

Review

Sports-Related Concussion Assessment in Professional Racing and Freestyle Bicycle Motocross (BMX): A Scoping Review and Call to Action

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Abstract: Bicycle Motocross (BMX), both Racing and Freestyle, have gained popularity since the 1960s, evidenced by their debuts within the 2008 and 2020 Olympics, respectively. Sports-related concussions (SRCs) are ubiquitous within cycling, particularly in the discipline of BMX. The management of concussion in sport is an important issue, and many international sporting bodies have published guidelines. In this review, literature is searched systematically in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA): Extension for Scoping Reviews for sports-related concussion assessment in Bicycle Motocross. Only two items were included within the review and shows the distinct lack of discipline specific, SRC assessment guidance and recommends further research to help apply the Sport Concussion Assessment Tool version 6 to BMX.

Keywords: sports-related concussion assessment; SRC; Bicycle Motocross; BMX; cycling governing bodies; concussion protocols.

1. Introduction

Injuries are common in sport. Injuries impact the athlete and can potentially impact other competitors. Sports-related concussion (SRC) is a mild brain injury that can be clinically complex to diagnose and manage, potentially leading to complications for the athlete and their fellow competitors if the concussed athlete is not immediately removed from the field of play (Purcell, Canadian Paediatric Society, & Sports Medicine, 2014). In recent years, SRC has been noted as a growing public health concern and has attracted both the attention of professional sporting bodies and governments. The United Kingdom (UK) Government, for example, issued a report in July 2021 entitled, 'Concussion in sport', which focused on the lack of awareness of

SRC and calls for sporting bodies to have clear evidence-based guidelines (House of Commons, 2021). A common misconception is that SRCs are exclusively associated with contact sports, but the risk is present in all sporting activities, particularly in cycling activities (Helmich et al., 2018).

The definition of sports-related concussion can be somewhat ambiguous, and it can be challenging to diagnose. In 2016, a consensus was defined during the fifth international conference on concussion in sport held in Berlin (McCroory et al., 2017), with the conclusions of the conference being known as 'The Berlin Statement'. 'The Berlin Statement' relates to sports broadly and does not account for the risks and challenges inherent to assessing head injuries within a specific



sport, particularly a unique and fast-paced sport such as Bicycle Motocross (BMX). Thus these guidelines, such as the Sport Concussion Assessment Tool (SCAT5) and the now SCAT6 (Sport Concussion Assessment Tool 6 (SCAT6), 2023), need to be adapted to specific sports to make them fit for purpose.

Cycling is a sport enjoyed by many amateurs and professionals (Department for Transport, 2021). The main governing cycling body in the UK is British Cycling, and The Union Cycliste Internationale (UCI) is the global governing body (L'Union Cycliste Internationale, 2022). In 2021, the UCI responded to the lack of SRC guidance in cycling and produced new concussion assessment guidelines, known as The Harrogate Consensus Agreement (Swart et al., 2021). The Harrogate Consensus Agreement outlined an in-field assessment for SRC across the ten disciplines of cycling recognised by the UCI. However, Swart et al. (2021) recognised that the assessment does not meet the cycling discipline-specific demands but instead should be used to formulate discipline-specific SRC assessments.

The need for discipline specific SRC assessment within the sport of cycling, increases as the number of professional and amateur cyclists increases. In England, the number of cyclists (aged five and above) who reported engaging in a cycling activity increased by 6% between 2019 and 2020 to 20% (Cycling UK, 2022). Many statistics categorise cycling as leisure or transport, which makes research within a specific discipline of cycling complex.

Bicycle Motocross is a discipline of cycling recognised by the UCI and is popular among all ages. There are two subdivisions of BMX according to the technical regulations of British Cycling, BMX Freestyle and BMX Racing (British Cycling, 2022). Bicycle Motocross Racing had its Olympic debut during the 2008 Olympics hosted in Beijing. More recently, BMX Freestyle appeared during the 2020 Olympics hosted in Tokyo and emphasises how popular both disciplines of this sport have become since the 1960s

(International Olympic Committee, 2022). Bicycle Motocross Freestyle competitions are where the rider performs a series of tricks, and the rider is scored based on the execution of their routine. In contrast, BMX racing is a sprint race on a track known as a pump track (British Cycling, 2022). The UCI provides 'Invalid Result Marks' for riders under the following categories: 'Did Not Finish (DNF)', 'Relegation (REL)', and 'Did Not Start (DNS)' (L'Union Cycliste Internationale, 2019). In these cases, the rider remains eligible to transfer to the next phase should they not receive two or more DNS (L'Union Cycliste Internationale, 2019). The 'Invalid Result Marks' system allows riders to continue within the competition should they not finish a phase. However, according to the current rules, if a rider did not finish a race due to suspected SRC, they would be penalised as 'Did Not Finish' for seeking medical assistance, thus emphasising the need for an SRC protocol and provision specific to the complex demands that arise in BMX.

2. Materials and Methods

A scoping review methodology was utilised throughout this study in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA): Extension for Scoping Reviews (Tricco et al., 2018), to systematically map and review the extent, range, and nature of the current SRC assessment guidelines specific to BMX. Seven online databases were searched: Ovid MEDLINE, EMBASE, Web of Science, CINAHL Plus, Cochrane Library, Scopus, and PubMed, as well as the grey literature. Studies discussing SRC assessment in BMX (both Racing and Freestyle) were included.

2.1 Patients and Public Involvement

The nature of this review is to examine publications discussing sports-related concussion assessment in BMX, therefore there was no requirement for patient engagement.

2.2 Protocol

A six-step *a priori* protocol was followed:

2.2.1 Step one: Defining the research question

The following research question was addressed:

To investigate the assessment tools and guidance that are currently in place for assessing SRC in BMX.

A. The key objectives and principal reasons for completing this study are:

- 1) To systematically map and review the extent, range, and nature of the research in the assessment of SRC in BMX;
- 2) To provide a narrative to summarise the key findings in the literature of the assessment tools currently used to identify SRC in BMX;
- 3) To identify gaps within the academic and grey literature of SRC assessment in BMX.

B. The secondary objectives, are to collect evidence and data for use in further research in order to:

- 1) Develop a protocol to assess for SRC specific to the nature and demands of BMX biking;
- 2) Develop a management and return-to-play policy for SRC in BMX biking;
- 3) Propose pragmatic rule changes for BMX racing so that SRC assessment can take place without penalty or disqualification of the rider.

2.2.2 Step two: Finding the Relevant Articles

Ovid MEDLINE(R) ALL <1946 to June 27, 2022>		
1	Brain Concussion/ or Concussion.mp.	15243
2	Sports related concussion.mp.	694
3	SRC.mp.	39079
4	exp Brain Injuries, Traumatic/	21665
5	head injury.mp. or Craniocerebral Trauma/	35972
6	concussion assessment.mp.	779
7	scat5.mp.	53
8	scat.mp.	842
9	BMX.mp.	367
10	bicycle motocross.mp.	23
11	cycling.mp. or Bicycling/	80014
12	1 or 2 or 3 or 4 or 5	97307
13	6 or 7 or 8	1520
14	9 or 10 or 11	80321
15	12 and 13 and 14	3
16	12 and 14	882
17	13 and 14	8

Figure 1. Final pilot search.

A pilot search was conducted on Ovid MEDLINE for papers detailing sports related

concussion assessment within Bicycle Motocross/BMX. The final pilot search is presented in Figure 1. The final search strategy was conducted across the remaining six digital databases; EMBASE, Web of Science, CINAHL Plus, Cochrane Library, Scopus, and PubMed. A search of the internet, using Google, and the grey literature was also conducted. Having initially undertaken the search on 28th June 2022 it was then repeated on 2nd February 2023 and no further additional studies were identified from the original search.

2.2.3 Step three: Selection of Relevant Articles

Of the 2,136 studies identified from the databases only 1,035 were assessed for eligibility along with two reports from the grey literature. Publications were included within this study if they discussed SRC assessment in BMX.

The article selection process has been presented on a PRISMA 2020 flow diagram and can be found in Figure 2. One report and one study were included in this review.

2.2.4 Step four: Charting the Data

The data were charted under the following headings; Year of Publication, Journal Title, Methods, Methodology, Discipline of Cycling, Assessment Tool, and Key Findings. Due to the small number of papers identified, Microsoft Word was used to manage the data extraction.

An assessment of paper quality was conducted using The Physiotherapy Evidence Database (PEDro) scale (Maher, Sherrington, Herbert, Moseley, & Elkins, 2003).

2.2.5 Step five: Collating, Summarising and Reporting the Results

Due to the small number of work included, Microsoft Word was used to manage the summary of results.

2.2.6 Step six: Consultation Exercise with Key Stakeholders

This step was not undertaken in this research paper, but it is hoped that it will be done as part of a larger body of concussion research work within cycling.

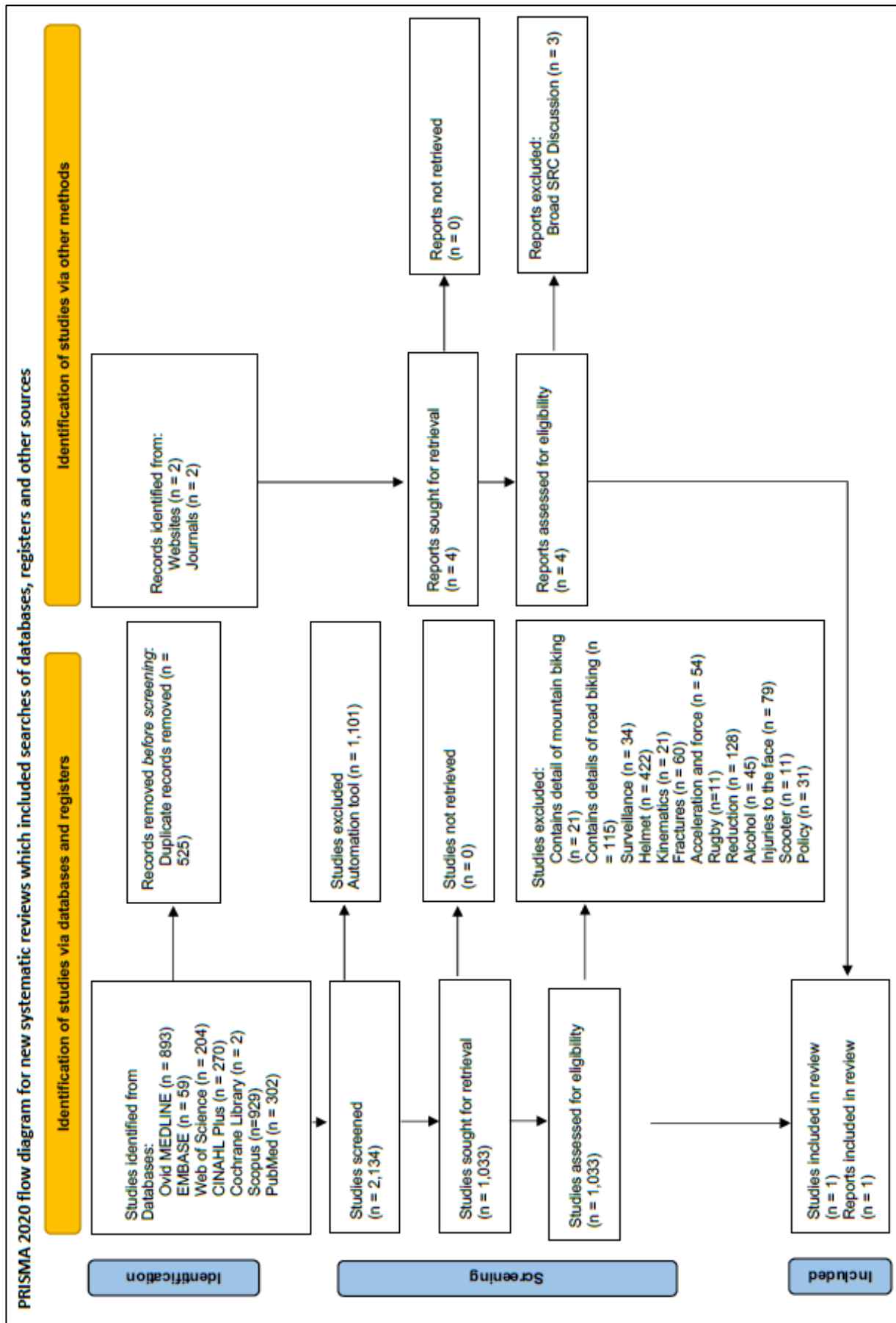


Figure 2. PISMA 2020 Flow Diagram

3. Results

Table 1. Data extraction.

Author(s) and Year of Publication	Journal Title	Methods	Methodology	Discipline of Cycling	Assessment Tool	Key Findings
Swart et al., 2021	Sports Medicine and Health Science	Meeting of experts	Meeting report	General and BMX	SCAT5	- SRC is common in cycling - Lack of consensus for SRC management - BMX biking provides a setting for sideline assessment
BMX New Zealand, 2017	-	-	-	BMX	SCAT3	- Concussion is complex and a serious injury - A table condensing 'what you see' and 'what they feel' - The presentation of a pocket card showing the high-risk features, orientating questions, a 'following a crash' assessment flowchart

From the one report and one study included in this scoping review of SRC assessment in BMX, the results were as shown in Table 1.

3.1 Publication Dates of the Included Studies

The year of publication for the selected work ranged from 2017-2021. The year of publication maps the production of the literature and helps answer study objective A1.

3.2 Methods and Methodology

Of the included literature, the methods and methodologies used varied.

The Harrogate consensus agreement (Swart et al., 2021) used an interview method where the UCI invited a panel of seven experts in the field of cycling medicine to collaborate their knowledge to produce a consensus agreement specific to the needs and demands of cycling. Prior to the conference the experts were asked to prepare a presentation for the meeting based on a review of the existing literature and practice. The conference findings were presented using qualitative methodology to produce a meeting report. The report is the current UCI guideline on SRC assessment in cycling but is not specific for the individual cycling disciplines, including BMX.

The other publication recognised in this study, the BMX New Zealand's Concussion Awareness Card (BMX New Zealand, 2017), did not follow any specific method or methodology and was categorised as other. It is an informational piece produced by the

cycling governing body of New Zealand to help participants understand what concussion is and how to identify it. The Harrogate consensus agreement (Swart et al., 2021) identified how cycling concussion presents a unique challenge, and calls for more work to develop protocols within each cycling discipline to meet the varying natures of the participation environment.

3.3 Assessment of Publication Quality

The included literature was assessed for quality using the PEDro Scale (Maher et al., 2003). The PEDro Scale is used to assess if results are reliable and meaningful for the use in clinical practice.

A score of < 4 was considered 'poor', 4 to 5 was considered 'fair', 6 to 8 was considered 'good' and 9 to 10 was considered 'excellent' (Cashin & McAuley, 2020). The quality of the two papers used in this review were considered poor, as they scored zero on the PEDro Scale. The quality of the included papers is important for objectives A2 and A3 of this study, to understand the extent of the available research in this area and identify gaps.

3.4 Discipline of Cycling

The included studies contained discussions on BMX. The publication by Swart et al. (2021) included the term BMX, but the discussion remained around general cycling disciplines and thus was categorised as general cycling. Only the publication by BMX New Zealand (2017) details BMX exclusively.

3.5 Assessment Tool

From the two articles selected, one discussed the Sport Concussion Assessment Tool 3 (SCAT3), and one discussed the updated form of the SCAT3, known as The Sport Concussion Assessment Tool 5 (SCAT5). The assessment tool used in the publication aids in mapping current best practices and relates to objectives A2 and B1 of this study.

4. Discussion

4.1 Interpretation of Results

The findings of this scoping review have found a distinct lack of specific guidelines for SRC assessment in BMX, with only two papers relating to SRC assessment in BMX being identified. All included papers were of low methodological quality as per the PEDro scoring system. Although, there are guidelines for SRC assessment in cycling broadly, they do not meet the challenging and sport-specific circumstances that present during BMX events, either freestyle or racing.

4.1.1 Publication Dates of Included Papers

The short range of the publication dates suggests that there is a failure by individual sporting bodies to complete further research and implement discipline-specific SRC assessment guidelines. Swart et al.'s work, published in 2021, provides a broad assessment approach for use within cycling, though does specifically mention the challenges of assessment in BMX. The 2017 publication, by BMX New Zealand, deals specifically with BMX. In the wider literature on SRC assessment, it was found that the Concussion in Sport Group (CISG) has been hosting quadrennial conferences since 2001 to formulate evidence-based standardised concussion assessments that should inform clinical practice (Aubry et al., 2002; McCrory et al., 2005; McCrory et al., 2017; McCrory et al., 2009; McCrory et al., 2013) within specific sporting disciplines. The lack of publications relating to SRC assessment in BMX shows a failure of the cycling governing bodies, such as The Union Cycliste Internationale (UCI), to implement the recommendations of the

CISG and should be addressed urgently with further work in this area.

4.1.2 Assessment of Publication Quality

An assessment of publication quality was made using the PEDro Scale, and it was found that all papers were scored as 'poor'. The nature of SRC assessment and guideline publications has been criticised by authors such as Casper et al. (2021), who claim the five international concussion in sport conferences have produced biased, narrow, and compromised reports that are not focused on public health principles and lack patient-centred care. Casper et al. (2021) also suggest that these consensus statements are methodologically flawed owing to the impression of a lack of peer review. Peer-reviewing publications provides the scrutiny of other field experts and permits advances in knowledge to best inform the construction of concussion assessment tools within sport. Therefore, evidence based research, such as this review, needs to be conducted along with stakeholder engagement to provide high quality and effective guidance for SRC assessment.

4.1.3 Discipline of Cycling Used in the Included Papers

The Concussion awareness guideline produced by BMX New Zealand (2017), which is the official guidance for use during BMX events by Cycling New Zealand, produced a guidance document specific to BMX. The guideline itself was a raw application of a concussion assessment tool and did not provide any specific advice on how an assessment should be conducted during an event.

The Harrogate consensus agreement (Swart et al., 2021) broadly discussed concussion assessment in cycling, but does acknowledge BMX. The consensus panel acknowledged that evaluation of SRC varies between road-side and track-side events and that BMX events provide an environment where side-line assessment is more possible. Side-line assessment is more possible during BMX events as races take place on a short course that allows greater access to the injured participant and the ability to temporarily discontinue participation to facilitate a side-

line assessment. However, although a sideline assessment could potentially be carried out, under the current UCI provision of 'Invalid Result Marks', the participant would be penalised for seeking medical assistance,

and thus SRC assessment in BMX requires rule changes by the UCI.

4.1.4 Assessment Tool Used in the Included Papers

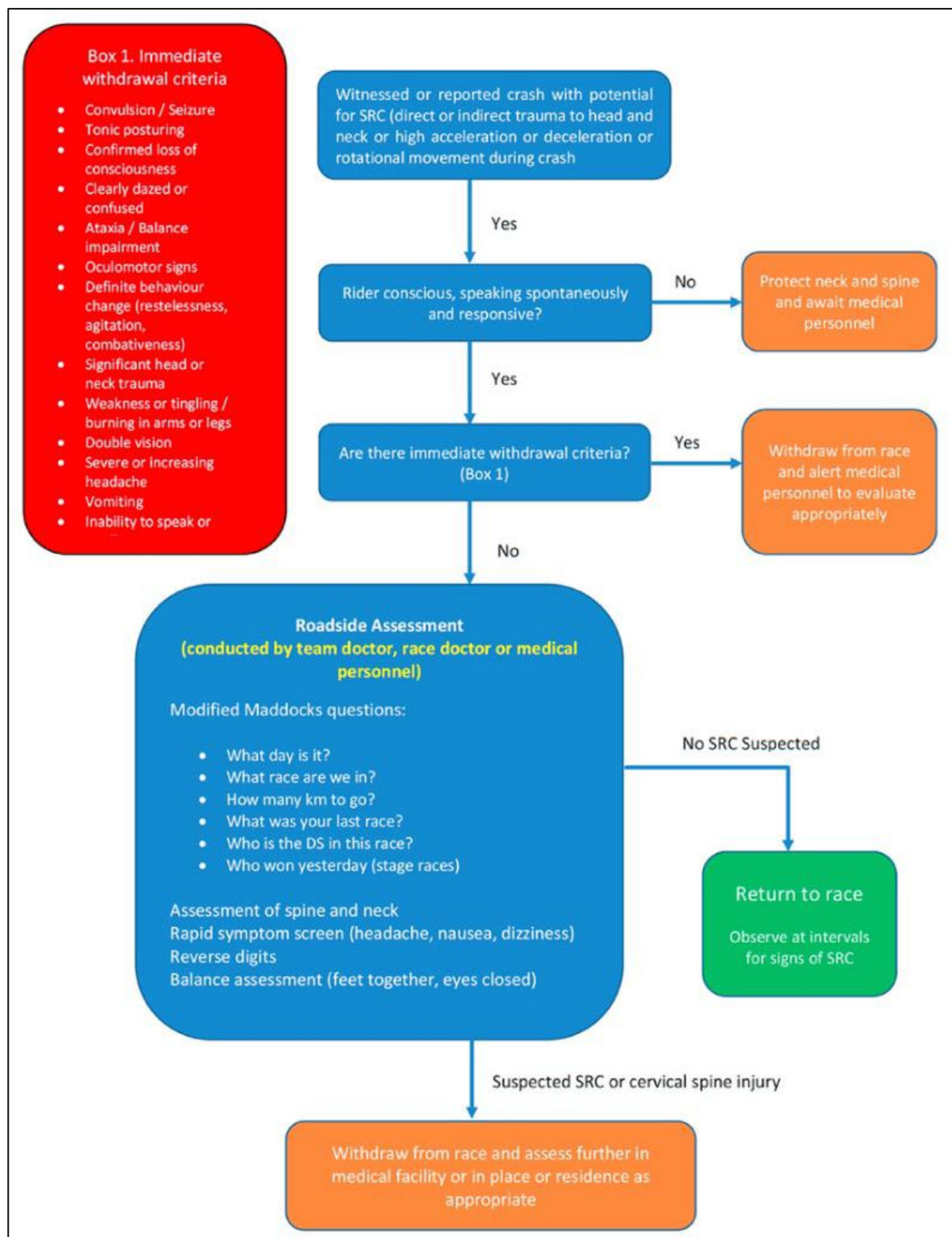


Figure 3. Sports-Related Concussion (SRC) assessment in the field, including immediate recognition and road-side assessment.

All articles used a version of the standardised Sports Concussion Assessment tool as recommended by the CISG. It was noted that the BMX New Zealand protocol (2017) used the SCAT3, an older version of the current SCAT6. This guideline was published by BMX New Zealand in October 2017, while the SCAT6 was published in 2023 after the sixth international conference on concussion in sport held in 2022 (R. J. Echemendia et al., 2017; Ruben J Echemendia et al., 2017; McCrory et al., 2017). National governing bodies should use the current guidance offered by the international sanctioning body.

The Harrogate consensus agreement (Swart et al., 2021) recommended the use of the SCAT5 in line with the Berlin Statement. The expert panel members acknowledged the need to develop discipline-specific applications of the SCAT5 and encouraged their paper to be a base for this formulation. The authors proposed a three-stage diagnostic process, involving (Swart et al., 2021):

- 1) Initial assessment immediately following potential concussive event,
- 2) Re-assessment immediately following completion of the race on the same day of the injury, and
- 3) Re-assessment the day following the initial injury.

The immediate removal of a rider would initiate the three-stage process during an event where the cyclist experiences trauma to the head and/or neck, or is exposed to high acceleration/deceleration, or rotational movement. The panel stated that concussion recognition should not solely fall on the medical team but should involve all key staff present working as part of a team. The panel detail an 'in the field assessment tool' (Swart et al., 2021), presented in Figure 3. The flow diagram provides three questions for the recognition of concussion and advice on when to refer back to the medical team. The latter stage of the tool is the road-side assessment, which must be conducted by medical personnel to ensure it is conducted correctly and for the safety of the cyclist. The 'in the field assessment tool' (Swart et al.,

2021), presented in Figure 3, is tailored for road cycling competitions, but with minor revision, such as modifying the Maddock's questions, could be applied to BMX events to provide a BMX Concussion Assessment Protocol.

4.2 Study Limitations

The authors acknowledge the limitations of this study.

4.2.1 Search Term

Due to the low number of studies identified, the inclusion criteria allowed the inclusion of The Harrogate consensus agreement. Although this paper did not specifically make a provision for BMX assessment it did discuss how application of concussion assessments can be complex and did specifically mention BMX in this context.

4.2.2 Low Quality of Evidence

Through mapping the current literature, it was found that publications were of low quality, which evidences the gap of SRC assessment, specific for BMX, within the literature. There is a need for further study to provide peer reviewed SRC assessment evidence specific to the discipline of BMX. All of the included papers neglected to engage with key stakeholders such as BMX riders and general cyclists, family members, and coaches to inform the guideline, but they did refer to knowledge transfer via education (Swart et al., 2021). Stakeholder engagement is essential in formulating guidelines to aid the understanding of participant perceptions of assessing for SRC and how application to BMX can best be made.

4.2.3 Deferral of Stage Six of the Research Protocol

The authors acknowledged that this omission represents a missed opportunity to engage stakeholders to confirm the findings and aid knowledge transfer, but it is hoped that this work will be carried out within future BMX concussion research projects.

5. Conclusions

This is the first scoping review that systematically maps the current literature on SRC assessment in BMX. This scoping review

found that there is a lack of studies within the area, and further work is required to safeguard BMX participants adequately. From the identified papers, it was found that the Sports Concussion Assessment Tool version five (SCAT5) (now updated to SCAT6), produced under the advice of the Concussion in Sport Group (CISG), was the most up-to-date tool available in use to assess for SRC in BMX events. However SCAT6, is not a discipline-specific tool and requires adaption for the needs and demands of the specific sport. Additionally, rule changes are required within the sport of BMX to facilitate these SRC assessments and this will require further work by the cycling governing bodies. Thus, further research is required to understand how the SCAT6, as well as other concussion assessment tools and protocols, can be implemented most effectively within the cycling discipline of BMX.

Conflicts of Interest: The authors declare no conflict of interest.

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