Article:
Sokol-Randell, D, Rotundo, MP, Tierney, G orcid.org/0000-0002-4666-4473 et al. (2 more authors) (2021) Frequent but limited assessment of potentially concussed players in Gaelic Football: an opportunity to learn from other sports. Irish Journal of Medical Science (1971 -), 190 (2). pp. 787-792. ISSN 0021-1265

https://doi.org/10.1007/s11845-020-02390-5

Title:

Frequent but limited assessment of potentially concussed players in Gaelic Football: an opportunity to learn from other sports

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Word Count: 2978

Abstract Word Count: 200

Number of Tables: 3

Number of Figures: 0

INTRODUCTION

In recent years, mild Traumatic Brain Injury (mTBI) including Sport-Related Concussion (SRC) has emerged as a major public health concern. The 5th International Conference on Concussion in Sport (ICCS) defined concussion as a change in brain function caused by biomechanical forces.[1] Athletes involved in high-impact sports such as American football, soccer, ice hockey and rugby consistently experience high rates of SRC.[2,3] However, very little data exists on less globalized and amateur sports played around the world.

The Gaelic Athletic Association (GAA) is the largest sporting organization in the Republic of Ireland. One of the most popular sports that the organization presides over is Gaelic Football, a fast-paced contact sport played on a grass pitch that is similar to rugby and soccer.[4.5] Players are required to wear mouthguards, but no helmets are used. Similar to soccer, strategic body contact is encouraged to gain and maintain ball control. Although less contact is permitted in comparison to rugby, the pace and intensity of Gaelic Football gives rise to frequent high-impact

collisions.[4,5] A 2017 survey of 80 GAA athletes revealed that 54% reported a personal history of concussion, with 44% reporting more than one incidence.[6] Confirming this, a 2019 survey suggested that while 57.5% of athletes suspected they had suffered a SRC in the past, many were undiagnosed.[7] SRC awareness in the GAA has increased over recent years, manifesting in the development of the Concussion Management Guidelines for Gaelic Games,[8] an ICCS-based approach to diagnosing and treating SRC. Despite this, management of SRC in an acute setting appears to remain challenging.

The importance of accurate identification, assessment and removal of athletes suspected of having suffered a SRC cannot be understated. Research suggests that suffering multiple concussions in a short period of time may lead to Second Impact Syndrome, a potentially fatal condition characterized by rapid swelling of the brain.[9] In the long-term, research suggests that repeated mTBI over the course of a career may lead to neuro-cognitive and emotional deficits [10,11] as well as neurodegenerative disease such as Chronic Traumatic Encephalopathy.[12] Indeed, professional soccer players are significantly more likely to die from neurodegenerative disease than matched controls.[13]

Recommendations from the ICCS state that players suspected of having sustained a concussion must be removed from play and assessed using an accepted international standardized protocol such as the Sports Concussion Assessment Tool 5 (SCAT-5).[1,14] In Gaelic Football, there is limited research investigating whether this is occurring. However, footage of Gaelic Football matches is widely available, rendering in-game medical decision-making susceptible to scrutiny. Using video incident analysis the present study will investigate PCEs that occurred during the 2018 and 2019 GAA inter-county seasons and championships. The aim of this study is to determine if PCEs in the GAA NFL are assessed in accordance with GAA concussion guidelines, and relate these findings to what is currently occurring in other sports.

METHODS

Video Incident analysis has been demonstrated to be a valid method of analyzing situational factors, mechanisms and signs of injury related to SRC.[15–17] We have previously used and reported a similar methodology.[18,19] Consistent with prior work, a PCE is defined as any event in which a player is unable to resume play in a meaningful capacity within five seconds of a direct and visible head contact.[18,19] The term PCE is not synonymous with SRC; PCEs include a broad spectrum of head impacts that may or may not lead to a clinical

diagnosis.[18] Ambiguous events were excluded, such as those involving clear player embellishment, questionable head contact, or minor contact where the blow could not possibly produce a concussive force.[18,19]

Match footage was retrieved from the GAAGO online streaming service and was analyzed using QuickTime Player v10.5 which enables frame-by-frame viewing at 720-1080p resolution. Reviewers were permitted to re-watch and pan the footage at their discretion. In player-to-player contact, we defined "Player 1" (P1) as the player who sustained head contact and "Player 2" (P2) as an involved player who did not. If both players sustained head contact during a PCE, P1 was defined as the one who was assessed for a longer period of time. Reviewers recorded whether the injured player was assessed by medical personnel, the duration of assessment and subsequent RTP decision. In light of the GAA 'blood-sub' rule requiring that all players with visible blood be removed, reviewers also recorded whether or not each PCE caused bleeding. The time at which each PCE occurred was also recorded to search for a relationship with the RTP decision. Finally, consistent with our prior work and a recent international consensus statement, reviewers searched for visible signs of concussion, including *lying motionless*, *impact seizure*, *tonic posturing*, motor incoordination - *ataxia, no protective action—floppy*, and *blank/vacant look*.[18–20]

Ethical approval was granted by the Social Research Ethics Committee of the Cork Teaching Hospitals. (Ref: 10/09/2019/02)

Descriptive statistics were reported as means, counts or frequencies and their associated percentages. A Fisher's exact test was used to confirm a relationship between the duration of assessment and multiple signs of concussion. As well, Fisher's exact test was used to search for an association between RTP decision and visible bleeding by varying number of concussion signs. Statistical significance was set at $p<0.01$ for all statistical analyses.

To test for reliability, five non-2018/2019 matches were analyzed independently by both reviewers for raw agreement for identification of PCEs. Second, each reviewer analyzed 30 PCEs identified from exhibition and All-Ireland club matches (not included in data analysis) using the adapted PCE assessment spreadsheet. Agreement was 100.0% for the identification of PCEs. For the PCE assessment spreadsheet, raw agreement was 96.5% and Cohen's kappa coefficient of 0.83 (95% CI 0.799 to 0.861). A Cohen's Kappa value greater than 0.8 is indicative of almost perfect agreement.[21,22] All discrepancies from the inter-rater reliability were discussed and resolved. Subsequently, two independent reviewers identified PCEs throughout 59 and 52 matches of the 2018 and 2019 GAA inter-county seasons and championships, respectively.

In summary, after achieving a favourable inter-rater reliability result, two reviewers independently identified PCEs throughout 59 and 52 matches of the 2018 and 2019 GAA inter-county seasons and championships, respectively. Each PCE was evaluated based on the parameters outlined above, and data was recorded for statistical analysis. Reviewers consulted each other and collaborated if any questions or difficulties arose during the analysis.

RESULTS

Throughout the 2018 & 2019 GAA NFL seasons combined, we identified a total of 235 incidents over 111 matches. Seven of these involved both P1 and P2 sustaining a PCE, resulting in 242 PCEs (2.18 per match, 58.14 per 1000 match hours of exposure). (Table 1) Of the 242 PCEs, 211 (87.2%) were assessed by a doctor and/or physiotherapist, identifiable by the lettering on their attire. The majority of assessments were under 1 minute in length (82.0%, n=173). All assessment duration data is summarized in Table 1. Considering all on-pitch assessments, there was a significant association between the number of concussion signs and duration of assessment. Players displaying multiple signs of concussion were significantly more likely to receive a longer assessment ($p<0.01$).

We observed 181 (74.8%) PCEs that displayed 0 signs of concussion and 61 (25.2%) that displayed 1 or more. Of the 61 PCEs that produced 1 or more sign of concussion, 9 (14.8%) were removed from play. This data is summarized in more detail in Table 1. Players displaying multiple signs of concussion were significantly more likely to be removed than players with 0 signs ($p<0.01$). When comparing the rate of removal between players displaying only 1 sign of concussion to those with 0 signs, no significant difference was found. ($p=0.10$).

Thirty-one (12.8%) players suffering a PCE received no assessment before RTP, while 189 (78.1%) players were assessed on pitch before RTP. Ten (4.1%) were taken to the sideline before RTP. (Table 1) Six of these 10 players (60.0%) were visibly bleeding following the associated PCE (Table 2) and 3 (30.0%) suffered the associated PCE in the last minute of the first half. Twelve (5.0%) players were removed from play and did not RTP for the rest of the game. (Table 1) Seven of these 12 (58.3%) players were visibly bleeding, (Table 2) and 1 (8.3%) suffered the associated PCE in the last minute of the match. Overall, 14 (5.8%) PCEs produced visible signs of bleeding, and 13 (92.9%) of these players were removed either temporarily or permanently. (Table 2) Players with multiple signs of concussion were significantly more likely to show visible signs of bleeding, ($p<0.01$). (Table 1)

Our findings in Gaelic Football were compared to similar research performed in three international soccer tournaments and Australian super rugby, as displayed in Table 3.

DISCUSSION

The GAA's Concussion Management Guidelines recommend that athletes suspected of concussion be removed from play immediately and medically assessed using the SCAT-5 protocol.(1) Over two seasons, while the majority of players (87.2%) received some form of assessment following a PCE, 88.6% of these were under 2 minutes in length. When compared to prior research in soccer,[18] it is evident that PCEs were assessed far more frequently in Gaelic Football, but the duration of assessment was similarly short in duration. In rugby, more Head Injury Events (HIEs) were missed in-game (32.9%) than in Gaelic Football, resulting in a lower percentage assessed. This suggests that sideline medical staff in rugby may face decreased visibility, given the clustered nature of play. However, including those that qualified for immediate removal, almost all (97.9%) assessments that occurred in rugby were completed off-pitch using the Head Injury Assessment (HIA) protocol,[23] an adapted version of the SCAT-5. This protocol takes a *minimum* of 10 minutes to complete.[14] Throughout our research in Gaelic Football, we were unable to identify any assessments that resembled the SCAT-5. This highlights a need to better educate medical personnel on standardized assessment protocols. Cursory and remarkably brief assessments may be in the interest of managers and fans who want to see their players continue playing in the game, but may be detrimental in the long run to all stakeholders, especially the athlete.

Over the course of two seasons and 111 matches of GAA NFL play, 4.1% of players suffering a PCE were taken to the sideline before RTP, and only 5.0% were removed from the match. Similarly, only 2.1% of players suffering a PCE in professional soccer were removed. This is in marked contrast to rugby, in which 40.0% of HIEs resulted in permanent removal from the match. Only 1 (1.4%) HIE resulted in RTP following an assessment on pitch, compared to 78.1% in Gaelic Football. Over a third (35.7%) of off-field assessments in rugby resulted in diagnosis of SRC, which indicates the importance and effectiveness of a thorough, standardized assessment.

The possibility remains that a proportion of the players taken to the sideline or removed from the match in Gaelic Football were properly assessed off-screen. However, we noted that 6 (60.0%) of players taken to the sideline were bleeding and 3 (30.0%) suffered the associated PCE in the last minute of play of the first half, leaving only 1 (10.0%) player who was neither bleeding nor injured in the last minute of a half before being taken to the sideline. Similarly, of the 12 players who were removed from play, 7 (58.3%) were bleeding and 1 (8.3%) had suffered the associated PCE in the last minute of the second half. Given that 92.9% of players with visible blood following a PCE were taken off either temporarily or permanently, we observed a strong adherence to the 'blood-sub' rule. However,

this calls into question why players who suffered a PCE were taken to the sideline or removed. It appears likely that they were removed simply due to bleeding regulations or convenient timing circumstances, rather than to receive a concussion assessment.

By international consensus, the six signs of concussion recorded in this study are believed to be the most useful for identifying a possible concussion on video incident analysis. The exact predictive value of each sign has yet to be determined, and the presence of any one sign does not necessarily indicate that a concussion has occurred. However, it has been agreed that the presence of any one or more of these signs on video analysis necessitates immediate removal of an athlete from play, pending a professional assessment.[20] In Gaelic Football, of the 46 players who displayed 1 sign following a PCE, only 6.5% were removed from play, while only 40.0% of players with 2 or more signs were removed. We discovered that players with 1 or more signs of concussion were significantly more likely to be removed than those displaying 0 signs ($p<0.01$). However, this relationship did not exist when players with only 1 sign were compared to those with 0 signs. Based on our observations, players with multiple visible signs of concussion are removed more frequently because they are often incapacitated and significantly more likely to be bleeding ($p<0.01$), reducing the ambiguity of the clinical decision. Medical personnel must be vigilant of the large population of players who display only 1 sign of concussion and are permitted to RTP in 93.5% of cases.

Based on our findings, we propose a number of possible barriers to SRC assessment in Gaelic Football. Firstly, the pace of the game prevents sideline medical staff from effectively identifying PCEs. Increased pressure from the fans, players, and referees to make rapid clinical decisions may increase the likelihood of inappropriate diagnosis and RTP decision. Strategies must be designed to improve PCE identification and make clinical decisions less pressured and time-sensitive. Integrating the use of video incident analysis by sideline medical staff or external concussion spotters may facilitate SRC surveillance, especially in cases where concussive signs may only appear transiently.[24–27] This is all the more relevant in sports such as Gaelic Football where a large pitch with many players limits visibility. However, this would require a standardized training protocol and high-quality, live video footage available at the sideline which would be expensive to deploy widely. A reasonable suggestion is to train referees to spot PCEs; they have superior visibility and can enforce the removal of players at any level of the game. This is being trialed in South African rugby.[28] Another possible intervention may be a variant of the Concussion Interchange Rule, which was introduced to the National Rugby League in 2014. This rule permits a player with a suspected concussion to be removed from play and assessed for up to 15 minutes without a substitution being tallied against the

player's team, providing more time for thorough assessment.[16] As displayed in Table 6, this rule is commonly used in rugby, allowing for extended HIA assessments to frequently occur off-pitch.

Second, concussion presentation is highly variable across players.[1,29] This may be attributed to heterogenous presentation, non-specific nature of clinical signs, and absence of an objective biomarker. This is yet another impasse to appropriate diagnosis and RTP decision. At present, there is no on-pitch screening tool that medical staff can use to rapidly determine whether a player should be removed for assessment. Therefore, until one is found, medical staff must err on the side of caution and remove players who have sustained a PCE, pending a SCAT-5 assessment, as is commonplace in rugby.[30] Finally, a deep-rooted culture that promotes toughness, perseverance, and loyalty to one's team represents a powerful barrier.[18] While indubitably admirable and entertaining, these qualities lead players to downplay their symptoms to avoid being substituted or appearing 'weak'. A cumulative effort from the GAA, player associations, sponsors, managers, players and the public must be encouraged to promote a change in the culture surrounding concussion.

This study has limitations including using broadcaster game replays. Thus, reviewers were unable to control camera views, angles, and quality, impacting our ability to evaluate PCEs. The statistics of PCE incidence and signs of concussion presented in this study likely represent a minimum estimate; the true incidence of PCE with transient signs of concussion may be higher. Additionally, reviewers had no access to in-game audio information to integrate into the analysis. It is also possible that players occasionally exaggerate or feign injury to gain ball possession or a freekick/penalty for their team. We made every effort to exclude these events. We had no access to medical reports from the games so we cannot infer which PCEs were actually associated with medically diagnosed concussion. Future research will help to elucidate this relationship.

Little is known about the reliability and validity of reviewers observing concussion signs on video analysis. Although the specific signs have been well defined through international consensus, it is difficult to infer the sensitivity of our analysis as there is no accepted "gold standard" identification system. Thus, there was inevitably an element of subjectivity in our analysis. Finally, as with any video review study involving more than one reviewer, we acknowledge the possibility that inter-reviewer bias may have played a role in data collection and analysis. However, we attempted to mitigate this by achieving both a high raw agreement and Cohen's kappa coefficient.

CONCLUSION

Our study demonstrates that Gaelic Football players who suffer PCEs frequently only receive brief assessments and almost universally RTP without a standardized screen for concussion. Clear parallels exist between Gaelic Football and professional soccer, as in both sports, concussion assessment and RTP decision practices do not comply with the recommendations of the ICCS. Conversely, in Australian super rugby, assessments follow a standardized protocol and players RTP less frequently, resulting in fewer players continuing to play following concussion. Advancements in PCE management in rugby are still evolving, but are a step in the right direction and present a useful paradigm for the GAA to emulate. The introduction of video incident analysis, external spotters, and concussion substitutions may be of benefit to Gaelic Football. Timely identification and effective assessment of SRC in Gaelic Football is conducive to reducing the potential risk of the adverse immediate and long-term outcomes of SRC.

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296 **Tables**

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Number of PCEs		Assessment Duration						Player Outcome					Bleeding
Number of Concussion Signs	2018-2019 Seasons	0-29s	30-59s	1:00–1:29	1:30–1.59	2:00+	Total No. (%)	RTP with No Assessment No. (%)	RTP after On-Pitch Assessment No. (%)	RTP after removal to SL No. (%)	Removed No. (%)	Total No. (%)	Bleeding No. (%)
0	181 (74.8)	92 (83.6)	43 (68.3)	5 (38.5)	1 (100.0)	1 (50.0)	**142 (75.1)**	31 (17.1)	142 (78.5)	5 (2.8)	3 (1.7)	**181 (74.8)**	5 (2.8)
1	46 (19.0)	15 (13.5)	17 (27.0)	6 (46.2)	0 (0.0)	1 (50.0)	**40 (20.8)**	0 (0.0)	39 (84.8)	4 (8.7)	3 (6.5)	**46 (19.0)**	6 (13.0)
2	10 (4.1)	3 (2.7)	2 (3.2)	1 (7.7)	0 (0.0)	0 (0.0)	**6 (3.1)**	0 (0.0)	6 (60.0)	0 (0.0)	4 (40.0)	**10 (4.1)**	2 (20.0)
3	3 (1.2)	0 (0.0)	0 (0.0)	1 (7.7)	0 (0.0)	0 (0.0)	**1 (0.5)**	0 (0.0)	1 (33.3)	0 (0.0)	2 (66.7)	**3 (1.2)**	1 (33.3)
4	2 (0.8)	0 (0.0)	1 (1.6)	0 (0.0)	0 (0.0)	0 (0.0)	**1 (0.5)**	0 (0.0)	1 (50.0)	1 (50.0)	0 (0.0)	**2 (0.8)**	0 (0.0)
Total	**242 (100.0)**	**110 (58.2)**	**63 (33.3)**	**13 (6.9)**	**1 (0.5)**	**2 (1.1)**	**189 (100.0)**	**31 (12.8)**	**189 (78.1)**	**10 (4.1)**	**12 (5.0)**	**242 (100.0)**	**14 (5.8)**

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302 **Table 1:** Number of concussion signs by number of PCEs, assessment duration, player outcome, and visible bleeding (%).

RTP Decision	No. of Players	Bleeding
RTP with No Assessment	31	0 (0.0)
RTP after On-Pitch Assessment	189	1 (0.5)
RTP after removal to SL	10	6 (60.0)
Removed	12	7 (58.3)
Total	**242**	**14 (5.8)**

Table 2: RTP decision and bleeding (%).

Category	Gaelic Football (current study)	Soccer (*Cusimano et al.* 2019)(18)	Rugby (Makdissi *et al.* 2018)(30)
SRC incidence (per 1000 match hours)	NA	NA	20.5
PCE/HIE incidence (per 1000 match hours)	58.1	39.8	42.2
Frequency of PCE/HIE Assessment (%)	87.2	33.8	67.1
PCE/HIE not assessed(%)	12.8	66.2	32.9
Duration of Assessment	0-29s (52.1%)	59.9s (mean)	NA
Percentage of assessments occurring on SL/off-pitch (%)	4.7	NA	97.9
RTP after assessment on pitch (%)	78.1	31.6	1.4
RTP after assessment on SL/off-pitch (%)	4.1		25.7
Removed from play (%)	5.0	2.1	40.0

Table 3: Major assessment and RTP findings in Gaelic Football compared with existing SRC research in soccer and rugby.