

Review article

## A Systematic Review and Qualitative Analysis of Concussion Knowledge amongst Sports Coaches and Match Officials

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### Abstract

Sport-related concussion (SRC) is a public health issue of increasing concern. Sports coaches and match officials are important stakeholders in facilitating early recognition, immediate management and appropriate return-to-play following SRC. This systematic review analyses the current evidence on SRC knowledge amongst sports coaches and match officials. The review was conducted in accordance to PRISMA guideline. A qualitative analysis of knowledge on identification, management, prevention and consequences of SRC as well as return-to-play principles was performed. The Appraisal Tool for Cross-sectional Studies was employed to assess the quality and reliability of each study. Searches were conducted on PubMed, Medline Ovid, Web of Science, CINAHL, SPORTDiscus and Psycinfo. Studies included were primary studies in English published in peer-reviewed journals assessing the level of concussion knowledge or education level amongst coaches, officials or both, regardless of sports or competitive level. A total of 20880 studies were identified, from which 27 were included in this review. There were 26 cross-sectional studies and one randomized controlled trial; 20 assessed SRC knowledge amongst coaches, one considered only officials and six studies assessed both groups. Concussion knowledge amongst coaches and match officials was deemed moderate in most studies, although significant knowledge gaps were identified. There is considerable room for further education on SRC amongst coaches and officials, particularly with the less commonly recognized symptoms of SRC and misconceptions about SRC management and prevention. Beyond knowledge assessment, further investigation should explore the translation of concussion knowledge to on-field management of players with SRC.

**Key words:** Concussion, systematic review, sports coaches, match officials.

### Introduction

Concussions were first documented by Hippocrates “approximately 2400 years ago” (Mullally, 2017). The 5<sup>th</sup> International Conference on Concussion in Sport (McCrory et al., 2017) defined sports-related concussion (SRC) as “a traumatic brain injury induced by biochemical forces” that “typically results in the rapid onset of short-lived impairment of neurological function that resolves spontaneously” (McCrory et al., 2017). The consensus statement mentions characterizing symptoms of SRC such as somatic (e.g. headache), cognitive (e.g. feeling like in a fog) and emotional symptoms (e.g. lability), as well as other features like physical signs (e.g. loss of consciousness), cognitive impairment, balance impairment, behavioral changes and

sleep-wake disturbances. Furthermore, there are now tools to aid in recognition of SRC e.g. Sport Concussion Assessment Tool 5 (SCAT5) (Echemendia et al., 2017a), and recommendations for management of SRC and subsequent return to play e.g. graduated return to sport (McCrory et al., 2017).

Increased awareness of this condition (Zhang et al., 2016) and understanding of the long-term sequelae of concussion (Kushner, 1998; McKee and Daneshvar, 2015; Tagge et al., 2018; Zhou et al., 2013), has led to some authors labelling it a public health crisis (Harrison, 2014). This increased knowledge has also prompted a number of high profile lawsuits, such as that in the United States National Football League (NFL) (Sirisena et al., 2017) and a possible class-action suit by former Australian National Rugby League players, in light of new evidence of concussion-related injuries (Buckland et al., 2019). Such lawsuits have also increased research in this field.

With governments encouraging increased exercise and sports participation to combat the international physical inactivity epidemic, there is growing interest in SRC (Belechri et al., 2001; Wallace et al., 2017). In the United States of America alone, it is estimated that 3.8 million SRC are reported each year, across multiple competitive sports (Harmon et al., 2013). These numbers may be simply the tip of the iceberg, as many such incidences go unreported (Daneshvar et al., 2011), due to factors such as lack of awareness amongst coaches (Graham et al., 2014), parents (Weerdenburg et al., 2016), match officials (Griffin et al., 2017), sports trainers, and athletes themselves (Taylor and Sanner, 2015). In light of the wide-ranging repercussions of SRC, numerous measures have been put in place, such as changes to legislation (Gibson et al., 2015), game rules (Benson et al., 2013) and increased emphasis on coach education (Emery et al., 2017; Patel et al., 2017).

Immediate removal from play and assessment of players after sustaining SRC is the minimum standard of care for the safety of athletes (McCrory et al., 2017). Even though SRC is a medical diagnosis, healthcare professionals may not always be on-site for all amateur or school sporting events (Kroshus et al., 2017b) leaving coaches and officials to be the first responders to concussed players. While tools like Concussion Recognition Tool 5th Edition (CRT5) also provide guidance to non-medical professionals in decision making for removal of play (Echemendia et al., 2017b), the appropriate use of such tools is contingent on knowledge and awareness of SRC. Inadequate immediate management of SRC has been reported, beckoning the

need for better concussion education amongst sports clubs, coaches and other important stakeholders (Haran et al., 2016). Furthermore, given that coaches play an important role in influencing an athlete's decision to report concussions (Baugh et al., 2014), it is pertinent that they demonstrate and communicate knowledge on the consequences SRC and thereby encourage SRC reporting.

The objective of this systematic review was to explore the knowledge level of SRC amongst sports coaches and matches officials to guide further discussion on educational programmes, policy change and guidelines.

## Methods

### Search strategy

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were applied while conducting the review (Liberati et al., 2009). A systematic search was conducted using PubMed, Medline Ovid, Web of Science, CINAHL, SPORTDiscus and Psycinfo for studies published from 1<sup>st</sup> January 2001 to 5<sup>th</sup> January 2019. The first International Conference on Concussion in Sport was held in November 2001 (Aubry, 2002), and hence only studies from this year onwards were included, allowing for assessment of current concussion knowledge based on the international consensus. Search terms used included a combination of population and concussion terms (Table 1). The term "Knowledge" was deliberately excluded as a criterion for the search to include more potential studies.

### Screening and review process

The results of all searches were entered into the Veritas's Covidence software (Innovation, 2017) where title and abstract screening for eligible studies was performed. This entailed a 2-stage process, initially by independent reviewers PC and QY, and subsequently by reviewers DS, JP and SS. Full texts of remaining studies were then assessed for eligibility by all 5 reviewers. Disagreements were resolved by consensus discussion at each stage. The following eligibility criteria were used in the screening and reviewing process.

### Inclusion criteria

Primary studies published in English in peer-reviewed journals from 1st Jan 2001 till 5th Jan 2019 were included. The studies that were included assessed level of concussion knowledge and/or level of education on concussion

amongst coaches and/or match officials in all sporting levels (professional, amateur, college or school sports).

### Exclusion criteria

Studies that were not related to the level of concussion knowledge and/or level of education on concussion amongst coaches and/or match officials as well or studies assessing concussion knowledge amongst athletic trainers instead of coaches were excluded. Studies with no abstract available for screening and those without available English translation were also excluded.

### Study analysis

Information regarding concussion knowledge was extracted from each study, particularly pertaining to the following domains:

- 1) Identification of concussion
- 2) Initial management of concussion
- 3) Return to play (RTP)
- 4) Prevention of concussion
- 5) Consequences of concussion

These domains were frequently assessed amongst the studies reviewed which are relevant to coaches and sports officials according to international consensus (McCrory et al., 2017). Other information such as prior concussion education and desire for further concussion education were also documented. The Appraisal Tool for Cross-sectional Studies (AXIS) was employed to assess the quality and reliability of each study (Downes et al., 2016).

## Results

### Search findings

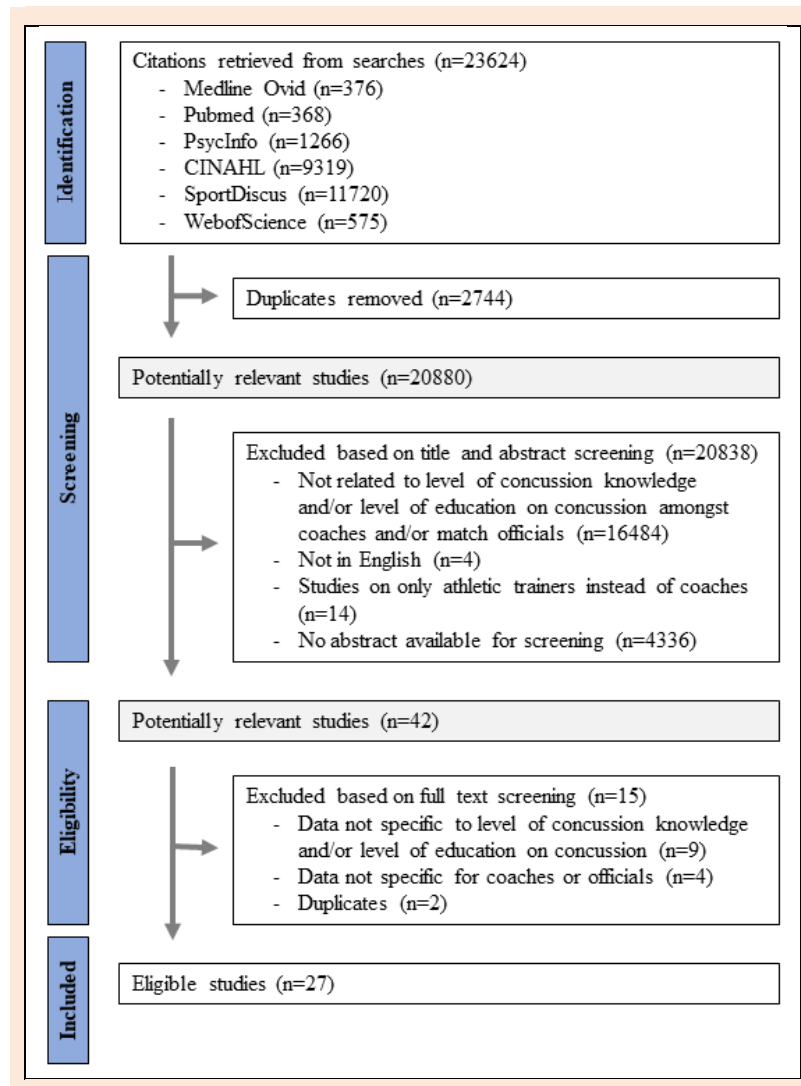
The search identified 20880 studies after exclusion of 2744 duplicates, with 42 full texts assessed for eligibility. 27 studies were eventually included (Figure 1).

### Characteristics of studies

There were 26 cross-sectional studies (Refer to Table 2) and one randomised control trial (Glang et al., 2010) of which 20 studies assessed concussion knowledge amongst coaches, one explored knowledge amongst officials while six studies assessed both. The randomised controlled trial by Glang et al. (2010) involved 75 coaches who went through an interactive e-learning program as part of the intervention arm. Pre-test results were used to determine baseline concussion knowledge of this study population.

**Table 1.** Search terms and strategy.

Search terms				
Population terms		<i>Coach</i>	<i>Official</i>	<i>Referee</i>
Concussion terms	Keywords	<i>Concussion</i>	<i>Traumatic brain injury</i>	<i>TBI</i>
		<i>Mild brain injury</i>	<i>Head injury</i>	<i>Craniocerebral trauma</i>
	MeSH terms	<i>Brain concussion</i>		<i>Brain injuries, Traumatic</i>
Search strategy (search example on Medline Ovid)				
Search 1 (Population terms)		<i>coach* OR official? OR referee? OR umpire?</i>		
Search 2 (Concussion keywords)		<i>concussion OR traumatic brain injur* OR TBI OR mTBI OR mild brain injur* OR craniocerebral trauma OR head injur*</i>		
Search 3 (Concussion MeSH terms)		<i>Brain Concussion/ OR Brain Injuries, Traumatic/</i>		
Search 4 (All concussion terms)		<i>Search 2 OR Search 3</i>		
Search 5 (Population + Concussion terms)		<i>Search 1 AND Search 4</i>		



**Figure 1. PRISMA flowchart of included studies.**

Fifteen studies took place within the United States (Refer to Table 2), with other studies from Canada (n=3), Australia (n=2), Ireland (n=2), the United Kingdom (n=2), Germany (n=1), Italy (n=1) and New Zealand (n=1). Twelve studies assessed coaches and officials across multiple different sports, while others were specific for Rugby (n=6), Hockey (n=4), American football (n=3), Soccer (n=1) and Wrestling (n=1). Across all studies, a total of 3750 coaches and 1790 officials were included. The smallest study involved eight coaches (Kirk et al., 2018), and the largest study involved 1324 referees (Kroshus et al., 2017a). Two studies included coaches and officials across different tiers (Mathema et al., 2016; Saunders et al., 2013), 12 studies focused on high school or junior school sports, four on college sports, six on amateur sports and three on professional or semi-professional sports.

A large proportion (13 out of 27) of studies crafted original questionnaires to assess concussion knowledge (Refer to Table 2), many of which were utilised and adapted in subsequent studies. There was a variety of questionnaire types including open-ended, multi-choice, true-false and scenario-based questions.

### Quality assessment

The AXIS guideline was employed to assess a study's quality and risk of bias based on 20 criteria, as summarised in Table 3. Studies were found to be unsatisfactory in an average of five criteria. All except one study (Bramley et al., 2011) did not manage to take measures to limit or characterise non-responders, and most studies were at risk of selection bias as participants were invited to participate via a voluntary opt-in system. Response rates were low, with only seven (Bramley et al., 2011; Broglio et al., 2010; Faure and Pemberton, 2011; Fraas et al., 2014; Mathema et al., 2016; Niederer et al., 2018; Valovich McLeod et al., 2007) having a response rate of more than 60%. Only one study (Bramley et al., 2011) satisfied all 20 criteria.

### Results of individual studies

**Identification of concussion:** Twenty-four of the 27 studies (Refer to Table 2) assessed for knowledge on identification of SRC. Most studies employing scored questionnaires reported concussion identification scores of above 50% (38.9% to 90.5%) amongst both coaches and officials.

**Table 2. Characteristics of individual studies.**

Authors	Study title	Country	Study population			Study design	Concussion knowledge assessed (Yes/No)					AXIS Critical Appraisal (areas of concern)
			Tier	Personnel	Sports		IDofCON	IMofCON	RPP	PrCON	CofCON	
Clacy et al, 2016	A knock to the system: A new sociotechnical systems approach to sport-related concussion.	Australia	Amateur	17 Coaches 6 Officials	Rugby	Original open-ended questionnaire	Yes	Yes	No	Yes	No	<b>Total concerns: 6</b> 6, 7, 9, 14, 13, 15
Mathema et al, 2016	Concussed or Not? An Assessment of Concussion Experience and Knowledge Within Elite and Semiprofessional Rugby Union.	Wales	Professional & Semi-professional	44 Coaches 33 Referees	Rugby	Original multiple-choice questionnaire	Yes	Yes	Yes	Yes	Yes	<b>Total concerns: 3</b> 7, 14 & 18
Griffin et al, 2017	Concussion knowledge and experience among Welsh amateur rugby union coaches and referees	Wales	Amateur	333 Coaches 283 Officials	Rugby	Multiple-choice questionnaire	Yes	Yes	Yes	Yes	Yes	<b>Total concerns: 4</b> 6, 7, 13, 14
King et al, 2010	First-aid concussion knowledge of rugby league team management, administrators and officials in New Zealand.	New Zealand	Amateur	50 Coaches 3 Officials	Rugby	Open-ended & multiple-choice questionnaire	Yes	Yes	Yes	Yes	Yes	<b>Total concerns: 7</b> 3, 6, 7, 13, 14, 18, 19
Hunt et al, 2018	Knowledge, Attitudes and Concussion Information Sources Among First Nations in Ontario.	Canada	High school	64 Coaches + Officials	Hockey	Multiple-choice questionnaire	Yes	No	Yes	No	No	<b>Total concerns: 4</b> 6, 7, 13 & 14
Niederer et al, 2018	Return-to-play after concussion: state of knowledge, frequency of use and application barriers of guidelines among decision-makers in rugby.	Germany	Professional & Semi-professional	61 Coaches 109 Officials	Rugby	Original multiple-choice & scenario-based questionnaire	No	No	Yes	No	No	<b>Total concerns: 3</b> 6, 7, 13, 14
Kroshus, 2017	Calling Injury Timeouts for the Medical Evaluation of Concussion: Determinants of Collegiate Football Officials' Behavior.	United States	College	1324 Officials	Hockey	Original scenario-based questionnaire	No	Yes	No	No	No	<b>Total concerns: 6</b> 6, 7, 9, 13, 14 & 19
Guilmette, 2007	A survey of concussion knowledge and management among New England high school football coaches	United States	High school	62 Coaches	American football	Original true-false & Scenario-based questionnaire	Yes	Yes	Yes	No	No	<b>Total concerns: 4</b> 6, 7, 13 & 14
Faure, 2011	An Examination of Idaho High School Football Coaches' General Understanding of Concussion.	United States	High school	77 Coaches	American football	Original open-ended questionnaire and Interview (10 coaches)	Yes	Yes	Yes	No	No	<b>Total concerns: 7</b> 5, 6, 7, 9, 14, 15 & 19
O'Donoghue et al, 2009	Assessment of High School Coaches' Knowledge of Sport-Related Concussions.	United States	High school	126 Coaches	Unspecified	Original multiple-choice questionnaire	Yes	Yes	Yes	No	No	<b>Total concerns: 4</b> 6, 7, 13 & 14
Kirk et al, 2018	Concussion in University Level Sport: Knowledge and Awareness of Athletes and Coaches.	Ireland	College	8 Coaches	Unspecified	Multiple-choice questionnaire	Yes	Yes	Yes	No	No	<b>Total concerns: 7</b> 3, 4, 5, 6, 7, 13 & 14

IDofCON : Identification of concussion; IMofCON : Initial management of concussion; RPP : Return-to-play principles; PrCON : Prevention of Concussion; CofCON Consequences of concussion.

**Table 2. Continue....**

Authors	Study title	Country	Study population			Study design	Concussion knowledge assessed (Yes/No)					AXIS Critical Appraisal (areas of concern)
			Tier	Personnel	Sports		IDofCON	IMofCON	RPP	PrCON	CofCON	
Kroshus et al, 2016	Concussion Knowledge and Communication Behaviours of Collegiate Wrestling Coaches	United States	College	89 Coaches	Wrestling	Multiple-choice & scenario-based questionnaire	Yes	Yes	No	Yes	Yes	<b>Total concerns: 6</b> 5, 6, 7, 13, 14, 19
Fraas et al, 2014	Concussion knowledge and management practices among coaches and medical staff in Irish professional rugby teams.	Ireland	Professional	11 Coaches	Rugby	Multiple-choice questionnaire	Yes	Yes	Yes	No	No	<b>Total concerns: 5</b> 3, 5, 6, 7 & 14
Esquivel et al, 2013	Concussion Management, Education, and Return-to-Play Policies in High Schools: A Survey of Athletic Directors, Athletic Trainers, and Coaches.	United States	High School	119 Coaches	Unspecified	Original multiple-choice & open-ended questionnaire	Yes	Yes	Yes	No	No	<b>Total concerns: 5</b> 6, 7, 9, 13 & 14
Broglia et al, 2010	Concussion occurrence and knowledge in Italian football (soccer)	Italy	Amateur	27 Coaches	Soccer	Multiple-choice questionnaire	Yes	Yes	Yes	No	Yes	<b>Total concerns: 4</b> 6, 7, 14, 19
Kroshus, 2016	Content, Delivery, and Effectiveness of Concussion Education for US College Coaches	United States	College	1818 Coaches	Unspecified	Multiple-choice & scenario-based questionnaire	Yes	Yes	Yes	Yes	No	<b>Total concerns: 4</b> 6, 7, 13 & 14
Bramley et al, 2012	Do Youth Hockey Coaches Allow Players with a Known Concussion to Participate in a Game?	United States	High School	314 Coaches	Hockey	Original scenario-based questionnaire	No	Yes	No	No	No	<b>Total concerns: 0</b>
Guo, 2017	Exploring Gaps in Concussion Knowledge and Knowledge Translation Among Coaches of Youth Female Hockey.	Canada	Amateur	130 Coaches	Hockey	Multiple-choice questionnaire	Yes	Yes	No	Yes	No	<b>Total concerns: 4</b> 6, 7, 13 & 14
Chrisman et al, 2014	Implementation of concussion legislation and extent of concussion education for athletes, parents, and coaches in Washington State.	United States	High School	270 Coaches	American football & soccer	Original multiple-choice questionnaire	Yes	Yes	Yes	No	No	<b>Total concerns: 5</b> 6, 7, 9, 13 & 14
White et al, 2013	Knowledge about sports-related concussion: is the message getting through to coaches and trainers?	Australia	Amateur	519 Coaches	Unspecified	Multiple-choice questionnaire	Yes	Yes	Yes	Yes	Yes	<b>Total concerns: 5</b> 6, 9, 7, 13 & 14
Naftel et al, 2014	Knowledge and management of sports concussions among coaches and certified athletic trainers in Alabama.	United States	High school	402 Coaches	Unspecified	Original multiple-choice questionnaire	Yes	No	Yes	No	No	<b>Total concerns: 5</b> 6, 7, 9, 13 & 14
Saunders et al, 2012	Knowledge of Coaching Education Students Regarding Sport-Related Concussions.	United States	Mixed	150 Coaches	Unspecified	Multiple-choice questionnaire	Yes	Yes	Yes	No	No	<b>Total concerns: 6</b> 6, 7, 9, 13, 14, 15, 19
Shroyer, 2016	Knowledge of Concussions by High School Coaches in a Rural Environment.	United States	High school	52 coaches	Unspecified	Multiple-choice questionnaire	Yes	No	Yes	No	No	<b>Total concerns: 7</b> 6, 7, 10, 11, 13, 14, 19

IDofCON : Identification of concussion; IMofCON : Initial management of concussion; RPP : Return-to-play principles; PrCON : Prevention of Concussion; CofCON Consequences of concussion.



Table 2. Continue....

Authors	Study title	Country	Study population			Study design	Concussion knowledge assessed (Yes/No)					AXIS Critical Appraisal (areas of concern)
			Tier	Personnel	Sports		IDofCON	IMofCON	RPP	PrCON	CofCON	
Hossler, 2013	New Jersey Coaches' Knowledge in Recognizing and Managing Concussion	United States	High school	537 Coaches	Unspecified	Multiple-choice & scenario-based questionnaire	Yes	Yes	No	No	Yes	<b>Total concerns: 6</b> 6, 7, 9, 13, 14 & 15
Glang, 2010	Online training in sports concussion for youth sports coaches	United States	Below high school	75 Coaches	Unspecified	Multiple-choice questionnaire	Yes	No	No	No	No	<b>Total concerns: 4</b> 6, 7, 13, 14
Valovich McLeod, 2007	Sport-related concussion misunderstanding among youth coaches.	United States	Below high school	156 Coaches	Unspecified	Original multiple-choice & scenario-based questionnaire	Yes	Yes	No	No	No	<b>Total concerns: 5</b> 6, 7, 13, 14 & 18
Mrazik, 2011	Sport-related concussions: knowledge translation among minor hockey coaches.	Canada	Mixed	Coaches	Hockey	Original multiple-choice & scenario-based questionnaire	Yes	Yes	Yes	Yes	No	<b>Total concerns: 5</b> 6, 7, 9, 13 & 14

IDofCON : Identification of concussion; IMofCON : Initial management of concussion; RPP : Return-to-play principles; PrCON : Prevention of Concussion; CofCON Consequences of concussion.

The exception to this was one study based in Italy where identification of SRC-associated symptoms was poor, with only 38.9% of SRC signs and symptoms being correctly identified by 27 Soccer coaches (Broglia et al., 2010). Otherwise, studies consistently reported high proficiency in identifying common physical symptoms of SRC such as 'confusion', 'dizziness', 'headache' and 'loss of consciousness' (Chrisman et al., 2014; Clacy et al., 2016; Esquivel et al., 2013; Faure and Pemberton, 2011; Fraas et al., 2014; Guilmette et al., 2009; Guo et al., 2017). Conversely, identification of emotional and psychological symptoms of SRC such as 'nervousness', 'sleep disturbance' and 'behavioural change' were reported to be poor in a third of the studies. Regarding the perception that loss of consciousness is present in all players suffering SRC, eight studies reported correct understanding amongst majority of coaches and officials, while three studies by Kroshus et al. (2016b), King et al. (2010) and Valovich McLeod et al. (2007) identified more than 30% of coaches holding the false perception.

Only one study directly compared concussion symptoms recognition scores between coaches and referees, which revealed a marginally but significantly higher score amongst referees (Mathema et al., 2016).

**Initial management of concussion:** Twenty-two studies (Refer to Table 2) assessed for knowledge on immediate management of SRC. More than half of the studies reported general awareness amongst majority of coaches and officials of the importance of immediate removal from play and medical referral. A study by McLeod et al. (2007) highlighted that 32.7% of coaches felt that concussion without loss of consciousness does not necessitate removal from play and Kroshus et al. (2016b) reported that 28.4% of coaches thought it was safe to return a player to game if symptoms lasted less than 15 minutes. Mathema et al. (2016) revealed that a higher proportion of officials, compared to coaches, were more likely to remove players who were 'knocked out' but felt fine without

other symptoms of concussion (85% vs 61%) and those who showed signs of concussion but subsequently felt fine (94% vs 86%).

**Return to play (RTP)/subsequent management:** Nineteen studies (Refer to Table 2) assessed knowledge on RTP and subsequent management, of which only three included officials (Griffin et al., 2017; Hunt et al., 2018; King et al., 2010). Two studies reported poor RTP knowledge amongst more than 300 officials in total (Griffin et al., 2017; Hunt et al., 2018) while all three referees assessed in the study by King et al. (2010) agreed that players displaying any sign or symptoms of concussion should not be allowed to return to play. Nine studies reported a general awareness amongst coaches that RTP decision should be guided by physicians after medical clearance. Studies by Faure and Pemberton (2011), Niederer et al. (2018) and Chrisman et al. (2014) revealed that a large proportion of coaches were unfamiliar with graduated RTP or other systematic approaches to making RTP decisions.

**Prevention of concussion:** Nine studies (Refer to Table 2) assessed knowledge on prevention of SRC, four (Clacy et al., 2016; Griffin et al., 2017; King et al., 2010; Mathema et al., 2016) of which included officials. The majority of coaches and officials in the studies believed that protective equipment such as headgears was preventive of SRC. Kroshus et al. (2016a) reported that coaches who previously received concussion education were less likely to think that wearing a helmet prevents SRC. Clacy et al. (2016) reported a difference in self-perceived roles in prevention of SRC amongst rugby coaches and match officials; coaches focused on "training properly" and "teaching /correcting technique" while officials aim to "facilitate safe play" and "follow formal guidelines about safe play".

**Consequences of concussion:** Seven studies (Refer to Table 2) assessed knowledge on consequences of SRC, three of which included officials (Griffin et al., 2017;

**Table 3. Appraisal Tool for Cross-Sectional Studies (AXIS).**

Assessment criteria	No. of satisfactory studies
1. Were the aims/objectives of the study clear?	27
2. Was the study design appropriate for the stated aim(s)?	27
3. Was the sample size justified?	24
4. Was the target/reference population clearly defined? (Is it clear who the research was about?)	26
5. Was the sample frame taken from an appropriate population base so that it closely represented the target/reference population under investigation?	22
6. Was the selection process likely to select subjects/participants that were representative of the target/reference population under investigation?	2
7. Were measures undertaken to address and categorise non-responders?	1
8. Were the risk factor and outcome variables measured appropriate to the aims of the study?	27
9. Were the risk factor and outcome variables measured correctly using instruments/measurements that had been trialled, piloted or published previously?	17
10. Is it clear what was used to determined statistical significance and/or precision estimates? (e.g. p-values, confidence intervals)	24
11. Were the methods (including statistical methods) sufficiently described to enable them to be repeated?	24
12. Were the basic data adequately described?	27
13. Does the response rate raise concerns about non-response bias?	7
14. If appropriate, was information about non-responders described?	1
15. Were the results internally consistent?	24
16. Were the results presented for all the analyses described in the methods?	27
17. Were the authors' discussions and conclusions justified by the results?	27
18. Were the limitations of the study discussed?	24
19. Were there any funding sources or conflicts of interest that may affect the authors' interpretation of the results?	20
20. Was ethical approval or consent of participants attained?	27

King et al., 2010; Mathema et al., 2016). The majority of coaches and officials were aware of consequences of SRC and their long-term health consequences. Using the same set of questionnaires, two studies compared concussion consequence knowledge between coaches and referees (Griffin et al., 2017; Mathema et al., 2016). Griffin et al. (2017) reported a mean score of 11.7 out of 16, with no difference between Welsh amateur rugby coaches and referees, while Mathema et al. (2016) reported a higher mean score of 12 out of 16 amongst Welsh professional and semi-professional rugby referees, compared to coaches with a mean score of 10.5. Gaps in knowledge regarding long-term consequences like early-onset cognitive and memory deficits were also reported in the study by Griffin et al. (2017).

**Prior concussion education and desire for concussion education:** Ten studies (Broglia et al., 2010; Chrisman et al., 2014; Faure and Pemberton, 2011; Fraas et al., 2014; Hossler et al., 2013; Kroshus et al., 2016a; Mathema et al., 2016; Naftel et al., 2014; O'Donoghue et al., 2009; Valovich McLeod et al., 2007) assessing for level of prior education on SRC amongst coaches or officials revealed varied results. In the United States, two studies involving high school coaches (Chrisman et al., 2014; Faure and Pemberton, 2011) and one (Kroshus et al., 2016a) involving college coaches reported that the majority of coaches have received prior education on SRC. This is in comparison to seven other studies (Broglia et al., 2010; Fraas et al., 2014; Hossler et al., 2013; Mathema et al., 2016; Naftel et al., 2014; O'Donoghue et al., 2009; Valovich McLeod et al., 2007) reporting that less than 50% of coaches had received formal education on SRC. Math-

ema et al. (2016) reported that 55% of referees had received prior concussion education. All five studies comparing concussion knowledge between those with prior concussion education and those without revealed a significantly higher concussion knowledge score in the former group (Griffin et al., 2017; Hossler et al., 2013; Kroshus et al., 2016a; O'Donoghue et al., 2009; Valovich McLeod et al., 2007).

Nine studies (Faure and Pemberton, 2011; Fraas et al., 2014; Griffin et al., 2017; Guo et al., 2017; Kroshus et al., 2016a; Mathema et al., 2016; Naftel et al., 2014; Niederer et al., 2018; O'Donoghue et al., 2009) enquired about desire for education on SRC, with majority of coaches and officials reporting their interest and need for further education on SRC. Three studies (Griffin et al., 2017; Guo et al., 2017; Mathema et al., 2016) reported that integration into pre-existing training courses, online courses and websites were the preferred format of SRC education amongst coaches and officials.

## Discussion

**Overall SRC knowledge and knowledge gaps:** The level of knowledge regarding identification, initial management and RTP in SRC was moderate amongst majority of coaches and match officials. Most could identify common signs and symptoms of SRC, understood the importance of immediate removal from play and returned players to play only under the guidance of medical advice. However, important gaps in knowledge were still present and telling in recognition, management and prevention of SRC. For example, while coaches and officials recognised common physical and cognitive signs and symptoms of SRC, most

failed to recognise emotional signs and symptoms as well as sleep disturbances. A study involving over four hundred participants with minor to severe traumatic brain injury revealed that the prevalence of insomnia symptoms to be as high as 50.2% (Ouellet et al., 2006). Furthermore, not only is insomnia distressing (Department of Veterans Affairs, 2009), the presence of sleep disturbance has been associated with prolonged recovery time (Bramley et al., 2016). Mental health sequelae such as depression have also been found to be associated with SRC (Rice et al., 2017), and given that psychiatric symptoms are commonly under-reported (Meier et al., 2015), improving knowledge of such symptoms may expedite the recognition of such concussion-related issues. This is particularly important for coaches who have continued interaction with players beyond the initial injury.

While the majority of coaches and officials understood that loss of consciousness is not a necessary feature for the diagnosis of concussion, a significant proportion of coaches failed to recognise and appropriately manage SRC without loss of consciousness (Valovich McLeod et al., 2007). It is known that loss of consciousness is not predictive of the severity of or recovery from SRC (Splete, 2002) and players should still be immediately removed from play and managed accordingly. While coaches and officials rightfully rely on medical advice regarding RTP decision, most were unfamiliar with the concept of graduated RTP as recommended by international consensus since the first International Conference on Concussion in Sport in 2001 (Aubry, 2002) and reiterated in the 5<sup>th</sup> International Conference on Concussion in Sport (McCrory et al., 2017). Graduated RTP involves progressively stepping up activity from symptom-limited to light aerobic exercises, followed by sport-specific exercises, non-contact and full contact practise before returning to sport, with at least 24 hours for each step of progression (Table 4). Even though such protocols are prescribed by physicians, coaches are often intimately involved in administering them and ensuring that the level of activity progression is appropriate. Understanding the concept of symptom-exacerbation threshold and applying it to encourage sub-threshold level of progressive activity can safely improve post-concussion symptoms, hasten recovery and restore function (Leddy et al., 2018). With their expertise in the specific sport, these can be further tailored to the individual player and sport. Hence a collaborative approach to RTP amongst clinicians, coaches and athletes is recommended (Ardern et al., 2016).

Regarding concussion prevention, the misconception that headgears had a protective role against SRC was commonly held amongst coaches and officials

(Griffin et al., 2017; King et al., 2010; Kroshus et al., 2016b; Mathema et al., 2016; Mrazik et al., 2011; White et al., 2014). Meta-analysis suggests that preventive equipment like headgears and mouth pieces may prevent superficial head injury but do not reduce the relative risk of SRC (Schneider et al., 2017). In fact, one study amongst American football high school players revealed that poor helmet fit was associated with more symptoms and longer symptom duration (Greenhill et al., 2016). Such preconceptions are clinically relevant and dangerous: it has been found that players tend to play more aggressively when using headgear, possibly due to the misconception of a headgear's concussion preventive efficacies (Menger et al., 2016). A recent randomised controlled trial likewise revealed that the use of helmet in American football was associated with increase head impact exposure (Swartz et al., 2019). Coaches should play a role in challenging and correcting such ideas and focusing on improving equipment fitting, tackling technique and strategies to reduce player-to-player contact. Such measures were advocated in the Heads-Up Football programme, which, when implemented alongside practice regulations on player-player contact, have been found to lower injury rates and concussion rates amongst players of ages 11 to 15 (Kerr et al., 2015). Officials can also play a role in the prevention of SRC by stricter enforcement of rules, such as red cards for high elbows in head duels in professional soccer which has been shown to reduce the risk of head contact and concussion (Beaudouin et al., 2019).

**Comparison of SRC knowledge between coaches and officials:** Amongst the few studies comparing SRC knowledge between the two groups (King et al., 2010; Mathema et al., 2016), officials fared better in identifying and instigating initial management of SRC but had poorer knowledge regarding RTP. This may be influenced by the roles these personnel play, where officials “facilitate safe play” and “follow formal guidelines about safe play” while coaches focus on “training properly” and “teaching /correcting technique”. Notably, unlike officials, coaches may also have a personal agenda and adopt a “win-at-all-cost” mentality which may account for the difference in attitude towards recognising and removing players who sustained a SRC (Cusimano et al., 2017). Officials are in the position to call for timeouts during games for the medical evaluation of possible injuries by athletic trainers and physicians. On the other hand, officials are seldom involved in the RTP process, which is usually dictated by medical professionals and administered by the coaches.

**Lack of standardised questionnaire in testing concussion knowledge:** Almost half of the studies utilised

**Table 4. Graduated Return-to-sport strategy (McCrory et al., 2017).**

Stage	Aim	Activity	Goal at each step
1	Symptom-limited activity	Daily activities that do not provoke symptoms	Gradual reintroduction of work/school activities
2	Light aerobic exercise	Walking or stationary cycling at slow or medium pace. No resistance training.	Increase heart rate
3	Sport-specific exercise	Running or skating drills. No head impact activities	Add movement
4	Non-contact training drills	Harder training drills, e.g. passing drills. May start progressive resistance training.	Exercise, coordination and increased thinking
5	Full contact training	Following medical clearance, participate on normal training activities.	Restore confidence and assess functional skills by coaching staff
6	Return to sport	Normal game play	



original questionnaires to assess concussion knowledge. Some original questionnaires were crafted to examine other factors related to concussion knowledge such as behaviour determinants (Kroshus et al., 2017a), perceived responsibilities (Clacy et al., 2016) and knowledge translation (Guo et al., 2017). In terms of assessment of concussion knowledge, a variety of questionnaires were employed, including yes/no, Likert scale, multiple choice and open-ended questions. Some tested knowledge on SRC via direct questions while others were situational and complex, for example, assessing knowledge of concussion recognition and removal from play within one question based on a specific scenario. The lack of a standardised and validated questionnaire hinders head-to-head comparison of concussion knowledge amongst different study populations. The questionnaires developed by Mathema et al. (2016) assessed for symptom recognition, management, RTP, prevention and consequences of SRC comprehensively, providing quantitative scores for symptom recognition, RTP and consequences. The questionnaires were customised to be unique and role-specific for the various subject populations, namely coaches, referees, players and medical staff. King et al. (2010) adapted various tools from previously published studies and created a similar questionnaire assessing the different domains of SRC knowledge and providing quantitative scores. These studies were comprehensive in the assessment of concussion knowledge and future studies assessing concussion knowledge should consider applying these questionnaires to allow for better comparison between different study populations.

**Selection bias:** Most studies included in this review have utilised an opt-in method in engaging participants, had low response rates and did not manage to account for non-responders. These factors contribute to a selection bias as participants who agree to partake in the questionnaires may have better concussion knowledge or more interest in the topic of SRC. Those with less concussion knowledge may be less willing to partake in the study, despite anonymity of study measures. However, “opt-out” methods are often deemed to violate the ethical principles in consent taking and thus difficult to employ. Balancing gold-standard research design and ethical considerations, over-representation of concussion knowledge should be suspected and considered in most studies.

**Impact of education on concussion knowledge:** The level of concussion education amongst coaches and officials appear to be inadequate despite increasing efforts to increase awareness with less than 50% of personnel having prior education in many studies (Broglio et al., 2010; Fraas et al., 2014; Hossler et al., 2013; Mathema et al., 2016; Naftel et al., 2014; O'Donoghue et al., 2009; Valovich McLeod et al., 2007). It is however reassuring that concussion knowledge is consistently higher amongst those with prior education on SRC group (Griffin et al., 2017; Hossler et al., 2013; Kroshus et al., 2016a; O'Donoghue et al., 2009; Valovich McLeod et al., 2007). This suggests that there is much room for further education programmes to improve awareness of SRC amongst these

key stakeholders. Beyond applying their knowledge to recognition and management of SRC, coaches also have an active role in educating players about SRC. A study assessing high school rugby player's SRC knowledge revealed that majority of athletes obtain information on SRC from teachers and coaches (Sye et al., 2006). Furthermore, anticipated response from coaches to concussion reporting has been found to be a significant barrier to self-reporting of SRC amongst both high school (Cranmer and LaBelle, 2018) and college athletes (Delaney et al., 2015). Breaking the stigma of negative coach responses regarding SRC reporting could significantly increase SRC recognition and reduce delay to medical attention. A recent study found significantly lower rates of SRC and faster return to full participation amongst high school football players with coaches who underwent Centers for Disease Control and Prevention's (CDC) Head's Up programme (Shanley et al., 2019).

**Ethical considerations in management of concussion:** Several studies also explored ethical issues that may affect the management of SRC. In the study by Bramley et al. (2011), more than 300 coaches were given scenarios for which they would indicate whether or not they were likely to allow a player to continue play. Worryingly, only 80.8% of coaches indicated that they would remove an elite player from play if he sustained a concussion not limiting his ability to play during the early part of a championship game with many college scouts attending, compared to 99.0% and 80.3% for a player who sustained a severe and minor concussion without any context respectively. Kroshus et al. (2016b) found a significantly larger proportion of coaches believed that an athlete should continue wrestling after sustaining SRC in a regional qualifier for the NCAA tournament compared to the first match of the season. These findings suggest that other than knowledge, contextual considerations such as the importance of the match or the role of the player involved also influence coaching decisions on SRC management. There is a lack of literature regarding the translation of SRC knowledge to safe practise in the field and future research could investigate other factors affecting coaches' and official's immediate management and RTP decisions in SRC.

**Future considerations in SRC education:** The internet has been increasingly used as an educational tool in many fields, with online courses and websites being commonly preferred means of education amongst coaches and officials. To be effective, online learning programmes need to be user-friendly, updated regularly and administratively friendly (Blamey et al., 2004). Several studies have demonstrated the effectiveness of online education programmes on SRC, such as the “Concussion in Sports: What You Need to Know” by CDC (Parker et al., 2015), and ACTive: Athletic Concussion Training using Interactive Video Education (Glang et al., 2010). The use of mobile applications not only provide educational information but can also be equipped with tools to aid in the recognition and immediate management of SRC. One such example is the “Concussion Recognition and

Response” mobile app (Shurlock and Kelly, 2017) developed based on CDC guidelines on SRC. Future studies can explore the efficacy of such mobile health apps.

Apart from imparting SRC knowledge, educational programmes can also encourage learning based on coaches’ own experiences with concussion. Guiding coaches to reflect on their own experiences in recognising and managing concussion can help coaches to tie in theoretical knowledge and practical applications. Reflective learning amongst coaches involves six components: 1) Identifying the coaching issues, 2) Role framing, 3) Issue setting, 4) Strategy generation, 5) Experimenting and 6) Evaluation (Gilbert and Trudel, 2001). Of note, role framing involves examining the relationship between ethics, values, attitudes and practise for each individual (Nelson and Cushion, 2006). The coaching issue is identified based on the coaches’ individual experiences and coaching approach, and strategies to overcome these challenges can be discussed, implemented and evaluated. This allows for both knowledge and ethical factors to be addressed in such reflecting learning processes.

### Limitations & future research

This systematic review was limited to studies in English due to lack of available translated sources. This may have accounted for the poor representation amongst countries beyond the Western hemisphere. Notably, other than two studies from Australia and one from New Zealand, there were no other reports on concussion knowledge levels amongst coaches or officials within the rest of the Asia-Pacific region. While this could highlight the lack of investigation into SRC knowledge within these regions, selection bias cannot be excluded.

A more detailed comparison of SRC knowledge across studies was limited by the lack of standardised methodology. It also limits the evaluation of the effectiveness of concussion education policies across various sporting tiers, countries or sports which could account for the variability in reported knowledge levels.

Although other important stakeholders such as team physicians, athletic trainers and parents were excluded from this systematic review, team physicians are invaluable in providing on-site concussion assessment and providing return-to-play advice, while athletic trainers and parents play an important role in education as well as encouraging care-seeking behaviour amongst youth athletes. Future works could assess SRC knowledge amongst these important stakeholders in prevention, recognition and management of SRC.

### Conclusion

This systematic review summarises the existing literature for SRC knowledge amongst sports coaches and match officials, highlighting important knowledge gaps in identification, management, RTP, prevention and consequences of SRC. While legislation and provision of education toolkits are a step in the right direction, there is much room for improvement regarding knowledge levels amongst important stakeholders in concussion prevention, recognition and management. Given that majority of coaches and officials

are keen on seeking further education on SRC, accessibility of such educational programmes and information sources should be improved.

Beyond knowledge, further research is needed to investigate other factors contributing to prevention, recognition and management of SRC. A more reflective approach to concussion education can help coaches and officials integrate theoretical knowledge and its practical application.

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### References

- Arderm, C.L., Glasgow, P., Schneiders, A., Witvrouw, E., Clarsen, B., Cools, A., Gojanovic, B., Griffin, S., Khan, K.M., Moksnes, H., Mutch, S.A., Phillips, N., Reurink, G., Sadler, R., Gräware Silbernagel, K., Thorborg, K., Wangensteen, A., Wilk, K.E. and Bizzini, M. (2016) 2016 Consensus statement on return to sport from the First World Congress in Sports Physical Therapy, Bern. *British Journal of Sports Medicine* **50**, 853-864.
- Aubry, M. (2002) Summary and agreement statement of the first International Conference on Concussion in Sport, Vienna 2001. *British Journal of Sports Medicine* **36**, 6-7.
- Baugh, C.M., Kroshus, E., Daneshvar, D.H. and Stern, R.A. (2014) Perceived Coach Support and Concussion Symptom-Reporting: Differences between Freshmen and Non-Freshmen College Football Players. *The Journal of Law, Medicine & Ethics* **42**, 314-322.
- Beaudouin, F., aus der Fünter, K., Tröb, T., Reinsberger, C. and Meyer, T. (2019) Head injuries in professional male football (soccer) over 13 years: 29% lower incidence rates after a rule change (red card). *British Journal of Sports Medicine* **53**, 948-952.
- Belechri, M., Petridou, E., Kedikoglou, S. and Trichopoulos, D. (2001) Sports injuries among children in six European union countries. *European Journal of Epidemiology* **17**, 1005-1012, 2001/11/01.
- Benson, B.W., McIntosh, A.S., Maddocks, D., Herring, S.A., Raftery, M. and Dvořák, J. (2013) What are the most effective risk-reduction strategies in sport concussion? *British Journal of Sports Medicine* **47**, 321-326.
- Blamey, P.J., Martin, L.F.A. and Fiket, H.J. (2004) A Digital Processing Strategy to Optimize Hearing Aid Outputs Directly. *Journal of the American Academy of Audiology* **15**, 716-728.
- Bramley, H., Henson, A., Lewis, M.M., Kong, L., Stetter, C. and Silvis, M. (2016) Sleep Disturbance Following Concussion Is a Risk Factor for a Prolonged Recovery. *Clinical Pediatrics* **56**, 1280-1285.
- Bramley, H., Kroft, C., Polk, D., Newberry, T. and Silvis, M. (2011) Do Youth Hockey Coaches Allow Players With a Known Concussion to Participate in a Game? *Clinical Pediatrics* **51**, 283-287.
- Broglio, S.P., Vagnozzi, R., Sabin, M., Signoretti, S., Tavazzi, B. and Lazzarino, G. (2010) Concussion occurrence and knowledge in Italian football (soccer). *Journal of Sports Science and Medicine* **9**, 418-30.
- Buckland, M.E., Sy, J., Szentmariay, I., Kullen, A., Lee, M., Harding, A., Halliday, G. and Suter, C.M. (2019) Chronic traumatic encephalopathy in two former Australian National Rugby League players. *Acta Neuropathologica Communications* **7**, 97.
- Chrisman, S.P., Schiff, M.A., Chung, S.K., Herring, S.A. and Rivara, F.P. (2014) Implementation of Concussion Legislation and Extent of Concussion Education for Athletes, Parents, and Coaches in Washington State. *The American Journal of Sports Medicine* **42**, 1190-1196.
- Clacy, A., Goode, N., Sharman, R., Lovell, G.P. and Salmon, P.M. (2016) A knock to the system: A new sociotechnical systems approach to sport-related concussion. *Journal of Sports Science* **35**, 2232-2239.
- Cranmer, G.A. and LaBelle, S. (2018) Using the Disclosure Decision-Making Model to Understand High School Football Players’ Disclosures of Concussion Symptoms. *International Journal of Sport Communication* **11**, 241-260.

- Cusimano, M.D., Topolovec-Vranic, J., Zhang, S., Mullen, S.J., Wong, M. and Ilie, G. (2017) Factors Influencing the Underreporting of Concussion in Sports: A Qualitative Study of Minor Hockey Participants. *Clinical Journal of Sport Medicine* **27**, 375-380.
- Daneshvar, D.H., Nowinski, C.J., McKee, A.C. and Cantu, R.C. (2011) The Epidemiology of Sport-Related Concussion. *Clinics in sports medicine* **30**, 1-17.
- Delaney, J.S., Lamfookon, C., Bloom, G.A., Al-Kashmiri, A. and Correa, J.A. (2015) Why University Athletes Choose Not to Reveal Their Concussion Symptoms During a Practice or Game. *Clinical Journal of Sport Medicine* **25**, 113-125.
- Department of Veterans Affairs, D.o.D., USA. (2009) VA/DoD clinical practice guideline for management of concussion/mild traumatic brain injury. *Journal of Rehabilitation Research & Development* **46**, 1-68.
- Downes, M.J., Brennan, M.L., Williams, H.C. and Dean, R.S. (2016) Development of a critical appraisal tool to assess the quality of cross-sectional studies (AXIS). *BMJ Open* **6**, e011458.
- Echemendia, R.J., Meeuwisse, W., McCrory, P., Davis, G.A., Putukian, M., Leddy, J., Makdissi, M., Sullivan, S.J., Broglio, S.P., Raftery, M., Schneider, K., Kissick, J., McCrea, M., Dvorak, J., Sills, A.K., Aubry, M., Engebretsen, L., Lossemore, M., Fuller, G., Kutcher, J., Ellenbogen, R., Guskiewicz, K., Patricios, J. and Herring, S. (2017a) The Sport Concussion Assessment Tool 5th Edition (SCAT5). *British Journal of Sports Medicine* **51**, 848-850.
- Echemendia, R.J., Meeuwisse, W., McCrory, P., Davis, G.A., Putukian, M., Leddy, J., Makdissi, M., Sullivan, S.J., Broglio, S.P., Raftery, M., Schneider, K., Kissick, J., McCrea, M., Dvorak, J., Sills, A.K., Aubry, M., Engebretsen, L., Lossemore, M., Fuller, G., Kutcher, J., Ellenbogen, R., Guskiewicz, K., Patricios, J. and Herring, S. (2017b) The Concussion Recognition Tool 5th Edition (CRT5). *British Journal of Sports Medicine* **51**, 870-871.
- Emery, C.A., Black, A.M., Kolstad, A., Martinez, G., Nettel-Aguirre, A., Engebretsen, L., Johnston, K., Kissick, J., Maddocks, D., Tator, C., Aubry, M., Dvořák, J., Nagahiro, S. and Schneider, K. (2017) What strategies can be used to effectively reduce the risk of concussion in sport? A systematic review. *British Journal of Sports Medicine* **51**, 978-984.
- Esquivel, A., Haque, S., Keating, P., Marsh, S. and Lemos, S. (2013) Concussion Management, Education, and Return-to-Play Policies in High Schools. *Sports Health: A Multidisciplinary Approach* **5**, 258-262.
- Faure, C.E. and Pemberton, C.L.A. (2011) An Examination of Idaho high school football coaches' general understanding of concussion. (Report). *The Sport Journal* **14**.
- Fraas, M.R., Coughlan, G.F., Hart, E.C. and McCarthy, C. (2014) Concussion knowledge and management practices among coaches and medical staff in Irish professional rugby teams. *Irish Journal of Medical Science (1971 -)* **184**, 425-430.
- Gibson, T.B., Herring, S.A., Kutcher, J.S. and Broglio, S.P. (2015) Analyzing the Effect of State Legislation on Health Care Utilization for Children With Concussion. *JAMA Pediatrics* **169**, 163-168.
- Gilbert, W.G. and Trudel, P. (2001) Learning to Coach Through Experience: Reflection in Model Youth Sport Coaches. *Journal of Teaching in Physical Education* **21**, 16-34.
- Glang, A., Koester, M.C., Beaver, S., Clay, J. and McLaughlin, K. (2010) Online Training in Sports Concussion for Youth Sports Coaches. *Int J Sports Sci Coach* **5**, 1-11.
- Graham, R., Rivara, F.P., Ford, M.A., Spicer, C.M., Youth, C.o.S.-R.C.i. and Council, N.R. (2014) *Sports-related concussions in youth: improving the science, changing the culture*. National Academies Press (US).
- Greenhill, D.A., Navo, P., Zhao, H., Torg, J., Comstock, R.D. and Boden, B.P. (2016) Inadequate Helmet Fit Increases Concussion Severity in American High School Football Players. *Sports Health: A Multidisciplinary Approach* **8**, 238-243.
- Griffin, S.A., Ranson, C., Moore, I. and Mathema, P. (2017) Concussion knowledge and experience among Welsh amateur rugby union coaches and referees. *BMJ Open Sport Exercise and Medicine* **3**, e000174.
- Guilmette, T.J., Malia, L.A. and McQuiggan, M.D. (2009) Concussion understanding and management among New England high school football coaches. *Brain Injury* **21**, 1039-1047.
- Guo, D., Verweel, L. and Reed, N. (2017) Exploring Gaps in Concussion Knowledge and Knowledge Translation Among Coaches of Youth Female Hockey. *Clinical Journal of Sport Medicine*.
- Haran, H.P., Bressan, S., Oakley, E., Davis, G.A., Anderson, V. and Babl, F.E. (2016) On-field management and return-to-play in sports-related concussion in children: Are children managed appropriately? *Journal of Science and Medicine in Sport* **19**, 194-199.
- Harmon, K.G., Drezner, J.A., Gammons, M., Guskiewicz, K.M., Halstead, M., Herring, S.A., Kutcher, J.S., Pana, A., Putukian, M. and Roberts, W.O. (2013) American Medical Society for Sports Medicine position statement: concussion in sport. *British Journal of Sports Medicine* **47**, 15-26.
- Harrison, E.A. (2014) The First Concussion Crisis: Head Injury and Evidence in Early American Football. *American Journal of Public Health* **104**, 822-833.
- Hossler, P., Phang, K.-A. and Passannante, M. (2013) New Jersey Coaches' Knowledge in Recognizing and Managing Concussion. *Internet Journal of Allied Health Sciences and Practice* **11**, 10-18.
- Hunt, C., Michalak, A., Johnston, E., Lefkimmatis, C., Macumber, L., Jocko, T. and Ouchterlony, D. (2018) Knowledge, Attitudes and Concussion Information Sources Among First Nations in Ontario. *Canadian Journal of Neurological Sciences* **45**, 283-289.
- Innovation, V.H. (2017) *Covidence systematic review software*. Veritas Health Innovation Melbourne, VIC.
- Kerr, Z.Y., Yeargin, S., Valovich McLeod, T.C., Nittoli, V.C., Mensch, J., Dodge, T., Hayden, R. and Dompier, T.P. (2015) Comprehensive Coach Education and Practice Contact Restriction Guidelines Result in Lower Injury Rates in Youth American Football. *Orthopaedic Journal of Sports Medicine* **3**.
- King, D., Hume, P. and Clark, T. (2010) First-aid, concussion knowledge of rugby league team management, administrators and officials in New Zealand. *New Zealand Journal of Sports Medicine* **37**, 56-68.
- Kirk, B., Pugh, J., Cousins, R. and Phillips, S. (2018) Concussion in University Level Sport: Knowledge and Awareness of Athletes and Coaches. *Sports* **6**, 102-108.
- Kroshus, E., Baugh, C.M. and Daneshvar, D.H. (2016a) Content, Delivery, and Effectiveness of Concussion Education for US College Coaches. *Clinical Journal of Sport Medicine* **26**, 391-397.
- Kroshus, E., Kerr, Z.Y., DeFreese, J.D. and Parsons, J.T. (2016b) Concussion Knowledge and Communication Behaviors of Collegiate Wrestling Coaches. *Health Commun* **32**, 963-969.
- Kroshus, E., Parsons, J. and Hainline, B. (2017a) Calling Injury Timeouts for the Medical Evaluation of Concussion: Determinants of Collegiate Football Officials' Behavior. *Journal of Athletic Training* **52**, 1041-1047.
- Kroshus, E., Rivara, F.P., Whitlock, K.B., Herring, S.A. and Chrisman, S.P.D. (2017b) Disparities in Athletic Trainer Staffing in Secondary School Sport: Implications for Concussion Identification. *Clinical Journal of Sport Medicine* **27**, 542-547.
- Kushner, D. (1998) Mild Traumatic Brain Injury. *Archives of Internal Medicine* **158**, 1617-1624.
- Leddy, J.J., Haider, M.N., Ellis, M. and Willer, B.S. (2018) Exercise is Medicine for Concussion. *Current Sports Medicine Reports* **17**, 262-270, Aug.
- Liberati, A., Altman, D.G., Tetzlaff, J., Mulrow, C., Gotzsche, P.C., Ioannidis, J.P.A., Clarke, M., Devereaux, P.J., Kleijnen, J. and Moher, D. (2009) The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate healthcare interventions: explanation and elaboration. *BMJ* **339**, b2700-b2700.
- M. O'Donoghue, E., Onate, J., Lunen, B. and Peterson, C. (2009) Assessment of High School Coaches' Knowledge of Sport-Related Concussions. *Athletic Training & Sports Health Care* **1**, 120-132.
- Mathema, P., Evans, D., Moore, I.S., Ranson, C. and Martin, R. (2016) Concussed or Not? An Assessment of Concussion Experience and Knowledge Within Elite and Semiprofessional Rugby Union. *Clinical Journal of Sport Medicine* **26**, 320-325.
- McCrory, P., Meeuwisse, W., Dvorak, J., Aubry, M., Bailes, J., Broglio, S., Cantu, R.C., Cassidy, D., Echemendia, R.J., Castellani, R.J., Davis, G.A., Ellenbogen, R., Emery, C., Engebretsen, L., Feddermann-Demont, N., Giza, C. C., Guskiewicz, K. M.,



- Herring, S., Iverson, G.L., Johnston, K.M., Kissick, J., Kutcher, J., Leddy, J.J., Maddocks, D., Makdissi, M., Manley, G.T., McCrea, M., Meehan, W.P., Nagahiro, S., Patricios, J., Putukian, M., Schneider, K.J., Sills, A., Tator, C.H., Turner, M. and Vos, P.E. (2017) Consensus statement on concussion in sport—the 5th international conference on concussion in sport held in Berlin, October 2016. *British Journal of Sports Medicine* **51**, 838-847.
- McKee, A.C. and Daneshvar, D.H. (2015) The neuropathology of traumatic brain injury. In: *Traumatic Brain Injury, Part I*. Eds: Grafman, J. and Salazar, A.M. Elsevier. 45-66.
- Meier, T.B., Brummel, B.J., Singh, R., Nerio, C.J., Polanski, D.W. and Bellgowan, P.S.F. (2015) The underreporting of self-reported symptoms following sports-related concussion. *Journal of Science and Medicine in Sport* **18**, 507-511.
- Menger, R., Menger, A. and Nanda, A. (2016) Rugby headgear and concussion prevention: misconceptions could increase aggressive play. *Neurosurgery Focus* **40**, E12-18.
- Mrazik, M., Bawani, F. and Krol, A.L. (2011) Sport-Related Concussions: Knowledge Translation Among Minor Hockey Coaches. *Clinical Journal of Sport Medicine* **21**, 315-319.
- Mullally, W.J. (2017) Concussion. *The American Journal of Medicine* **130**, 885-892.
- Naftel, K.G., Yust, E.M., Nichols, M.H., King, W.D. and Davis, D. (2014) Knowledge and Management of Sports Concussions among Coaches and Certified Athletic Trainers in Alabama. *Southern Medical Journal* **107**, 418-425.
- Nelson, L.J. and Cushion, C.J. (2006) Reflection in Coach Education: The Case of the National Governing Body Coaching Certificate. *Sport Psychologist* **20**, 174-183.
- Niederer, D., Engeroff, T., Lange, K., Vogt, L. and Banzer, W. (2018) Return-to-play after concussion: state of knowledge, frequency of use and application barriers of guidelines among decision-makers in rugby. *Brain Injury* **32**, 1096-1102.
- O'Donoghue, E.M., Onate, J.A., Van Lunen, B. and Peterson, C.L. (2009) Assessment of High School Coaches' Knowledge of Sport-Related Concussions. *Athletic Training & Sports Health Care* **1**, 120-132.
- Ouellet, M.C., Beaulieu-Bonneau, S. and Morin, C.M. (2006) Insomnia in patients with traumatic brain injury: frequency, characteristics, and risk factors. *Journal of Head Trauma Rehabilitation* **21**, 199-212.
- Parker, E.M., Gilchrist, J., Schuster, D., Lee, R. and Sarmiento, K. (2015) Reach and knowledge change among coaches and other participants of the online course: "concussion in sports: what you need to know". *Journal of Head Trauma Rehabilitation* **30**, 198-206.
- Patel, D.R., Fidrocki, D. and Parachuri, V. (2017) Sport-related concussions in adolescent athletes: a critical public health problem for which prevention remains an elusive goal. *Translational Pediatrics* **6**, 114-120.
- Rice, S.M., Parker, A.G., Rosenbaum, S., Bailey, A., Mawren, D. and Purcell, R. (2017) Sport-Related Concussion and Mental Health Outcomes in Elite Athletes: A Systematic Review. *Sports Medicine* **48**, 447-465.
- Saunders, E.A., Burdette, G.T., Metzler, J.N., Joyner, A.B. and Buckley, T.A. (2013) Knowledge of Coaching Education Students Regarding Sport-Related Concussions. *Athletic Training & Sports Health Care* **5**, 11-19.
- Schneider, D.K., Grandhi, R.K., Bansal, P., Kuntz, G.E., Webster, K.E., Logan, K., Barber Foss, K.D. and Myer, G.D. (2017) Current state of concussion prevention strategies: a systematic review and meta-analysis of prospective, controlled studies. *British Journal of Sports Medicine* **51**, 1473-1482.
- Shanley, E., Thigpen, C., Kissenberth, M., Gilliland, R.G., Thorpe, J., Nance, D., Register-Mihalik, J.K. and Tokish, J. (2019) Heads Up Football Training Decreases Concussion Rates in High School Football Players. *Clinical Journal of Sport Medicine*.
- Shroyer, J. and Stewart, C. (2016) Knowledge of Concussions by High School Coaches in a Rural Environment. *The Physical Educator* **73**, 373-387.
- Shurlock, J. and Kelly, S. (2017) Concussion recognition and response: instant pitch-side assessment? *British Journal of Sports Medicine* **51**, 543-544.
- Sirisena, D., Walter, J. and Probert, J. (2017) National Football League concussion lawsuit: what it means for other sports and observations from Singapore Rugby. *British Journal of Sports Medicine* **51**, 696-697.
- Splete, H. (2002) Predicting recovery after a concussion. (Loss of Consciousness not Key Factor). In: *Family Practice News*. Vol. 32, pp. 1+.
- Swartz, E.E., Myers, J.L., Cook, S.B., Guskiewicz, K.M., Ferrara, M.S., Cantu, R.C., Chang, H. and Broglio, S.P. (2019) A helmetless-tackling intervention in American football for decreasing head impact exposure: A randomized controlled trial. *Journal of Science and Medicine in Sport* **22**, 1102-1107.
- Sye, G., Sullivan, S.J., McCrory, P. and Milne, C. (2006) High school rugby players' understanding of concussion and return to play guidelines \* Commentary. *British Journal of Sports Medicine* **40**, 1003-1005.
- Tagge, C.A., Fisher, A.M., Minaeva, O.V., Gaudreau-Balderrama, A., Moncaster, J.A., Zhang, X.-L., Wojnarowicz, M.W., Casey, N., Lu, H., Kokiko-Cochran, O.N., Saman, S., Ericsson, M., Onos, K.D., Veksler, R., Senatorov, V.V., Kondo, A., Zhou, X.Z., Miry, O., Vose, L.R., Gopaul, K.R., Upreti, C., Nowinski, C.J., Cantu, R.C., Alvarez, V.E., Hildebrandt, A.M., Franz, E.S., Konrad, J., Hamilton, J.A., Hua, N., Tripodis, Y., Anderson, A.T., Howell, G.R., Kaufer, D., Hall, G.F., Lu, K.P., Ransohoff, R.M., Cleveland, R.O., Kowall, N.W., Stein, T.D., Lamb, B.T., Huber, B.R., Moss, W.C., Friedman, A., Stanton, P.K., McKee, A.C. and Goldstein, L.E. (2018) Concussion, microvascular injury, and early tauopathy in young athletes after impact head injury and an impact concussion mouse model. *Brain* **141**, 422-458.
- Taylor, M.E. and Sanner, J.E. (2015) The Relationship Between Concussion Knowledge and the High School Athlete's Intention to Report Traumatic Brain Injury Symptoms: A Systematic Review of the Literature. *The Journal of School Nursing* **33**, 73-81.
- Valovich McLeod, T.C., Schwartz, C. and Bay, R.C. (2007) Sport-Related Concussion Misunderstandings Among Youth Coaches. *Clinical Journal of Sport Medicine* **17**, 140-142.
- Wallace, J., Covassin, T., Nogle, S., Gould, D. and Kovan, J. (2017) Knowledge of Concussion and Reporting Behaviors in High School Athletes With or Without Access to an Athletic Trainer. *Journal of athletic training* **52**, 228-235.
- Weerdenburg, K., Schneeweiss, S., Koo, E. and Boutis, K. (2016) Concussion and its management: What do parents know? *Paediatr Child Health* **21**, e22-e26.
- White, P.E., Newton, J.D., Makdissi, M., Sullivan, S.J., Davis, G., McCrory, P., Donaldson, A., Ewing, M.T. and Finch, C.F. (2014) Knowledge about sports-related concussion: is the message getting through to coaches and trainers? *British Journal of Sports Medicine* **48**, 119-124.
- Zhang, A.L., Sing, D.C., Rugg, C.M., Feeley, B.T. and Senter, C. (2016) The Rise of Concussions in the Adolescent Population. *Orthopaedic Journal of Sports Medicine* **4**, 2325967116662458.
- Zhou, Y., Kierans, A., Kenul, D., Ge, Y., Rath, J., Reaume, J., Grossman, R.I. and Lui, Y.W. (2013) Mild Traumatic Brain Injury: Longitudinal Regional Brain Volume Changes. *Radiology* **267**, 880-890.

### Key points

- In general, knowledge on sports-related concussion is moderate amongst coaches and officials, though important knowledge gaps were identified.
- Most coaches and officials express interest in further concussion education, demonstrating room for improvement in current educational programmes

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