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Davis, G.A. [orcid.org/0000-0001-8293-4496](https://orcid.org/0000-0001-8293-4496), Makdissi, M., Bloomfield, P. et al. (15 more authors) (2019) International consensus definitions of video signs of concussion in professional sports. *British Journal of Sports Medicine*. ISSN 0306-3674

<https://doi.org/10.1136/bjsports-2019-100628>

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This article has been accepted for publication in *British Journal of Sports Medicine*, 2019, following peer review, and the Version of Record can be accessed online at <https://doi.org/10.1136/bjsports-2019-100628>

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## **International consensus definitions of video signs of concussion in professional sports.**

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### **Disclosures**

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**ICJME disclosure forms have been provided.**

### **Contributorship**

GD and MM contributed to the conception of the work. All authors contributed to the acquisition, analysis or interpretation of data, drafting the work or revising it critically for important intellectual content, final approval of the version published, and agreement to be accountable for all aspects of the work.

### **Funding Info**

No funding was required for this study.

### **Acknowledgements**

Not applicable

### **Ethical approval information**

As this study does not contain any patient data, research ethics committee approval was not required.

### **Data sharing statement**

Not applicable.

### **Patient involvement**

Not applicable.

### **What are the new findings?**

- Video review has rapidly become an important tool in professional sports for the identification of brief early signs of a possible concussion. Currently however there is little consistency across sporting codes regarding the definition and interpretation of the video signs.
- Expert members from seven national and international sporting codes agreed on the inclusion of six signs for the identification of a possible concussion: lying motionless, motor incoordination, impact seizure, tonic posturing, no protective action - floppy and blank/vacant look.
- Consensus definitions were developed for all six video signs.

### **How might it impact on clinical practice in the future?**

- Video review can assist sideline physicians in identifying possible concussions which may otherwise not be detected.
- Consistent definitions of video signs of possible concussion across sporting codes, will facilitate further research on the reliability of video signs in the diagnosis of concussion, and allow a determination of which signs (if any) should mandate permanent removal from play.

## **Abstract**

**Background** The use of video to assist professional sporting bodies with the diagnosis of sport-related concussion (SRC) has been well established, however there has been little consistency across sporting codes with regards to which video signs should be used, and the definitions of each of these signs.

**Aim** The aims of this study were to develop a consensus for the video signs considered to be most useful in the identification of a possible SRC, and to develop a consensus definition for each of these video signs across the sporting codes.

**Methods** A brief questionnaire was used to assess which video signs were considered to be most useful in the identification of a possible concussion. Consensus was defined as >90% agreement by respondents. Existing definitions of these video signs from individual sports were collated, and individual components of the definitions were assessed and ranked. A modified Delphi approach was then used to create a consensus definition for each of the video signs.

**Results** Respondents representing seven sporting bodies (AFL, CA, MLB, NFL, NHL, NRL, WR) reached consensus on eight video signs of concussion. Thirteen representatives from the seven professional sports ranked the definition components. Consolidation and refinement of the video signs and their definitions resulted in consensus definitions for six video signs of possible concussion: lying motionless, motor incoordination, impact seizure, tonic posturing, no protective action - floppy and blank/vacant look.

**Conclusions** These video signs and definitions have reached international consensus, are indicated for use by professional sporting bodies, and will form the basis for further collaborative research.

## **Introduction**

The diagnosis and management of sport-related concussion (SRC) has evolved substantially over recent decades, with international collaboration enhancing research efforts.<sup>1</sup>

The identification of possible concussive injuries is not always readily apparent from the sidelines, often despite having experienced medical staff available. The use of video technology has been adopted by many professional sports to assist with the detection of possible concussive injuries.<sup>2-15</sup> In a previous study, the authors examined the use of video review in a number of national and international professional sports.<sup>16</sup> Signs that were found to be common to most international professional sports included lying motionless/loss of responsiveness and motor incoordination. The video signs considered by the majority of sports as most predictive of a diagnosis of SRC included motor incoordination, impact seizure, tonic posturing and lying motionless.<sup>16</sup> There was no universal consensus however as to the definitions of each of the video signs or how they should be interpreted (i.e. which video sign mandated permanent removal from play). Currently, there is minimal evidence on the positive and negative predictive value of the video signs of SRC to guide management decisions.

A consensus of terminology and definitions is critical to inform each sporting body on the appropriate use of video technology as an aid to the management of SRC, and to advance the scientific research to address a number of outstanding questions, such as predictive value of video signs for the diagnosis of SRC, and the potential use of these data to assist the sporting codes with management and prevention strategies.

The aims of this study were to develop a consensus for the video signs considered to be most useful in the identification of a possible SRC, and to develop a consensus definition for each of these video signs across the sporting codes.

## **Methods**

Senior medical advisers and chief medical officers from major international sporting codes, including the Australian Football League (AFL), Cricket Australia (CA), Major League Baseball (MLB), National Football League (NFL), National Hockey League (NHL), National Rugby League (NRL) and World Rugby (WR) participated in the previous study,<sup>16</sup> and were purposively sampled and invited to participate in this study.

In the previous study,<sup>16</sup> 17 different video signs of possible concussion were identified as currently being used by international professional sports. These include:

- Lying motionless
- Motor incoordination/ataxia/staggering gait/stumbles/stagger
- No protective action - floppy
- No protective action - tonic
- Cervical hypotonia
- Uncontrolled fall to ground
- Controlled fall
- Impact seizure/convulsion
- Tonic posturing

- Blank/vacant look
- Dazed
- Slow to get up
- Clutching at head
- Walking away from pitch disengaged with game
- Disorientation
- Confusion/behaviour change
- Facial injury/fracture

A brief questionnaire was developed and sent out to participants in the current study to assess which video signs were considered to be most useful in the identification of a possible concussion. Consensus was defined as >90% agreement by respondents.

For video signs that reached >90% agreement, existing definitions were obtained from each of the participating sports and a qualitative analysis was performed by two experienced clinicians (GD, MM). Individual components of each definition were categorised as either (i) reaching, or (ii) failing to reach consistency across the professional sports. A modified Delphi approach was then used to create consensus definitions for each of the video signs. At each stage, respondents from all sports were invited to provide additional comments or suggestions for improving the definitions.

## **Results**

Eleven representatives from six different sports (AFL, CA, MLB, NFL, NRL, WR) responded quantitatively, and two representatives from one sport (NHL) responded qualitatively to the initial questionnaire.

The results are summarised in Supplementary Table 1.

Video signs with >90% agreement were:

- Lying motionless
- Motor incoordination/ataxia/staggering gait/stumbles/stagger
- No protective action - floppy
- No protective action - tonic
- Cervical hypotonia
- Impact seizure/convulsion
- Tonic posturing
- Blank/vacant look

Thirteen representatives from seven professional sports (AFL, CA, MLB, NFL, NHL, NRL, WR) were involved in the modified Delphi approach resulting in a consensus definition for each of the video signs.

The final consensus definitions of the video signs of possible concussion are detailed in the table.

<p><b>Lying motionless</b></p>	<p>Lying without purposeful movement on the playing surface, for &gt;2 seconds*. Does not appear to move or react purposefully, respond or reply appropriately to the game situation (including teammates, opponents, umpires or medical staff). Concern may be shown by other players or match officials.</p> <p>[*&gt;2 secs for removal and assessment of the athlete. Significantly longer periods of lying motionless may necessitate immediate and permanent removal from play, depending on the circumstances.]</p>
<p><b>Motor incoordination</b></p>	<p>Appears unsteady on feet (including losing balance, staggering/stumbling, struggling to get up, falling), or in the upper limbs (including fumbling). May occur in rising from the playing surface, or in the motion of walking/running/skating.</p>
<p><b>Impact seizure</b></p>	<p>Involuntary clonic movements that comprise periods of asymmetric and irregular rhythmic jerking of axial or limb muscles</p>
<p><b>Tonic posturing</b></p>	<p>Involuntary sustained contraction of one or more limbs (typically upper limbs), so that the limb is held stiff despite the influence of gravity or the position of the player. The tonic posturing could involve other muscles such as the cervical, axial, and lower limb muscles. Tonic posturing may be observed while the athlete is on the playing surface, or in the motion of falling, where the player may also demonstrate no protective action*.</p> <p>[*This was previously known as no protective action - stiff]</p>
<p><b>No protective action - floppy</b></p>	<p>Falls to the playing surface in an unprotected manner (i.e., without stretching out hands or arms to lessen or minimise the fall) after direct or indirect contact to the head. The player demonstrates loss of motor tone (which may be observed in the limbs and/or neck*) before landing on the playing surface.</p> <p>[*When the player's arms are being held by a tackling opponent, this may only be observed in the neck, which was previously known as cervical hypotonia]</p>
<p><b>Blank/vacant look</b></p>	<p>The player exhibits no facial expression or apparent emotion in response to the environment.*</p> <p>[*May include a lack of focus/attention of vision. Blank/vacant look is best appreciated in reference to the athlete's normal or expected facial expression]</p>

## Discussion



The use of video technology to assist with the diagnosis of possible concussion has been widely adopted by international professional sports,<sup>1-3 5-15 17</sup> however the variability in the video signs used, and their definition has resulted in some confusion when comparing methods and results across the different sports. Common terminology and definitions are crucial to advance scientific and collaborative research, with the ultimate objective of improving game day management of SRC.

The current study has identified six video signs that are considered to be most useful in the identification of a possible concussion. While there are other video signs that also occur following possible concussive injuries, these are considered non-specific (e.g. facial injury, clutching at head), or too difficult to objectively assess on video (e.g. confusion, behaviour change). As such the six video signs defined in this study are considered by the representatives of seven national and international professional sporting bodies to be the most useful signs of a possible concussion that can be assessed using current video technology. The presence of any one sign does not necessarily indicate that concussion has occurred, but rather, the presence of any of these signs indicate the need to remove the athlete from the playing arena for formal assessment and evaluation from a suitably qualified health practitioner.

#### Lying motionless

The duration of lying motionless has been arbitrarily defined as >2 seconds. There was unanimous agreement that duration  $\leq 1$  second was too short, and that the ideal definition falls between 2 and 5 seconds. Some sporting codes have previously stipulated that lying motionless >5 seconds mandates permanent removal from play, but, in the absence of supporting evidence for this recommendation, the authors' consensus opinion is that >2 seconds is the appropriate duration to mandate assessment, although, it is acknowledged that future research is required to confirm the optimum cut off.

#### Motor incoordination

Earlier definitions of motor incoordination have incorporated several synonyms of unsteadiness. The current definition has included the most commonly used and appropriate terms, and overcomes the problems of separate definitions for incoordination in the process of attempting to rise from one's feet, and in the process of motion across the playing surface by combining both into a convenient, simplified definition.

#### Impact seizure

The current International League Against Epilepsy (ILAE) definition of a seizure is "a transient occurrence of signs and/or symptoms due to abnormal excessive or synchronous neuronal activity in the brain",<sup>18</sup> but this is impractical for use in video assessment of sports concussion. The proposed definition is consistent with earlier definitions of impact seizures,<sup>17</sup> however the term impact seizure is preferred over "impact convulsion" in keeping with the 2017 ILAE classification.<sup>18</sup>

#### Tonic posturing

The definition of tonic posturing for the athlete lying on the playing surface is consistent with previous definitions.<sup>17</sup> However, in the process of a concussive injury when the athlete is upright (often a clash while jumping in the air), the athlete may fall to the playing surface unresponsive, and traditionally many have referred to this as "ragdoll". But, if the athlete has tonic posturing as they fall, then they are not "floppy" like a ragdoll, but "stiff" due to tonic

posturing. To clarify this distinction, no protective action - stiff has been incorporated into the definition of tonic posturing.

#### No protective action - floppy

This definition is of the video sign that some refer to as “ragdoll”. However, in some circumstances, the athlete’s arms are held tightly to the torso by a tackling opponent, and as the athlete and opponent fall to the ground, there is no opportunity for the athlete to place the arms out to protect themselves from the fall. In this circumstance, if the athlete is “floppy”, then the only evidence for this on video may be observed in the neck – that is, cervical hypotonia. Given that cervical hypotonia is a form of no protective action - floppy, it has been incorporated in the definition as such.

#### Blank/vacant look

This video sign is difficult to define, because in part, it requires an appreciation of the athlete’s normal facial appearance and expressions. This is often best appreciated by the team doctor or trainer, and, in sports with helmets with face masks, there may be no clear view of the face and eyes to adequately assess for this video sign. Nevertheless, in sports in which the video clearly provides the observer with a view of the face, this definition is considered appropriate and valid.<sup>10</sup>

#### Limitations

This study is a consensus study performed by representatives from international professional sporting codes. Most of the original studies of video signs in these sports were conducted among professional male athletes,<sup>2-15 18</sup> and therefore, application of these video signs to females and amateur athletes requires validation. While many of the data that formed the basis for these definitions were acquired in individual sports, and reached good levels of validity and reliability, no study has yet validated the current definitions across multiple sporting codes, and further research is required to determine the reliability of these definitions when used by observers of different backgrounds, including medical practitioners, certified athletic trainers and allied health personnel.

#### Conclusion

This consensus study provides a practical list of video signs of concussion in sport, and importantly, provides operational definitions for each of these video signs. These definitions and video signs are suitable for use in all sporting codes, however, the predictive value of each sign, or groups of signs, remains to be determined, and will form the basis of further research.

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