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**An evaluation of World Rugby's concussion management
process: results from Rugby World Cup 2015**

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3 **An evaluation of World Rugby's concussion management process: results from**
4 **Rugby World Cup 2015**
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11 **Running title:** World Rugby HIA process
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An evaluation of World Rugby's concussion management process: results from Rugby World Cup 2015

ABSTRACT

Objective – to evaluate World Rugby's concussion management process during Rugby World Cup (RWC) 2015.

Design – a prospective, whole population study.

Population – 639 international rugby players representing 20 countries.

Method– the concussion management process consisted of 3 time-based, multi-faceted stages: an initial on-pitch and/or pitch-side assessment of the injury, a follow-up assessment within 3 hours and an assessment at 36-48 hours. The initial on-pitch assessment targeted obvious signs of concussion, which if identified lead to a 'permanent removal from play' decision and a diagnosis of concussion. If the on-pitch diagnosis was unclear, a 10-minute off-pitch assessment was undertaken for signs and symptoms of concussion leading to a 'suspected concussion with permanent removal-from-play' or a 'no indication of concussion with return-to-play' decision. Evaluations at 3-hours and 36-48 hours post-match lead to diagnoses of 'confirmed concussion' or 'no concussion'. Medical staff's decision-making was supported during each stage by real-time video review of events. Players diagnosed with confirmed concussion followed a 5-stage graduated-return-to-play protocol before being allowed to return to training and/or competition.

Results – players were evaluated for concussion on 49 occasions, of which 24 resulted in diagnoses of concussion. Fourteen players showing on-pitch signs of concussion were permanently removed from play: 4 of 5 players removed from play following off-pitch medical room evaluation were later diagnosed with a confirmed concussion. Five players not exhibiting in-match signs or symptoms of concussion were later diagnosed with concussion. The overall incidence of concussion during RWC 2015 was 12.5 concussions/1000 player-match-hours.

Conclusion – the concussion management process reported in this study supports the implementation of a multi-modal, multi-time-based concussion evaluation process supported by real-time video reviews.

INTRODUCTION

Concussion, a traumatic brain injury that may present with transient, fluctuating, evolving or delayed signs and symptoms, has attracted growing attention among sports physicians, athletes, media and the public.[1] Interest has focused, in particular, on questions about consistency in the identification of concussed athletes and their subsequent management and rehabilitation.[2,3] Despite worldwide interest and the intervention of several national and international concussion groups, limited progress has been made in answering these questions.[3-8] Advances in the practical, immediate management of concussion have been constrained by a lack of progress in the development of an accepted operational definition of concussion that can be used to identify concussed athletes during match play.[9-11] While the immediate effects of most concussions are short-lived, typically resolving within days, athletes who continue to play following a concussive event may increase their risk of developing short, medium and long-term consequences including reduced playing performance, non-concussion injuries and an increased risk of developing subsequent concussions and long-term conditions such as chronic traumatic encephalopathy and amyotrophic lateral sclerosis.[12-14]

The reported incidence of concussion in elite 15-a-side rugby union (rugby) has increased from ~4 to ~13 injuries/1000 player-match-hours over the past 10 years.[15,16] It is not possible to determine conclusively from the published data whether this represents a real increase in the incidence, a secondary effect arising from greater clarity and expansion of diagnostic criteria for concussion or a greater tendency by players and physicians to identify and report concussions due to increased awareness of the potential adverse health effects. This latter viewpoint is supported by the fact that overall injury rates in rugby have remained unchanged over the same period.[16] In the absence of universal agreement on an operational protocol for evaluating concussion,[8] World Rugby introduced a pitch-side protocol specifically for elite rugby in 2012.[17] This protocol was subsequently developed further from 2013 to 2015 with the focus on the need to recognise and remove players suspected of sustaining concussion.[11] These developments led World Rugby to integrate the match-day concussion management protocol, referred to as the Head Injury Assessment (HIA) process, into the Laws of the Game in August 2015.[18] The primary objectives of this paper are to describe the HIA process with enhanced capabilities provided by access to pitch-side real-time and medical room review video facilities and to evaluate the process during Rugby World Cup (RWC) 2015.

METHOD

This was a prospective, whole population (teams: 20; players: 639; matches: 48) cohort study describing the management of head impact events at RWC 2015. The HIA process is included within the Laws of the Game of Rugby Union and the injury audit was approved by World Rugby's Institutional Ethics Committee: all players provided signed informed consent for their injury data to be recorded.

World Rugby HIA Process

The World Rugby HIA process is a multi-faceted, multi-point-in-time assessment process aimed at identifying players with a confirmed or suspected concussion and informing players' subsequent injury management. The overall process consists of a number of inter-related elements:

Education and training:

- (i) All players and team management completed a concussion education session within the previous 12 months.
- (ii) All players completed a baseline concussion assessment (SCAT 3 minimum) within the previous 12 months.
- (iii) All team medical and tournament match-day medical staff completed the World Rugby training modules for 'Concussion Management' and 'Medical Protocols for Match-day Medical Staff'.
- (iv) All team doctors, match-day doctors and match-day immediate care leads attended a face-to-face pre-tournament HIA process and concussion management training session.

HIA process:

The HIA process consists of 3 time-based assessment stages designed to include the full range of potential concussion presentation formats, as summarised in Figure 1.

- (i) *HIA-1 stage*: consists of 2 sub-sections –
 - (a) Section 1: a player is immediately and permanently removed from further participation in a match if the player's team doctor or the match-day doctor identifies any sign(s) of concussion (see Box 1). Match-day doctors had access to pitch-side real-time video facilities to assess the event and to support their decision-making. Players removed

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3 from a match with any of these criteria are deemed to have a confirmed concussion and
4 despite the confirmed concussion diagnosis subsequently undergo post-match HIA-2
5 and HIA-3 assessments.
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8 (b) Section 2: team medical staff, match-day doctor or referee must request an off-pitch
9 assessment (lasting up to 10-minutes) for any player who has a head impact event
10 where the injury diagnosis is not immediately clear. Players must be led unaided to a
11 pre-designated medical room for an assessment that includes three sequential domains
12 comprised of the Maddocks' and SAC questions, a tandem gait test and an assessment
13 and recognition of any symptoms and clinical signs of concussion (see Box 1). Match-
14 day doctors and team doctors were supported in their clinical decision-making by a real-
15 time video review system, which provided instant replays of match events from up to 30
16 camera angles/feeds both pitch-side and in the medical room. The HIA-1 (Section 2)
17 assessment is not intended to provide a clinical diagnosis of concussion but a triage to
18 determine whether a player may have a suspected concussion and therefore whether
19 they may return to play or not. An abnormal test result in any domain or a clinical
20 judgement of suspected concussion mandates the removal of the player from the
21 match. A 'normal' HIA-1 (Section 2) assessment enables the team doctor to allow the
22 player to return to the match. All players undergoing an HIA-1 (Section 2) assessment,
23 irrespective of the outcome, are required to undertake follow-up HIA-2 and HIA-3
24 assessments to determine whether a player has a confirmed concussion.
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38 (ii) *HIA-2 stage*: consists of a SCAT 3 evaluation (excluding the Glasgow Coma Scale and
39 Maddocks' questions) within 3 hours of injury to assess clinical progress and to provide an
40 early diagnosis of concussion for (a) players removed from the pitch following an HIA-1
41 (Section 1 or Section 2) assessment, (b) if a post-match video review of match events
42 indicates a player may have sustained a head injury, and (c) players who did not undergo
43 an HIA-1 assessment but developed sign(s) or symptom(s) of concussion within 3 hours of
44 the match. Any abnormal outcome from a player's HIA-2 examination is considered a
45 diagnosis of concussion unless proven otherwise. All players undergoing an HIA-2
46 assessment are required to undertake an HIA-3 assessment.
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54 (iii) *HIA-3 stage*: consists of a clinical assessment of a player supported by an expanded SCAT
55 3 symptom checklist that identifies the number, maximum severity and duration of
56 concussion symptoms. HIA-3 also includes a cognitive assessment, preferably using a
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3 computerised neuro-cognitive tool such as CogSport (or as a minimum the SAC
4 assessment) and a balance assessment using the balance error scoring system and tandem
5 gait balance tests. The HIA-3 assessment is completed (a) after 2 nights rest (typically 36-
6 48-hours post-injury), (b) if a player, who did not undergo an HIA-2 assessment, develops
7 sign(s) or symptom(s) of concussion between 3 and 48-hours post-match or (c) if a post-
8 match video review of match events indicates that a player may have sustained a head
9 injury. Any abnormal outcome from a player's HIA-3 examination is considered a diagnosis
10 of concussion unless proven otherwise.
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19 The 3-stage process therefore leads to a diagnosis of concussion if one or more of the following
20 outcomes is reported:
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- 22 (a) The player had any Criteria 1 sign(s) of concussion (see Box 1) during the on-pitch
23 evaluation that resulted in his removal from play. (HIA-1, Section 1).
24
25 (b) Any Criteria 1 sign(s) of concussion were identified during the medical room video
26 reviews of the player's head impact event.
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28 (c) The 3-hour, post-injury (HIA-2) assessment is 'abnormal'.
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30 (d) The 36-48-hour, post-injury (HIA-3) assessment is 'abnormal'.
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32 (e) The treating doctor deemed the player to have sustained a concussion.
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Box 1. HIA-1 stage: signs and symptoms of concussion leading to a player's immediate and permanent removal from play.

HIA-1: signs and symptoms leading to immediate and permanent removal from play

Section 1: Criteria 1 signs of concussion

Section 2: Symptoms

Tonic posturing	Headache
Convulsion	Feeling of dizziness
Confirmed loss of consciousness	Experiencing 'pressure in the head'
Suspected loss of consciousness	Nauseated or feeling like vomiting
Balance disturbance / ataxia	Experiencing blurred vision
Player not orientated in time, place or person	Worried by light or noise
Clearly dazed	Feeling as though slowing down
Definite confusion	Feeling as if 'in a fog'.
Definite behavioural change	Feeling unwell
On field identification of sign/symptom of concussion	
Oculomotor signs (e.g. spontaneous nystagmus)	

World Rugby injury surveillance study:

All teams were required to take part in the routine RWC Injury Surveillance Study, which followed the international consensus statement for rugby injury surveillance studies:[19] a full description and the results obtained from this study are presented in a separate report.[20] Within this broader injury audit, team doctors were required to report details of all confirmed concussions resulting from match and training activities: the injury surveillance study therefore, provides a cross-check on the HIA process and provides an additional time-based assessment for concussions that develop more than 48-hours post-match.

World Rugby graduated-return-to-play protocol

All players sustaining a confirmed concussion completed a 5-stage graduated-return-to-play protocol as described in previous publications.[3-8]

Untoward Incident Review

All players and team management involved in RWC 2015 were required to sign a Terms of Participation document, which included a section specifically related to player welfare matters. Of relevance to this study was the requirement that players and team management must comply with

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3 the HIA process and graduated-return-to-play protocol and failure to do so was regarded as
4 misconduct and the relevant parties would be subject to an 'Untoward Incident Review' lead by
5 World Rugby's Chief Executive Officer, Head of Legal Services and Chief Medical Officer.
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8 9 10 **Data collection and statistical analyses**

11 The HIA process assessments, including the influence of video reviews on the identification of head
12 impact events and concussion diagnoses were recorded on a tablet computer-based system (CSx,
13 Auckland, New Zealand), pre-loaded with every player's SCAT 3 baseline data. All test results were
14 automatically uploaded onto a secure World Rugby database.
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18 Player-flow through the HIA process was evaluated descriptively. Assessments of differences in
19 players' anthropometric data were made using unpaired t-tests, in numbers of injuries using chi-
20 square tests, in incidence and mean severity of injuries using z-tests and in median severities of
21 injury using Mann-Whitney U tests:[21] statistical significance was accepted at $p < 0.05$ values.
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27 Statistical analyses were conducted in Microsoft®Excel®2008 for Mac
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32 **RESULTS**

33 **Sample characteristics**

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35 Figure 2 summarises the player flow through each stage of the HIA concussion management
36 process. There were 49 cases when players were evaluated for concussion (43 players once; 3
37 players twice); of these, 24 cases resulted in diagnoses of confirmed concussion (22 players once;
38 one player twice), which corresponds to a concussion prevalence amongst the players of 3.8% and
39 an incidence of 12.5 concussions/1000 player-match-hours. Of the 24 confirmed concussions, 15
40 were sustained by backs and 9 by forwards ($p=0.120$): there were no statistically significant
41 differences in the mean age (backs: $p=0.234$, forwards: $p=0.697$), stature (backs: $p=0.078$,
42 forwards: $p=0.115$) or body mass (backs: $p=0.968$, forwards: $p=0.123$) of backs or forwards
43 sustaining concussions compared to all backs and forwards competing at RWC 2015 (Table 1).
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Table 1: Anthropometric data for the total and the concussed populations.

Playing position (number of players)	Mean (standard deviation)		
	Age, years	Stature, cm	Body mass, kg
Total population -			
Backs (n=279)	26.5 (3.5)	182.6 (6.0)	93.0 (8.9)
Forwards (n=360)	28.2 (3.8)	188.5 (7.1)	112.6 (9.0)
All players (n=639)	27.4 (3.8)	185.9 (7.2)	104.1 (13.2)
Concussed population -			
Backs (n=15)	25.4 (3.2)	184.3 (5.5)	93.1 (7.9)
Forwards (n=9)	27.7 (3.8)	186.0 (4.7)	109.1 (5.5)
All players (n=24)	26.3 (3.6)	184.9 (5.1)	99.1 (10.5)

Player outcomes in the HIA management process

Of the 49 cases evaluated for concussion, 39 were first assessed during matches: in these 39 cases, players were removed from play immediately on 14 occasions following the identification of signs of concussion (Box 1) during the on-pitch HIA-1 (Section 1) evaluation and on 5 occasions because there was an abnormal off-pitch HIA-1 (Section 2) assessment indicating a suspected concussion. Four of the 5 players suspected of sustaining a concussion were later diagnosed with confirmed concussions following an abnormal HIA-2 (3 players) or HIA-3 (1 player) evaluation. Of the 20 players not suspected of sustaining a concussion following their HIA-1 (Section 2) evaluation, one player was later diagnosed with a concussion following a normal HIA-2 evaluation and an abnormal HIA-3 evaluation. Eight players presented within 3 hours post-match either with a suspicion of concussion or had experienced a head impact event identified on post-match video review, of which 2 were diagnosed with concussion following abnormal HIA-2 evaluations and 1 diagnosed with a concussion following a normal HIA-2 but an abnormal HIA-3 evaluation. Two further players presented 36-48-hours post-match, both of whom were diagnosed with concussion following abnormal HIA-3 evaluations. Of the 19 players removed from the field of play during the game, one player did not complete an HIA-2 or an HIA-3 examination (due to a fractured mandible injury sustained in the same incident) and two players completed HIA-2 examinations (abnormal) but did not complete HIA-3 examinations. Of the 20 players with a normal HIA-1 (Section 2) evaluation, all completed HIA-2 and 18 completed HIA-3 examinations.

Video review outcomes

Pitch-side, real-time videos and medical room video reviews were used to identify or confirm 11 of the 19 head contact events that led to the immediate and permanent removal of players from the field of play. Video review was also used to assist team doctors in their evaluations in 5 of these incidents. In addition, pitch-side videos were used to identify 13 of the 20 head injury incidents that returned 'normal' HIA-1 results and were used to assist team doctors in their evaluations in 5 of these incidents. Post-match video analysis was used to identify a head contact incident that subsequently resulted in an abnormal HIA-3 and a diagnosis of confirmed concussion.

Concussion severity and return-to-play

The mean and median severities of all concussions were 7.7 (95% CI: 6.1 to 9.3) and 6 (95% CI: 5 to 8) days, respectively. There were no significant differences in the mean or median severities as a function of the stage within the HIA process that the concussions were first confirmed (Table 2). Seventeen of the 24 players with a confirmed concussion (71%) returned to play in ≤ 7 days and 7 (29%) in ≥ 8 days.

Table 2. Severity of concussion as a function of the stage within the HIA process that concussion was first confirmed

HIA stage at which concussion was confirmed	n	Severity, days	
		Mean (95% CI)	Median (95% CI)
HIA-1 (Section 1)	14	7.9 (5.3 to 10.5)	6.0 (5 to 8)
HIA-2	6	6.5 (4.7 to 8.3)	5.5 (5 to 6)
HIA-3	4	8.8 (5.1 to 12.5)	9.0 (5 to 12)

Every player with a confirmed concussion followed World Rugby's graduated-return-to-play protocol and returned within the recommended time-frame of the protocol.

DISCUSSION

Each stage of the HIA concussion management process made a contribution to the diagnosis of at least one of the 24 confirmed concussions reported in this study. The proportions of cases in which contributions were made were: HIA-1 (Section 1) – 58%; HIA-1 (Section 2) – 17%; HIA-2 – 54%; HIA-3 – 38%; pitch-side video (incident identification) – 46%; pitch-side video (signs of concussion) – 21%; post-match video analysis (incident identification) – 4%; post-match video

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3 analysis (signs of concussion) – 4%. Post-match video analysis identified a head impact event
4 missed on match day that resulted in a confirmed concussion. Only one player (4.2%) who
5 returned a normal HIA-1 (Section 2) evaluation (and consequently was not removed from play)
6 was later diagnosed with a confirmed concussion following a normal HIA-2 evaluation and an
7 abnormal HIA-3 evaluation. Importantly, diagnoses of confirmed concussion were reached via 7 of
8 the 8 possible HIA pathways (Figure 2).
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15 The summary above highlights a major advantage of the 3-time-point HIA process, as it identified
16 5 'delayed concussions' that might otherwise have been missed if the process had relied on in-
17 match assessments alone. This is an important result that must influence future recommendations
18 about how and when athletes should be evaluated for concussion. At the present time, concussion
19 consensus statements provide guidance for on-pitch/side-line evaluation of players and make
20 recommendations for follow-up assessments only for those players diagnosed with suspected or
21 confirmed concussion.[3-8] None of the consensus statements present recommendations for
22 further post-match assessments for those players not diagnosed with a confirmed or suspected
23 concussion during the on-pitch/side-line evaluation. In this study, 25% of all confirmed
24 concussions were 'delayed' concussions, which were only identified post-match. Furthermore, our
25 findings support the role of real-time pitch-side video and medical room video reviews in managing
26 head impact events during play, as the use of video contributed to the majority of concussion
27 cases identified during play.
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40 **Development of concussion**

41 While this study evaluated the contribution made by each stage of the HIA process, it did not set
42 out to evaluate the reliability of individual tests for concussion, as each test has been
43 independently studied previously or is recommended by one or more concussion consensus
44 groups.[3-8] It is recognised that the sensitivity and specificity associated with each test means
45 that some test results may be false positives and others may be false negatives. It is also
46 recognised that there will be an assessment threshold-level above which a diagnosis of concussion
47 will be recognised and below which a diagnosis will not be recognised. If, for the purposes of the
48 following discussion, it is assumed that the outcomes from the HIA-1, HIA-2 and HIA-3 evaluations
49 presented in Figure 2 represent valid assessments of a player's condition with regard to concussion
50 at the moment in time when the test was carried out, the study provides important new insights
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3 into both the complexity and the variations observed in the presentation of concussion in the elite
4 tournament setting.
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8 It is generally accepted that concussions can manifest in a range of presentations including
9 transient signs such as ataxia or loss of consciousness and/or short and medium-term symptoms
10 such as headache or irritability.[22-24] These effects, some of which resolve within
11 seconds/minutes while others resolve within hours/days, are generally considered to be caused by
12 changes in various pathophysiological processes, such as ionic shifts, altered metabolism, impaired
13 connectivity and changes in neurotransmission.[22-24] The range of concussion presentations
14 observed in this study can all be explained by adopting a simplified two-phase process consisting
15 of:
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24 Phase-1: a rapidly developing effect leading to transient signs such as tonic posturing and ataxia,
25 which would be observed during the HIA-1 assessment stage but which are likely to have resolved
26 by the time of the HIA-2 and HIA-3 assessments, Figure 3a.
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29 Phase-2: a slower-developing effect leading to longer-lasting symptoms such as lack of
30 concentration and susceptibility to light and noise, Figure 3b.
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34 At any point in time, it can be assumed that athletes being assessed for concussion will exhibit the
35 sum of the signs and symptoms derived from these two phases, Figure 3c. The manifestation of
36 each player's concussion status during HIA-1 (5-10 minutes post-event), HIA-2 (3-hours post-
37 match) and HIA-3 (36-48-hours post-match) assessments would therefore depend on the relative
38 magnitudes and rates of development of and recovery from these two phases of concussion. While
39 this is a very simplistic model of an athlete's development and recovery from concussion, it serves
40 to describe and explain the results observed in this study, especially how players can be cleared of
41 concussion during on-pitch assessments (absence of phase-1 effects) but develop symptoms of
42 concussion 36-48 hours post-match (development of phase-2 effects); the model therefore
43 highlights why it is important to incorporate post-match assessments within a diagnostic protocol
44 for concussion.
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Strengths and limitations of study

This study has a number of strengths. In particular, it is a whole population, prospective study with all concussions being evaluated by experienced physicians, who underwent specific training for the assessment and management of concussion prior to the start of the tournament. Data were collected in real-time using a computer-based system with a high level of compliance. In terms of the study limitations, the number of concussions recorded is relatively small, which limits the conclusions that can be drawn from the results. Although no concussions were identified in the injury surveillance study that had not previously been identified through the HIA process, delayed presentations beyond 48-hours cannot be ruled out. It is also recognised that the concussion management process used at RWC 2015 represents the most comprehensive evaluation process currently available in rugby and it is likely that such a high-level process would only be achievable at the elite professional level of rugby.

Conclusion

The concussion management process used at RWC 2015 and reported in this paper provides a strong case to support the implementation of a multi-modal, multi-time-based concussion evaluation process incorporating video review. It has also identified the most important elements of the overall process, which can be utilised at other levels of the game. Ongoing injury surveillance is also recommended at least until the processes involved in the presentation of delayed-onset concussion are more clearly understood.

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What are the new findings?

- This is the first study to evaluate a multi-modal, multi-timeframe head injury management process in the elite adult professional sport setting.
- Real-time video and match-day doctors provided important elements of the comprehensive concussion management process.
- Concussions presented in timeframes varying from minutes to at least 48 hours post-head impact.

How might it impact on clinical practice in the future?

- A multi-time-based assessment process is recommended for the identification of transient, developing and delayed concussions.
- Real-time video review should be integrated, where possible, into the concussion assessment process.
- Players sustaining head impacts should be monitored for at least 48 hours post-match for signs/symptoms of concussion.

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3 Figure 1. Flow chart of HIA Concussion management protocol.
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10 Figure 2. Data flow for players undergoing assessments for concussion.
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15 Figure 3. Theoretical model for the development and recovery from short and long-term signs and
16 symptoms of concussion.
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18 Figure 3a. Short-term signs and symptoms
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20 Figure 3b. Medium-term signs and symptoms
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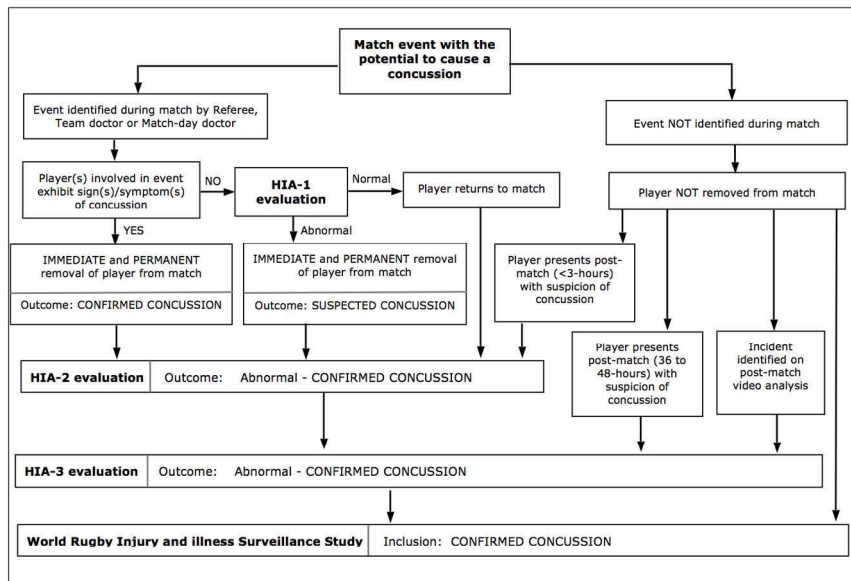
22 Figure 3c. Combined signs and symptoms
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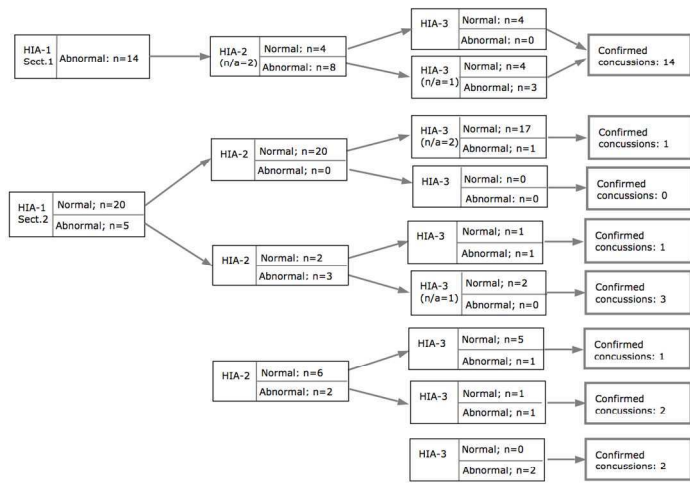
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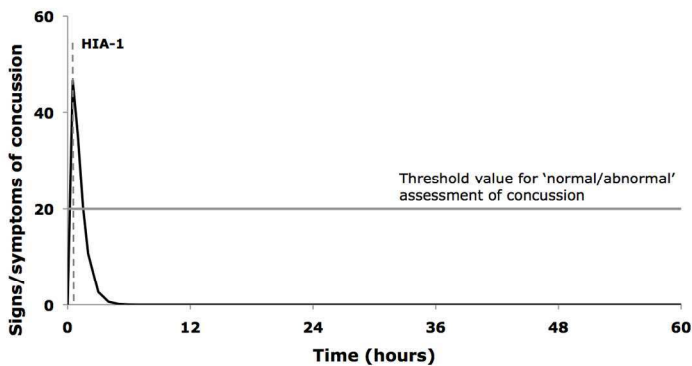
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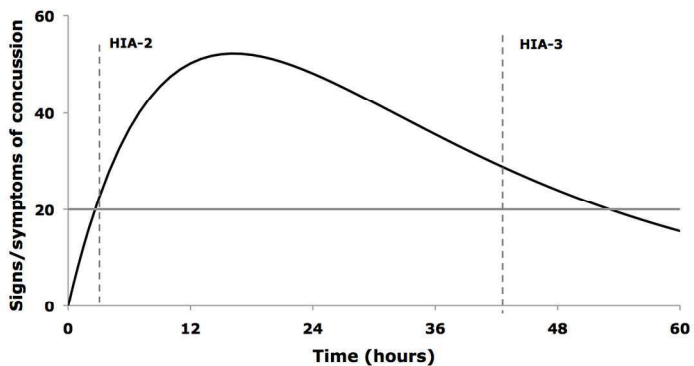


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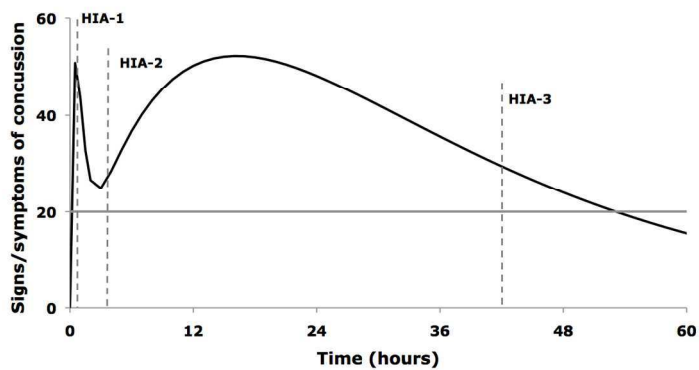
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