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Medical Assessment of Potential Concussion in Elite Football

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Medical Assessment of Potential Concussion in Elite Football

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

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ABSTRACT

Objective: The objective is to determine if suspected concussions in elite football are medically assessed according to the International Conferences on Concussion in Sport consensus statement recommendations.

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

Participants: All professional football players in the UEFA 2016 Championship 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 medically assessed PCEs, 8 resulted in 3 signs of concussion, and 1 resulted in 4 signs; all assessments concluded in same-game return for the injured athletes.

Conclusions: PCEs were frequent events in the 2016 UEFA Euro championship, but were rarely assessed concordant with the International Conferences on Concussion in Sport consensus

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statement recommendations. There is an imperative need to improve the assessment and management of players suspected of concussion in elite football.

Trial Registration: Not applicable

Patient and Public Involvement: Patients and or public were not involved.

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Strengths and limitations of this study

- In this study, we sought to determine if suspected concussions in elite football are medically assessed according to the International Conferences on Concussion in Sport consensus statement recommendations to improve concussion awareness and safety measures in football-dominant nations.
- This study shows that there is an urgent need to improve the assessment and management of players suspected of concussion in the realm of elite football
- The major weakness of this study is that video analysis provides limited information on the details of medical evaluation for PCEs and thus cannot always provide information on whether or not an appropriate medical decision is made.

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[1]. 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[2]. 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[3]. 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)[4] [5]. Furthermore, 15-25% of mTBI cases are associated with adverse long-term physical, cognitive, and emotional sequelae[1]. 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[6] [7]. Football is the world's most popular and

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fastest growing sport; an estimated 270 million people play the sport in various professional, semi-professional, and/or organized formal recreational capacities[8]. By virtue of its widespread popularity, football's cumulative contribution to total SRC is likely to significantly overshadow other sports. Moreover, concussion awareness and safety measures remain relatively underdeveloped in many football-dominant nations[9]. Such conditions are conducive to large numbers of undiagnosed concussions, inappropriate management, and increased risk of potentially severe neurological consequences among vulnerable and/or improperly rehabilitated football athletes.

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 4th and 5th International Conferences on Concussion in Sport in 2012 and 2016, respectively, provide clear recommendations for assessment of athletes sustaining a potential concussive event (PCE) during a competitive event[10 11]. 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[12]. In this study, we used video analysis to characterize PCEs and their assessment in the 2016 Men's UEFA European Championship to determine if improvements had been made over the two-year gap between tournaments.

METHODS

Video Analysis by trained observers

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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 [12-15]. 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[15]. 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[12 16]. 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

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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

		PCE assessment (n)		RTP Outcome when medically assessed (n)	
No. of concussion signs	No. of PCE (% total)	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

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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[12]. 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)	
No. of	WC	Euro	WC	Euro	WC	Euro	WC	Euro

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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[1 17]. 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[1 6 7]. 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

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assessment of an athlete with a suspected concussion were published and reiterated in consensus statements following the 4th and 5th International Conferences on Concussion in Sport held in 2012 and 2016, respectively[10 11]. These endeavors have been supported and endorsed by football's major international governing body FIFA[10 11]. 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[10 11]. 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[18]. Overall, our data highlights an obvious need to improve concussion assessment in the realm of elite football, and

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suggest that significant and persistent knowledge uptake and/or attitudinal barriers to implementation may exist.

Barriers to Implementation

Several factors may contribute to weak implementation of SRC assessment protocols in elite football. First, a misperception and/or lack of awareness of SRC risk among football athletes, coaches, franchises, and related organizations may limit enforcement. Advances in the prevention and proper management of SRC require that sporting associations attend to concussion with the same diligence typically applied to doping and other serious breaches. Second, the high stakes of competitive sport may pressure team medical staff to ignore PCEs, or inappropriately shorten examination and encourage RTP, particularly in situations when the team needs a result. In a widely-publicized and recent example illustrating the pressures that team doctors may experience, a long-serving female team doctor from Chelsea Football Club was publically criticized, demoted, and eventually forced out of the club for fulfilling her medical obligation to assess an injured player in stoppage time of a Premier League game. Third, factors that normally contribute to under-reporting in other sports may be relevant as implementation barriers in football[19]. For instance, a culture of toughness and loyalty to the team may either openly or subtly encourage athletes to downplay concussion or inappropriately accelerate RTP following injury[19 20]. Furthermore, athletes are influenced by a strong desire to win, and fear of letting their teams or nations down, which may also encourage underreporting of SRC symptoms. Fourth our data suggest that significant gaps in knowledge translation exist, and highlight the need for improved knowledge dissemination and uptake at multiple levels including international football associations such as FIFA and UEFA, individual franchises, as well as associated staff, coaches, athletes and the wider spectrum of stakeholders in the sport. Research

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

Limitations

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

Future directions

Overall, our data indicate that PCEs occur relatively frequently (at least one per game) in elite level football matches, but are rarely assessed in a manner concordant with the 2012 or 2016 International Conferences on Concussion in Sport consensus recommendations. Major international tournaments such as the FIFA World cup and UEFA European Championships feature elite-level athletes and are among the most widely broadcasted and followed sporting events on the planet[21]. The norms that persist on such a stage are likely to influence attitudes towards concussion on a global scale. The upcoming 2018 FIFA men's World Cup offers the

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opportunity to set a new precedent for excellence in enforcement of concussion assessment, and initiate beneficial improvements in concussion awareness and the implementation of proper assessment protocols in the sport.

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Author Contributorship

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

Competing Interest

None declared.

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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
Introduction			
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
Methods			
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
Results			

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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
Discussion			
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
Other information			
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.

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

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ABSTRACT

Objective: The objective is to determine if suspected concussions in elite football are medically assessed according to the International Conferences on Concussion in Sport consensus statement recommendations.

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

Participants: All professional football players in the UEFA 2016 Championship 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).

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

Conclusions: PCEs were frequent events in the 2016 UEFA Euro championship, but were rarely assessed concordant with the International Conferences on Concussion in Sport consensus statement recommendations. There is an imperative need to improve the assessment and management of players suspected of concussion in elite football.

Trial Registration: Not applicable

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Strengths and limitations of this study

- In this study, we sought to determine if suspected concussions in elite football are medically assessed according to the International Conferences on

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Concussion in Sport consensus statement recommendations to improve concussion awareness and safety measures in football-dominant nations.

- This study shows that there is an urgent need to improve the assessment and management of players suspected of concussion in the realm of elite football
- The major weakness of this study is that video analysis provides limited information on the details of medical evaluation for PCEs and thus cannot always provide information on whether or not an appropriate medical decision is made.

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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,

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sports participation is recognized as one of the leading causes of concussion[1]. 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[2]. 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[3]. 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)[4 5]. Furthermore, 15-25% of mTBI cases are associated with adverse long-term physical, cognitive, and emotional sequelae[1]. 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[6 7]. Football is the world's most popular and fastest growing sport; an estimated 270 million people play the sport in various professional, semi-professional, and/or organized formal recreational capacities[8]. By virtue of its widespread popularity, football's cumulative contribution to total SRC is likely to significantly overshadow other sports. Moreover, concussion awareness and safety measures remain relatively underdeveloped in many football-dominant nations[9]. Such conditions are conducive to large numbers of undiagnosed concussions, inappropriate management, and increased risk of potentially severe neurological consequences among vulnerable and/or improperly rehabilitated football athletes.

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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 4th and 5th International Conferences on Concussion in Sport in 2012 and 2016, respectively, provide clear recommendations for assessment of suspected concussions during a competitive event[10 11]. 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[10 11]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[12]. 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 [12-15]. 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

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PCEs were defined 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[12 16]. The term PCE is not used synonymously with SRC. Instead, it captures the broad range of in-game scenarios involving head collisions; recognizing that the higher the number of concussion signs associated with a PCE, the greater the index for suspicion that it may represent a *bona fide* concussion. 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.

Training of Reviewers

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[15]. The standardized data collection form was used to provide a person viewing digital video images with a consistent way of coding and accounting for the majority of circumstances and mechanisms leading to concussion. The standardized data form was adapted from a validated form used in a prior study on concussion[15]. The form was accompanied by a detailed data dictionary outlining the codes associated with each variable.

Video Analysis

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

Statistical Analysis

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

Patient and Public Involvement:

Patients and or public were not involved.

RESULTS

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

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		PCE assessment (n)		RTP Outcome when medically assessed (n)	
No. of concussion signs	No. of PCE (% total)	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

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Table 2 compares PCE assessment and outcome in Euros 2016 versus our data from our previously published PCE analysis of WC 2014[12]. 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)	
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

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Concussion is an inherent risk associated with sports participation and SRC is now recognized as a major public health concern[1 17]. 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[1 6 7]. 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 assessment of an athlete with a suspected concussion were published and reiterated in consensus statements following the 4th and 5th International Conferences on Concussion in Sport held in 2012 and 2016, respectively[10 11]. These endeavors have been supported and endorsed by football's major international governing body FIFA[10 11]. The CISG recommendations 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[10 11]. In a previous study on the Men's 2014 FIFA WC, we found that 63% of elite-level football athletes

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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[18]. 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

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Several factors may contribute to weak implementation of SRC assessment protocols in elite football. First, the high stakes of competitive sport and rules of the games may pressure team medical staff to ignore PCEs, or inappropriately shorten examination and encourage RTP, particularly in situations when the team needs a result. In a widely-publicized and recent example illustrating the pressures that team doctors may experience, a long-serving female team doctor from Chelsea Football Club was publically criticized, demoted, and eventually forced out of the club for fulfilling her medical obligation to assess an injured player in stoppage time of a Premier League game. The current rules of the game, including running time and limited substitutions, further discourage pulling player for medical assessment. For the recent 2018 WC competition, FIFA implemented a new protocol for head injuries and concussions. This includes giving the referee the ability to stop the match for 3 minutes if a head injury is suspected for an on-pitch assessment. 3 minutes is not sufficient time to complete a SCAT3/5. The SCAT5 explicitly states on the form "The SCAT5 cannot be performed correctly in less than 10 minutes"[19]. Second, factors that normally contribute to under-reporting in other sports may be relevant as implementation barriers in football[20]. For instance, a culture of toughness and loyalty to the team may either openly or subtly encourage athletes to downplay concussion or inappropriately accelerate RTP following injury[20 21]. Furthermore, athletes are influenced by a strong desire to win, and fear of letting their teams or nations down, which may also encourage underreporting of SRC symptoms. Third, our data suggest that significant gaps in knowledge translation exist, and highlight the need for improved knowledge dissemination and uptake at multiple levels including international football associations such as FIFA and UEFA, individual franchises, as well as associated staff, coaches, athletes and the wider spectrum of stakeholders in the sport. Research identifying barriers to implementation such as knowledge translation bottlenecks, followed by strategic targeting of such

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

Limitations

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

Future directions

Overall, our data indicate that PCEs occur relatively frequently (at least one per game) in elite level football matches, but are rarely assessed in a manner concordant with the 2012 and 2016 CISG recommendations. Major international tournaments such as the FIFA World cup and UEFA European Championships feature elite-level athletes and are among the most widely broadcasted and followed sporting events on the planet[22]. The norms that persist on such a stage are likely to

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influence attitudes towards concussion on a global scale. Future major international tournaments offer the opportunity to set a new precedent for excellence in enforcement of concussion assessment, and initiate beneficial improvements in concussion awareness and the implementation of proper assessment protocols in the sport.

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Author Contributorship

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

Data Sharing Statement

We are happy to share data published in this study but most if not all data is already included in the manuscript and/or in the public domain.

Competing Interest

None declared.

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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
Introduction			
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
Methods			
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
Results			

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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
Discussion			
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
Other information			
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.

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

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

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ABSTRACT

Objective: The objective is to determine if suspected concussions in elite football are medically assessed according to the International Conferences on Concussion in Sport consensus statement recommendations.

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

Participants: All professional football players in the UEFA 2016 Championship 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

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

Conclusions: PCEs were frequent events in the 2016 UEFA Euro championship, but were rarely assessed concordant with the International Conferences on Concussion in Sport consensus statement recommendations. There is an imperative need to improve the assessment and management of players suspected of concussion in elite football.

Trial Registration: Not applicable

Strengths and limitations of this study

- In this study, we sought to determine if suspected concussions in elite football are medically assessed according to the International Conferences on Concussion in Sport consensus statement recommendations to improve concussion awareness and safety measures in football-dominant nations.
- This study shows that there is an urgent need to improve the assessment and management of players suspected of concussion in the realm of elite football
- The major weakness of this study is that video analysis provides limited information on the details of medical evaluation for PCEs and thus cannot always provide information on whether or not an appropriate medical decision is made.

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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[1]. 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[2]. 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[3]. 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)[4 5]. Furthermore, 15-25% of mTBI cases are associated with adverse long-term physical, cognitive, and emotional sequelae[1]. 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.

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Athletes involved in football, also called 'soccer' in North America, consistently experience among the highest rates of concussion[6 7]. Football is the world's most popular and fastest growing sport; an estimated 270 million people play the sport in various professional, semi-professional, and/or organized formal recreational capacities[8]. By virtue of its widespread popularity, football's cumulative contribution to total SRC is likely to significantly overshadow other sports. Moreover, concussion awareness and safety measures remain relatively underdeveloped in many football-dominant nations[9]. Such conditions are conducive to large numbers of undiagnosed concussions, inappropriate management, and increased risk of potentially severe neurological consequences among vulnerable and/or improperly rehabilitated football athletes.

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 4th and 5th International Conferences on Concussion in Sport in 2012 and 2016, respectively, provide clear recommendations for assessment of suspected concussions during a competitive event[10 11]. 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[10 11]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

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current practices at the elite level[12]. 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 [12-15]. 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

PCEs were defined 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[12 16]. The term PCE is not used synonymously with SRC. Instead, it captures the broad range of in-game scenarios involving head collisions; recognizing that the higher the number of concussion signs associated with a PCE, the greater the index for suspicion that it may represent a *bona fide* concussion. 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.

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Training of Reviewers

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[15]. The standardized data collection form was used to provide a person viewing digital video images with a consistent way of coding and accounting for the majority of circumstances and mechanisms leading to concussion. The standardized data form was adapted from a validated form used in a prior study on concussion[15]. The form was accompanied by a detailed data dictionary outlining the codes associated with each variable.

Video Analysis

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

Statistical Analysis

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

Patient and Public Involvement:

Patients and or public were not involved.

RESULTS

PCE incidence at Euro 2016

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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

		PCE assessment (n)		RTP Outcome when medically assessed (n)	
No. of concussion signs	No. of PCE (% total)	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

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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[12]. 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)

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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[1 17]. 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[1 6 7]. 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

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and its potentially serious long-term consequences. To aid this effort, clear protocols for on-field assessment of an athlete with a suspected concussion were published and reiterated in consensus statements following the 4th and 5th International Conferences on Concussion in Sport held in 2012 and 2016, respectively[10 11]. These endeavors have been supported and endorsed by football's major international governing body FIFA[10 11]. The CISG recommendations 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[10 11]. 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. 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

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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[18]. 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

Several factors may contribute to weak implementation of SRC assessment protocols in elite football. First, the high stakes of competitive sport and rules of the games may pressure team medical staff to ignore PCEs, or inappropriately shorten examination and encourage RTP, particularly in situations when the team needs a result. In a widely-publicized and recent example illustrating the pressures that team doctors may experience, a long-serving female team doctor from Chelsea Football Club was publically criticized, demoted, and eventually forced out of the club for fulfilling her medical obligation to assess an injured player in stoppage time of a Premier League game. The current rules of the game, including running time and limited substitutions, further discourage pulling player for medical assessment. For the recent 2018 WC competition, FIFA implemented a new protocol for head injuries and concussions. This includes giving the referee the ability to stop the match for 3 minutes if a head injury is suspected for an on-pitch assessment. 3 minutes is not sufficient time to complete a SCAT3/5. The SCAT5 explicitly states on the form "The SCAT5 cannot be performed correctly in less than 10 minutes"[19]. Second, factors that normally contribute to under-reporting in other sports may be relevant as implementation barriers in football[20]. For instance, a culture of toughness and loyalty to the team may either openly

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or subtly encourage athletes to downplay concussion or inappropriately accelerate RTP following injury[20 21]. Furthermore, athletes are influenced by a strong desire to win, and fear of letting their teams or nations down, which may also encourage underreporting of SRC symptoms. Third, our data suggest that significant gaps in knowledge translation exist, and highlight the need for improved knowledge dissemination and uptake at multiple levels including international football associations such as FIFA and UEFA, individual franchises, as well as associated staff, coaches, athletes and the wider spectrum of stakeholders in the sport. Research identifying barriers to implementation such as knowledge translation bottlenecks, followed by strategic targeting of such impediments will be imperative to improved implementation of risk-reducing practices (including but not limited to medical assessment) that ultimately safeguard the long-term brain health of football athletes. Fourth, there may be a misperception and/or lack of awareness of SRC risk among football athletes, coaches, franchises, and related organizations, which could limit enforcement. Advances in the prevention and proper management of SRC require that sporting associations attend to concussion with the same diligence typically applied to doping and other serious breaches. Reaching out directly to stakeholders, including FIFA, national team coaches and their staff physicians, as well as the intended beneficiaries of this work (athletes) will be imperative to widespread knowledge dissemination and uptake efforts.

In order to increase effectiveness of current football concussion protocols, it would be beneficial for football governing bodies to examine how other professional sports deal with concussions. For example, in NFL American football, the latest concussion protocol published in 2018 stipulates that each team during game day must be assigned a Sideline Unaffiliated Neurotrauma Consultant ("Sideline UNC"), a physician that is impartial and independent from any Club.[1]Additionally, the protocol also stipulates that a video Unaffiliated Neurotrauma Consultant

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be present in a stadium booth with access to multiple views of video[22]. Having impartial evaluators would help significantly in curtailing issues such as doctors from home teams facing pressure to return players to the game and examining the nature of potential concussive impacts. Providing broadcast video to side-line medical personnel in real time is also a recommendation by a recently published study that examined current practices related to video review of concussion in professional sports internationally[23]. Football authorities should consider implementing these rules which would help aid in the screening for concussion and treat it as soon as possible.

Limitations

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

Future directions

Overall, our data indicate that PCEs occur relatively frequently (at least one per game) in elite level football matches, but are rarely assessed in a manner concordant with the 2012 and 2016 CISG recommendations. Major international tournaments such as the FIFA World cup and UEFA European Championships feature elite-level athletes and are among the most widely broadcasted and followed sporting events on the planet[24]. The norms that persist on such a stage are likely to influence attitudes towards concussion on a global scale. Future major international tournaments offer the opportunity to set a new precedent for excellence in enforcement of concussion

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assessment, and initiate beneficial improvements in concussion awareness and the implementation of proper assessment protocols in the sport.

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Author Contributorship

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

Data Sharing Statement

We are happy to share data published in this study but most if not all data is already included in the manuscript and/or in the public domain.

Competing Interest

None declared.

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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
Introduction			
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
Methods			
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
Results			

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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
Discussion			
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
Other information			
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.

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