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1 **Title:**

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

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47 **INTRODUCTION**

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

53 The Gaelic Athletic Association (GAA) is the largest sporting organization in the Republic of Ireland. One  
54 of the most popular sports that the organization presides over is Gaelic Football, a fast-paced contact sport played on  
55 a grass pitch that is similar to rugby and soccer.[4,5] Players are required to wear mouthguards, but no helmets are  
56 used. Similar to soccer, strategic body contact is encouraged to gain and maintain ball control. Although less contact  
57 is permitted in comparison to rugby, the pace and intensity of Gaelic Football gives rise to frequent high-impact

58 collisions.[4,5] A 2017 survey of 80 GAA athletes revealed that 54% reported a personal history of concussion, with  
59 44% reporting more than one incidence.[6] Confirming this, a 2019 survey suggested that while 57.5% of athletes  
60 suspected they had suffered a SRC in the past, many were undiagnosed.[7] SRC awareness in the GAA has increased  
61 over recent years, manifesting in the development of the Concussion Management Guidelines for Gaelic Games,[8]  
62 an ICCS-based approach to diagnosing and treating SRC. Despite this, management of SRC in an acute setting appears  
63 to remain challenging.

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

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

## 79 **METHODS**

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

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

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

98 Ethical approval was granted by the Social Research Ethics Committee of the Cork Teaching Hospitals. (Ref:  
99 10/09/2019/02)

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

104 To test for reliability, five non-2018/2019 matches were analyzed independently by both reviewers for raw  
105 agreement for identification of PCEs. Second, each reviewer analyzed 30 PCEs identified from exhibition and All-  
106 Ireland club matches (not included in data analysis) using the adapted PCE assessment spreadsheet. Agreement was  
107 100.0% for the identification of PCEs. For the PCE assessment spreadsheet, raw agreement was 96.5% and Cohen’s  
108 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  
109 perfect agreement.[21,22] All discrepancies from the inter-rater reliability were discussed and resolved. Subsequently,  
110 two independent reviewers identified PCEs throughout 59 and 52 matches of the 2018 and 2019 GAA inter-county  
111 seasons and championships, respectively.

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

116

## 117 **RESULTS**

118 Throughout the 2018 & 2019 GAA NFL seasons combined, we identified a total of 235 incidents over 111  
119 matches. Seven of these involved both P1 and P2 sustaining a PCE, resulting in 242 PCEs (2.18 per match, 58.14 per  
120 1000 match hours of exposure). (Table 1) Of the 242 PCEs, 211 (87.2%) were assessed by a doctor and/or  
121 physiotherapist, identifiable by the lettering on their attire. The majority of assessments were under 1 minute in length  
122 (82.0%, n=173). All assessment duration data is summarized in Table 1. Considering all on-pitch assessments, there  
123 was a significant association between the number of concussion signs and duration of assessment. Players displaying  
124 multiple signs of concussion were significantly more likely to receive a longer assessment ( $p<0.01$ ).

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

130 Thirty-one (12.8%) players suffering a PCE received no assessment before RTP, while 189 (78.1%) players  
131 were assessed on pitch before RTP. Ten (4.1%) were taken to the sideline before RTP. (Table 1) Six of these 10  
132 players (60.0%) were visibly bleeding following the associated PCE (Table 2) and 3 (30.0%) suffered the associated  
133 PCE in the last minute of the first half. Twelve (5.0%) players were removed from play and did not RTP for the rest  
134 of the game. (Table 1) Seven of these 12 (58.3%) players were visibly bleeding, (Table 2) and 1 (8.3%) suffered the  
135 associated PCE in the last minute of the match. Overall, 14 (5.8%) PCEs produced visible signs of bleeding, and 13  
136 (92.9%) of these players were removed either temporarily or permanently. (Table 2) Players with multiple signs of  
137 concussion were significantly more likely to show visible signs of bleeding, ( $p<0.01$ ). (Table 1)

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

## 140 DISCUSSION

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

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

161 The possibility remains that a proportion of the players taken to the sideline or removed from the match in  
162 Gaelic Football were properly assessed off-screen. However, we noted that 6 (60.0%) of players taken to the sideline  
163 were bleeding and 3 (30.0%) suffered the associated PCE in the last minute of play of the first half, leaving only 1  
164 (10.0%) player who was neither bleeding nor injured in the last minute of a half before being taken to the sideline.  
165 Similarly, of the 12 players who were removed from play, 7 (58.3%) were bleeding and 1 (8.3%) had suffered the  
166 associated PCE in the last minute of the second half. Given that 92.9% of players with visible blood following a PCE  
167 were taken off either temporarily or permanently, we observed a strong adherence to the 'blood-sub' rule. However,

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

171 By international consensus, the six signs of concussion recorded in this study are believed to be the most  
172 useful for identifying a possible concussion on video incident analysis. The exact predictive value of each sign has yet  
173 to be determined, and the presence of any one sign does not necessarily indicate that a concussion has occurred.  
174 However, it has been agreed that the presence of any one or more of these signs on video analysis necessitates  
175 immediate removal of an athlete from play, pending a professional assessment.[20] In Gaelic Football, of the 46  
176 players who displayed 1 sign following a PCE, only 6.5% were removed from play, while only 40.0% of players with  
177 2 or more signs were removed. We discovered that players with 1 or more signs of concussion were significantly more  
178 likely to be removed than those displaying 0 signs ( $p < 0.01$ ). However, this relationship did not exist when players  
179 with only 1 sign were compared to those with 0 signs. Based on our observations, players with multiple visible signs  
180 of concussion are removed more frequently because they are often incapacitated and significantly more likely to be  
181 bleeding ( $p < 0.01$ ), reducing the ambiguity of the clinical decision. Medical personnel must be vigilant of the large  
182 population of players who display only 1 sign of concussion and are permitted to RTP in 93.5% of cases.

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



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

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

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

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

222 **CONCLUSION**

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

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296 **Tables**297  
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300

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. (%)
<b>0</b>	181 (74.8)	92 (83.6)	43 (68.3)	5 (38.5)	1 (100.0)	1 (50.0)	<b>142 (75.1)</b>	31 (17.1)	142 (78.5)	5 (2.8)	3 (1.7)	<b>181 (74.8)</b>	5 (2.8)
<b>1</b>	46 (19.0)	15 (13.5)	17 (27.0)	6 (46.2)	0 (0.0)	1 (50.0)	<b>40 (20.8)</b>	0 (0.0)	39 (84.8)	4 (8.7)	3 (6.5)	<b>46 (19.0)</b>	6 (13.0)
<b>2</b>	10 (4.1)	3 (2.7)	2 (3.2)	1 (7.7)	0 (0.0)	0 (0.0)	<b>6 (3.1)</b>	0 (0.0)	6 (60.0)	0 (0.0)	4 (40.0)	<b>10 (4.1)</b>	2 (20.0)
<b>3</b>	3 (1.2)	0 (0.0)	0 (0.0)	1 (7.7)	0 (0.0)	0 (0.0)	<b>1 (0.5)</b>	0 (0.0)	1 (33.3)	0 (0.0)	2 (66.7)	<b>3 (1.2)</b>	1 (33.3)
<b>4</b>	2 (0.8)	0 (0.0)	1 (1.6)	0 (0.0)	0 (0.0)	0 (0.0)	<b>1 (0.5)</b>	0 (0.0)	1 (50.0)	1 (50.0)	0 (0.0)	<b>2 (0.8)</b>	0 (0.0)
<b>Total</b>	<b>242 (100.0)</b>	<b>110 (58.2)</b>	<b>63 (33.3)</b>	<b>13 (6.9)</b>	<b>1 (0.5)</b>	<b>2 (1.1)</b>	<b>189 (100.0)</b>	<b>31 (12.8)</b>	<b>189 (78.1)</b>	<b>10 (4.1)</b>	<b>12 (5.0)</b>	<b>242 (100.0)</b>	<b>14 (5.8)</b>

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

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

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**Table 2:** RTP decision and bleeding (%).

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

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