic targeting of such  
11 impediments will be imperative to improved implementation of risk-reducing practices (including  
12 but not limited to medical assessment) that ultimately safeguard the long-term brain health of  
13 football athletes. Fourth, there may be a misperception and/or lack of awareness of SRC risk  
14 among football athletes, coaches, franchises, and related organizations, which could limit  
15 enforcement. Advances in the prevention and proper management of SRC require that sporting  
16 associations attend to concussion with the same diligence typically applied to doping and other  
17 serious breaches. Reaching out directly to stakeholders, including FIFA, national team coaches  
18 and their staff physicians, as well as the intended beneficiaries of this work (athletes) will be  
19 imperative to widespread knowledge dissemination and uptake efforts.  
20  
21  
22  
23  
24  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41

42 In order to increase effectiveness of current football concussion protocols, it would be  
43 beneficial for football governing bodies to examine how other professional sports deal with  
44 concussions. For example, in NFL American football, the latest concussion protocol published in  
45 2018 stipulates that each team during game day must be assigned a Sideline Unaffiliated  
46 Neurotrauma Consultant (“Sideline UNC”), a physician that is impartial and independent from any  
47 Club.<sup>1</sup> Additionally, the protocol also stipulates that a video Unaffiliated Neurotrauma Consultant  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

1 Abraham. *et al.* (2018)

2  
3 be present in a stadium booth with access to multiple views of video<sup>22</sup>. Having impartial evaluators  
4  
5 would help significantly in curtailing issues such as doctors from home teams facing pressure to  
6  
7 return players to the game and examining the nature of potential concussive impacts. Providing  
8  
9 broadcast video to side-line medical personnel in real time is also a recommendation by a recently  
10  
11 published study that examined current practices related to video review of concussion in  
12  
13 professional sports internationally<sup>23</sup>. Football authorities should consider implementing these rules  
14  
15 which would help aid in the screening for concussion and treat it as soon as possible.  
16  
17

### 18 ***Limitations***

19  
20 Video analysis provides limited information on the details of medical evaluation for PCEs and thus  
21  
22 cannot always provide information on whether or not an appropriate medical decision is made. In  
23  
24 some PCEs, full description of variables may be limited by the camera angles available for the  
25  
26 video clip. Some game events may be misidentified as PCEs if players simulate or feign injury.  
27  
28 Finally, it is possible, though unlikely, that some PCEs do not result in stoppage of play and the  
29  
30 athlete continues to play resulting in a PCE being erroneously excluded from analysis.  
31  
32  
33  
34  
35  
36  
37

### 38 ***Future directions***

39  
40 Overall, our data indicate that PCEs occur relatively frequently (at least one per game) in elite  
41  
42 level football matches, but are rarely assessed in a manner concordant with the 2012 and 2016  
43  
44 CISG recommendations. Major international tournaments such as the FIFA World cup and UEFA  
45  
46 European Championships feature elite-level athletes and are among the most widely broadcasted  
47  
48 and followed sporting events on the planet<sup>24</sup>. The norms that persist on such a stage are likely to  
49  
50 influence attitudes towards concussion on a global scale. Future major international tournaments  
51  
52 offer the opportunity to set a new precedent for excellence in enforcement of concussion  
53  
54  
55  
56  
57  
58  
59

1 Abraham. *et al.* (2018)

2  
3 assessment, and initiate beneficial improvements in concussion awareness and the implementation  
4  
5 of proper assessment protocols in the sport.  
6  
7

### 8 9 **Funding Statement**

10  
11 This work is supported by the Canadian Institutes of Health Research Strategic Team Grant in  
12  
13 Applied Injury Research #TIR-103946 and the Ontario Neurotrauma Foundation.  
14  
15

### 16 17 18 **Author Contributorship**

19  
20 Research concept and design by M.D.C; data collection and analysis by K.J.A, J.C., A.S., C.T.,  
21  
22 and A.Z.; manuscript writing by K.J.A, J.C., and M.D.C. Guarantor: K.J.A. Dr. Michael Cusimano  
23  
24 is a non-paid volunteer on the expert advisory committee and the concussion committee of  
25  
26 Parachute Canada a not-for-profit injury prevention organization. He is a neurosurgeon at St.  
27  
28 Michael's hospital who wishes he would never see one more brain injured person and that we can  
29  
30 prevent every brain injury in the future.  
31  
32  
33  
34  
35

### 36 37 **Data Sharing Statement**

38  
39 We are happy to share data published in this study but most if not all data is already included in  
40  
41 the manuscript and/or in the public domain.  
42  
43  
44

### 45 46 **Competing Interest**

47  
48 None declared.  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

1  
2  
3  
4  
5  
6  
7  
8  
9  
10  
11  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21  
22  
23  
24  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

Abraham. *et al.* (2018)

## REFERENCES

1. Mannix R, Meehan WP, Pascual-Leone A. OPINION Sports-related concussions - media, science and policy. *Nat Rev Neurol* 2016;12(8):486-90. doi: 10.1038/nrneurol.2016.99
2. Coronado VG, Haileyesus T, Cheng TA, et al. Trends in Sports- and Recreation-Related Traumatic Brain Injuries Treated in US Emergency Departments: The National Electronic Injury Surveillance System-All Injury Program (NEISS-AIP) 2001-2012. *J Head Trauma Rehab* 2015;30(3):185-97. doi: 10.1097/Htr.000000000000156
3. Langlois JA, Rutland-Brown W, Wald MM. The epidemiology and impact of traumatic brain injury - A brief overview. *J Head Trauma Rehab* 2006;21(5):375-78. doi: 10.1097/00001199-200609000-00001
4. Zemek R, Barrowman N, Freedman SB. Clinical risk score for persistent postconcussion symptoms among children with acute concussion in the ED (vol 315, pg 1014, 2016). *Jama-J Am Med Assoc* 2016;315(23):2624-24. doi: 10.1001/jama.2016.7407
5. Guskiewicz KM, Marshall SW, Bailes J, et al. Recurrent concussion and risk of depression in retired professional football players. *Med Sci Sport Exer* 2007;39(6):903-09. doi: 10.1249/mss.0b013e3180383da5
6. Covassin T, Swanik CB, Sachs ML. Sex differences and the incidence of concussions among collegiate athletes. *J Athl Training* 2003;38(3):238-44.
7. Agel J, Evans TA, Dick R, et al. Descriptive epidemiology of collegiate men's soccer injuries: National Collegiate Athletic Association Injury Surveillance System, 1988-1989 through 2002-2003. *J Athl Train* 2007;42(2):270-7. [published Online First: 2007/08/22]
8. Kunz M. 265 million playing football. *FIFA magazine*, 2007:10-15.
9. Broglio SP, Vagnozzi R, Sabin M, et al. Concussion occurrence and knowledge in Italian football (soccer). *J Sport Sci Med* 2010;9(3):418-30.
10. McCrory P, Meeuwisse WH, Aubry M, et al. Consensus statement on concussion in sport: the 4th International Conference on Concussion in Sport held in Zurich, November 2012. *Brit J Sport Med* 2013;47(5):250-58. doi: 10.1136/bjsports-2013-092313
11. McCrory P, Meeuwisse WH, Dvorak J, et al. 5th International Conference on Concussion in Sport (Berlin). *Brit J Sport Med* 2017;51(11):837-37. doi: 10.1136/bjsports-2017-097878
12. Cusimano MD, Casey J, Jing RW, et al. Assessment of Head Collision Events During the 2014 FIFA World Cup Tournament. *Jama-J Am Med Assoc* 2017;317(24):2548-49. doi: 10.1001/jama.2017.6204
13. Makdissi M, Davis G. Using video analysis for concussion surveillance in Australian football. *J Sci Med Sport* 2016;19(12):958-63. doi: 10.1016/j.jsams.2016.02.014
14. McCrea M, Guskiewicz KM, Marshall SW, et al. Acute effects and recovery time following concussion in collegiate football players - The NCAA Concussion Study. *Jama-J Am Med Assoc* 2003;290(19):2556-63. doi: DOI 10.1001/jama.290.19.2556
15. Lawrence DW, Hutchison MG, Cusimano MD, et al. Interrater Agreement of an Observational Tool to Code Knockouts and Technical Knockouts in Mixed Martial



Abraham. *et al.* (2018)

- 1  
2  
3           Arts. *Clin J Sport Med* 2014;24(5):397-402. doi: Doi  
4           10.1097/Jsm.0000000000000047  
5  
6 16. Makdissi M, Davis G. The reliability and validity of video analysis for the assessment of  
7           the clinical signs of concussion in Australian football. *J Sci Med Sport*  
8           2016;19(10):859-63. doi: 10.1016/j.jsams.2016.02.015  
9  
10 17. Jordan BD. The clinical spectrum of sport-related traumatic brain injury. *Nat Rev Neurol*  
11           2013;9(4):222-30. doi: 10.1038/nrneurol.2013.33  
12  
13 18. Group IS. UEFA Injury Study Report, 2016:15.  
14  
15 19. Sport concussion assessment tool - 5th edition. *Br J Sports Med* 2017;51(11):851-58.  
16           doi: 10.1136/bjsports-2017-097506SCAT5 [published Online First: 2017/04/28]  
17  
18 20. Cusimano MD, Topolovec-Vranic J, Zhang S, et al. Factors Influencing the  
19           Underreporting of Concussion in Sports: A Qualitative Study of Minor Hockey  
20           Participants. *Clin J Sport Med* 2017;27(4):375-80. doi: Doi  
21           10.1097/Jsm.0000000000000372  
22  
23 21. Cusimano MD, Cho N, Amin K, et al. Mechanisms of Team-Sport-Related Brain Injuries  
24           in Children 5 to 19 Years Old: Opportunities for Prevention. *Plos One* 2013;8(3) doi:  
25           ARTN e58868  
26           10.1371/journal.pone.0058868  
27  
28 22. Ellenbogen RG, Batjer H, Cardenas J, et al. National Football League Head, Neck and  
29           Spine Committee's Concussion Diagnosis and Management Protocol: 2017-18  
30           season. *Br J Sports Med* 2018;52(14):894-902. doi: 10.1136/bjsports-2018-099203  
31           [published Online First: 2018/03/20]  
32  
33 23. Davis GA, Makdissi M, Bloomfield P, et al. International study of video review of  
34           concussion in professional sports. *Br J Sports Med* 2018 doi: 10.1136/bjsports-2018-  
35           099727 [published Online First: 2018/09/29]  
36  
37 24. FIFA. 2014 FIFA World Cup breaks online streaming records, 2014.  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

**STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies***

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	3
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	3
<b>Introduction</b>			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	5,6
Objectives	3	State specific objectives, including any prespecified hypotheses	6
<b>Methods</b>			
Study design	4	Present key elements of study design early in the paper	6,7
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6,7
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants	6,7
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6,7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6,7
Bias	9	Describe any efforts to address potential sources of bias	7
Study size	10	Explain how the study size was arrived at	7
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	7
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	7
		(b) Describe any methods used to examine subgroups and interactions	7
		(c) Explain how missing data were addressed	7
		(d) If applicable, describe analytical methods taking account of sampling strategy	7
		(e) Describe any sensitivity analyses	N/A
<b>Results</b>			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	7,8,9
		(b) Give reasons for non-participation at each stage	N/A
		(c) Consider use of a flow diagram	N/A
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	7,8,9
		(b) Indicate number of participants with missing data for each variable of interest	0
Outcome data	15*	Report numbers of outcome events or summary measures	7,8,9
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	N/A
		(b) Report category boundaries when continuous variables were categorized	N/A
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	N/A
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	7,8,9
<b>Discussion</b>			
Key results	18	Summarise key results with reference to study objectives	10,11,12
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	12
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	11,12
Generalisability	21	Discuss the generalisability (external validity) of the study results	10,11,12
<b>Other information</b>			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	13

\*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

**Note:** An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at [www.strobe-statement.org](http://www.strobe-statement.org).