Amsterdam 2022 process: A summary of the methodology for the Amsterdam International Consensus on Concussion in Sport

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ABSTRACT

The purpose of this paper is to summarise the consensus methodology that was used to inform the International Consensus Statement on Concussion in Sport (Amsterdam 2022). Building on a Delphi process to inform the questions and outcomes from the 5th International Conference on Concussion in Sport, the Scientific Committee identified key questions, the answers to which would help encapsulate the current science in sport-related concussion and help guide clinical practice. Over 3½ years, delayed by 2 years due to the pandemic, author groups conducted systematic reviews on each selected topic. The 6th International Conference on Concussion in Sport was held in Amsterdam (27–30 October 2022) and consisted of 2 days of systematic review presentations, panel discussions, question and answer engagement with the 600 attendees, and abstract presentations. This was followed by a closed third day of consensus deliberations by an expert panel of 29 with observers in attendance. The fourth day, also closed, was dedicated to a workshop to discuss and refine the sports concussion tools (Concussion Recognition Tool 6 (CRT6), Sport Concussion Assessment Tool 6 (SCAT6), Child SCAT6, Sport Concussion Office Assessment Tool 6 (SCOAT6) and Child SCOAT6). We include a summary of recommendations for methodological improvements for future research that grew out of the systematic reviews.

INTRODUCTION

Research on sport-related concussion (SRC) has evolved substantially over the past three decades. The number of peer-reviewed publications in scientific journals has continued to increase, especially in recent years. This highlights the need for ongoing and updated recommendations for the integration of new evidence into clinical practice.

The Concussion in Sport Group (CISG) has published two summary and agreement statements[1 2] and three consensus statements on SRC,[3–5] the last being the Consensus Statement on Concussion in Sport following the 5th International Conference held in Berlin in 2016.[4] The purpose of each of the statements was to provide recommendations, based on the available research literature at the time of publication, to inform the prevention, detection and management of SRC. As the science has evolved, so too have the recommendations from the consensus process.[6 7] These documents are not guidelines, but rather statements that reflect the current state of the evidence base and are intended to be adapted to inform healthcare practices in different geographical areas and sport-specific populations. For example, the findings from the Consensus Statement published in 2017 were used to inform the Canadian Guideline on Concussion in Sport,[8] Living Guideline for Paediatric Concussion Care,[9] and Guidelines for Adults with concussion/mild traumatic brain injury (mTBI) and prolonged symptoms.[10 11] Along with the advancing science, the process used to inform these statements has developed over time. The purpose of this paper is to summarise the methodology for the Amsterdam 2022 International Consensus on Concussion in Sport and the resulting consensus statement.

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THE CONSENSUS METHODOLOGY

The Amsterdam 2022 International Consensus on Concussion in Sport used a consensus conference methodology which is outlined below. The consensus process included identification of research questions, preparation of 10 systematic reviews,[12–21] the open consensus conference (2 days), closed expert panel consensus meeting (EPCM) (1 day), and a meeting to determine the format for practical tools for the identification, evaluation, and management of SRC (1 day). In addition to this methodology paper, each of the 10 systematic reviews, the International Consensus Statement on Concussion in Sport, and the 'tools' (Sport Concussion Assessment Tool 6 (SCAT6), Child SCAT6, Sport Concussion Office Assessment Tool 6 (SCOAT6), Child SCOAT6, and Concussion Recognition Tool 6 (CRT6)) will be published as separate documents .

Formation of the organising and scientific committees

For transparency in the consensus development process, we outline the procedure used to select the co-chairs, scientific committee and expert panel (from here on referred to as the panellists). The co-chairs of the meeting were appointed by the organising committee. The organising committee included the international sport federations that handled the logistics and provided financial support for the meeting. The organising committee included a representative, often the chief medical officer, from the International Olympic Committee, Fédération Internationale de l'Automobile, Fédération Equestre Internationale, Fédération Internationale de Football Association, International Ice Hockey Federation, and World Rugby. The scientific committee members were nominated by the co-chairs.[7] Two members of the scientific committee were nominated by the Concussion in Para Sport Group. For the first time in the Concussion In Sport (CIS) consensus process, an experienced scholar with expertise in medical ethics was included on the scientific committee (MMcN). The scientific committee was responsible for identifying the topics for the systematic reviews (building on the

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Delphi process used to inform the topics for the Consensus Statement published in 2017)[6] and identifying lead authors. Lead authors were selected by the scientific committee based on their research and/or clinical expertise, including contributions and impact in each of the concussion-related areas. The expert panel was selected by the scientific committee with the intention of engaging a diverse group of scientists and clinicians with differing clinical, geographical, sporting and content expertise. Each of the panellists and coauthors was invited to complete a questionnaire to identify their professional experience and background from the lens of equity, diversity and inclusion (EDI). This questionnaire included questions related to the level of sport worked within (e.g., professional, recreational), years of practice, area of practice, sex and gender, race and ethnicity, disability status, geographical representation, and other important aspects of lived experiences with SRC. A statement on EDI is included in the consensus statement and each of the systematic reviews. Each panellist also completed a conflict of interest and disclosure statement, which included sources of funding, areas of clinical and research interest, involvement with charitable trusts, involvement with professional sports, and other commercial interests, including developing technology.

Selection of topics and important considerations for systematic reviews

For the Consensus Statement on Concussion in Sport in 2016, a modified Delphi technique was used to inform the development of key questions.[6] A total of 12 systematic reviews were completed in preparation for the Consensus Statement in 2016. The output of these reviews informed the resulting key topic areas in the that Consensus Statement (the 11 'R's'): Recognise, Remove, Re-evaluate, Rest, Rehabilitation, Refer, Recovery, Return-to-sport, Reconsider, Residual effects and sequelae, and Risk Reduction.[4]

For the Amsterdam 2022 International Consensus on Concussion in Sport, the key questions evolved and were modified by the scientific committee to include: (1) A section on paediatrics within each systematic review; (2) Exploring possible alignment with definitions of mTBI rather than a systematic review on the definition; and (3) A review on retirement.[4] Ten systematic review questions were ultimately selected to identify and evaluate the evidence on SRC to inform the consensus conference regarding: prevention, sideline screening, office assessment, rest and exercise, rehabilitation, persisting symptoms, recovery, return to sport and school, potential long-term consequences, and retirement from sport.

Paediatric considerations

Rather than conducting a specific systematic review focused on paediatric considerations, two coauthors with relevant expertise in paediatrics were engaged in each of the systematic reviews. Review questions specific to paediatric considerations were included in each of the reviews (where relevant). In each review, age-specific details were extracted wherever possible for each age category of child (5–12 years), adolescent (13–18 years) and adult (>18 years). A session in the open conference and consensus statement for the paediatric athlete was also included.

Para sport considerations

To facilitate an inclusive approach to concussion and representation of the para athlete, scientific committee members with expertise in para sport were engaged and considerations for the para athlete were included for each of the reviews (where relevant and when evidence was available). A session dedicated to the para athlete was included in the consensus conference and statement.

Athlete perspectives

Given the importance of including the athlete voice in SRC research, athletes representing a variety of sports, levels of competition, levels of impairment and experiences related to concussion were engaged in the consensus conference.[22 23] An athlete voice panel discussion and prerecorded athlete/stakeholder videos were part of the consensus conference. Key points raised by the athlete stakeholders during the athlete panels and prerecorded videos were discussed during the consensus meeting.

Definition

The scientific committee met with the authors of the recently developed American College of Rehabilitation Medicine (ACRM) Diagnostic Criteria for Mild Traumatic Brain Injury[24] in advance of the consensus meeting. The previous definition of concussion from the Consensus Statement published in 2017 was reviewed by the expert panellists, who discussed possible alignment with the ACRM Diagnostic Criteria for mTBI both prior to the consensus conference and then at the expert panel meeting.

SYSTEMATIC REVIEWS

The 10 systematic reviews were drafted before the meeting to inform the presentations, discussion and consensus process (see figure 1). A standardised process for the development and completion of the systematic reviews was developed in alignment with the author guidelines of the *British Journal of Sport Medicine* (*BJSM*) and in light of the reporting requirements to be in accordance with the preferred reporting items for systematic reviews and meta-analyses guidelines.[25 26] This process was reviewed *a priori* by the scientific committee, expert librarians, lead authors and methods authors (see description below) and was shared with the *BJSM* systematic review editors for feedback. One of the scientific committee members led the development of the methodological process and coordinated the writing of the reviews (KJS). Two expert librarians were engaged in the process from inception of the reviews and throughout the process (KAH and ZP).

Authors

Coauthors for each of the systematic reviews were selected by the scientific committee from authors contributing to the literature on the topic under study and/or recognised clinicians working in the area. The initial list of coauthors was developed by the scientific committee and subsequently reviewed and edited by the lead authors. In some cases, as the review criteria were defined, additional coauthors were sought for areas of expertise that were subsequently identified in the review but were outside the expertise of the current author group. A 'methods author' was identified for each of the reviews. Each methods author was a graduate student, postdoctoral scholar or academic faculty member with expertise and training in research methodology, epidemiology and critical appraisal. The role of the methods authors was to implement the standardised process for each of the reviews and to communicate with the lead author and team of methods authors. The methods author also participated in the administrative aspects of the review, acted as one of two reviewers at each step during the review process (eg, title and abstract screen, full text screen, data extraction and risk of bias (ROB) assessment) and assisted in the data synthesis, summary of results and writing

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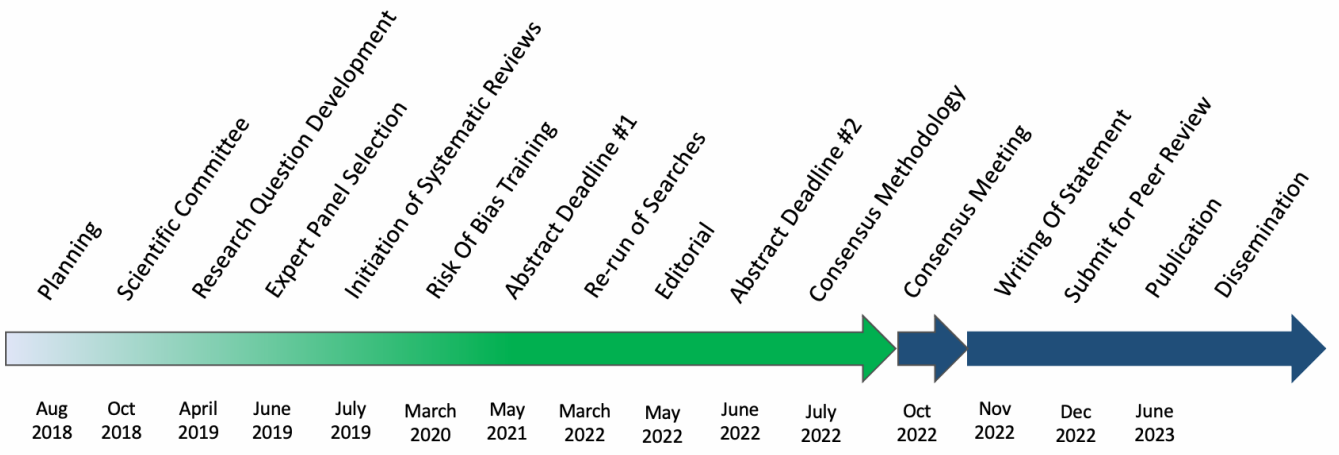

Figure 1 Timeframe of the international concussion consensus process.

of the review. Lead authors and methods authors met monthly during the writing of the reviews beginning in May 2019. To ensure the reviews had adequate support for meta-analyses, an epidemiologist with appropriate meta-analyses expertise (PER) was engaged and helped inform the summarisation of results and completion of meta-analyses where appropriate.

Templates were developed to ensure consistency in methodological content across reviews and to improve overall efficiency of review content. Initial details (including participant, intervention, comparison, outcomes, study design, proposed keywords, potential databases to be searched, date limits for search, inclusion and exclusion criteria) were developed by the lead author, methods author, coauthors and librarians. Inclusion criteria were discussed among the author groups and varied depending on the nature of the research question. For example, systematic reviews asking an intervention question (eg, exercise, rehabilitation) focused on studies related to interventions (eg, randomised controlled trials (RCTs), quasi-experimental designs); those focusing on risk of poor outcomes included study designs that could assess risk (eg, cohort and case-control studies), and reviews with a clinical assessment focus included studies that could inform diagnosis (eg, diagnostic accuracy studies, cohort, case control, case series). For all systematic reviews, a protocol was developed by the author teams, reviewed by the coauthors, methods lead (KS), and an additional coauthor with expertise in methodology (JDC), and subsequently registered with the International prospective register of systematic reviews (PROSPERO).

Search strategies

Two expert health science librarians were involved in all 10 systematic reviews. To ensure consistency and rigour across the reviews, a standard search was developed for the concepts of concussion and sports, which were common across all the systematic reviews. To develop the standard search concepts, exploratory searching was first conducted using the studies included in the systematic reviews done for the Berlin 2016 International Consensus on Concussion in Sport. The standard search concepts were jointly developed by the two librarians for Medline (via Ovid).[27] This standard

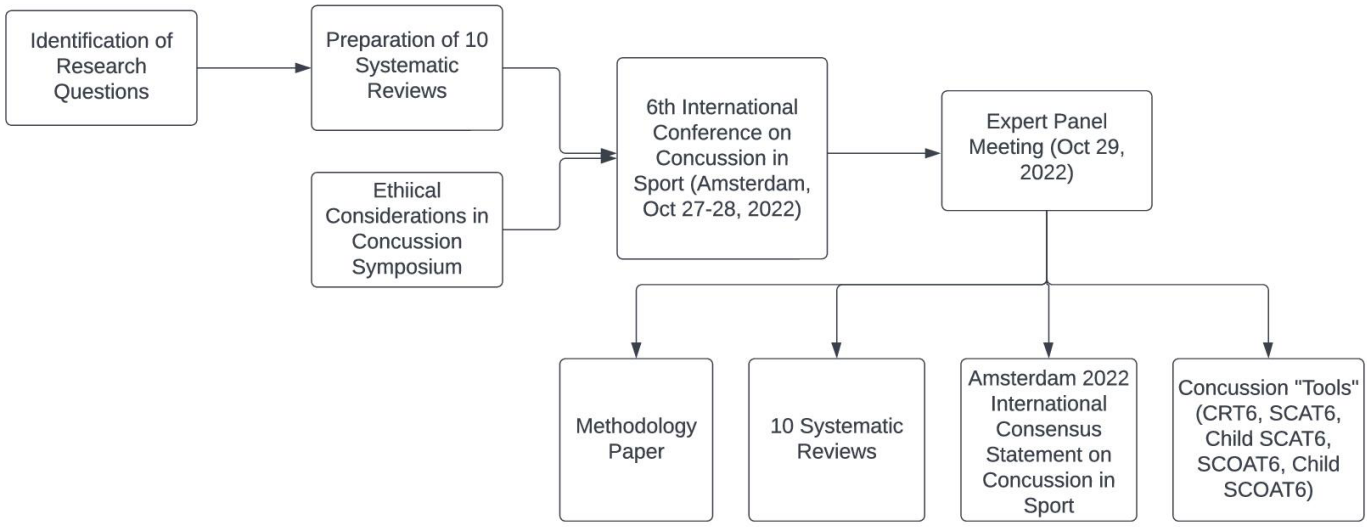

Figure 2 Overview of the international concussion consensus process and outputs. CRT6, Concussion Recognition Tool 6; SCAT6, Sport Concussion Assessment Tool 6; SCOAT6, Sport Concussion Office Assessment Tool 6.

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search was then piloted against all the included studies from the 12 systematic reviews from the Berlin 2016 International Consensus on Concussion in Sport. The lead authors for the current 10 reviews then reviewed the standard search for completeness, and changes were made where required. The database searches were all limited by date between 2001 to the date of the search (March 2022) and are described in each review. Additionally, the standard search strategy for Medline was peer-reviewed for completeness and accuracy by an additional librarian who was knowledgeable in systematic reviews, using the Canadian Agency for Drugs and Technologies in Health Peer Review of Electronic Search Strategies Checklist (2016).[28]

The standard search strategy for 'sport' and 'concussion' was then translated to all databases common across all reviews. These included: Embase (via Ovid), American Psychological Association (APA) PsycInfo (via Ovid), Cochrane Central Register of Controlled Trials (via Ovid), Cumulated Index to Nursing and Allied Health Literature (CINAHL) [via Elton B Stephans Company (EBSCO)], and SportDiscus (via EBSCO). In addition, some reviews included a search of Scopus or the Web of Science Core Collection (which includes Science Citation Index, Social Sciences Citation Index, Arts & Humanities Citation Index, Conference Proceedings Citation Index-Science, Conference Proceedings Citation Index-Social Science & Humanities, and Emerging Sources Citation Index). Furthermore, some reviews included a search of Education Resources Information Center (ERIC) (EBSCO) or the Cochrane Database of Systematic Reviews (Ovid). Therefore, the standard search strategy for the concussion and sports concepts was also created for these four databases.

Each of the standard search concepts incorporated subject headings and keyword terms searched in the title, abstract and author-supplied keyword fields. Database syntax and Boolean operators were used to create a highly sensitive search strategy. The standard search strategies for all databases are available in the online supplemental file A. The Medline search is annotated to provide a search narrative.[27]

Each librarian worked with five review teams. The author group developed and reviewed the initial search terms for the third (and in some cases fourth) search concepts, inclusion and exclusion criteria, and database selection. For each of the systematic reviews, the author teams provided relevant seed studies. These studies were analysed for keywords and subject headings, which then informed the development of the additional search concepts (eg, rest, sideline, etc) specific to each review. The additional search concepts were then added to the standard search and piloted with the provided seed studies as well as the included studies from the relevant systematic review from the Berlin 2016 International Consensus on Concussion in Sport. This strategy optimised the inclusion of all relevant studies in the final search. Each final search was first developed in Medline and was peer reviewed by the other librarian as well as reviewed by the lead author for the review. The Medline searches were then translated to all identified databases selected for each review, and the results were uploaded into Covidence. Covidence automatically de-duplicated the uploaded records. These searches can be found with each of the systematic reviews in the online supplemental material.[12–18]

Screening of citations

For each systematic review, the methods author(s) and/or lead author completed a rapid screen to exclude clearly irrelevant records (e.g., reviews, opinion papers, non-human studies and conference proceedings). Following this, each author group participating in the title and abstract screen on each review was provided with a random sample of 50 titles/abstracts in Excel for a calibration exercise. This exercise demonstrated that the inclusion/exclusion criteria were clearly defined and that all screeners were applying them in a consistent manner. This also helped confirm an acceptable initial inter-rater agreement of at least 80% across all reviewers. In the event inter-rater agreement did not reach 80%, the inclusion/exclusion criteria were reviewed, any sources of discrepancy were identified, criteria were modified/clarified, and a second random sample of 50 title/abstract citations was reviewed. Each citation in the title and abstract screen was independently reviewed by a methods author and a paired coauthor. In the case of discrepancies, a third reviewer was engaged, typically the lead author.

The full-text manuscripts for all citations were then acquired by a reference librarian and uploaded to Covidence. The full-text screen was completed independently by a methods author and paired coauthor, including reasons for exclusion. Discrepancies were again resolved by a third author.

Data extraction

A data extraction table was created for each review by the methods author and lead author and reviewed by all authors. Data extraction was again completed in duplicate by a methods author and/or lead author and paired coauthor, with coauthors selected for citations based on their specific area of expertise wherever relevant (e.g., a manuscript evaluating diagnostic utility of a cognitive test would be reviewed by an author with expertise in assessment of cognitive function). Wherever possible, articles on paediatrics were assigned to the paediatrics authors and articles that aligned with coauthor's areas of expertise were assigned to the relevant coauthor. The paired data extraction tables were then reviewed and combined to form one row in the final data extraction tables, typically by the methods author or lead author, and subsequently reviewed by all authors. Additional details, where relevant, are included in each of the reviews. In some reviews, coauthors were also asked to review the reference lists of extracted papers (including other systematic reviews in some cases) and recommend additional relevant articles for possible inclusion in the systematic review.

Risk of bias

To assess ROB, modified versions of the Scottish Intercollegiate Guidelines Network (SIGN) methodology checklists and notes for RCTs, cohort studies, case-control studies, and diagnostic studies were used.[29 30] The checklist included assessment of bias relevant to each study design and an overall impression from the reviewer on the quality of the study. A standardised training process was implemented for coauthors of all 10 reviews. Three authors with expertise in epidemiology (JDC, GMS, KJS) prepared a summary of key points related to the critical appraisal for each type of study design. All coauthors were asked to read a manuscript using the design of the SIGN tool (ie, RCT, cohort, case control and diagnostic) and complete the adapted SIGN worksheet (see online supplemental files B–E). An interactive online training session for each study design attended by all authors was held via ZOOM and was recorded for reference for authors who were unable to attend or who wished to review the content. One review also completed the Downs and Black checklist[31] for methodological quality.[32–50]

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For some reviews, a rating for the overall level of evidence was assigned for each subtopic area based on a hierarchical 'level of evidence' grading system, modified from that established by the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) Working Group.[51 52] Based on the evolution of expectations for systematic reviews over the time that passed between the start of the review process and submission for peer review, the systematic reviews that had not originally included GRADE amend their protocols to include either GRADE or the Strength of Recommendations Taxonomy.[53]

Effects of the COVID-19 pandemic

Due to the global COVID-19 pandemic, the conference that was originally planned to occur in Paris in October of 2020 was delayed for 1 year to October 2021. A second postponement of the meeting occurred for one more year to October 2022. Given the interval between the original searches and the postponements of the conference, top-up searches were run for the systematic reviews at the end of March 2022 and all newly identified records underwent the process as outlined above. Similarly, because the original call for abstracts was for the October 2020 conference, a second call occurred in 2022 to include the most up-to-date research.

Additional points relating to the systematic reviews

For each review, paediatric and parasport athlete-specific considerations were included where relevant and when literature was available. Because these reviews focused on SRC, but additional research in other areas of concussion/TBI may be important to the discussion, authors could expand as necessary on their discussion sections to include potentially relevant literature from related populations (eg, mTBI) and other conditions (eg, cardiovascular disease, vestibular disorders, psychiatric disorders) or injuries (eg, musculoskeletal injury, moderate/severe TBI) that may be relevant. In the case of the review on possible long-term effects, a body of literature that included primarily case series did not meet inclusion criteria for the review, but a decision was made to include a discussion of these articles in the introduction and discussion to better contextualise the contribution of such research to the field.

CONSENSUS CONFERENCE FORMAT

The *consensus conference* was a 2-day open meeting that included engaged discussion with attendees, abstract presenters, expert panellists and coauthors of the reviews (see figure 1). In addition to reviewing and evaluating published literature, each systematic review question was augmented by abstracts submitted by authors worldwide. Submitted abstracts were reviewed by three reviewers and ranked on a scale from 0 to 6 (1=outside the scope of the conference, regardless of quality, 2=not acceptable (case studies, general opinion, or other opinion based), 3=good, 4=very good, 5=excellent, and 6=exceptional). In the case of a discrepancy where some reviewers score <3 (do not include) and others three or greater (accept), a fourth reviewer was engaged. The top two ranked abstracts within each systematic review category were selected to be presented orally. A total of 343 abstracts were accepted for poster presentation and 21 were presented orally during the conference.

A minimum of 20 min of discussion was allotted following each review presentation, during which questions raised, panel answers and discussion points were formally documented by appointed scribes. To ensure as many participants as possible could share in the discussion, questions and comments were limited to 1 min and responses were asked to be equally concise. To be transparent, and in keeping with the disclosures from the authors and speakers, all who participated in the discussion were asked to share their name and affiliations and to disclose potential conflicts of interest. In addition, participants were encouraged to meet with presenters and share additional comments/questions in the break time after each presentation and throughout the 2-day conference. Scribed discussions were shared with presenters in advance of the EPCM to further inform the consensus deliberations.

Attendee feedback and input on future research

Throughout development of the consensus methodology, writing of the systematic reviews and consensus process, a desire to improve processes moving forward and to identify areas of priority for future research were discussed. Thus, during the final session of the 2-day consensus conference, the audience was polled to identify priority areas for future research. All attendees were invited to share feedback regarding additional content areas for future conferences, what the participants enjoyed most and areas for improvement. The results are summarised in the consensus statement.

Expert panel consensus meeting (EPCM)

The third day of the meeting was the EPCM. The EPCM process included discussion on each of the topics in the Consensus Conference (i.e., definition, the 10 systematic reviews, paediatrics, para sport, ethical considerations) following a standardised process for each topic. Observers, also experts across a range of SRC-related areas, were present at the EPCM. The observers were invited to the consensus meeting based on their role as coauthors on the systematic reviews and were asked to provide input to the lead author of the review(s) and to all panellists prior to the meeting, at the breaks and afterwards.

At the outset of the EPCM meeting, procedural rules of engagement (e.g., contributing to the discussion, voting, inclusivity of many voices, etc) were clearly presented to all panellists and observers by the chairs. The key points and summary statement for each topic were presented by the lead author of the systematic review/content topic area including any relevant additional points of discussion from the consensus conference. Discussion regarding the summary statement ensued. The 28 expert panellists who were present then participated in an anonymous electronic vote on the statements as presented. Vote categories included: 'Agree', 'Agree with minor revisions', 'Abstain', 'Disagree' or 'Disagree with an alternate statement' (open text). Following the vote, unless at least 80% of the panellists voted 'agree' (i.e., either of 'agree' or 'agree with minor revisions'), an open discussion ensued, and the statements and key points were amended accordingly. If consensus was not reached, a second vote was then taken on amended wording and recorded. To be considered a consensus recommendation, at least 80% of expert member panellists must have agreed with the recommendation. In the resulting consensus statement, the outcomes of the vote for each statement (i.e., proportion agreeing or disagreeing with the statement, along with alternate opinions) were summarised, including alternate/dissenting views by topic area. The two co-chairs of the conference co-moderated the panel, with scribes recording the discussion notes. The co-moderators alternated topics, and the moderator of the specific topic did not vote, but the other moderator participated in the anonymous vote. If agreement did not reach the required 80% agreement, then the recommendation for that question was documented in the Consensus Statement as a majority view, not consensus, and the main dissenting views were listed

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and summarised. A follow-up online consensus meeting to discuss the output from the systematic review on potential long-term effects and chronic traumatic encephalopathy on the final proposed text for the consensus statement was held in follow-up to the inperson meeting. When writing the consensus statement, it became apparent that further modifications to the return to sport strategy were necessary (see detail in writing of the consensus statement section below). The text was amended accordingly and the updated return to sport strategy was subsequently discussed and voted on at the online meeting. The scientific committee ethicist was part of the expert panel discussions but did not participate in the voting.

'Tools' meeting—CRT6, SCAT6, Child SCAT6, SCOAT6 and Child SCOAT6

The final day of the conference engaged authors from the systematic reviews for the sideline screening and office assessment and included paediatric and parasport perspectives. The purpose was to refine the tool development based on the outputs of the systematic reviews, consensus conference and expert panel meeting. During this day, the SCAT6, Child SCAT6, SCOAT6, Child SCOAT6, CRT6, and para sport adaptations to the tools were discussed and frameworks for the tools agreed on. Discussions from the day were also scribed for reference while refining the tools. Once complete, the tools were circulated to the author group for refining and then formatted. The importance of culturally appropriate translations of the tools was highlighted.

WRITING OF THE CONSENSUS STATEMENT

At the Expert Panel meeting, the text for inclusion in the consensus statement from each systematic review and content area was voted on. This text was included in the statement accompanied by qualifying text to create continuity between sections of the consensus statement. In the consensus statement, a summary of recommendations, level of agreement for the recommendation, and dissenting viewpoints, were summarised. Paediatric, para sport and ethical considerations, along with future directions, were also included. Given the overlap in findings from multiple systematic reviews that would inform the return to learn and sport strategies, the lead authors from the reviews on Rest and Exercise, Rehabilitation, Persisting Symptoms, Recovery, and Return to Sport and Learn worked together to refine these strategies and ensure consistent messaging throughout the statement based on the aligned systematic reviews. Following this process, minor content edits were suggested to the return to sport strategy and a second vote with the expert panel ensued with the return to sport strategy. The co-chairs of the scientific committee (JP, KS) combined the text and drafted the consensus statement, which was subsequently reviewed and edited by all expert panellists.

Ethical perspectives

A section in the consensus statement was dedicated to ethical considerations regarding SRC clinical practice and research to ensure that key points related to ethics in concussion were discussed. The ethicist held an independent ethics symposium to discuss topics relevant to ethics and concussion and subsequently highlighted key points during the consensus conference and EPCM. This section reinforces the need to maintain patient confidentiality (an important reminder more than a new addition), a point about real and potential conflicts of interest arising from the various roles physicians, healthcare professionals and expert scientists undertake, and the need for all participants to declare potential conflicts of interest as they speak at the conference (whether as expert panellists or from the floor).

Methodological considerations and future directions

Throughout the consensus process and writing of the systematic reviews, limitations and gaps in the current body of the SRC literature were identified. While the science has advanced in many areas, common methodological limitations were identified across reviews, with some differences based on the type of question under consideration. Where possible, we have addressed some of these limitations in the consensus statement and have referred to these below. Here we address several methodological issues—including both a summary of the challenge and a recommendation for future research.

Definition of concussion

Challenge: Across studies, the definition of concussion was frequently not included, was unclear and, if defined, in many cases differed between studies. Thus, there is a chance that study participants are misclassified by concussion status (yes/no) and/or the definition for diagnosis of concussion differs between studies, making comparisons across studies challenging. *Solution:* Include and reference an operationalised definition of concussion.

Definition of recovery

Challenge: Outcomes of recovery were often not operationalised (i.e, valid measurable observations). For example, the outcome of recovery may be 'resolution of symptoms' or 'cleared to return to sport', but the criteria for these outcomes and how they were specifically measured were not described. Given the heterogeneity of concussion outcomes, comparison between studies may not be possible. Measurement bias based on errors in the classification of outcome may result from outcomes lacking clear criteria. *Solution:* All concussion outcome measures should be clearly defined, operationalised, validated and responsive. To address this point, in the consensus statement we have proposed common operational definitions for outcomes to facilitate common definitions of recovery and we also recommend that authors consider including symptoms, objective measures and functional outcomes to define or determine recovery. Measures such as the SCAT6, Child SCAT6, SCOAT6, and Child SCOAT6 are multifaceted tools that can be used to evaluate athletes/patients acutely and in the office follow-up setting.

Factors that may affect outcome

Challenge: In many studies, potential confounding and effect-modifying factors such as age, sex, socioeconomic status, previous history of concussion, genetics, premorbid diagnosis, pre-existing disability, and other factors that may affect risk for the outcome of interest (ie, concussion, persisting symptoms, other long-term outcomes) are not considered. *Solution:* Future studies should measure and be powered appropriately to evaluate the effect of factors that may impact the outcome under study.

Selection of study participants

Challenge: Participants selected in studies may not have the same relationship with the outcome of interest as potential participants who are not included in the study (selection bias). For example, in a study of prognosis following concussion, a cohort of at-risk adolescents should be followed to understand the spectrum of recovery trajectories rather than studying only those presenting to a specialty clinic, where only those who are more likely to have persisting symptoms may attend (because those who have begun to recover may not attend the clinic). This would result in an overestimation of the time to recovery. *Solution:* Inception or incidence cohorts (rather than prevalent cases) should be employed where possible.

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Generalisability

Challenge: Many studies include select samples of high performance male athletes, and are primarily from North America. There are not enough studies of children <12 years, women, non-binary genders and para athletes. *Solution:* Future studies should be inclusive and more studies need to be undertaken that include all age groups, sexes, genders, races and ethnicities, para athletes, and all levels of sport participation, and geographical regions.

Study design and ROB

Challenge: Many studies reviewed had a high ROB. *Solution:* High quality studies taking into consideration appropriate study design for the question being raised, unbiased selection of participants, measurement or control for potential confounders, consideration of effect modification (eg, sex, gender, age), and operationally defined valid outcomes at the outset are needed to move the field of concussion forward. For questions related to interventional studies, RCTs are recommended; for questions related to prognosis, inception cohort studies or case-control studies are recommended; and for studies related to diagnosis, diagnostic accuracy studies using an independent gold standard are recommended. In areas where less is known, descriptive study designs that can generate hypotheses (cross-sectional studies, case series, case studies) can also inform future hypothesis-testing studies. Considering a pragmatic approach to concussion, qualitative designs to better understand the sociocultural, psychosocial, health-related and other contexts will enable a richer understanding of the complex issues that face athletes, coaches, parents, officials, clinicians, researchers and all stakeholders involved in concussion. A comprehensive approach, understanding strengths and limitations of different designs, will advance our understanding of this heterogeneous injury. Ultimately, this will inform strategies to optimise the health and safety of athletes and minimise the effects of concussions.

CONCLUSION

The Scientific Committee guiding the Amsterdam 2022 International Consensus on Concussion in Sport focused on implementing a rigorous methodology that informed the systematic reviews, consensus conference and process, and ultimately the consensus statement. This evolved from previous CISG consensus meetings but was also informed by more recent clinical consensus meeting processes that followed updated international best practice aiming for a consensus outcome that is scientifically rigorous, pragmatic, and inclusive. While many advances have been made, we have also identified targeted areas for the future to continue building on the work to date, ultimately aiming to improve the health and safety of athletes of all ages, from all sports, genders, physical impairments and geographical regions.

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