PEER REVIEW HISTORY

ARTICLE DETAILS

TITLE (PROVISIONAL)	Medical Assessment of Potential Concussion in Elite Football: A Video Analysis of the 2016 UEFA European Championship
AUTHORS	Abraham, Karan; Casey, Julia; Subotic, Arsenije; Christopher, Tarzi; Zhu, Alice; Cusimano, Michael

VERSION 1 - REVIEW

REVIEWER	Scott Zuckerman Vanderbilt University Medical Center United States
REVIEW RETURNED	10-Jul-2018

GENERAL COMMENTS	The authors sought to determine if suspected concussions in elite football are medically assessed according to the International Conferences on Concussion in Sport consensus statement recommendations. The authors watched games played in the Men's UEFA European Championship (10 June – 10 July 2016) for potential concussive events (PCEs). Sixty-nine total PCEs (1.35 per match) were identified in 51 games. Forty-eight PCEs (69.6%) resulted in two observable signs of concussion, 13 (18.8%) resulted in three signs, and 1 (1.4%) resulted in four signs in the injured athletes. Nineteen (27.5%) PCEs were medically assessed by sideline healthcare personnel while 50 (72.5%) were not. Of the 50 PCEs that were not medically assessed, 44 (88%) PCEs resulted in two or more signs of concussion among injured athletes. Of the 19 medically assessed PCEs, 8 resulted in 3 signs of concussion, and 1 resulted in 4 signs; all assessments concluded in same-game return for the injured athletes. The authors concluded that PCEs were frequent events but were rarely assessed concordant with the International Conferences on Concussion in Sport consensus. To my knowledge, CISG guidelines do not itemize when a patient needs to be evaluated. Can the authors articulate what specific guidelines they used from the CISG document to define the event as a PCE? I see they defined this in their document as removed from play, but where is this in the expert document? Also the methods section should be reorganized with subsections. Potential information to include are – description of how videos were coded, how coders were instructed and tested, the setting of how the videos were watched, and how data was collected. These should be divided into appropriate sub-headings to organize the

	methods and allow the authors to be as descriptive as possible. A statistical section is also recommended. How was disorientation defined through video analysis? To my knowledge, this is very difficult to assess by watching a video, whereas seizure or clutching can definitely be observed through video. Also if a player was carted off, how did the coders tell if they were assessed for concussion? What if the assessment took place off camera and this could not be seen – is this a possibility? According to the authors, no PCEs resulted in concussions? Again, it is interesting that only 19 of 69 PCEs were assessed, but where in the guidelines does it define that an athlete HAS to be assessed if they are remove dfrom play? It is possible they go to the sideline after an apparent head collision, only to have some hip pain or “wind knocked out” without neurologic symptoms. In this case, there is no reason to evaluate for a concussion, yet this would count as a non-evaluation. What do the authors think of this scenario? Page 10 line 3 – the authors say “clear guidelines for a suspected concussion” – these may be “head impacts” but are they truly suspected concussion? This is the crux of the paper and needs to be very clearly defined in the methods section especially, and results. My concern is that even though an impact occurred on video, there may have been no concern for an actual concussion. This would jeopardize the premise of the manuscript. I commend the authors for their rigorous data collection. However, despite the large amount of work that went into this video analysis, this point needs to be clarified.

REVIEWER	Mohammad Haider University at Buffalo, SUNY USA
REVIEW RETURNED	27-Aug-2018

GENERAL COMMENTS	Thank you for giving me the opportunity to review this manuscript. The authors of this manuscript analyzed video footage of football games during the UEFA 2016 for signs of concussions after PCEs and compared them to the RTP decisions. It was a wonderful manuscript to read and I recommend publication even without my suggested minor revisions: 1. One Page 4, line 31: The Langlois publication says 1.8-3.4 million TBI, majority of them being mTBI in sports (not 1.8-3.4 million mTBI) 2. Page 5, end of introduction: Please clearly state your hypothesis and mention over here that you will be comparing with the 2014 WC which are in the results. 3. Page 7: Please include a measure of inter rater reliability. You have 4 reviewers so I recommend a weighted Cohen's Kappa or Krippendorff's Alpha.

	4. Page 10, line 10 and remainder of the manuscript: You can use Concussion In Sport Guidelines (CISG) instead of always saying 2012 and 2016 international concussion in sport consensus. 5. Page 11, line 12: I do not think there is lack of awareness of concussions in UEFA, just lack of implementation, so please add a reference or move it lower than the other reasons and say that there could be a lack of awareness. The rest of the discussion on inadequate implementation of consensus statement recommendations is great. Thank you.

REVIEWER	Graham Dean Cochrane University of Alabama at Birmingham Birmingham, AL USA Position: MD/PhD Trainee in Rehabilitation Science
REVIEW RETURNED	05-Sep-2018

GENERAL COMMENTS	Overall, I greatly enjoyed this manuscript and think it provides a wealth of information on the prevalence of potential concussive events in football and lack of proper implementation of existing concussion guidelines. I believe the methods and limitations of these methods are well described throughout the manuscript. I have some minor comments on separate sections of the manuscript below, none of which I deem necessary for acceptance of the manuscript but would like the authors to consider: Introduction: I would be interested in the incidence of SRC in other countries, especially those where football is more commonly played than the US. The statistics presented here are commonly cited in SRC research, but from my experience there is a misconception that rates are higher in the US due to American football being much more common vs. other countries where traditional football is more common. As your audience for this is a more international audience, showing that SRC is a problem internationally would be more relevant to your study. Methods / Results I am interested in the two individuals who showed no signs of SRC based on your criteria for a PCE; did they just get up in less than 5 seconds, but not "immediately"? It's interesting to me that one of those was medically assessed while so many with observable signs were not. Secondly, I would like to know if any observable signs resulted in a greater likelihood of medical assessment? I know you have so few that were assessed on the sideline, but if there are any patterns that might be helpful data to present to say spotters may be focusing on some signs over others. Also, I would be interested in knowing if certain teams have greater rates of medical assessment than others (couldsuggest different levels of training / caution by different staff). Discussion Finally, I think a major implementation limitation that goes unmentioned in the literature is how the current rules of soccer(running time, limited substitutions) prevents or at least discourages pulling a player for medical assessment. This is touched on a bit through the mentioning of the medical professional from Chelsea, but I think should be explicitly

	commented on by the authors. This is a major problem across sports (such as traditional SCAT testing for hockey being difficult due to skates / equipment), and the need for practical sports-specific consideration for implementation is necessary beyond just better general knowledge and acknowledgement of the "high stakes" nature of professional sports.

VERSION 1 – AUTHOR RESPONSE

Response to Reviewer 1:

We thank the reviewer for their insightful comments and questions. Please see our responses below.

1. “Can the authors articulate what specific guidelines they used from the CISG document to define the event as a PCE? I see they defined this in their document as removed from play, but where is this in the expert document…. the authors say “clear guidelines for a suspected concussion” – these may be “head impacts” but are they truly suspected concussion? This is the crux of the paper and needs to be very clearly defined in the methods section especially, and results.”

Response:

We thank the reviewer for seeking clarification, and we agree that the terminology used and its relationship to the CISG expert document needs to be more clearly explained in our manuscript. We used the term ‘potential concussive event’ (PCE) to define any event in which an athlete experiences significant head contact and is unable to immediately resume play (i.e. not necessarily removed from play). This was meant to capture the broad range of in-game scenarios involving head collisions; some innocuous, and others more serious. PCE is therefore meant to be separate, not synonymous, with the term sport-related concussion (SRC; a bona fide brain injury). While many PCEs are unlikely to result in bona fide concussions, it is clear that CISG recommendations must extend to PCEs in which the index of suspicion for concussion is high (e.g. PCEs with multiple signs of concussion). We hope the reviewer can agree that quality of assessment that an athlete receives in such a scenario ultimately determines whether or not PCEs leading to concussion are properly identified. As described in our results section, 44 out of the 50 (88%) non-assessed PCEs, involved athletes who exhibited 2 or more signs of concussion. We believe that this raises a legitimate concern that some concussions may be missed. Thus, the crux of paper is not that all PCEs need to be assessed; rather it is that proper assessment is needed in situations in which a high degree of suspicion for concussion is warranted. Please note that we have added text to both the methods and discussion to clarify these points.

2. “Also the methods section should be reorganized with subsections… A statistical section is also recommended.”

Response: We have modified our methods section as advised, thank you. It has now been divided into 1) coding of events 2) Training of reviewers 3) video analysis and 4) statistical analysis.

3. “How was disorientation defined through video analysis? To my knowledge, this is very difficult to assess by watching a video, whereas seizure or clutching can definitely be observed through video.”

Response: To identify disorientation, our reviewers were instructed to identify signs of confusion, unsteadiness in gait, lack of coordination, abnormal eye movements (footage permitting), and impaired decision-making (e.g. walking in the wrong direction) in the aftermath of a PCE. In other words, we were looking for obvious signs of disorientation, but agree with the reviewer that this is quite hard to identify and that there is an element of subjectivity that is difficult to avoid when relying

on video footage. We added a statement in our ‘limitations’ section to ensure that this limitation is explained.

4. “Also if a player was carted off, how did the coders tell if they were assessed for concussion? What if the assessment took place off camera and this could not be seen – is this a possibility?”

Response: In general, when assessments did occur, they happened on the field rather than off it. If a player was carted off, this involved medical personnel, so this would be scored as a medical assessment. Therefore, there is no concern that these might represent false negatives. However, as we have explained already in our limitations section, we are unable to comment on the quality of assessment.

Response to Reviewer 2:

We sincerely appreciate the reviewer’s careful review of our manuscript and are encouraged to hear that it was ‘wonderful’ to read. Below, we indicate how the specific comments/suggestions have been addressed.

1. “One Page 4, line 31: The Langlois publication says 1.8-3.4 million TBI, majority of them being mTBI in sports (not 1.8-3.4 million mTBI)”

Response: We thank the reviewer for noticing this error and we have modified the statement to more accurately reflect the Langlois paper’s findings.

2. “Page 5, end of introduction: Please clearly state your hypothesis and mention over here that you will be comparing with the 2014 WC which are in the results.”

Response: The objective of our study was stated at the end of the introduction, but we have modified the text to make it clearer as suggested by the reviewer.

3. “Page 7: Please include a measure of inter rater reliability. You have 4 reviewers so I recommend a weighted Cohen's Kappa or Krippendorff's Alpha.”

Response: We have included a Cohen’s Kappa measure of inter rater reliability in the “Video analysis” section in the methods.

4. “Page 10, line 10 and remainder of the manuscript: You can use Concussion In Sport Guidelines (CISG) instead of always saying 2012 and 2016 international concussion in sport consensus.”

Response: We have made the suggested change to the text, thank you.

5. “Page 11, line 12: I do not think there is lack of awareness of concussions in UEFA, just lack of implementation, so please add a reference or move it lower than the other reasons and say that there could be a lack of awareness. The rest of the discussion on inadequate implementation of consensus statement recommendations is great.”

Response: We have modified our discussion as suggested. The possibility of lack of awareness has been moved down the list of points and the language has been modified to reflect the speculative nature of these points.

Response to Reviewer 3:

1. “Overall, I greatly enjoyed this manuscript and think it provides a wealth of information on the prevalence of potential concussive events in football and lack of proper implementation of existing concussion guidelines.”

Response: We thank the reviewer for their positive feedback and helpful suggestions.

2. “I am interested in the two individuals who showed no signs of SRC based on your criteria for a PCE; did they just get up in less than 5 seconds, but not "immediately"?”

Response: To clarify, this incident met our criteria for a ‘potential concussive event’ in that significant head contact occurred, and the athletes were unable to immediately resume play. Despite what appeared to be serious contact (which likely prompted the on-field assessment), the two athletes did not exhibit any observable signs of SRC as defined in our methods.

3. “Secondly, I would like to know if any observable signs resulted in a greater likelihood of medical assessment? Also, I would be interested in knowing if certain teams have greater rates of medical assessment than others (could suggest different levels of training / caution by different staff).”

Response: We thank the reviewer for raising these interesting questions. In this analysis, we were not able to identify any differences in assessment rates between teams or in concussion signs. However, these are questions that might be better addressed longitudinally if data from past and future analyses of elite football tournaments can be collated and interrogated for any significant trends.

4. “Finally, I think a major implementation limitation that goes unmentioned in the literature is how the current rules of soccer (running time, limited substitutions) prevents or at least discourages pulling a player for medical assessment. This is touched on a bit through the mentioning of the medical professional from Chelsea, but I think should be explicitly commented on by the authors.”

Response: The reviewer raises an excellent point. We have now directly elaborated on how the current rules of the game may represent an additional implementation barrier (please see ‘barriers to implementation’ section under our discussion).

VERSION 2 – REVIEW

REVIEWER	Scott Zuckerman Vanderbilt University Medical Center United States
REVIEW RETURNED	30-Jan-2019

GENERAL COMMENTS	BMJ Open – Elite Football Video Concussion In the abstract, can the authors mention how many actual concussions occurred? Did the authors think about sign of “blank vacant look” or “motor incoordination” – these have all been well studied in NHL and Australian Rugby – see paper by Echemendia, Davis, Gardner and more. Who were the observers – medical professionals? Game experts? Important to know

	Kappa of 0.9 – very good, much better than some commonly quotes studies – why do the authors think the kappa and interrater reliability was so high? Historically these are high for easy signs like clutching head or slow to get up, but not as high for things like seizure or motor disequilibrium How ere PCEs defined exactly? And were there instances where one observer thought a PCE occurred but the others didn't? Establishing our N is important Were these videos broadcast based from TV feeds or medically devoted video streams? Along those lines, is it possible a medical evaluation was done but just not seen on video? If play was stopped enough to call it a PCE, why wasn't the player assessed – why do the authors think they were NOT evaluated? High stakes of game? Importance of winning? Athlete refusal? These are all potential barriers to concussion valuation Major thrust of this paper should be what signs lead to a concussion – how many concussions occurred? Is it possible that athletes were assessed by a medical professional but just could not be seen? There are a lot of interesting results here – I would compare these results to studies of NHL hockey and NFL American football – these leagues have concrete concussion protocols where athletes are removed from play immediately. There is a lot of video research out there, and the authors should try and integrate these publications to the discussion of prior research. Clearly the authors have done a lot of work here – rigorous video study of concussions, but with this missing information, it's hard to make sense of these results. We really need to know how many concussions occurred to make sense of this. As is, it's a nice contribution, but it can be made much stronger by knowing how many diagnosed concussions occurred.

REVIEWER	Mohammad Nadir Haider University at Buffalo, SUNY USA
REVIEW RETURNED	29-Oct-2018

GENERAL COMMENTS	The authors have responded to my suggestions adequately and I recommend publication.

REVIEWER	Graham D. Cochrane University of Alabama at Birmingham Birmingham, AL United States of America
REVIEW RETURNED	05-Nov-2018

GENERAL COMMENTS	I have reviewed the authors' responses to each of the original reviewers' comments (my own included) and believe comments/concerns were addressed appropriately. I appreciate

	the authors' consideration of my suggestions. I do not have any further suggestions for further changes to this manuscript.

VERSION 2 – AUTHOR RESPONSE

Response to reviewers 2 and 3:

We thank the reviewers for their helpful comments and suggestions and very much appreciate their feedback that no further work is required for publication of this manuscript. Given these statements and the important public health implications of our findings, we trust and anticipate that there will be no further delays in the publication of our manuscript.

Responses to Reviewer 1:

We thank the reviewer again for taking the time to once again review our manuscript. We wish to highlight that several questions addressed below were already asked and fully addressed in the first round of revisions. We have once again worked hard to clarify any comments and questions, and feel strongly now that after two rounds of review and having already fully satisfied the recommendations of two other reviewers that there will be no further delay in the publication of our manuscript. Please find our response to individual questions below.

1. “In the abstract, can the authors mention how many actual concussions occurred?”

Response: We thank the reviewer for raising this point. However, we wish to highlight that this is neither feasible nor is it in keeping with primary objective of this study. First, as we have already clearly outlined in the abstract, the purpose of this study is to determine if elite football athletes are “medically assessed according to the International Conferences on Concussion in Sport consensus statement recommendations” following a ‘potential concussive event’ (PCE) – defined as any event in which an athlete experiences significant head contact and is unable to immediately resume play. Simply re-stated, we are asking if the current consensus recommendations for proper assessment are being implemented adequately. Second, the lack of formal assessments and identification of the players involved, preclude accurate determination of how many “actual concussions” occurred. A UEFA injury study report mentions that "During EURO 2008, as many as five head injuries were recorded, including fractures, concussions and wounds. However, during EURO 2012 only one head injury was reported and during EURO 2016 only two.” However, this information cannot be reliably verified, and to include this in the abstract would not be in keeping with maintaining highest standards of scientific reporting which we always strive to abide by.

2. “Did the authors think about sign of “blank vacant look” or “motor incoordination” – these have all been well studied in NHL and Australian Rugby – see paper by Echemendia, Davis, Gardner and more.”

Response: Our current methods (as already detailed in the methods) are based on established observable physical signs of concussion already published in the field. While we did not specifically report “blank look” or “motor incoordination,” these would be captured by our measures that we have used including “disorientation” and “signs of obvious disequilibrium”

3. “Who were the observers – medical professionals? Game experts? Important to know”

Response: Observers are graduate and undergraduate research trainees, all with many years of competitive soccer playing experience, who received formal training under the guidance of a highly experienced neurosurgeon and leader in concussion and brain injury research, Dr. Michael Cusimano. As stated in the methods: “The standardized data collection form was used to provide a person viewing digital video images with a consistent way of coding and accounting for the majority of circumstances and mechanisms leading to concussion. The standardized data form was adapted from a validated form used in a prior study on concussion15.”

4. “Kappa of 0.9 – very good, much better than some commonly quotes studies – why do the authors think the kappa and interrater reliability was so high? Historically these are high for easy signs like clutching head or slow to get up, but not as high for things like seizure or motor disequilibrium”

Response: The high Kappa value is likely due to the1) emphasis on intensive and detailed training and methodology 2) use of clear cut definitions and criteria for the measures.

5. “How ere PCEs defined exactly? And were there instances where one observer thought a PCE occurred but the others didn’t? Establishing our N is important.”

Response: We are left puzzled as to why the question (asked and fully addressed in the first round of revisions) is being repeated again by the reviewer. First, this has been explicitly defined in the manuscript “PCEs were defined as any event in which one or more athletes experienced a head impact injury (through direct contact with another athlete, ball, or object in the environment) and were unable to immediately resume play following impact.” Second, please see the enclosed response that we included in our prior response to this question “We thank the reviewer for seeking clarification, and we agree that the terminology used and its relationship to the CISG expert document needs to be more clearly explained in our manuscript. We used the term ‘potential concussive event’ (PCE) to define any event in which an athlete experiences significant head contact and is unable to immediately resume play (i.e. not necessarily removed from play). This was meant to capture the broad range of in-game scenarios involving head collisions; some innocuous, and others more serious. PCE is therefore meant to be separate, not synonymous, with the term sport-related concussion (SRC; a bona fide brain injury). While many PCEs are unlikely to result in bona fide concussions, it is clear that CISG recommendations must extend to PCEs in which the index of suspicion for concussion is high (e.g. PCEs with multiple signs of concussion). We hope the reviewer can agree that quality of assessment that an athlete receives in such a scenario ultimately determines whether or not PCEs leading to concussion are properly identified. As described in our results section, 44 out of the 50 (88%) non-assessed PCEs, involved athletes who exhibited 2 or more signs of concussion. We believe that this raises a legitimate concern that some concussions may be missed. Thus, the crux of paper is not that all PCEs need to be assessed; rather it is that proper assessment is needed in situations in which a high degree of suspicion for concussion is warranted. Please note that we have added text to both the methods and discussion to clarify these points.”

6.“Were these videos broadcast based from TV feeds or medically devoted video streams? Along those lines, is it possible a medical evaluation was done but just not seen on video?”

Response: These videos are based off high quality TV streams. Regarding the second question, we are once again left wondering why a question that we already addressed has been asked again. Please see our previous response: “In general, when assessments did occur, they happened on the field rather than off it. If a player was carted off, this involved medical personnel, so this would be scored as a medical assessment. Therefore, there is no concern that these might represent false negatives. However, as we have explained already in our limitations section, we are unable to comment on the quality of assessment.” Moreover, we explicitly state the following under limitations in our manuscript: “In some PCEs, full description of variables may be limited by the camera angles available for the video clip.”

7. “If play was stopped enough to call it a PCE, why wasn’t the player assessed – why do the authors think they were NOT evaluated? High stakes of game? Importance of winning? Athlete refusal? These are all potential barriers to concussion valuation”

Response: We encourage the reviewer to read the discussion section of the manuscript, specifically the part entitled “barriers to implementation” in which all of these factors have been fully elaborated upon.

8. “Major thrust of this paper should be what signs lead to a concussion – how many concussions occurred?”

Response: Please see our prior response to the same question already asked and addressed above.

9. “Is it possible that athletes were assessed by a medical professional but just could not be seen?”

Response: Please see our prior response to the same question already asked and addressed above.

10. “There are a lot of interesting results here – I would compare these results to studies of NHL hockey and NFL American football – these leagues have concrete concussion protocols where athletes are removed from play immediately. There is a lot of video research out there, and the authors should try and integrate these publications to the discussion of prior research.”

Response: We thank the reviewer for this helpful suggestion and have included the following text and references to our discussion: “In order to increase effectiveness of current football concussion protocols, It would be beneficial for football governing bodies to examine how other professional sports deal with concussions. For example, in NFL American football, the latest concussion protocol published in 2018 stipulates that each team during game day must be assigned a Sideline Unaffiliated Neurotrauma Consultant (“Sideline UNC”), a physician that is impartial and independent from any Club.1Additionally, the protocol also stipulates that a video Unaffiliated Neurotrauma Consultant be present in a stadium booth with access to multiple views of video.1 Having impartial evaluators would help significantly in curtailing issues such as doctors from home teams facing pressure to return players to the game and examining the nature of potential concussive impacts. Providing broadcast video to side-line medical personnel in real time is also a recommendation by a recently published study that examined current practices related to video review of concussion in professional sports internationally.2 Football authorities should consider implementing these rules which would help aid in the screening for concussion and treat it as soon as possible.”

1. Ellenbogen RG, Batjer H, Cardenas J, et al. National Football League Head, Neck and Spine Committee's Concussion Diagnosis and Management Protocol: 2017-18 season. Br J Sports Med 2018;52(14):894-902. doi: 10.1136/bjsports-2018-099203 [published Online First: 2018/03/20]

2. Davis GA, Makdissi M, Bloomfield P, et al. International study of video review of concussion in professional sports. Br J Sports Med 2018 doi: 10.1136/bjsports-2018-099727 [published Online First: 2018/09/29]

11. “Clearly the authors have done a lot of work here – rigorous video study of concussions, but with this missing information, it’s hard to make sense of these results. We really need to know how many concussions occurred to make sense of this. As is, it’s a nice contribution, but it can be made much stronger by knowing how many diagnosed concussions occurred.”

Response: We thank the reviewer for appreciating the hard work needed to complete this study. However, we wish to explicitly clarify once again that this is not a “video study of concussions”. As stated clearly in our objective and in a prior response to the reviewer’s question, this study seeks to answer a very simple question: are the current recommendations for evaluation of suspected concussions (or potential concussive events) being implemented adequately in the realm of elite

soccer. As such, how many diagnosed concussions occurred, while important and potentially an interesting question for future research, is first unrelated to the primary objective of this study and second, impossible to ascertain retrospectively for the reasons already outlined in our previous response. This should have no bearing on the results, interpretation and discussion enclosed in our manuscript.