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Usefulness of Video Review of Possible Concussions in National Youth Rugby League

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ABSTRACT

A new concussion interchange rule (CIR) was introduced in 2014 for the National Rugby League and National Youth Competition (NYC). The CIR allows a player suspected of having sustained a concussion to be removed from play and assessed without an interchange being tallied against the player's team. Participants included all NYC players who used the CIR during the 2014 season. 2 raters completed video analysis of 131 (of a total of 156 reported) uses of the CIR, describing injury characteristics, situational factors, and concussion signs. The incidence rate was 44.9 (95 % CI: 38.5–52.3) uses of the CIR per 1 000 NYC player match hours, or approximately one CIR use every 1.3 games. Apparent loss of consciousness/unresponsiveness was observed in 13 % of cases, clutching the head in 65 %, unsteadiness of gait in 60 %, and a vacant stare in 23 %. Most incidences occurred from a hit-up (82 %). There appeared to be some instances of video evidence of injury but the athlete was cleared to return to play in the same game. Video review appears to be a useful adjunct for identifying players suffering possible concussion. Further research is required on the usefulness of video review for identifying signs of concussive injury.

Introduction

Rugby league is a high intensity collision sport and, as a consequence, participation in the sport carries an inherent risk of injury [16]. Rugby league involves 2 teams of 13 on-field players each, with 4 interchange players who can be switched in and out of the game. Interchanges are limited to 12 per team (which was reduced to 8 in 2016). The game is played continuously in two 40-min halves [11]. The published incidence rates of concussion in this sport might vary due to both risk factors (i. e., age and level of play) and methodological factors (i. e., differences in injury definitions used between different studies, differences in medical resources, and concussion expertise) [5]. At the National Rugby League (NRL) level, a video analysis of medically diagnosed concussions in 3 clubs from the 2013 season revealed an incidence rate of 14.8 concussions per 1 000 player match hours or one concussion every 4 games [6]. The incidence of concussion at one NRL club over a 15-year period (1998–2012) was reported to be 28.3 concussions per 1 000 player match hours [24].

The NRL implemented a new the concussion interchange rule (CIR) commencing in the 2014 season. The CIR requires the mandatory removal of any player suspected of having sustained a concussion (i. e., observed signs suggestive of a concussion or self-reported symptoms; or the trainer or teammate reports signs, behaviors, or other differences not considered to be normal for the player) in line with the international consensus statement from the Concussion in

Sport Group [21]. The teams are given a 15-min assessment window for a club medical officer to complete the Sports Concussion Assessment Tool 3rd edition (SCAT-3) and any other assessment deemed necessary. If the player, following this assessment, is then cleared of concussion, then they are permitted to return to play. If they return within the 15-min assessment period, then the team has not used one of its interchanges (i. e., the team receives a free interchange). If the player is cleared to return to play outside of this 15-min assessment window, then the team is charged with an interchange. If the athlete is not cleared to return to play, the interchange is not charged. In addition to the implementation of the CIR, the NRL facilitated the construction of a video booth on the sideline at every match for the purpose of reviewing incidences of injury during the match to assist club medical staff to determine whether a player should be removed under the CIR.

The use of video footage is a unique and objective method to analyse mechanisms and characteristics of concussion. Video analysis of concussion has been conducted in a number of collision and contact sports such as Australian Rules Football [2, 19, 20], boxing [23], soccer [1], taekwondo [17], ice hockey [12, 13], and lacrosse [18]. One of the most practical outcomes of such studies has been improved sideline decision-making through the identification of video signs that should result in automatic removal from play [2]. However, video analysis is not considered an adequate replacement for clinical assessment [20].

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We recently reviewed the use of the concussion interchange rule (CIR) at the NRL level during the first season of its implementation and found an incidence of 24.0 (95 % CI: 20.7–27.9) uses of the CIR per 1 000 NRL player match hours, or approximately one CIR use every 2.4 games [7]. We further identified that most incidences occurred from a hit-up (62 %) and occurred during a tackle where the initial contact was with the upper body (80 %). In addition, of the 70 players who demonstrated 3 or more of the 4 primary observable signs of concussion, 43 % (30/70) returned to play in the same game.

This study was designed to replicate and extend our previous work at the NRL level [7]. The aim of this study was to provide both an identical description and evaluation of the use of the CIR at the National Youth Competition (NYC, the under-20s competition) level as that conducted at the NRL level [7]. A further objective was to describe the match situational factors (i. e., location on the field, playing position, type of play, and foul play) involving the use of the CIR at the NYC level. In addition, we evaluated the use of the CIR and its association with video evidence of possible concussion signs.

Methods & Materials
Participants

Participants for this study were NYC players who used the CIR during the 2014 season. Each use of the CIR during the 2014 National Youth Competition season was included in the study.

Procedure

This study conducted a video analysis of 131 uses of the concussion interchange rule in the National Rugby League's National Youth Competition during the 2014 season. There was no video analysis conducted on any event that was not logged and assessed by club medical staff. The lead researcher obtained information on the use of the CIR (i. e., the player's name and round in which the CIR was used). All uses of the CIR (where video of the events was available; 131/156 events or 84 %) were independently reviewed by 2 raters. Both raters have experience in the identification of concussion on the sideline. The 2 raters determined whether any of 5 signs [loss of consciousness (usually inferred by evidence of unresponsiveness, evidence of player's body going limp, and often including eyes being closed and body going limp immediately after being struck); seizures; clutching of the head; unsteadiness of gait; or possible impairment in cognition or awareness as evidenced by a blank or vacant stare] were present, absent, or indeterminable based on the available footage of the incident for every case. When there was disagreement between the 2 raters, both raters reviewed and discussed those cases in an effort to reach a consensus. In the cases where consensus could not be achieved, ratings from a third rater were used. The final consensus decision data were used in the frequency data described in the Results section below. This study was approved by the University of Newcastle Human Ethics Committee. The methodology used was in compliance with the ethical standards of the International Journal of Sports Medicine [10].

The digital records of events leading to the use of the CIR were independently reviewed by 2 raters using the Quicktime Multimedia Player V.7.7.5. Full match replays were reviewed. However, not all videos that were reviewed were captured by a professional broadcaster, so the quality of the video footage varied considerably de-

pending on the provider. Many games were reviewed using only a single, wide-angled camera that was fixed on the field and did not provide any replay of an incident. The only circumstances that rendered a reported use of the CIR ineligible for inclusion were: (i) any event where the video of the player was obstructed by other players or the match official(s), or (ii) where the incidence was unable to be located following a full match review. The coding taxonomy and field locations used to analyze each application of the CIR video were pre-determined and adopted an identical methodology to previous studies in this setting [7, 8] (▶ Table 1).

Statistical analysis

Most of the analyses in this paper are descriptive (i. e., frequency statistics). Inter-rater reliability analyses using Cohen's kappa (κ) statistics [9] were used to determine consistency among the 2 raters for (i) the overall rating of all concussion signs, and (ii) each of the 5 individual signs. Unlike the total percent agreement, Cohen's kappa considers the proportional agreement that could occur simply by chance. The κ coefficients are calculated by considering the proportion of rater agreement and the expected proportion [9]. Using the interpretations of κ described by McHugh [22], κ agreement was categorized as almost perfect (>0.90), strong (0.80–0.90), moderate (0.60–0.79), weak (0.40–0.59), minimal (0.21–0.39), and none (0–0.20). All analyses were performed using IBM SPSS Statistics V.23.0 [14] and used 2-sided tests for significance at the 0.05 level, with 95 % CIs.

Results

The CIR was used 156 times in the NYC during the 2014 season. There were 25 cases in which an incident leading to the use of the CIR could

▶ **Table 1** Definition of terms.

Term	Definition
Ball Carrier	The player in possession of the ball.
Tackler	The defensive player making the tackle on the ball carrier.
Hit-up	A type of play where the ball carrier charges directly into an organized defensive line.
Possible Loss of Consciousness	Inferred by evidence of unresponsiveness, loss of muscle tone (body going limp) immediately after being struck, or not bracing for the fall and impacting with the playing surface.
Unsteadiness of Gait	Gait ataxia, unable to stand steadily unaided, or walk normally. Upon standing and walking the player has unsteadiness, wobbly legs, balance problems, stumbles or falls over, or cannot walk straight independently.
Clutching Head	The player holds his head or face in the palm of his hand or hands, or the player rubs his head in a manner that appears to demonstrate that he is experiencing discomfort.
Vacant Stare	The player is not visually focused on the doctor/trainer when being spoken to, or assessed and asked to attend, and/or the player appears to be looking off into the distance.
Seizure	Tonic posturing – stiffening of limbs or convulsions

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▶ **Table 2**   Summary of video analysis findings.

	Total Sample (N = 131)			No Return to Play (n = 70)			Returned to Play (n = 61)		
	Yes	No	Missing	Yes	No	Missing	Yes	No	Missing
	% (n)	% (n)	% (n)	% (n)	% (n)	% (n)	% (n)	% (n)	% (n)
Unresponsive/Loss of Consciousness	13.0 (17)	72.5 (95)	14.5 (19)	18.6 (13)	64.3 (45)	17.1 (12)	6.6 (4)	82.0 (50)	11.5 (7)
Clutching Head	64.9 (85)	26.0 (34)	9.1 (12)	62.9 (44)	27.1 (19)	10.0 (7)	67.2 (41)	24.6 (15)	8.2 (5)
Unsteadiness of Gait	60.3 (79)	26.0 (34)	13.7 (18)	60.0 (42)	28.6 (20)	11.4 (8)	60.7 (37)	23.0 (14)	16.4 (10)
Vacant Stare	22.9 (30)	29.8 (39)	47.3 (62)	28.6 (20)	31.4 (22)	40.0 (28)	16.4 (10)	27.9 (17)	55.7 (34)
Possible Seizure	4.6 (6)	93.1 (122)	2.3 (3)	18.6 (13)	64.3 (45)	17.1 (12)	3.3 (2)	96.7 (59)	0 (0)

not be identified on review of the video footage available, or the video quality was so poor that conducting a review was not possible. This resulted in a total of 131 cases in the current study. The CIR was used for 88 players on one occasion, 18 players on 2 occasions, and 2 players on 3 or more occasions throughout the season. The CIR was not used more than once in the same match for any player. Taking into account the players with multiple CIR use, data were available on a total of 129 individual players. The incidence rate was 44.9 (95 % CI: 38.5–52.3) uses of the CIR per 1 000 NYC player match hours, or approximately one CIR use every 1.3 games.

Observable signs of possible concussion

The proportion of players with possible signs of concussion on video analysis in the entire sample was as follows: LOC or unresponsiveness = 13 %, clutching of the head = 65 %, unsteadiness of gait = 60 %, vacant stare = 23 %, and possible seizure = 5 %. Having 3 or more signs of possible concussion occurred in 19 %. Overall, there were 61 players (47 %) who returned to play in the same game. Of these, 7 % (n = 4) had video evidence of possible LOC or unresponsiveness, 67 % (n = 41) clutched their head following contact, 61 % (n = 37) had video evidence of gait ataxia, 16 % (n = 10) had video evidence of a blank or vacant stare, 3 % (n = 2) had video evidence of a seizure-like activity, and 11.5 % had 3 or more signs of possible concussion (n = 7); ▶ **Table 2**). Those who did not return to play had higher rates of possible LOC than those who returned to play in the same game (18.6 % vs. 6.6 %; χ^2(1, 131) = 4.17, p = 0.041, RR = 2.8, 90 % CI: 1.07–8.51). 4 of the 17 players with video evidence of possible LOC returned to play in the same game. Overall, there were 25 cases showing video evidence of 3 or more signs of injury, and 7 of those athletes (28 %) returned to play in the same game. There were 12 players who had no observable signs of concussion on review of the video footage of the incident that led to the player being removed from play under the CIR. For this group, 33 % (4/12) returned to play in the same game.

Circumstances when the CIR was used

There were 91 (69 %) uses of the rule that occurred in the middle corridor, whereas 40 (31 %) were observed in the side corridor. There were 22 (17 %) uses of the rule that occurred in the defensive quarter, 47 (36 %) in the midfield defensive quarter, 33 (25 %) in the midfield attacking quarter, and 29 (22 %) in the attacking quarter of the field.

The CIR was used to remove 86 players that were in the forward positions (66 %) compared to 45 (34 %) backline players (χ^2 = 12.8, p < 0.001; expected frequencies set to be equal even though there

are 6 forwards and 7 backs on the field). The CIR was used to remove the ball carrier on 50 (38 %) occasions compared to 80 times (61 %) for a tackler (χ^2 = 6.9, p < 0.009). There were 41 (31 %) uses of the CIR when there was only one player involved in the tackle. There were 68 (52 %) uses where 2 tacklers were involved, 19 (15 %) where 3 tacklers were involved, and 2 (2 %) when there were 4 tacklers involved.

The large majority (82 %, 107/131 cases) of players removed from play under the CIR were struck in the head/face. Secondary contact was observed in 27 % (36/131) of cases, with most of these cases involving impact with the playing surface (78 %, 28/36). Referee-identified and -reported foul play accounted for 8 % (11/131) of injuries, with 64 % (7/11) of these players being placed on report by the match official (i. e., referred to the match review committee for potential citing and further disciplinary action as determined by the league's judiciary). There were 6 different plays or situations that were coded for the 131 uses of the CIR. The hit-up was the most common play that resulted in using the CIR, accounting for 82 % of instances; no other play accounted for more than 10 % of the CIR use.

Inter-rater reliability (IRR)

The overall IRR for the identification of concussion signs between the 2 raters was κ = 0.69 (95 % CI: 0.67–0.70), which is considered to be moderate agreement [22]. The IRRs for each individual sign are presented in ▶ **Table 3**. Rater agreement was minimal for possible LOC. Possible LOC was coded 17 times in total. One rater was more conservative in coding LOC and coded 11 of these instances as not present and one as indeterminate. Rater agreement was weak to moderate for most of the other signs. After the first round of ratings, the 2 primary raters were able to agree on all but 14 cases involving discrepancies. Therefore, a third rater was used to facilitate a consensus decision for the frequency calculations in 14 cases.

Discussion

This paper provides a video analysis of uses of the CIR in the NYC during its first season of use. It summarizes antecedent events and contextual factors associated with the implementation of the CIR. The CIR was used a total of 156 times, which corresponds to approximately one CIR use every 1.3 games. At the professional level during the 2014 season, the CIR was used 167 times, which corresponds to approximately one CIR use every 2.4 games [7]. The concussion interchange rule was used much more frequently with forwards than backs. This result is similar to previous findings from rugby league studies that examined tackling exposure and playing position (i. e.,

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▶ **Table 3** Inter-rater reliability for each concussion sign.

Concussion Sign	f sign	Raw Agree-ment (n)	IRR (κ)	95 % CI
Unresponsive/Loss of Consciousness	17	5	0.29	0.23–0.35
Clutching Head	96	68	0.54	0.18–0.90
Unsteadiness of Gait	89	64	0.62	0.59–0.65
Vacant Stare	36	20	0.62	0.37–0.88
Possible Seizure	6	4	0.87	N/A
Overall (all signs)	244	167	0.69	0.67–0.70

f: frequency that the concussion sign was rated by at least one rater; n: number; N/A: not applicable due to low frequency of data

frequency of tackles each playing position was involved in) [3, 4, 15]. Of the 6 coded plays or situations in which the CIR was used, the hit-up (82 % of cases) was the only play that accounted for more than 10 % of the CIR use. Previous studies have shown that forwards are involved in tackles more frequently than other playing positions [3, 15]. Both of these findings were also consistent with the prior video analysis of NRL players [7]. The frequencies with which players clutched their heads or had unsteadiness of gait were similar to the frequencies found in NRL players. However, the rates of LOC (13.0 % vs. 30.9 %; $\chi^2(1, 293) = 13.1$, p < 0.001, RR = 2.4, 90 % CI = 1.5–3.8) and vacant stare (22.9 % vs. 58.6 %; $\chi^2(1, 293) = 37.8$, p < 0.001, RR = 2.6, 90 % CI = 1.9–3.5) in the NYC were much lower than that reported in our past study of professional NRL players [7]. The discrepancy observed for the vacant stare likely reflects, at least in part, our reduced ability to code that sign at the NYC level compared with the NRL level due to the video quality (i. e., a lack of footage with sufficient zoom-in on the player to determine the presence or absence of a vacant stare). The reasons for the lower rate of possible LOC in the NYC compared with the NRL are unknown but could also be due in part to video quality. They could also be related to the lower body weight, strength, and power of the younger NYC athletes.

The rates in which the CIR was used in specific locations of the field corresponded well to the rates at which tackles occurred in those locations of the field. King and colleagues examined the locations on the field in which tackles occurred during NYC matches (i. e., a total of 18 084 tackles). The percentages of tackles that occurred in playing zones were as follows: midfield defensive quarter = 39 %, defensive quarter = 14 %, midfield attacking quarter = 27 %, and attacking quarter = 18 % [15]. The field locations in the present study in which the CIR was used were as follows: midfield defensive quarter = 36 %, defensive quarter = 17 %, midfield attacking quarter = 25 %, and attacking quarter = 22 %.

A considerable number of players returned to play in the same game despite demonstrating evidence of one or more observable signs of concussion on post-hoc video analysis, which was also the case in the prior NRL study [7]. For example, at the professional level, there was video evidence of possible LOC in 50 players and 19 (i. e., 38 %) returned to play in the same game [7]. In the present study, there was video evidence of possible LOC in 17 players, and 4 (i. e., 23.5 %) returned to play in the same game. It is possible that this trend reflects a more conservative approach taken by the medical

staff at the NYC level, compared with the NRL, in regards to return-to-play decision-making. There were 2 instances at the NYC level, where players who appeared to have subtle video evidence of post-impact tonic posturing in one of their upper limbs were returned to play. It is not known, however, whether those players actually experienced a brief post-traumatic seizure. A limitation of this study was that we were not able to determine which players removed under the CIR actually had a medically diagnosed concussion and which players had the diagnosis of concussion excluded. Moreover, we could not determine how many players were initially removed from play, returned to play in the same game, and were then later diagnosed with a concussion.

It is important to note that the video quality and identification of events at the NYC level was poorer than the video quality at the NRL level, which resulted in considerably more missing data for the NYC cases compared to cases from the NRL data (n = 114; 17.4 % vs. n = 39; 4.8 %). Access to a professionally recorded full-match replay at this level was not always available, so the quality of the video footage varied considerably depending on the provider. Most of the games at the NYC level were reviewed using only one wide-angled camera that was fixed to the field of play, without any zoom-in, and no replay of any incident. This was the catalyst to a large portion of missing data in this study and could also have influenced the rate at which signs could be identified – especially brief LOC and a vacant stare.

The inter-rater reliabilities for the concussion signs in this study ranged from weak to very high [22] depending on the specific sign. The overall inter-rater reliability for all signs coded in this study was moderate. A factor influencing inter-rater reliability is restricted ranges (e. g., coding video evidence of overt signs of concussion as present, absent, or indeterminable, 3 possible values). Having well quantified constructs of interest (i. e., well defined concussive signs) is also an important factor for improving inter-rater reliability [7].

The new concussion interchange rule was used frequently during the first season at the NYC level. Many players were removed under the CIR and then cleared to return to play in the same game, suggesting that the CIR was being used as intended when there was a suspicion of injury. Moreover, many players were removed and not returned to play, suggesting that the CIR has benefit for player health and welfare. In some cases, however, there appeared to be video evidence of injury but the athlete was cleared to return to play. It is reasonable to assume that some injuries were not identified during the sideline assessment, but we have no way of determining the clinical status of the athlete during the sideline assessment. It is possible that an athlete can appear to be concussed on slow-motion video analysis, or actually be concussed, but not show overt clinical evidence of the injury on the sideline, during the remainder of the game (if returned to play), or in the days following the game. More research is needed on the inter- and intra-rater reliability, accuracy, and predictive usefulness of video analyses in sports. Future rugby league video analysis could conduct a more comprehensive examination of all tackles throughout the entire season to establish base rates of certain at-risk plays and provide a clearer picture of the incidence of injury by type of play. Examining base rates of these signs in rugby league match play would improve our understanding of the reliability of these signs for making in-play decisions from the sideline and of using video review to remove a player from play for further assessment.

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Acknowledgements

Conflict of Interest

Andrew Gardner has a clinical practice in neuropsychology involving individuals who have sustained sport-related concussion (including current and former athletes). He has operated as a contracted concussion consultant to the Australian Rugby Union (ARU) from July 2016. He has received travel funding from the Australian Football League (AFL) to present at the Concussion in Football Conference in 2013. Previous grant funding includes the NSW Sporting Injuries Committee, the Brain Foundation, and the Hunter Medical Research Institute, supported by Jennie Thomas, and the Hunter Medical Research Institute, supported by Anne Greaves.

Grant Iverson has been reimbursed by the government, professional scientific bodies, and commercial organizations for discussing or presenting research relating to mild TBI and sport-related concussion at meetings, scientific conferences, and symposiums. He has a clinical and consulting practice in forensic neuropsychology involving individuals who have sustained mild TBIs (including professional athletes). He has received research funding from several test publishing companies, including ImPACT Applications, Inc., CNS Vital Signs, and Psychological Assessment Resources (PAR, Inc.).

References

[1] Andersen TE, Larsen Ø, Tenga A, Engebretsen L, Bahr R. Football incident analysis: a new video based method to describe injury mechanisms in professional football. Br J Sports Med 2003; 37: 226–232

[2] Davis G, Makdissi M. Use of video to facilitate sideline concussion diagnosis and management decision-making. J Sci Med Sport 2016, doi:10.1016/j.jsams.2016.02.005

[3] Gabbett T, Ryan P. Tackling technique, injury risk, and playing performance in high-performance collision sport athletes. Int J Sport Sci Coach 2009; 4: 521–533 Available from http://multi-science.metapress.com/openurl.asp?genre = article&id = doi:10.1260/174795409790291402

[4] Gabbett TJ. Influence of playing position on the site, nature, and cause of rugby league injuries. J Strength Cond Res 2005; 19: 749–755

[5] Gardner A, Iverson GL, Levi CR, Schofield PW, Kay-Lambkin F, Kohler RMN, Stanwell P. A systematic review of concussion in rugby league. Br J Sports Med 2015; 49: 495–498

[6] Gardner AJ, Iverson GL, Quinn TN, Makdissi M, Levi CR, Shultz SR, Wright DK, Stanwell P. A preliminary video analysis of concussion in the National Rugby League. Brain Inj 2015; 29: 1182–1185

[7] Gardner AJ, Iverson GL, Stanwell P, Ellis J, Levi CR. A video analysis of use of the new 'concussion interchange rule' in the National Rugby League. Int J Sports Med 2016; 37: 267–273

[8] Gardner AJ, Stanwell P, Levi CR, Quinn T, Makdissi M, Shultz SR, Wright D, Iverson GL. A video analysis of concussion in the National Rugby League: a preliminary study. Brain Inj 2015 [Epub ahead of print]

[9] Hallgren KA. Computing inter-rater reliability for observational data: an overview and tutorial. Tutor Quant Methods Psychol 2012; 8: 23–34

[10] Harriss DJ, Atkinson G. Ethical standards in sport and exercise science research: 2016 update. Int J Sports Med 2015; 36: 1121–1124

[11] Hoskins W, Pollard H, Hough K, Tully C. Injury in rugby league. J Sci Med Sport 2006; 9: 46–56

[12] Hutchison MG, Comper P, Meeuwisse WH, Echemendia RJ. A systematic video analysis of National Hockey League (NHL) concussions, part I: who, when, where and what? Br J Sports Med 2013; 1–6

[13] Hutchison MG, Comper P, Meeuwisse WH, Echemendia RJ. A systematic video analysis of National Hockey League (NHL) concussions, part II: how concussions occur in the NHL. Br J Sports Med 2013; 1–6

[14] IBM Corp. IBM SPSS Statistics for Macintosh, Version 22.0. Armonk, NY: IBM Corp;

[15] King D, Hume P, Clark T. Video analysis of tackles in professional rugby league matches by player position, tackle height and tackle location. Int J Perform Anal Sport 2010; 10: 241–254

[16] King DA, Hume PA, Milburn PD, Guttenbeil D. Match and training injuries in rugby league: a review of published studies. Sport Med 2010; 40: 163–178

[17] Koh JO, Watkinson EJ, Yoon Y-J. Video analysis of head blows leading to concussion in competition Taekwondo. Brain Inj 2004; 18: 1287–1296

[18] Lincoln AE, Caswell SV, Almquist JL, Dunn RE, Hinton RY. Video incident analysis of concussions in boys' high school lacrosse. Am J Sports Med 2013; 41: 756–761

[19] Makdissi M, Davis G. Using video analysis for concussion surveillance in Australian football. J Sci Med Sport 2016, doi:10.1016/j.jsams.2016.02.014

[20] Makdissi M, Davis G. The reliability and validity of video analysis for the assessment of the clinical signs of concussion in Australian football. J Sci Med Sport 2016, doi:10.1016/j.jsams.2016.02.015

[21] McCrory P, Meeuwisse WH, Aubry M, Cantu B, Dvorák J, Echemendia RJ, Engebretsen L, Johnston K, Kutcher JS, Raftery M, Sills A, Benson BW, Davis GA, Ellenbogen RG, Guskiewicz K, Herring SA, Iverson GL, Jordan BD, Kissick J, McCrea M, McIntosh AS, Maddocks D, Makdissi M, Purcell L, Putukian M, Schneider K, Tator CH, Turner M. Consensus statement on concussion in sport: the 4th International Conference on Concussion in Sport held in Zurich, November 2012. Br J Sports Med 2013; 47: 250–258

[22] McHugh ML. Interrater reliability: the kappa statistic. Biochem Med 2012; 22: 276–282

[23] Miele VJ, Bailes JE. Objectifying when to halt a boxing match: a video analysis of fatalities. Neurosurgery. 2007; 60: 307–315 discussion 315–316

[24] Savage J, Hooke C, Orchard J, Parkinson R. The incidence of concussion in a professional Australian rugby league team, 1998–2012. J Sports Med 2013; doi:10.1155/2013/304576