Australian Physical Activity Clinical Practice Guideline

for people with moderate to severe traumatic brain injury

2024

The BRIDGES Guideline development group

Front cover image:

This image was painted by Gabby Vassallo, a member of the BRIDGES Guideline Leadership Group with lived experience of severe traumatic brain injury.

Mindset [is Everything]

This painting is a metaphor for my journey of getting back my life, after sustaining a TBI. My love of cycling continued after my accident, despite sustaining serious injuries from being struck by a car while riding my bike. For me, being able to ride my bike again not only improved my overall physical wellbeing but was great for my mental health, and I remain an active advocate for getting everyone 'off the couch', especially after TBI. This painting's brainwave moves right to left from the jagged start in the early days, to a smooth rolling track, representing my rehab journey progression.

-Gabby Vassallo

Endorsing organisations:

AUSTRALIAN PHYSIOTHERAPY ASSOCIATION

ESSA EXERCISE & SPORTS SCIENCE AUSTRALIA

RMSANZ Rehabilitation Medicine Society of Australia and New Zealand

Copyright information:

Copies of the guideline, administrative and technical reports which contain all relevant evidence are freely accessible at:
https://www.imh.org.au/bridges
https://doi.org/10.25910/7103-d425
https://doi.org/10.25910/mge0-re86

ISBN: 978-1-74210-577-2

Publication Approval:

Australian Government
National Health and Medical Research Council

The guideline recommendations on pages 22-32 of this document were approved by the Chief Executive Officer of the National Health and Medical Research Council (NHMRC) on 18 April 2024 under section 14A of the *National Health and Medical Research Council Act 1992*. In approving the guideline recommendations, NHMRC considers that they meet the NHMRC standard for clinical practice guidelines. This approval is valid for a period of five years.

NHMRC is satisfied that the guideline recommendations are systematically derived, based on the identification and synthesis of the best available scientific evidence, and developed for health professionals practising in an Australian health care setting.

This publication reflects the views of the authors and not necessarily the views of the Australian Government.

Responsible Organisation

The development of the Australian Physical Activity Clinical Practice Guideline for people with moderate to severe traumatic brain injury (TBI) was led by Associate Professor Leanne Hassett (Sydney School of Health Sciences and Institute for Musculoskeletal Health, The University of Sydney; and Sydney Health Partners) and Dr Liam Johnson (Department of Physiotherapy, The University of Melbourne, and Institute for Musculoskeletal Health, The University of Sydney), Australia.

Funding Sources

The Australian Physical Activity Clinical Practice Guideline for people with moderate to severe TBI is the major output from the BRIDGES (BRain Injury: Developing GuidElineS for physical activities) research, which was funded by an Australian Government National Health and Medical Research Council 2020-21 Medical Research Future Fund Traumatic Brain Injury Mission, Stream 2, grant (MRF2009099).

Recommended citation

Hassett L, Johnson L, on behalf of the BRIDGES Guideline Development Group. Australian Physical Activity Clinical Practice Guideline for people with moderate to severe traumatic brain injury. 2024.

ISBN: 978-1-74210-577-2

BRIDGES Guideline Development Team

BRIDGES Guideline Steering Group:

Leanne Hassett, Liam Johnson, Sakina Chagpar, Abby Haynes, Belinda Wang, Kerry West, Daniel Cheung [Students: Pien Alferink, Ella Bracone]

BRIDGES Guideline Leadership Group:

Leanne Hassett, Liam Johnson, Adrian Bauman, Catherine Carty, Kelly Clanchy, Anthony Okely, Adam Scheinberg, Catherine Sherrington, Anne Tiedemann, Sean Tweedy, Gabby Vassallo, Gavin Williams, Luke Wolfenden [Methodological advisor: Zachary Munn]

BRIDGES Development Group:

Leanne Hassett, Liam Johnson, Rhys Ashpole, Adrian Bauman, Olivia Beattie, Francesca Brady, Catherine Carty, Sakina Chagpar, Kelly Clanchy, Domenic Denichilo, Alexandra Edmonson, Abby Haynes, Kate Heine, Sonia Hoppe, Anthony Mamo, Peter Mayhew, Anthony Okely, Nick Rushworth, Sania Salim, Benjamin Sammut, Adam Scheinberg, Catherine Sherrington, Grahame Simpson, Anne Tiedemann, Sean Tweedy, Gabby Vassallo, Sarah Veli-Gold, Belinda Wang, Nicholas Waters, Kerry West, Bhavini Whiteside, Gavin Williams, Julie Witts, Kieren Witts, Luke Wolfenden [Methodological advisor: Zachary Munn]

Acknowledgement of country

The BRIDGES team acknowledges the traditional custodians of country throughout Australia and their connections to land, sea, and community. We pay our respect to their elders past and present and extend that respect to all Aboriginal and Torres Strait Islander peoples today.

Abstract

Background

In 2020, the World Health Organization (WHO) released updated physical activity and sedentary behaviour guidelines, which for the first-time included a guideline for people living with disability. The disability guideline is based on evidence from the general population and eight common health conditions causing disability, but did not include people with traumatic brain injury (TBI), nor did it consider the rehabilitation phase of recovery from injury.

In 2019, the Australian federal government launched the Traumatic Brain Injury Mission. The Mission was tasked with providing $50 million over 10 years under the Medical Research Future Fund (MRFF) to support research. The goal of the Mission is to better predict recovery outcomes after a TBI, identify the most effective care and treatments, and reduce barriers to support people to live their best possible life after TBI.

In 2021, our team was funded through the MRFF TBI Mission to develop an Australian Physical Activity Clinical Practice Guideline for people living with moderate to severe TBI (msTBI). The overarching project to guide the development of the guideline was called BRIDGES (BRain Injury: Developing GuidElineS for physical activities).

Objective

To develop an Australian clinical practice guideline to support the clinical decision-making of health professionals working with people with msTBI and increase uptake of safe and beneficial physical activity by people living with msTBI.

Methods

The overarching BRIDGES project was guided by the Exploration Preparation Implementation Sustainment (EPIS) framework. We used a Grading of Recommendations Assessment, Development and Evaluation (GRADE) ADOLOPMENT approach to determine whether to 'adapt' or 'adopt' the WHO guideline or develop *de novo* recommendations. We established guideline leadership and development groups, conducted a rapid systematic review to identify direct evidence in TBI, and reviewed guidelines in other relevant health conditions (i.e., stroke, cerebral palsy) to identify indirect evidence. To further inform guideline development and implementation considerations, we conducted an audit of brain injury services in Australia and qualitative consultations with key stakeholders, including people with msTBI.

Results

Direct evidence for the prescription of physical activity for people with msTBI is limited. The clinical practice guideline developed incorporates 10 *de novo* evidence-based recommendations with additional good practice points and precautionary practice points to guide clinical decision-making. The physical activity recommended is aerobic exercise, strength training, mobility training, sport and physical recreation, and promotion of physical activity. The physical activity is recommended for children, adolescents, adults, and older adults across the continuum of rehabilitation.

Conclusion

While there remain evidence gaps that require further research, and further work on how the guideline can be implemented into clinical practice is needed, physical activity interventions tailored to the individual's goals and needs should be standard clinical practice for health professionals working with people with msTBI in Australian rehabilitation, community, home, and school (for children and adolescents) settings.

Plain Language Summary

Physical activity has many benefits for health and social wellbeing. However, many people around the world are not physically active, and this is more common for people living with disability, including people living with a traumatic brain injury (TBI). The BRIDGES (BRain Injury: Developing GuidElineS for physical activities) project aimed to develop a clinical practice guideline to support the decision-making of health professionals working with people living with moderate to severe TBI (msTBI). The guideline aims to provide recommendations on how people with msTBI living in Australia can gain the benefits of physical activity and limit the negative effects from physical inactivity.

The guideline was developed by a team of experts in msTBI from all states and territories of Australia. Experts included healthcare professionals, academics, people living with msTBI and family members, community physical activity providers, and members of TBI advocacy groups. The development of the guideline was created from a combination of summarising the most recent evidence on physical activity for people with msTBI and other similar health conditions, an audit of how physical activity is delivered across Australia, and by asking children, adolescents, adults, and older adults living with msTBI, as well as other key stakeholders, about their experiences and perspectives of physical activity.

The guideline recommends that physical activity can be delivered and promoted to people of all ages with msTBI across hospital and community settings. Regular aerobic fitness exercise and muscle strength training is recommended for all ages and should be tailored to suit individual needs. This involves a process of assessment to prescribe suitable exercise modes and training dosages. Where appropriate, both fitness and muscle strength training should be commenced in rehabilitation and continue into a community physical activity setting as the person with msTBI progresses along their recovery journey.

The guideline also recommends that task-specific mobility training (such as walking and balance training) is provided for people of all ages with msTBI. Mobility training is aimed at achieving goals that involve the person returning to activities that are important to them and often critical to independent living. If the person with msTBI has difficulty with cognition (e.g., memory, attention, planning) or behaviour (e.g., initiation), these need to be considered when creating a mobility training plan.

The guideline also recommends that sport (an activity where there are rules and an element of competition such as wheelchair basketball or soccer/football) and physical recreation (leisure activities that involve physical exertion such as yoga, dance, or Tai Chi) are considered for people of all ages with msTBI based on an individual's preference. Health professionals should seek to deliver and/or facilitate such activities in relationship with relevant external providers. Caution should be considered in sport and physical recreation where there may be a risk of a head knock which may cause a second brain injury.

The guideline also recommends that physical activity is promoted by healthcare professionals to people of all ages with msTBI. Physical activity promotion should be conducted as early as possible in the rehabilitation journey through education, developing goals, identifying barriers, and engaging with the key support networks (such as family, friends, and support workers) of the person with msTBI.

The guideline was developed for healthcare professionals working with people living with msTBI. The BRIDGES team are planning to conduct studies to acquire further evidence to support physical activity provision and promotion to people with msTBI, and to develop Australian-based resources to support the implementation of the recommendations in the guideline. The BRIDGES team continue to monitor and evaluate the evidence underlying the recommendations, and plan to update this guideline in five years.

How to use this guideline

The Australian Physical Activity Clinical Practice Guideline for people with moderate to severe traumatic brain injury includes three reports. The first report is the **Administrative report** which provides information about the funding source and governance of the guideline, the conflict of interest policy and declarations, consumer involvement (including representation from subpopulations) in the development of the guideline, endorsing organisations, and the public consultation process.

The second report is the **Technical report**. The Technical report includes the detailed methodology used to develop the guideline as well as the Evidence to Decision (EtD) frameworks for each of the 10 clinical questions. Included with the EtD frameworks are the forest plots for the meta-analyses conducted (where appropriate) and the ratings of the quality of the evidence using relevant Risk of Bias tools.

The third and final report is this report, the **Guideline report**. The Guideline report is divided into four sections, and an Appendix. Section one is an executive summary of the guideline context, purpose, scope, methods, consumer involvement, and consultation process to provide an overview of the guideline development process. Section two lists the recommendations in a table to provide a brief, easy-to-access summary of the guideline recommendations. Although this guideline report is not suitable for people with visual impairments, section two enables the recommendations to be identified easily within the text. Section three provides further details underlying the recommendations for each clinical question, including the clinical need for each question, a summary of evidence, the recommendations and their justification, and the anticipated clinical impact of the recommendations. This section will be of particular use for health professionals wanting to implement the guideline recommendations into practice. Section four provides the plan for dissemination, implementation, monitoring, and evaluation of the guideline. This section will be useful for healthcare organisations wanting to implement the guideline into practice and includes plans to develop resources to support guideline implementation. The Appendix includes a list of acronyms and definition of terms used in the guideline document. It also details the three groups responsible for the development of the guideline and includes a physical activity questionnaire that can be used to measure physical activity levels of people with msTBI across the continuum of care.

Table of Contents

SECTION ONE:
Executive Summary

BRIDGES

Brain Injury: Developing Guidelines for Physical Activities

Executive summary

Context and background

There is irrefutable evidence confirming the multidimensional benefits of physical activity both to the individual who partakes in the activity, and to society more broadly (Bull et al., 2020; Hafner et al., 2020). Despite these benefits, physical inactivity is one of the leading global health challenges and little improvement has been achieved over time despite global targets being set and policies developed (Guthold et al., 2018). Adults and children living with disabilities are twice as likely not to meet recommended physical activity levels compared to those living without disability (Rimmer et al., 2012). This discrepancy requires urgent action to enable people with disability to gain the health and social benefits of being physically active.

Traumatic brain injury (TBI) is a leading cause of long-term disability. The incidence of moderate to severe TBI (msTBI) in Australia is approximately 2500 per year, almost nine times the incidence of spinal cord injury (Access Economics, 2009). Furthermore, while health conditions such as stroke are more common, TBI primarily affects people during their most economically productive years and the effects are lifelong. Consequently, the economic and social costs are very high – the lifetime cost of new cases of TBI in Australia was $10.5 billion in 2008 (Access Economics, 2009).

Adults and children who sustain a severe TBI (and sometimes moderate TBI) are likely to spend days to weeks in the acute care setting before being admitted to inpatient rehabilitation (AROC, 2020). Once admitted to inpatient rehabilitation the length of stay often extends from weeks to months (AROC, 2020). Physical inactivity from prolonged and sustained bed rest is extensive and extreme in the first days to weeks to months after a severe TBI, and this extends into inpatient rehabilitation (Hassett et al., 2015; Hassett et al., 2018). At the time of discharge from hospital, most people with msTBI are independent in their mobility (Ponsford et al., 2014) yet both adults and children with TBI continue long-term to be more physically inactive than age-matched peers (Pawlowski et al., 2013). The updated World Health Organization (WHO) physical activity and sedentary behaviour guidelines include for the first-time a specific guideline for adults and children living with disability (Carty et al., 2021). This public health guideline has been developed from the latest high-quality evidence including direct evidence from eight health conditions (including stroke but not TBI and not including physical activity interventions as part of rehabilitation) as well as indirect evidence from general age-specific populations. Physical activity clinical practice guidelines exist for other health conditions (e.g., Spinal Cord Injury; Hoekstra et al., 2020), however no physical activity clinical practice guideline currently exists to guide health professionals working with people living with msTBI. The development of an Australian physical activity clinical practice guideline for people living with msTBI will likely promote high-value and consistent evidence-based care for people living with msTBI across Australia. In 2019, the Australian federal government launched the Traumatic Brain Injury Mission. The goal of the Mission is to support research to better predict recovery outcomes after a TBI, identify the most effective care and treatments, and reduce barriers to support people to live their best possible life after TBI.

In 2021, our team was funded through the Medical Research Future Fund (MRFF) TBI Mission to develop an Australian Physical Activity Clinical Practice Guideline for people living with msTBI. The overarching project to guide the development of the guideline was called BRIDGES (BRain Injury: Developing GuidElineS for physical activities).

Scope and purpose

Population

This guideline provides recommendations for physical activity interventions for children and adolescents (5 to 17), adults (18 years or older) and older adults (65 years or older) living with msTBI. TBI is defined as an alteration in brain function caused by an external force to the head such as from road traffic accidents, falls, blast injuries, acts of violence, and sporting injuries (Menon et al., 2010). A moderate TBI is defined as post-traumatic amnesia between one to seven days and/or an altered level of consciousness (Glasgow Coma Scale score 9 to 12) or loss of consciousness between 30 minutes to 24 hours post-trauma (Bradshaw et al., 2008). A severe TBI is defined as post-traumatic amnesia duration longer than seven days, or a period of coma with Glasgow Coma Scale score of eight or less or a loss of consciousness greater than 24 hours (Bradshaw et al., 2008).

Target audience

This guideline is targeted at health professionals working with people with msTBI across the continuum of care to improve physical activity (aerobic exercise, strength training, mobility training, sport and recreation and overall promotion of physical activity). Health professionals most likely to be delivering physical activity interventions are physiotherapists and exercise physiologists. However, other health professionals, such as occupational therapists, recreation therapists, psychologists, and rehabilitation specialists, may also be involved. Health professionals are likely to engage and work with the following stakeholders when delivering and promoting physical activity.

Key stakeholders

- People with msTBI
- Family members and support workers
- Other health professionals, including physiotherapists and exercise physiologists, and other members of an interdisciplinary team
- Funding agencies (e.g., icare NSW)
- Community sport and recreation providers
- Patient advocacy groups (e.g., Brain Injury Australia, Heads Together for ABI, Connectivity TBI)

Target settings across the continuum of care

This guideline is relevant for any setting where health professionals are delivering and/or promoting physical activity to people living with msTBI. Settings are likely to include:

- Inpatient, transition, and outpatient rehabilitation settings
- Community settings (e.g., fitness centres, sporting fields, community centres)
- Home
- Schools

Subgroup considerations

The recommendations in this guideline have been developed to support all children, adolescents, adults, and older adults living with msTBI in Australia to be physically active to achieve a range of critical and important outcomes. From the review of evidence to inform the recommendations, most of the evidence is from studies including working age adults, with limited evidence on children, adolescents, and older adults. The BRIDGES team conducted additional studies as part of the guideline development process to obtain input from a diverse range of people living with msTBI. We sought to gain the perspective of people with msTBI across the continuum of care, with different injury severities, men and women, of all ages and diverse cultural backgrounds, and across all states and territories of Australia, including rural and remote settings. Additional barriers (e.g., language, cultural competence, remoteness, high support needs) to participating in physical activity and interacting with health services are likely in subpopulations of people living with msTBI. The following subpopulations have been identified as groups where further engagement and research should be prioritised in the future to ensure the success of implementing the guideline and avoid further increasing health inequities.

- **Aboriginal and Torres Strait Islander people**:
  Several studies globally indicate that Indigenous people experience a higher incidence and prevalence of TBI compared to non-Indigenous people (Fitts et al., 2019). The development of this guideline has included input from services working with Indigenous Australians living with msTBI as well as some input within our stakeholder focus groups and our preference survey. We have not however specifically talked with Indigenous individuals living with msTBI and people within their community to ensure the suitability of these recommendations and specific implementation considerations. It is likely additional barriers related to interacting with the health system and multiple health professionals (Fitts et al., 2019) as well as engaging in physical activity will be experienced by Indigenous Australians.

- **High support needs:**
  The development of this guideline has included input from services working with individuals living with very severe TBI (i.e., with physical, cognitive, and behavioural impairments) as well as some input within our stakeholder focus groups and our physical activity preference survey. We have not however specifically talked with individuals living with severe TBI if they were not able to participate in focus groups or complete an online survey (e.g., those with communication impairments or more significant physical or cognitive impairment). Focus groups with our multiple stakeholders highlighted the added challenges and barriers and additional resources (e.g., transport, attendant care, specialised equipment) needed for people living with high support needs to be physically active, particularly in the community. Additional input from people with msTBI with high support needs (and their support networks) would be important to ensure recommendations can be implemented successfully in this sub-group.

- **Older adults:**
  With an ageing population, the incidence of msTBI is growing in older adults (higher in females), often from sustaining a fall (Gardner et al., 2018). Most direct research evidence from msTBI informing this guideline is from adults of working age between 15-65 years. Additional evidence from stroke may be suitable for this older sub-group, although differences in impairments from the two health conditions exist (e.g., likely more cognitive and behavioural impairments after TBI). An additional consideration is that if the person with msTBI is over 65 years, they will not be eligible for funding through the National Disability Insurance Scheme to support physical activity participation, and they may not meet inclusion criteria for specialist brain injury services, which may result in their admission to general rehabilitation wards.

- **Children:**
  Most direct research evidence from msTBI informing this guideline is from adults of working age between 15-65 years. Additional evidence from cerebral palsy may be suitable for this younger sub-

group, although differences in impairments from the two health conditions exist (e.g., likely more cognitive and behavioural impairments after TBI). Studies that were conducted in children, usually did not include children under the age of 8 years old. Additional challenges were identified from our focus groups with stakeholders including added burden on parents (particularly with additional children to care for), and challenges for health professionals engaging with schools.

Culturally and Linguistically Diverse (CALD) populations:
The development of this guideline has included input from services working with people with msTBI from CALD communities, as well as some input within our stakeholder focus groups and our physical activity preference survey. We have not however specifically talked with people with msTBI with a CALD background or people within their community to ensure the suitability of these recommendations and specific implementation considerations. Previous research indicates there are likely to be barriers related to interacting with the health system due to cultural and language factors, as well as different cultures valuing physical activity in different ways.

People with msTBI living in and services working in regional and remote Australia:
The development of this guideline has included input from services with reach into rural and remote regions of Australia, two members of our Guideline Development Group living in regional or remote Australia (a clinician and a lived experience member), and some members of our stakeholder focus groups living in regional or remote Australia. Some barriers were identified through these means (e.g., social isolation and difficulty accessing services). We have not specifically focused on barriers and facilitators for those living in regional and remote Australia. Strategies to mitigate barriers to implementation, such as access to services, are needed to ensure the recommendations presented in this guideline can be successfully implemented in rural and remote Australia.

People with msTBI with low socioeconomic status:
The input of people with low socioeconomic status was not specifically targeted in the development of the guideline, though nor were they excluded. Barriers to seeking support and uptake of physical activity, including access to funding, social supports, and transport should be considered when planning for implementation of the guideline to ensure people with msTBI from low socioeconomic backgrounds are not further disadvantaged.

Clinical questions

The questions addressed in this guideline are presented in the PICO format (i.e., Population, Intervention, Comparison, and Outcome).

1. Should structured aerobic exercise training compared to control be used for adults and older adults with moderate to severe traumatic brain injury?
2. Should structured aerobic exercise training compared to control be used for children and adolescents with moderate to severe traumatic brain injury?
3. Should structured muscle strengthening training compared to control be used for adults and older adults with moderate to severe traumatic brain injury?
4. Should structured muscle strengthening training compared to control be used for children and adolescents with moderate to severe traumatic brain injury?
5. Should structured mobility training (i.e., gait, balance, and function training) compared to control be used for adults and older adults with moderate to severe traumatic brain injury?

6. Should structured mobility training (i.e., gait, balance, and function training) compared to control be used for children and adolescents with moderate to severe traumatic brain injury?
7. Should sport and physical recreation compared to control be used for adults and older adults with moderate to severe traumatic brain injury?
8. Should sport and physical recreation compared to control be used for children and adolescents with moderate to severe traumatic brain injury?
9. Should overall physical activity promotion compared to control be used for adults and older adults with moderate to severe traumatic brain injury?
10. Should overall physical activity promotion compared to control be used for children and adolescents with moderate to severe traumatic brain injury?

Patient and public involvement statement

People with msTBI were involved in all stages of the planning, development and management of the guideline. Gabby Vassallo, a person with lived experience, was an investigator on the broader BRIDGES project, ranked the outcomes of importance, and was a member of the Guideline Leadership and Development Groups. Nick Rushworth, the Chief Executive Officer of Brain Injury Australia, a national advocacy body for people with TBI, and a person with lived experience, was also a named investigator on the broader BRIDGES project. Nick was consulted prior to the Guideline Development Group meetings to discuss the involvement of people with lived experience, including himself, in the Guideline Development Groups. Qualitative consultations and stakeholder focus groups were conducted with people with msTBI to understand their preferences for, and barriers and facilitators to, physical activity. People with msTBI were also included as members of the Guideline Development Group that voted on and approved the guideline recommendations. While the Guideline was open to public consultation, it was hosted by TBI Connectivity, a not-for-profit organisation that aims to raise awareness of brain injury in the community. We intend to disseminate the guideline to the people with msTBI directly involved in the development of the guideline initially, before disseminating it to the general public more broadly. We will seek patient and public involvement in the further dissemination of the guideline.

Methods

Detailed methods for guideline development are available in the Technical Report. Below is a summary of the methods taken to develop the guideline.

GRADE ADOLOPMENT process

A GRADE ADOLOPMENT methodology (Schünemann et al., 2017) was used to develop the Australian Physical Activity Clinical Practice Guideline for people with msTBI.

Establishment of Guideline Groups

Three groups were responsible for the guideline development, co-chaired by A/Prof Leanne Hassett and Dr Liam Johnson: the Guideline Steering Group (conducting research and drafting the guideline), Leadership Group (overseeing the guideline development process) and the Development Group (voting on recommendation strength and finalising recommendation wording).

The Guideline Development Group consisted of members of the guideline steering and leadership groups as well as other key stakeholders representing all states and territories of Australia, including people with lived experience, their families and caregivers, clinicians and researchers working with children, adolescents, and adults living with msTBI, methodological experts, community physical activity providers, patient advocacy groups, and funding agencies. The composition of the Guideline Steering, Leadership and Development Groups is detailed in Appendix 3.

Selection of questions and outcomes of interest

The clinical questions were drafted by the Guideline Steering Group prior to commencing the guideline reviews and presented to the Guideline Leadership Group for discussion and approval of their adoption.

A range of outcomes were identified and selected for ranking of importance based on the patient perspective. From a list of 15 outcomes, the Guideline Leadership Group (including a member with lived experience) ranked each outcome in terms of level of importance to a person with msTBI for each clinical question. Only outcomes ranked critical (score 7-9/9) or important (score 4-6/9) for decision-making were included in the final list of outcomes.

Identification of credible existing guidelines

We identified and prioritised potentially relevant and credible existing guidelines from which to adapt, or adopt, to develop our guideline, and applied the GRADE ADOLOPMENT (Schünemann et al., 2017) criteria to determine their selection for our guideline.

A total of 13 guidelines were rated by the steering committee who then submitted their recommendations to the Guideline Leadership Group. Following discussions by the Guideline Leadership Group, it was agreed that the WHO physical activity and sedentary behaviour guidelines (Carty et al., 2021), Australian 'living' stroke guidelines (https://informme.org.au/guidelines/living-clinical-guidelines-for-strokemanagement, 2022), and cerebral palsy guidelines (Jackman et al., 2022) could provide credible indirect evidence where there was no/limited evidence in TBI. However, all three guidelines demonstrated questionable relevance and applicability, particularly with respect to their limited applicability to the condition (i.e., people with msTBI) and setting (i.e., rehabilitation and transitional care were not considered in the WHO guidelines). It was also decided by the Guideline Leadership Group to update the search strategy used by the WHO physical activity and sedentary behaviour disability guideline to examine the association between physical activity and health-related outcomes among people with stroke given the overlap in impairments experienced by stroke survivors and people with msTBI.

The Guideline Leadership Group then decided the creation of *de novo* recommendations was more appropriate than the adaptation or adoption of existing guidelines.

Identification of direct evidence in msTBI

Given the lack of direct evidence that could be acquired from the WHO physical activity and sedentary behaviour guideline, or other guidelines, the Guideline Leadership Group decided on an update to a recent rapid systematic review (Johnson et al., 2023) as the best source of direct evidence to inform the development of *de novo* recommendations. The Johnson et al. (2023) review was updated with searches run in December 2022 and the inclusion of non-randomised studies of interventions (NRSIs) in addition to randomised controlled trials. See Technical report and/or Johnson et al. (2023) for further methodological information. In total, 128 articles were included in the updated review to provide direct evidence to inform the development of the guideline.

We assessed the risk of bias (RoB) in each trial using Cochrane RoB tools. For RCTs and cross-over RCTs, the RoB-2 (Sterne et al., 2019) was used, while for NRSI, the ROBINS-I (Sterne et al., 2016) instrument was used. For all studies, a single reviewer independently assessed the domains of potential bias arising for each domain of the relevant tool. The level of potential bias was judged as low, high or unclear (due to a lack of information or uncertainty) for each domain.

For outcomes measured on the same scale, we calculated the mean difference (MD) and 95% confidence interval (CI) using a random-effects model. Where outcomes were measured using different assessments/measures, we calculated the standardised mean difference (SMD) (Hedges' g) and 95% CI using a random-effects model to pool estimates. Data were pooled in meta-analyses where appropriate and reasonable. Effect sizes were categorised as small (0.1 to 0.4), medium (0.5 to 0.7) or large (0.8 or greater). Where it was not possible or appropriate to pool data, study results were narratively synthesised.

Use of further evidence

Additional studies were completed to complement the evidence review but are not components of the GRADE ADOLOPMENT process. Their inclusion as part of the development of the guideline was considered important when determining the acceptability, feasibility, and resource requirements of the *de novo* guideline with key stakeholders, and the development of plans for future implementation of the guideline, including monitoring and surveillance.

Brain Injury rehabilitation services audit

We conducted an online audit via a REDCap survey of specialist and non-specialist brain injury services across Australia to identify how physical activity is currently delivered and promoted, and factors that influence delivery and promotion. A nominated site champion (i.e., a physiotherapist or exercise physiologist) completed the survey on behalf of their service.

Twenty-six services (20 adult, 5 paediatric, 1 all ages) across all eight Australian states and territories were included. Most services were based in metropolitan settings, four were based in regional/remote Australia. Physiotherapists and exercise physiologists were the main health professionals delivering physical activity interventions and considered this as central to their role. Most were delivering the types of physical activity recommended in the guideline (e.g., strength and mobility training), however *how* it was delivered often did not align with guideline recommendations. Using the Capability, Opportunity, Motivation-Behaviour (COM-B) framework (Michie et al., 2011), we explored barriers influencing physical activity delivery reported by health professionals. We identified capability (limited knowledge and skills), opportunity (limited resources and time), and motivation (priority, habits, beliefs) barriers, indicating implementation support will be needed to enable evidence-based care.

Qualitative interview and focus groups with people with lived experience

We conducted a study using qualitative approaches to generate attributes for a Discrete Choice Experiment (DCE) on preferences for community-based physical activity for people living with msTBI. Data was collected using focus groups and interviews to identify key concepts of physical activity participation by our four stakeholder groups: children (10+ years), adolescents, adults, and older adults living with msTBI. The detailed methods of this study have been published (Haynes et al., 2023). The qualitative work to develop the DCE has been used to inform the development of this guideline. The DCE survey results will aid with implementation of the guideline and advocacy for appropriate physical activity opportunities for people with msTBI.

Stakeholder focus groups

Focus group were conducted with six stakeholder groups (people with msTBI, family members, support workers, community-based physical activity providers, health professionals, and service funders; n=36) to identify barriers likely to influence the ability of health professionals to prescribe physical activity for people with msTBI, particularly in community settings. Barriers were identified across all levels of the socioecological model (Bronfenbrenner, 1994) (individual (e.g., "killer fatigue"), interpersonal (e.g., a siloed community of support), community (e.g., finding suitable community physical activity options), and policy (e.g., funding complexities), indicating the need to consider these when planning implementation support.

Evidence review and development of clinical recommendations

The Guideline Steering Group used the GRADE Evidence to Decision (EtD) framework to draft recommendations for each clinical question (Schünemann et al., 2013). The EtD framework uses explicit criteria to generate guideline recommendations, including whether the problem is a priority, the balance between the observed evidence of desirable and undesirable outcomes, overall certainty of evidence, relative values of patients for desirable and undesirable outcomes, resource use (including cost considerations) where applicable, impact of recommendation on health inequities, and the acceptability and feasibility of the recommendations.

Guideline Development Group meetings

The Guideline Development Group meetings were conducted online (via Zoom) spread across five days over a three-week period (13.5 hours in total). The Guideline Development Group used the GRADE EtD framework to make evidence recommendations for each clinical question. This included considering the size and precision of treatment effects along with the quality of the evidence, and by judging the balance between benefits and harms, values and preferences, resource use and other relevant considerations including equity, accessibility, and feasibility. The direction of the recommendation was expressed using the language described by GRADE as a recommendation FOR an intervention, AGAINST an intervention or NO recommendation. The strength of a recommendation for or against an intervention was expressed as *strong* or *conditional*. This recommendation, including the final wording, required greater than 50% agreement by the Guideline Development Group within three rounds of voting. Definitions from the GRADE Handbook were used throughout the guideline development process (Schünemann et al., 2013).

Good practice points and precautionary points were then discussed by the Guideline Development Group and the final wording of these points completed by the chair or co-chair after the meeting.

Stakeholder/public consultation

The draft guideline was released for public consultation between 4 September 2023 and 6 October 2023 in accordance with Section 14A of the Commonwealth National Health and Medical Research Council Act 1992 and accompanying regulations. The guideline was hosted by partner organisation Connectivity (www.connectivity.org.au), along with an online public consultation submission template to capture public feedback and comments about the guideline. Links to the guideline and submission template were circulated via electronic mail (e-mail) to key stakeholders identified by the Guideline Leadership Group and were invited to make submissions. The link to the guideline and submission template was also included in the fortnightly '*NHMRC Tracker*' newsletter (11/09/2023) and was circulated via the personal social media accounts of the guideline chair and co-chair (A/Prof

Hassett and Dr Johnson, respectively), and institutional-linked social media accounts (i.e., Connectivity; Institute of Musculoskeletal Health, University of Sydney). Seven responses were received during the public consultation, six of which were from physiotherapists, and one was from an exercise physiologist. De-identified submissions and responses are provided in the Public Consultation Summary Report.

We also sought endorsement for the guideline from relevant health professional bodies. Consistent with NHMRC requirements (NHMRC, 2018), and in parallel with the public consultation period, the guideline was distributed to independent reviewers for clinical and methodological review.

References

Access Economics. *The economic cost of spinal cord injury and traumatic brain injury in Australia*. 2009, The Victorian Neurotrauma Initiative.

Australian Rehabilitation Outcomes Centre. *AROC Impairments Specific Report on Brain Injury (Inpatient- Pathway 3) July 2019-June 2020*. 2020

Bradshaw B.G. Chairman Traumatic Brain Injury Task Force. *Report to the Surgeon General Traumatic Brain Injury Task Force May 15, 2007.* 2008.

Bronfenbrenner U. Ecological models of human development. *International Encyclopedia of Education, Vol 3, 2nd Ed. Oxford: Elsevier* 1994;1643-7

Bull FC, Al-Ansari SS, Biddle S, et al. World Health Organization 2020 guidelines on physical activity and sedentary behaviour. *Br J Sports Med.* 2020; 54(24): 1451-1462.

Carty C, van der Ploeg HP, Biddle SJH, et al. The first global physical activity and sedentary behavior guidelines for people living with disability. *J Phys Act Health*. 2021: 18(1): 86-93.

Fitts M, Bird K, Gilroy J, et al. A Qualitative Study on the Transition Support Needs of Indigenous Australians Following Traumatic Brain Injury. *Brain Impairment.* 2019; 20, 137–159.

Gardner RC, Dams-O'Connor K, Morrissey MR, Manley GT. Geriatric Traumatic brain injury: epidemiology, outcomes, knowledge gaps, and future directions. *J Neurotrauma*. 2018; 35(7): 889–906.

Guthold, R et al. Worldwide trends in insufficient physical activity from 2001 to 2016: a pooled analysis of 358 population-based surveys with 1.9 million participants. *Lancet Glob Health;* 2018. 6: e1077-e1086.

Hafner M, Yerushalmi E, Stepanek M, et al. Estimating the global economic benefits of physically active populations over 30 years (2020-2050)*. Br J Sports Med.* 2020; 54(24): 1482-1487.

Hassett L, Moseley A, Harmer A. The aetiology of reduced cardiorespiratory fitness among adults with severe traumatic brain injury and the relationship with physical activity: a narrative review. *Brain Imp.* 2015; 17: 43-54.

Hassett L, Wong S, Sheaves E, et al. Time use and physical activity in a specialised brain injury rehabilitation unit: an observational study. *Brain Inj.* 2018; 32(7): 850-857.

Haynes A, Howard K, Johnson L, et al. Physical activity preferences of people living with brain injury: formative qualitative research to develop a discrete choice experiment. *Patient.* 2023; 16(4): 385–398.

Hoekstra F, McBride CB, Borisoff J, et al. Translating the international scientific spinal cord injury exercise guidelines into community and clinical practice guidelines: a Canadian evidence-informed resource. *Spinal Cord.* 2020. 58(6): 647-657.

Jackman M, Sakzewski L, Morgan C, et al. Interventions to improve physical function for children and young people with cerebral palsy: international clinical practice guideline. *Dev Med Child Neurol*. 2022; 64(5): 536-549.

Johnson L, Williams G, Sherrington C, et al. The effect of physical activity on health outcomes in people with moderate-to-severe traumatic brain injury: a rapid systematic review with meta-analysis. *BMC Public Health.* 2023;23 (1): 63.

Menon DK, Schwab K, Wright DW, Maas AI. Position statement: definition of traumatic brain injury. *Arch Phys Med Rehabil*. 2010; 91: 1637–1640.

Michie S, van Stralen MM, West R. The behaviour change wheel: A new method for characterising and designing behaviour change interventions. *Implement Sci.* 2011; 6(42): 1-11.

Pawlowski J, Dixon-Ibarra A, Driver S. Review of the status of physical activity research for individuals with traumatic brain injury*. Arch Phys Med Rehabil.* 2013; 94(6): 1184-1189.

Ponsford, JL, Downing MG, Olver J, et al. Longitudinal follow-up of patients with traumatic brain injury: outcome at two, five, and ten years post-injury*. J Neurotrauma.* 2014; 31(1): 64-77.

Rimmer, JH et al. Physical activity for people with disabilities*. Lancet.* 2012. 380: 193-195.

Rohatgi A. WebPlotDigitizer (Version 4.5) [Computer software]. August 2021. [Accessed 12 Mar 2023]. Available online: http://arohatgi.info/WebPlotDigitizer

Schünemann HJ, Brozek J, Guyatt G, Oxman A. The GRADE handbook (2013). [Accessed 10 Mar 2022]. Available online: https://gdt.gradepro.org/app/handbook/handbook.html

Schunemann HJ, Wiercioch W, Brozek J, et al. GRADE Evidence to Decision (EtD) frameworks for adoption, adaptation, and de novo development of trustworthy recommendations: GRADE-ADOLOPMENT. *J Clin Epidemiol*. 2017; 81: 101-110.

Sterne JAC, Savović J, Page MJ, et al. RoB 2: a revised tool for assessing risk of bias in randomised trials. *BMJ.* 2019; 366: l4898.

Sterne JAC, Hernán MA, Reeves BC, et al. ROBINS-I: a tool for assessing risk of bias in non-randomized studies of interventions. *BMJ.* 2016; 355; i4919.

Stroke Foundation. Clinical Guidelines for Stroke Management. Available at https://informme.org.au/guidelines/livingclinical-guidelines-for-stroke-management. [Accessed 16 Nov 2022]. Available online: https://app.magicapp.org/#/guideline/Kj2R8j

SECTION TWO:
Recommendations Summary

BRIDGES
Brain Injury: Developing Guidelines for Physical Activities

Recommendations summary

Interpreting the recommendations

Evidence-based recommendations (EBR) have associated GRADE (Table 1) and GRADE Quality ratings (Table 2). Suggested Good practice points (GPP) and Precautionary Points (PP) were informed by the expertise of the Guideline Development Group.

Table 1. Summary of the strength of the evidence recommendations. The hierarchy is based on the GRADE approach (Schünemann et al., 2013).

Evidence Recommendation	Symbol	Explanation
Strong evidence recommendation **FOR**	❖❖❖❖	The guideline panel is confident that they can recommend the intervention based on the evidence. A recommendation is made that the intervention should be implemented
Conditional* evidence recommendation **FOR**	❖❖❖	The guideline panel is confident that they can probably recommend the intervention based on the evidence. A recommendation is made that the intervention may be implemented
Conditional* evidence recommendation **AGAINST**	❖❖	The guideline panel is confident that they probably cannot recommend the intervention based on the evidence. A recommendation is made that the intervention should not be implemented
Strong evidence recommendation **AGAINST**	❖	The guideline panel is confident that they cannot recommend the intervention based on the evidence. A recommendation is made that the intervention should definitely not be implemented
No recommendation	-	The guideline panel is unable to recommend for or against the intervention based on the evidence. A consensus-based opinion statement will be made.

* This table has been adapted from Schünemann et al. (2013) by replacing the term '*weak*' with '*conditional*' to avoid the potential unintended negative connotations and confusion associated with the term '*weak*'.

Table 2. GRADE levels of evidence quality

Certainty	Symbol	Definition
High	⊕⊕⊕⊕	We are very confident that the true effect lies close to that of the estimate of the effect
Moderate	⊕⊕⊕◯	We are moderately confident in the effect estimate. The true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different
Low	⊕⊕◯◯	Our confidence in the effect estimate is limited. The true effect may be substantially different from the estimate of the effect
Very low	⊕◯◯◯	We have very little confidence in the effect estimate. The true effect is likely to be substantially different from the estimate of effect

Table 3. Recommendations Summary

	Type	Recommendation	GRADE/Quality
1		**Aerobic exercise training in adults and older adults**	
1.1	**EBR**	For adults and older adults after moderate to severe traumatic brain injury, we suggest regular structured aerobic exercise that is individually-tailored and across the continuum of care.	❖❖❖ ⊕⊕○○
We suggest the following Good Practice Points (GPP) and Precautionary Points (PP):			
1.2	**GPP**	Aerobic exercise aims to achieve participation-level goals established collaboratively.	
1.3	**GPP**	Assessment of fitness is conducted prior to commencing an aerobic exercise program using a standardised or modified protocol and pre-exercise screening.	
1.4	**GPP**	Aerobic exercise is prescribed using the Frequency, Intensity, Time, and Type (FITT) principles according to American College of Sports Medicine guidelines for stroke and brain injury.	
1.5	**GPP**	That specificity of training is considered when prescribing mode of aerobic exercise.	
1.6	**GPP**	Exercise dosage is monitored (preferably using a heart rate monitor) when possible.	
1.7	**GPP**	Timing of aerobic exercise training considers the impact of fatigue on behaviour and participation in other activities including work and/or study.	
1.8	**GPP**	Aerobic exercise is transitioned from health settings to community-based physical activity settings where appropriate.	
1.9	**PP**	For adults on anti-epileptic medication, moderate to high intensity aerobic exercise may increase the risk of seizure if they are medically unwell or are not routinely taking their medication.	
1.10	**PP**	When calculating training heart rate for adults on beta-blocker medication, predicted maximum heart rate should be adjusted to account for the medications' heart rate lowering effect (HRmax pred-adj = 85%(220-age).	
1.11	**PP**	In the acute stage of recovery, consider mode of exercise and seek medical advice prior to commencing aerobic exercise for adults with additional complications such as orthopaedic injuries or craniotomy.	

2		Aerobic exercise training in children and adolescents	
2.1	**EBR**	For children and adolescents after moderate to severe traumatic brain injury, we suggest regular energetic play and/or exercise that is individually-tailored and across the continuum of care.	❖❖❖ ⨁◯◯◯
We suggest the following Good Practice Points (GPP) and Precautionary Points (PP):			
2.2	**GPP**	Energetic play and/or exercise aims to achieve participation-level goals established collaboratively where the child's voice is at the centre.	
2.3	**GPP**	Energetic play and/or exercise is incorporated into weekly routines and key supports (e.g., siblings, friends, teachers, support workers, and parents) are trained in facilitating this activity.	
2.4	**GPP**	Assessment of fitness is conducted for school aged children prior to commencing an energetic play and/or exercise program using a standardised or modified protocol and pre-exercise screening.	
2.5	**GPP**	Energetic play and/or exercise is prescribed using the Frequency, Intensity, Time, and Type (FITT) principles according to American College of Sports Medicine guidelines for stroke and brain injury.	
2.6	**GPP**	Timing of energetic play and/or exercise considers the impact of fatigue on behaviour and participation in other activities including school.	
2.7	**GPP**	Exercise dosage is monitored (preferably using a heart rate monitor) for older children and adolescents when possible.	
2.8	**GPP**	Energetic play and/or exercise is transitioned from health settings to community-based physical activity settings where appropriate.	
2.9	**PP**	For children and adolescents on anti-epileptic medication, moderate to high intensity energetic play and/or exercise may increase the risk of seizure if they are medically unwell or not routinely taking their medication.	
2.10	**PP**	When determining intensity of exercise, consider any medication that may influence heart rate or blood pressure.	
2.11	**PP**	In the acute stage of recovery, consider mode of energetic play and/or exercise and seek medical advice prior to commencing energetic play and/or exercise for children and adolescents with additional complications such as orthopaedic injuries or craniotomy.	

3		**Muscle strength training for adults and older adults with moderate to severe traumatic brain injury**	
3.1	**EBR**	For adults and older adults after moderate to severe traumatic brain injury, we recommend individually-tailored muscle strengthening exercise, including ballistic training, across the continuum of care.	❖❖❖❖ ⊕⊕⊕○
We suggest the following Good Practice Points (GPP):			
3.2	**GPP**	Assessment of muscle strength is conducted prior to commencing strength training.	
3.3	**GPP**	For very weak muscles, strength training is set-up to make it as easy as possible to elicit muscle activity (e.g., reducing friction, reducing or removing gravity, working in mid-range, electrical stimulation and/or electromyographic biofeedback, and supported weight bearing) and high repetitions are encouraged.	
3.4	**GPP**	Health professionals consider the muscle groups involved, and their function, when developing muscle strength training programs to improve mobility and other functional tasks.	
3.5	**GPP**	Health professionals consider specificity of training (i.e., power vs strength vs endurance) when prescribing mode of muscle strength training.	
3.6	**GPP**	Muscle strength training dosage is prescribed according to American College of Sports Medicine guidelines.	
3.7	**GPP**	Muscle strength training is transitioned from health settings to community-based physical activity settings where appropriate.	
4		**Muscle strength training for children and adolescents with moderate to severe traumatic brain injury**	
4.1	**EBR**	For children and adolescents after moderate to severe traumatic brain injury, we suggest regular muscle strengthening play and/or exercise that is individually-tailored and across the continuum of care.	❖❖❖
We suggest the following Good Practice Points (GPP):			
4.2	**GPP**	Muscle strength training aims to achieve goals established collaboratively where the child's voice is at the centre.	
4.3	**GPP**	Assessment of muscle strength is conducted for school aged children prior to commencing strength training.	
4.4	**GPP**	For very weak muscles, strength training is set-up to make it as easy as possible to elicit muscle activity (e.g., reducing friction, reducing or removing gravity, working in mid-range, electrical stimulation and/or	

		electromyographic biofeedback, and supported weight bearing) and high repetitions are encouraged.	
4.5	**GPP**	Muscle strength training dosage is prescribed according to American College of Sports Medicine guidelines.	
4.6	**GPP**	Health professionals consider the muscle groups involved, and their function, when developing muscle strength training programs to improve mobility and other functional tasks.	
4.7	**GPP**	Health professionals consider specificity of training (i.e., power vs strength vs endurance) when prescribing mode of muscle strength training.	
4.8	**GPP**	Muscle strength training is transitioned from health settings to community-based physical activity settings where appropriate.	
5		**Mobility training for adults and older adults with moderate to severe traumatic brain injury**	
5.1	**EBR**	For adults and older adults after moderate to severe traumatic brain injury, we recommend task-specific mobility training across the continuum of care.	❖❖❖❖ ⊕⊕⊕○
We suggest the following Good Practice Points (GPP):			
5.2	**GPP**	Mobility training aims to achieve participation-level and activity-level goals established collaboratively.	
5.3	**GPP**	The setting and supervision requirements for adults with significant cognitive and/or behavioural impairments is considered to maximise participation in mobility training and the transfer of training to real life tasks.	
5.4	**GPP**	Virtual reality interventions and body weight support treadmill training (with or without robotics) may be used as options to train mobility.	
5.5	**GPP**	Mobility training is incorporated into weekly routines with key supports (e.g., family, friends, support workers) trained in facilitating this activity where appropriate.	
5.6	**GPP**	Mobility training incorporates motor learning principles of task-specific, repetitive intensive practice.	
6		**Mobility training for children and adolescents with moderate to severe traumatic brain injury**	
6.1	**EBR**	For children and adolescents after moderate to severe traumatic brain injury, we suggest task-specific mobility training across the continuum of care.	❖❖❖ ⊕○○○
We suggest the following Good Practice Points (GPP):			
6.2	**GPP**	Mobility training aims to achieve participation-level and activity-level goals established collaboratively where the child's voice is at the centre.	

6.3	**GPP**	The setting and supervision requirements for children with significant cognitive and/or behavioural impairments is considered to maximise participation in mobility training and the transfer of training to real life tasks.	
6.4	**GPP**	Mobility training is incorporated into weekly routines with key supports (e.g., siblings, friends, teachers, support workers, and parents) trained in facilitating this activity.	
6.5	**GPP**	Mobility training is performed when the child is and isn't fatigued to enable practice of mobility at different capacities.	
6.6	**GPP**	Mobility training is delivered within an interdisciplinary model to enable management of any psychosocial impairments and/or adjustments to injury that may impact on training.	
6.7	**GPP**	Mobility training incorporates motor learning principles of task-specific, repetitive, intensive practice.	
7		**Sport and physical recreation for adults and older adults with moderate to severe traumatic brain injury**	
7.1	**EBR**	For adults and older adults after moderate to severe traumatic brain injury, we suggest participation in sport and physical recreation across the continuum of care considering their personal preference and capability.	❖❖❖ ⨁◯◯◯
We suggest the following Good Practice Points (GPP) and Precautionary Points (PP):			
7.2	**GPP**	Health professionals consider what sport and/or physical recreation the adult enjoyed and participated in prior to their brain injury when developing their rehabilitation program. Pre-injury activities may be a facilitator or may cause distress if physical, cognitive, or behavioural impairments restrict participation.	
7.3	**GPP**	Health professionals consider all aspects of the inclusion spectrum when suggesting options for sport and/or physical recreation.	
7.4	**GPP**	Health professionals establish relationships and work with external service providers to facilitate access and opportunities for their clients to participate in sport and/or physical recreation.	
7.5	**GPP**	Health professionals support the adult to facilitate participation in sport and/or physical recreation, including supporting preparation of funding requests, and identifying modifications, support, and adaptive or specialised equipment necessary to ensure the safety and appropriateness of the activity.	

7.6	**PP**	A knock to the head from sport participation may cause a second brain injury. Risk vs. benefit should be considered and discussed by the interdisciplinary team and advice provided to the adult and their family (if appropriate).	
8		**Sport and physical recreation for children and adolescents with moderate to severe traumatic brain injury**	
8.1	**EBR**	For children and adolescents after moderate to severe traumatic brain injury, we suggest participation in sport and physical recreation across the continuum of care considering their personal preference and capability.	❖❖❖
We suggest the following Good Practice Points (GPP) and Precautionary Points (PP):			
8.2	**GPP**	Health professionals consider what sport and/or physical recreation the child or adolescent enjoyed and participated in prior to their brain injury when developing their rehabilitation program. Pre-injury activities may be a facilitator or may cause distress if physical, cognitive, or behavioural impairments restrict participation.	
8.3	**GPP**	Health professionals consider all aspects of the inclusion spectrum when suggesting options for sport and/or physical recreation.	
8.4	**GPP**	Health professionals establish relationships and work with external service providers to facilitate access and opportunities for their clients to participate in sport and/or physical recreation.	
8.5	**GPP**	Health professionals support the child or adolescent and their family to facilitate participation in sport and/or physical recreation, including supporting preparation of funding requests, and identifying modifications, support, and adaptive or specialised equipment necessary to ensure the safety and appropriateness of the activity.	
8.6	**PP**	A knock to the head from sport participation may cause a second brain injury. Risk vs. benefit should be considered and discussed by the interdisciplinary team and advice provided to the child or adolescent and their family.	
9		**Overall physical activity promotion for adults or older adults with moderate to severe traumatic brain injury**	
9.1	**EBR**	For adults and older adults after moderate to severe traumatic brain injury, we suggest the promotion of physical activity across the continuum of care.	❖❖❖ ⨁⨁◯◯
We suggest the following Good Practice Points (GPP):			
9.2	**GPP**	Physical activity is promoted with consideration of current public health physical activity guideline	

		recommendations for adults and older adults living with disability.	
9.3	**GPP**	Health professionals initiate conversations with clients about a return to physical activity as early as possible, mindful of the potential for the early rehabilitation phase of recovery to be an opportune time to establish short and long-term goals, positive behaviours, and support systems.	
9.4	**GPP**	Pre-injury physical activity is assessed, and health professionals consider building on what the adult has done before (i.e., supporting a return to previous activity).	
9.5	**GPP**	Key aspects of the promotion of overall physical activity include exploring the clients understanding of the benefits of physical activity, identification of goals, utilising evidence-based behaviour change techniques to support self-management, and implementing activities that broadly encourage physical activity.	
9.6	**GPP**	Health professionals seek to identify barriers to engaging in physical activity and implement strategies to support the uptake of physical activity.	
9.7	**GPP**	Physical activity is incorporated into weekly routines and key supports (e.g., family, friends, and support workers) are trained in facilitating opportunities for activity where appropriate.	
10		**Overall physical activity promotion for children and adolescents with moderate to severe traumatic brain injury**	
10.1	**EBR**	For children and adolescents after moderate to severe traumatic brain injury, we suggest the promotion of physical activity across the continuum of care.	❖❖❖
We suggest the following Good Practice Points (GPP):			
10.2	**GPP**	Health professionals initiate conversations with the child or adolescent and their family about a return to physical activity as early as possible, mindful of the potential for the early rehabilitation phase of recovery to be an opportune time to establish short and long-term goals, positive behaviours, and support systems.	
10.3	**GPP**	Physical activity is promoted with consideration of current public health physical activity guideline recommendations for children and adolescents living with disability.	
10.4	**GPP**	Pre-injury physical activity is assessed, and health professionals consider building on what a child or	

		adolescent has done before (i.e., supporting a return to previous activity).	
10.5	**GPP**	Health professionals consider promoting opportunities for their clients to engage in physical activity within a fun and social setting e.g., play, school activities, sport.	
10.6	**GPP**	Physical activity is incorporated into weekly routines and key supports (e.g., siblings, friends, teachers, support workers, and parents) are trained in facilitating opportunities for activity.	
10.7	**GPP**	Health professionals seek to discuss barriers and facilitators to engaging in physical activity with the child or adolescent and key supports and implement strategies to support the uptake of physical activity.	

SECTION THREE:
Clinical Questions

BRIDGES
Brain Injury: Developing Guidelines for Physical Activities

Clinical question 1: Aerobic exercise training for adults and older adults with moderate to severe traumatic brain injury

Clinical question: Should structured **aerobic exercise** training compared to control be used for **adults and older adults** with moderate to severe traumatic brain injury?

Setting: Healthcare settings across the continuum of care:

- Inpatient, transition and outpatient rehabilitation settings
- Community settings (e.g., fitness centres, sporting fields, community centres)
- Home

Perspective: Health systems

Critical outcomes of interest:

- Cardiorespiratory fitness
- Co-morbidities and mortality

Important outcomes of interest:

- Walking capacity
- Combined mobility
- Physical activity
- Body composition
- Mood

Key definitions:

- Adults: ≥ 18 years
- Older adults: ≥ 65 years
- Aerobic exercise: Activity in which the body's large muscles move in a rhythmic manner for a sustained period. Aerobic exercise – also called endurance exercise – improves cardiorespiratory fitness. Examples include walking, running, swimming, and cycling.

Clinical need for question

Reduced aerobic fitness is a common and serious secondary physical impairment reported to affect people after msTBI both in the short- and long-term.

The gold standard measurement of aerobic fitness is peak oxygen uptake [VO_2peak], measured using expired gas analysis.

A review synthesised data from 11 studies with 234 adults with TBI (>50% severe; predominantly male and >1-year post-injury) who underwent a peak aerobic exercise test (Hassett et al., 2015). The mean (SD) VO_2peak from the 11 studies was 27 (7) $mL.kg^{-1}.min^{-1}$ (range 17 to 37 $mL.kg^{-1}.min^{-1}$). Comparing these values to age-matched data for able-bodied males (American College of Sports Medicine, 2000), all are below the average fitness level (41 $mL.kg^{-1}.min^{-1}$); and the pooled mean VO_2peak of the 11 studies is below the lowest fitness level rating (i.e., below the 10^{th} percentile fitness level; 33 $mL.kg^{-1}.min^{-1}$). Collectively these studies provide evidence that adults with TBI have markedly lower aerobic fitness levels than their age-matched peers.

Reduced aerobic fitness can directly restrict reintegration back into family, work, and community roles a person with msTBI previously held This is because the individual may no longer have the aerobic capacity to meet the metabolic demands of activities performed in these roles (Hassett et al., 2015).

Reduced aerobic fitness has also been shown in the general population to increase the risk of mortality and morbidity (Kodama et al., 2009; Lee et al., 2010), and is likely to exacerbate the risk for people living with msTBI who are already at an increased risk of morbidity and mortality (Izzy et al., 2022).

Summary of evidence

Direct evidence:

Twenty-four studies (12 RCTs and 12 NRSIs) were evaluated and included to provide data for the critical and important outcomes as well as adverse events.

Five RCTs compared fitness training to no intervention or non-active control on cardiorespiratory fitness outcome and the data was synthesised. Improvements in cardiorespiratory fitness are likely to be of a moderate to large effect (SMD: 0.53; 95% CI: 0.11 to 0.95; low certainty evidence). This converts to a mean VO_2peak value of 3.9 (95% CI: 0.8 to 7.1) $mL.kg^{-1}.min^{-1}$. The MD of 3.9 $mL.kg^{-1}.min^{-1}$ is above 1 metabolic equivalent (MET) (3.5 $mL.kg^{-1}.min^{-1}$) which has been shown in the general population to reduce risk of mortality by 15% (Kodama et al., 2009). No between group difference was seen in cardiorespiratory fitness in an RCT comparing a supervised fitness-centre based program to an unsupervised home-based program (Hassett et al., 2009).

Five RCTs compared fitness training to no intervention or non-active control on depression outcome and the data was synthesised. Aerobic fitness training can provide a moderate reduction in depression (SMD: -0.4; 95% CI: -0.8 to 0.05; very low certainty), particularly more than six months post-injury and after inpatient rehabilitation (SMD: -0.5; 95% CI: -0.9 to -0.1; low certainty evidence). This converts to a reduction on Hospital Anxiety Depression Scale (depression subscale) of 2.2 points (ranging between 4.1 to 0.4 points reduction).

There were mixed and small effects on combined mobility and walking endurance, and trivial or no effect on body composition. Participation in an aerobic training program increased overall physical activity (minutes per week and number of days per week active) in one study when measured at the end of the intervention. The certainty of the evidence of effect for all outcomes was rated as low or very low.

No studies have evaluated the effect of aerobic training on morbidity and mortality in adults with msTBI.

Indirect evidence:

The Australian and New Zealand Living Clinical Guidelines for Stroke Management refer to a Cochrane review of physical fitness training for people after stroke (Saunders et al., 2020). The Cochrane review showed there was moderate certainty evidence that aerobic fitness training compared to control improved cardiorespiratory fitness (VO_2peak; MD: 3.4 $ml.kg^{-1}.min^{-1}$; 95% CI: 2.98 to 3.83 $ml.kg^{-1}.min^{-1}$) and combined mobility (Berg Balance Scale; MD: 1.92 points; 95% CI: 0.16 to 3.68 points). There was high certainty evidence that aerobic fitness training improved walking capacity (six-minute walk text (6MWT); MD: 33.4 m; 95% CI: 19.04 to 47.78 m) and low certainty evidence there was a low risk of death (Risk difference 0.00 (-0.01 to 0.01)). Aerobic fitness training also improved mood, but the evidence was uncertain (Beck Depression Index; MD: -1.22; 95% CI: -5.62 to 3.19).

The WHO physical activity and sedentary behaviour guideline for disability was also reviewed (Carty et al., 2021). In particular, the health condition evidence summaries for stroke were reviewed. Relevant to this guideline, they reported: moderate-certainty evidence for improved gait speed and ability, walking distance and endurance, cardiorespiratory fitness, balance, mobility, and activities of daily living.

Please see **Clinical question 1** in the Technical Report for detailed study characteristics and meta-analyses that assisted with providing the evidence base for this clinical question.

Recommendations

	Type	Recommendation	GRADE/Quality
1		**Aerobic exercise training in adults and older adults**	
1.1	**EBR**	For adults and older adults after moderate to severe traumatic brain injury, we suggest regular structured aerobic exercise that is individually-tailored and across the continuum of care.	❖❖❖ ⊕⊕○○
We suggest the following Good Practice Points (GPP) and Precautionary Points (PP):			
1.2	**GPP**	Aerobic exercise aims to achieve participation-level goals established collaboratively.	
1.3	**GPP**	Assessment of fitness is conducted prior to commencing an aerobic exercise program using a standardised or modified protocol and pre-exercise screening.	
1.4	**GPP**	Aerobic exercise is prescribed using the Frequency, Intensity, Time, and Type (FITT) principles according to American College of Sports Medicine guidelines for stroke and brain injury.	
1.5	**GPP**	That specificity of training is considered when prescribing mode of aerobic exercise.	
1.6	**GPP**	Exercise dosage is monitored (preferably using a heart rate monitor) when possible.	
1.7	**GPP**	Timing of aerobic exercise training considers the impact of fatigue on behaviour and participation in other activities including work and/or study.	
1.8	**GPP**	Aerobic exercise is transitioned from health settings to community-based physical activity settings where appropriate.	
1.9	**PP**	For adults on anti-epileptic medication, moderate to high intensity aerobic exercise may increase the risk of seizure if they are medically unwell or are not routinely taking their medication.	
1.10	**PP**	When calculating training heart rate for adults on beta-blocker medication, predicted maximum heart rate should be adjusted to account for the medications' heart rate lowering effect (HRmax pred-adj = 85%(220-age).	

	Type	Recommendation	GRADE/Quality
1.11	**PP**	In the acute stage of recovery, consider mode of exercise and seek medical advice prior to commencing aerobic exercise for adults with additional complications such as orthopaedic injuries or craniotomy.	

Justification

Reduced aerobic fitness is a common secondary physical impairment after msTBI which can increase risk of morbidity and mortality and reduce participation in everyday activities. Although there is low or very low certainty direct evidence of effectiveness, aerobic fitness training may have moderate to large effects on critical and important outcomes, including cardiorespiratory fitness and mood, for individuals with msTBI. Similar and stronger effects have been shown in individuals after stroke. On balance, there are likely desirable effects and the undesirable effects such as adverse events are likely small (e.g., muscle soreness and fatigue). We found good acceptability from multiple stakeholders and data from our audit of brain injury services in Australia indicated that it is a feasible intervention to deliver in inpatient and post-rehabilitation settings. Support will be needed to implement the recommendations, especially for health services and professionals working with individuals with our identified subgroups (e.g., those with higher support needs).

Impact of clinical recommendation

Based on the recommendations, health professionals should prescribe aerobic exercise to adults and older adults with msTBI. An aerobic exercise program should be tailored to the adult's preferences and capabilities. A maximal or sub-maximal exercise test will enable health professionals to determine the program parameters for safety and effectiveness. Options for exercise tests validated in msTBI are a patient-specific treadmill test and a modified 20m shuttle test (Hassett et al., 2007). Other standard protocol treadmill, cycle or arm ergometer tests can be administered as maximal or sub-maximal exercise tests. Pre-exercise screening is an important aspect prior to fitness testing to determine suitability for a maximal or submaximal exercise test and to guide safety considerations for aerobic fitness training (Vitale et al., 1996).

The following recommendations for aerobic fitness training parameters are based on the American College of Sports Medicine (ACSM) guidelines for stroke and brain injury (Palmer-Mclean et al., 2009) and ACSM guidelines for deconditioned individuals:

- Frequency: 3-5x week.
- Mode: Exercise using large muscle groups in a rhythmical nature. Consider exercise history (e.g., cyclist may do best on a cycle ergometer) and specificity of training (e.g., if aiming to also improve walking, consider treadmill or walking/running modes of exercise).
- Intensity: 40/50-85% heart rate reserve (HRR) or 40-70%VO_2peak, or 13/20 rating on Borg scale of perceived exertion. [Calculation of HRR (or Karvonen method): 40-85% ((220-age) – HR_{rest}) + HR_{rest}].
- Duration: 20-60mins per session.
- Progress from intermittent to continuous training.
- Energy expenditure: 300kcal per session or 1000kcal per week.

Meeting the ACSM guidelines for aerobic exercise training may be difficult, particularly in very deconditioned individuals and early after injury. Training parameters should be monitored (e.g., using a heart rate monitor) and intensity and/or duration progressed to ensure the training continues to support overload principles for aerobic fitness training to be effective at improving cardiorespiratory fitness.

The use of a circuit class where patients rotate around a circuit of exercise stations is one strategy to achieve sufficient dosage of fitness training. This was demonstrated in an observational study (with embedded RCT) including 53 individuals with severe TBI undertaking inpatient rehabilitation. The circuit class provided a low intensity (37% HRR), long-duration (52mins) exercise session that met the caloric fitness criteria of 300 kcal per session for 62% (95% CI: 49 to 74) of participants (Hassett et al., 2012).

Feasibility and resource requirements:

We audited 21 services delivering rehabilitation to adults and/or older adults with msTBI across Australia. All services reported delivering aerobic exercise and using a range of devices and equipment to support the prescription of aerobic exercise training, including treadmills (95% of services), cross trainers (29%), cycle ergometers (76%), arm ergometers (57%), MOTOmed^{TM} (52%), steppers (24%), recumbent steppers (10%), and HR Monitors (76%). However, there are inconsistencies in the current delivery. For example, less than half of the services (9/21) reported conducting a fitness test to set the aerobic training parameters for their patients. The implementation of the aerobic exercise training recommendations will likely improve consistent delivery of aerobic training programs that are safe and effective at improving critical and important outcomes.

Cost data and cost effectiveness data is not available from any studies in msTBI for aerobic exercise training. The Guideline Development Group estimated the resource requirements (costs) for this intervention to be moderate, with the costs likely dependent on the needs of the person with msTBI. For example, whether a person with msTBI can independently participate in aerobic exercise training, or if they need one-on-one supervision or specific equipment to participate is likely to impact the costs associated with participation.

Please see **Clinical question 1** in the Technical Report for the full EtD framework that assisted with providing the recommendations for this clinical question.

References

Bateman A, Culpan FJ, Pickering AD, et al. The effect of aerobic training on rehabilitation outcomes after recent severe brain injury: a randomized controlled evaluation. *Arch Phys Med Rehabil*. 2001; 82(2): 174–182.

Carty C, van der Ploeg HP, Biddle SJ, et al. The first global physical activity and sedentary behavior guidelines for people living with disability. *J Phys Act Health*. 2021; 18(1): 86–93.

Chin LM, Chan L, Woolstenhulme JG, et al. Improved cardiorespiratory fitness with aerobic exercise training in individuals with traumatic brain injury. *J Head Trauma Rehabil.* 2015; 30(6): 382- 390.

Chin LM, Keyser RE, Dsurney J, Chan L. Improved cognitive performance following aerobic exercise training in people with traumatic brain injury. *Arch Phys Med Rehabil.* 2015; 96(4): 754-759.

Damiano D, Zampieri C, Ge J, Acevedo A, Dsurney J. Effects of a rapid-resisted elliptical training program on motor, cognitive and neurobehavioral functioning in adults with chronic traumatic brain injury. *Exp Brain Res*. 2016; 234(8): 2245-2252.

Dault MC, Dugas C. Evaluation of a specific balance and coordination programme for individuals with a traumatic brain injury. *Brain Inj.* 2002; 16(3): 231-244.

Devine JM, Wong B, Gervino E, Pascual-Leone A, Alexander MP. Independent, community-based aerobic exercise training for people with moderate-to-severe traumatic brain injury. *Arch Phys Med Rehabil.* 2016; 97(8): 1392-7.

Ding K, Tarumi T, Tomoto T, et al. A proof-of-concept trial of a community-based aerobic exercise program for individuals with traumatic brain injury. *Brain Inj*. 2021; 35(2): 233–240.

Ding K, Juengst SB, Neaves S, et al. Usability of a two-way personalized mobile trainer system in a community-based exercise program for adults with chronic traumatic brain injury. *Brain Inj.* 2022; 36(3): 359-367.

Driver S, O'Connor J, Lox C, Rees K. Evaluation of an aquatics programme on fitness parameters of individuals with a brain injury. *Brain Inj.* 2004; 18(9): 847–859.

Driver S, Rees K, O'Connor J, Lox C. Aquatics, health promoting self-care behaviours and adults with brain injuries. *Brain Inj.* 2006; 20(2): 133–141.

Driver S, Ede A. Impact of physical activity on mood after TBI. *Brain Inj.* 2009; 23(3): 203–212.

Grealy MA, Johnson DA, Rushton SK. Improving cognitive function after brain injury: the use of exercise and virtual reality. *Arch Phys Med Rehabil.* 1999; 80(6): 661-667.

Hassett, L., Harmer, A., Moseley, A., Mackey, M. Validity of the modified 20-metre shuttle test: assessment of cardiorespiratory fitness in people who have sustained a traumatic brain injury. *Brain Injury*. 2007; 21(10), 1069-1077.

Hassett LM, Moseley AM, Tate RL, et al. Efficacy of a fitness centre-based exercise programme compared with a home-based exercise programme in traumatic brain injury: a randomized controlled trial. *J Rehabil Med.* 2009; 41(4): 247-255.

Hassett L, Moseley, A Whiteside, B Barry, S, Jones T. Circuit class therapy can provide a fitness training stimulus for adults with severe traumatic brain injury: a randomised trial within an observational study. *J Physiother*. 2012; *58*(2): 105–112.

Hassett L, Moseley A, Harmer A. The aetiology of reduced cardiorespiratory fitness among adults with severe traumatic brain injury and the relationship with physical activity: a narrative review. *Brain Impair*. 2015; 17: 43–54.

Hassett L, Moseley AM, Harmer AR. Fitness training for cardiorespiratory conditioning after traumatic brain injury. *Cochrane Database Syst Rev.* 2017; 12: CD006123.

Hassett L. Physiotherapy management of moderate to severe traumatic brain injury: invited topical review. *J Physiother.* 2023; 69(3): 141-147.

Hoffman JM, Bell KR, Powell JM, et al. A randomized controlled trial of exercise to improve mood after traumatic brain injury. *PM R.* 2010; 2(10): 911–919.

Izzy S, Chen PM, Tahir Z, et al. Association of traumatic brain injury with the risk of developing chronic cardiovascular, endocrine, neurological, and psychiatric disorders. *JAMA Netw Open*. 2022; 5:e229478.

Jackson D, Turner-Stokes L, Culpan J, et al. Can brain-injured patients participate in an aerobic exercise programme during early inpatient rehabilitation? *Clin Rehabil.* 2001; 15(5): 535-544.

Kodama S, Saito K, Tanaka S, et al. Cardiorespiratory fitness as a quantitative predictor of all-cause mortality and cardiovascular events in healthy men and women: A meta-analysis. *JAMA*.2009. 301(19): 2024–2035.

Laskin J. *Physiological Adaptations to Concurrent Muscular Strength and Aerobic Endurance Training in Functionally Active Adults with a Physical Disability [Doctoral Thesis]*. University of Alberta, Canada, 2001.

Lee DC, Artero EG, Sui X, Blair SN. Mortality trends in the general population: the importance of cardiorespiratory fitness. *J Psychopharmacol*. 2010; 24(4 Suppl): 27–35.

Lee YS, Ashman T, Shang A, Suzuki W. Brief report: Effects of exercise and self-affirmation intervention after traumatic brain injury. *NeuroRehabil.* 2014; 35: 57-65.

Lilliecreutz EK, Felixson B, Lundqvist A, Samuelsson K. Effects of guided aerobic exercise and mindfulness after acquired brain injury: a pilot study. *Euro J Physiother.* 2017; 19(4): 229-236.

McMillan T, Robertson IH, Brock D, Chorlton L. Brief mindfulness training for attentional problems after traumatic brain injury: a randomised control treatment trial. *Neuropsychol Rehabil.* 2002;12(2): 117–25.

Morris TP, Costa-Miserachs D, Rodriguez-Rajo P, et al. Feasibility of aerobic exercise in the subacute phase of recovery from traumatic brain injury: a case series. *J Neurol Phys Ther.* 2018; 42(4): 268-275.

Palmer-McLean K, & Harbst KB. Chapter 38: Stroke and brain injury. In J. Durstine, G. Moore, P. Painter & S. Roberts (Eds.), *ACSM's exercise management for persons with chronic diseases and disabilities.* 2009. (pp. 287–297) (3rd ed.). Champaign, IL: Human Kinetics.

Pollock ML, Lowenthal DT, Foster C, et al. Acute and chronic responses to exercise in patients treated with beta blockers. *J Cardiopulm Rehabil.* 1991; 11: 132-44.

Saunders DH, Sanderson M, Hayes S, et al. Physical fitness training for stroke patients. *Cochrane Database Syst Rev.* 2020; Issue 3. Art. No: CD003316.

Schwandt M, Harris JE, Thomas S, et al. Feasibility and effect of aerobic exercise for lowering depressive symptoms among individuals with traumatic brain injury: a pilot study. *J Head Trauma Rehabil.* 2012; 27(2):99-103.

Tomoto T, Le T, Tarumi T, et al. Carotid arterial compliance and aerobic exercise training in chronic traumatic brain injury: a pilot study. *J Head Trauma Rehabil.* 2022; 37(5): 263–271.

Vitale AE, Sullivan SJ, Jankowski LW, Fleury J, Lefrancois C, Lebouthillier E. Screening of health risk factors prior to exercise or a fitness evaluation of adults with traumatic brain injury: A consensus by rehabilitation professionals. Brain Injury 1996; 10:367–375.

Weinstein AA, Chin LMK, Collins J, et al. Effect of aerobic exercise training on mood in people with traumatic brain injury: a pilot study. *J Head Trauma Rehabil.* 2017; 32(3): E49-E56.

Wender CLA, Sandroff BM, Krch D, et al. The preliminary effects of moderate aerobic training on cognitive function in people with TBI and significant memory impairment: a proof-of concept randomized controlled trial. *Neurocase.* 2021; 27(5): 430-435.

Wise EK, Hoffman JM, Powell JM, Bombardier CH, Bell KR. Benefits of exercise maintenance after traumatic brain injury. *Arch Phys Med Rehabil.* 2012; 93(8): 1319–23.

Wolman RL, Cornall C, Fulcher K, Greenwood R. Aerobic training in brain-injured patients. *Clin Rehabil.* 1994; 8: 253-257.

Clinical question 2: Aerobic exercise training for children and adolescents with moderate to severe traumatic brain injury

Clinical question: Should structured **aerobic exercise** training compared to control be used for **children and adolescents** after moderate to severe traumatic brain injury?

Setting: Healthcare settings across the continuum of care:

- Inpatient, transition and outpatient rehabilitation settings
- Community settings (e.g., fitness centres, sporting fields, community centres)
- Home
- Schools

Perspective: Health systems

Critical outcomes of interest:

- Cardiorespiratory fitness
- Co-morbidities and mortality

Important outcomes of interest:

- Walking capacity
- Combined mobility
- Physical activity
- Body composition
- Mood

Key definitions:

- Children and adolescents: 5 to 17 years
- Aerobic exercise: Activity in which the body's large muscles move in a rhythmic manner for a sustained period. Aerobic exercise – also called endurance exercise – improves cardiorespiratory fitness. Examples include walking, running, swimming, and cycling.

Clinical need for question

Reduced aerobic fitness is a secondary physical impairment likely to be experienced by children and adolescents after msTBI, particularly if the injury causes a long period of inactivity due to prolonged hospital admission. Comparing aerobic fitness test results of 19 children with severe TBI aged 8 to 17 years to normative values suggest children with severe TBI experience very low levels of cardiorespiratory fitness (i.e., mean aerobic fitness level of children with TBI = 29th percentile of normative values; Rossi, 1996).

This reduced aerobic fitness can persist long-term and may limit children and adolescents in returning to meaningful physical activity. Successful reintegration into physical activity such as active play, sport, exercise, and recreation is important for children and adolescents after msTBI, because it allows them to play and compete with their peers and provide a sense of accomplishment and acceptance. Therefore, sufficient cardiorespiratory fitness to participate in meaningful physical activity is needed for children and adolescents after msTBI.

Summary of evidence

Direct evidence:

Only one small NRSI was included describing three cases of children aged 7, 8, and 9 years old with severe TBI undertaking aerobic fitness training (Burnfield, 2021). All three participants improved on measures of fitness, but experienced trivial effects on balance and walking capacity.

Indirect evidence:

Given the limited evidence in children and adolescents, we also relied on studies relating to adults with msTBI, the WHO physical activity and sedentary behaviour guidelines relating to children with disability, and reviews and guidelines for children with cerebral palsy.

Adults with TBI participating in aerobic exercise demonstrated moderate to large effects on aerobic fitness and mood, though low certainty evidence (see Clinical question 1).

The WHO guidelines (Carty et al., 2021) identified children with intellectual disability experienced a small improvement in physical function from participation in moderate-to-vigorous physical activity (MVPA) (low certainty evidence). The WHO guidelines also found MVPA can have beneficial effects on cognition, including attention, executive function, and social disorders in children with attention deficit hyperactivity disorder (ADHD) (moderate certainty evidence).

A Cochrane systematic review on exercise interventions in cerebral palsy (Ryan et al., 2017) found aerobic training had a moderate effect on gross motor function in the short- (SMD: 0.53; 95% CI: 0.02 to 1.04; low quality evidence) and intermediate-term (MD: 12.96%; 95% CI: 0.52 to 25.40%), but no improvement in walking speed in the short- (MD: 0.09 m/s; 95% CI: -0.11 to 0.28 m/s; very low-quality evidence) or intermediate-term (MD: -0.17 m/s; 95% CI: -0.59 m/s to 0.24 m/s; low-quality evidence).

Please see **Clinical question 2** in the Technical Report for detailed study characteristics and meta-analyses that assisted with providing the evidence base for this clinical question.

Recommendations

	Type	Recommendation	GRADE/Quality
2		**Aerobic exercise training in children and adolescents**	
2.1	**EBR**	For children and adolescents after moderate to severe traumatic brain injury, we suggest regular energetic play and/or exercise that is individually-tailored and across the continuum of care.	❖❖❖ ⊕○○○
We suggest the following Good Practice Points (GPP) and Precautionary Points (PP):			
2.2	**GPP**	Energetic play and/or exercise aims to achieve participation-level goals established collaboratively where the child's voice is at the centre.	
2.3	**GPP**	Energetic play and/or exercise is incorporated into weekly routines and key supports (e.g., siblings, friends, teachers, support workers, and parents) are trained in facilitating this activity.	

	Type	Recommendation	GRADE/Quality
2.4	**GPP**	Assessment of fitness is conducted for school aged children prior to commencing an energetic play and/or exercise program using a standardised or modified protocol and pre-exercise screening.	
2.5	**GPP**	Energetic play and/or exercise is prescribed using the Frequency, Intensity, Time, and Type (FITT) principles according to American College of Sports Medicine guidelines for stroke and brain injury.	
2.6	**GPP**	Timing of energetic play and/or exercise considers the impact of fatigue on behaviour and participation in other activities including school.	
2.7	**GPP**	Exercise dosage is monitored (preferably using a heart rate monitor) for older children and adolescents when possible.	
2.8	**GPP**	Energetic play and/or exercise is transitioned from health settings to community-based physical activity settings where appropriate.	
2.9	**PP**	For children and adolescents on anti-epileptic medication, moderate to high intensity energetic play and/or exercise may increase the risk of seizure if they are medically unwell or not routinely taking their medication.	
2.10	**PP**	When determining intensity of exercise, consider any medication that may influence heart rate or blood pressure.	
2.11	**PP**	In the acute stage of recovery, consider mode of energetic play and/or exercise and seek medical advice prior to commencing energetic play and/or exercise for children and adolescents with additional complications such as orthopaedic injuries or craniotomy.	

Justification

Cardiorespiratory deconditioning is a common problem after msTBI likely to restrict reintegration back into previous roles within family, friends, school and community. Aerobic exercise is likely to address this problem. Whilst there was only one study with very low-quality evidence relating to aerobic exercise training in children and adolescents with msTBI, the indirect evidence from adults with msTBI, and children with other health conditions indicate moderate to large effects on critical and important outcomes (low to very low certainty evidence). Likely desirable effects include improving cardiovascular fitness, reducing depression, and improving gross motor function (depending on mode of aerobic exercise). Undesirable effects such as adverse events are likely small (e.g., muscle soreness and fatigue). If children are at risk of seizures and/or taking anti-seizure medication, aerobic exercise should not be participated in if the child is unwell or has not been taking their medication (clinical expertise input). Medications should be reviewed to determine if the child or adolescent is on any medication that may lower blood pressure or heart rate (e.g., Clonidine prescribed for behaviour regulation). The lower heart rate needs to be taken into consideration if using heart rate to set and monitor training parameters [HRmax pred-adj = 85%(220-age]. On the balance of risk vs. benefit, the likely benefit of aerobic exercise training outweighs the risk.

The recommendations are also informed by the multidisciplinary and lived-experience expertise of the Guideline Development Group, including those with experience in paediatric brain injury. There was good acceptability from multiple stakeholders (i.e., people with msTBI and their family members, health professionals, community physical activity providers, funders of physical activity interventions, and support workers). It was feasible to deliver aerobic exercise training in both inpatient and post-rehabilitation settings, although implementation support will be needed, especially for health services and professionals working with children and adolescents with higher support needs, and/or from other identified subgroups (e.g.., Aboriginal and Torres Strait Islander people).

Impact of clinical recommendation

Based on the recommendations, health professionals should prescribe aerobic exercise or facilitate energetic play in children and adolescents with msTBI. The aerobic exercise program should be tailored to the child's preferences and capabilities and should consider what physical activity the child or adolescent has previously enjoyed. A maximal or sub-maximal exercise test (in school aged children and adolescents) will enable health professionals to determine the program parameters for safety and effectiveness. Options for sub-maximal exercise tests include the six-minute walk test (Maher et al., 2008) or six-minute push test for children in wheelchairs (Verschuren et al., 2006). The modified 20m walk-run shuttle test (Rossi 1996) or other treadmill, cycle, or arm ergometer tests can be administered as maximal or sub-maximal exercise tests. Pre-exercise screening is an important aspect prior to fitness testing to determine suitability for a maximal or submaximal exercise test and to guide safety considerations for aerobic exercise training (Vitale et al., 1996).

The following recommendations for aerobic exercise training parameters are based on the ACSM guidelines for stroke and brain injury (Palmer-Mclean et al., 2009), and ACSM guidelines for deconditioned individuals:

- Frequency: 3-5x week.
- Mode: Exercise using large muscle groups in a rhythmical nature. Consider exercise history (e.g., cyclist may do best on a cycle ergometer) and specificity of training (e.g., if aiming to also improve walking, consider treadmill or walking/running modes of exercise).
- Intensity: 40/50-85% HRR or 40-70%VO_2peak, or 13/20 rating on Borg scale of perceived exertion. [Calculation of heart rate reserve (or Karvonen method): 40-85% ((220-age) – HR_{rest}) + HR_{rest}].
- Duration: 20-60mins per session.
- Progress from intermittent to continuous training.
- Energy expenditure: 300kcal per session or 1000kcal per week.

Based on adult studies in msTBI, meeting the ACSM guidelines for aerobic exercise training may be difficult, particularly in very deconditioned individuals and early on in rehabilitation. Training parameters should be monitored (e.g., using a heart rate monitor) and intensity and/or duration progressed to ensure the training continues to support overload principles for aerobic exercise training to be effective at improving cardiorespiratory fitness. As recommended for adults with msTBI, a circuit class is one strategy to achieve sufficient dosage of aerobic exercise training when high intensity exercise is challenging (Hassett et al., 2012).

Resource requirements:

We audited six paediatric services delivering rehabilitation across Australia to children and adolescents with msTBI. Five of the six services reported delivering aerobic exercise, and provide a range of devices and equipment to support the prescription of aerobic exercise training, including treadmills (83% of services), cross trainers (33%), cycle ergometers (67%), arm ergometers (17%), MOTOmed^{TM} (33%), and HR monitors (17%). However, there are inconsistencies in the current delivery. For example, none of the services reported conducting a fitness test to set the training parameters for their patients, and only three of the five sites providing aerobic exercise monitored intensity, either by observation or rating of perceived exertion. The implementation of the aerobic exercise training recommendations will likely improve consistent delivery of aerobic training programs that are safe and effective at improving critical and important outcomes.

Cost data and cost effectiveness data are not available from any studies in TBI for aerobic exercise. The Guideline Development Group estimated the resource requirements (costs) for this intervention to be moderate, and likely dependent on the needs of the child or adolescent with msTBI. For example, whether the child or adolescent with msTBI can independently participate in aerobic exercise, or if they need one-on-one supervision or specific equipment to participate.

Please see **Clinical question 2** in the Technical Report for the full EtD framework that assisted with providing the recommendations for this clinical question.

References

Bateman A, Culpan FJ, Pickering AD, et al. The effect of aerobic training on rehabilitation outcomes after recent severe brain injury: a randomized controlled evaluation. *Arch Phys Med Rehabil*. 2001; 82(2): 174–182.

Burnfield JM, Guilherme M, Buster C, Buster TW. Feasibility of motor-assisted elliptical to improve walking, fitness and balance following pediatric acquired brain injury: a case series. *J Pediatric Rehab Med.* 2021; 14(3): 539-551.

Carty C, van der Ploeg HP, Biddle SJ, et al. The first global physical activity and sedentary behavior guidelines for people living with disability. *J Phys Act Health*. 2021; 18(1): 86–93.

Hassett LM, Harmer AR, Moseley AM, Mackey MG. Validity of the modified 20-metre shuttle test: assessment of cardiorespiratory fitness in people who have sustained a traumatic brain injury. *Brain Inj.* 2007; 21(10): 1069 – 1077.

Hassett LM, Moseley AM, Tate RL, et al. Efficacy of a fitness centre-based exercise programme compared with a home-based exercise programme in traumatic brain injury: a randomized controlled trial. *J Rehabil Med.* 2009; 41(4): 247-255.

Hassett, L, Moseley, A, Whiteside, B, Barry, S, & Jones, T. Circuit class therapy can provide a fitness training stimulus for adults with severe traumatic brain injury: a randomised trial within an observational study. *J Physiother*. 2012; 58(2): 105–112.

Maher CA, Williams MT, Olds TS. The six-minute walk test for children with cerebral palsy. *Int J Rehabil Res.* 2008; 31(2): 185-88.

McMillan T, Robertson IH, Brock D, Chorlton L. Brief mindfulness training for attentional problems after traumatic brain injury: a randomised control treatment trial. *Neuropsychol Rehabil.* 2002; 12(2): 117–25.

Palmer-McLean K, & Harbst KB. Chapter 38: Stroke and brain injury. In J. Durstine, G. Moore, P. Painter & S. Roberts (Eds.), *ACSM's exercise management for persons with chronic diseases and disabilities.* 2009. (pp. 287–297) (3rd ed.). Champaign, IL: Human Kinetics.

Pangilinan PH, Giacoletti-Argento A, Shellhaas R, et al. Neuropharmacology in pediatric brain injury: a review. *PM R.* 2010; 2(12): 1127-1140.

Rossi C, Sullivan SJ. Motor fitness in children and adolescents with traumatic brain injury. *Arch Phys Med Rehabil.* 1996; 77(10): 1062–1065.

Ryan JM, Cassidy EE, Noorduyn SG, O'Connell NE. Exercise interventions for cerebral palsy. *Cochrane Database Syst Rev.* 2017; 6: CD011660.

Verschuren O, Takken T, Ketelaar M, Gorter JW, Helders PJM. Reliability and validity data for 2 newly developed shuttle run tests in children with cerebral palsy. *PM R.* 2006; 86(8): 1107-1117.

Vitale AE, Sullivan SJ, Jankowski LW, Fleury J, Lefrancois C, Lebouthillier E. Screening of health risk factors prior to exercise or a fitness evaluation of adults with traumatic brain injury: A consensus by rehabilitation professionals. Brain Injury 1996; 10: 367–375.

Clinical question 3: Muscle strength training for adults and older adults with moderate to severe traumatic brain injury

Clinical question: Should structured **muscle strengthening** training compared to control be used for **adults and older adults** after moderate to severe traumatic brain injury?

Setting: Healthcare settings across the continuum of care:

- Inpatient, transition and outpatient rehabilitation settings
- Community settings (e.g., fitness centres, sporting fields, community centres)
- Home

Perspective: Health systems

Critical outcomes of interest:

- Muscle strength
- Combined mobility

Important outcomes of interest:

- Walking capacity
- Balance
- Co-morbidities and mortality
- Body composition
- Physical activity

Key definitions:

- Adults: ≥ 18 years
- Older adults: ≥ 65 years
- Muscle strengthening exercise: exercise that increases skeletal muscle strength, power, endurance, and mass (e.g., strength training, resistance training, or muscular strength and endurance exercises).
- Ballistic training: is a type of muscle strengthening exercise in which the muscles perform movement against resistance, but do so quickly, and targets improving muscle power.

Clinical need for question

Reduced lower limb muscle strength commonly affects adults with msTBI. Adults with msTBI experience muscle weakness due to the upper motor neuron lesion causing a disruption to the motor neurons normally activating muscles. Muscle weakness is also due to disuse of muscles from prolonged inactivity, which causes the muscles to atrophy. Muscle weakness can be more significant in those with severe TBIs, due to hormonal disturbances from the brain injury and acute care management that causes hypercatabolism (Hassett et al., 2015).

Mobility limitations (e.g., reduced walking speed and endurance) are common in people with msTBI (Olver et al., 1996) and can restrict their ability to perform activities of daily living and access the community (Williams et al., 2022). The main contributor to mobility limitations following TBI is low muscle power generation from weak muscles (Williams et al., 2013).

Data from the general population show that adults with higher levels of leg strength have a 14% lower risk of death (HR: 0.86; 95% CI: 0.80 to 0.93; P<.001) compared with adults with lower leg strength (Garcia-Hermoso et al., 2018). People living with msTBI have been shown to be at increased risk of morbidity and mortality (Izzy et al., 2022).

Types of strength training

Muscle strength reflects the maximum amount of force a muscle can produce, whereas muscle power reflects how quickly force can be generated or the rate of force production (Williams et al., 2016). *Progressive resistance strength training* is a type of muscle strengthening exercise where individuals exercise their muscles against some type of resistance that is progressively increased as their strength improves, and targets improving muscle strength. *Ballistic strength training* is another type of muscle strengthening exercise in which the muscles perform movement against resistance, but do so quickly, and targets improving muscle power.

Progressive resistance strength training has been shown to improve muscle strength in neurological populations, such as stroke and TBI, but these improvements do not carry over into improvements at the activity level (i.e., mobility) (Dorsch et al., 2018; Williams et al., 2014). To improve the capacity to perform activities that are limited by muscle weakness, such as walking and other high level mobility tasks, muscle groups involved in these tasks need to be able to contract with strength and speed (i.e., powerfully). Ballistic exercise training has shown to be safe and feasible in neurological populations (Cordner et al., 2021).

Summary of evidence

Direct evidence:

One high-quality (PEDro scale score 8/10) RCT was identified that compared ballistic resistance training (e.g., leg extension jumps and calf raises both performed on a 'leg sled') with non-ballistic exercise rehabilitation (e.g., balance exercises and lower limb stretching) in adults living with msTBI (Williams et al., 2022).

Replacing three sessions per week of non-ballistic exercise rehabilitation with ballistic resistance training resulted in similar or better mobility (as measured by the High-level Mobility Assessment Tool (HiMAT) (0 to 54); MD: 3; 95% CI: 0 to 6; moderate certainty evidence) that was largely maintained at six months post-training. Ballistic resistance training and non-ballistic exercise rehabilitation had similar effects on the secondary outcome measures (i.e., muscle strength and walking speed). The non-ballistic exercise rehabilitation group was better than the ballistic exercise group on measure of balance (moderate certainty evidence). An exploratory subgroup analysis found that ballistic resistance training led to even greater improvements in mobility among those with more severe disability (baseline HiMAT score <27; MD: 6; 95% CI: 1 to 10). The clinically worthwhile difference in HiMAT is ≥4, therefore the effect of ballistic resistance training compared to non-ballistic exercise rehabilitation on mobility is likely to range between no difference to a large clinically important difference, particularly in those with more severe physical disability.

Indirect evidence:

The Australian and New Zealand Living Clinical Guidelines for Stroke Management were reviewed. They recommend "For stroke survivors with reduced strength in their arms or legs, progressive resistance training should be provided to improve strength. (Dorsch et al., 2018). *Strong recommendation, moderate quality evidence.*"

From a Cochrane review of physical fitness training for people after stroke (Saunders et al., 2020), there was low certainty evidence that strength training compared to control improved muscle strength (composite measure; SMD: 0.58; 95% CI: 0.06 to 1.1 higher), walking capacity (6MWT; MD: 24.98 m; 95% CI: 11.98 to 37.98 m further), and combined mobility (Berg Balance Scale; MD: 3.27 points; 95% CI: 2.15 to 4.38 points); and did not increase risk of death (Risk difference 0.00 (-0.02 to 0.02)).

The WHO physical activity and sedentary behaviour guidelines for people living with disability was also reviewed (Carty et al., 2021). In particular, the health condition evidence summaries for stroke were reviewed. Relevant to this guideline, they reported moderate-certainty evidence for improved gait speed and ability, walking distance and endurance, cardiorespiratory fitness, balance, and activities of daily living.

Please see **Clinical question 3** in the Technical Report for detailed study characteristics and meta-analyses that assisted with providing the evidence base for this clinical question.

Recommendations

	Type	Recommendation	GRADE/Quality
3		**Muscle strength training for adults and older adults with moderate to severe traumatic brain injury**	
3.1	**EBR**	For adults and older adults after moderate to severe traumatic brain injury, we recommend individually-tailored muscle strengthening exercise, including ballistic training, across the continuum of care.	❖❖❖❖ ⊕⊕⊕○
We suggest the following Good Practice Points (GPP):			
3.2	**GPP**	Assessment of muscle strength is conducted prior to commencing strength training.	
3.3	**GPP**	For very weak muscles, strength training is set-up to make it as easy as possible to elicit muscle activity (e.g., reducing friction, reducing or removing gravity, working in mid-range, electrical stimulation and/or electromyographic biofeedback, and supported weight bearing) and high repetitions are encouraged.	
3.4	**GPP**	Health professionals consider the muscle groups involved, and their function, when developing muscle strength training programs to improve mobility and other functional tasks.	
3.5	**GPP**	Health professionals consider specificity of training (i.e., power vs strength vs endurance) when prescribing mode of muscle strength training.	
3.6	**GPP**	Muscle strength training dosage is prescribed according to American College of Sports Medicine guidelines.	
3.7	**GPP**	Muscle strength training is transitioned from health settings to community-based physical activity settings where appropriate.	

Justification

Weakness is a common motor impairment after msTBI. Walking and mobility limitations are also common problems after a msTBI, with muscle weakness being a main contributor to these limitations. Progressive resistance strength training can improve muscle strength, but has little effect on activity-level outcomes, such as mobility, in neurological populations (Dorsch et al., 2018; Williams et al., 2014). The effect of ballistic exercise training compared to non-ballistic exercise rehabilitation on mobility is likely to range between no difference to a large clinically important difference, particularly in those with more severe physical disability. The single RCT that informs the evidence-based recommendation has a low risk of bias and provides moderate certainty evidence. On balance, we consider there are likely desirable effects and the undesirable effects such as adverse events are likely small (e.g., muscle soreness) and rare. We found good acceptability from multiple stakeholders and data from our audit of brain injury services in Australia indicated that it is a feasible intervention to deliver in inpatient and post-rehabilitation settings. Implementation support will be needed, especially for health services and professionals working with adults or older adults with higher support needs, and/or from other identified subgroups (e.g., adults and older adults with msTBI from Culturally and Linguistically Diverse (CALD) communities).

Impact of clinical recommendation

We audited 21 services delivering rehabilitation to adults and/or older adults with msTBI across Australia. All services reported delivering muscle strength exercise and utilised a range of equipment to deliver muscle strength training, including handheld weights (100% of services), resistance bands (90%), cuff weights (86%), weight machines (67%), tilt table (62%), jump trainer (43%), suspension slings/springs (43%), and weighted vests (19%). However, there is variability between services in the equipment used for strength training and dosage provided. The implementation of the recommendations will likely improve consistent delivery of muscle strength training programs that are safe and effective at improving critical and important outcomes.

Cost data and cost effectiveness data is not available from any studies in TBI for strength training. The Guideline Development Group estimated the resource requirements (costs) for this intervention to be moderate, and likely dependent on the needs of the adult or older adult with msTBI. For example, whether an individual with msTBI can independently participate in strength training, or if they need one-on-one supervision or specific equipment to participate.

The American College of Sports Medicine (ACSM, 2009) provides the following recommendations for muscle strengthening training:

- The most important principles of strength training are progressive overload, specificity, and variation.
    - progressive overload is the gradual increase of stress placed upon the body during exercise training and can be achieved through progressing total repetitions and/or speed of repetitions, exercise intensity, training volume, and/or reducing length of rest periods.
    - specificity refers to the fact that the physiological adaptations to resistance training are specific to how training is prescribed, including the muscle actions involved, speed and range of movement, the muscle groups trained, energy systems involved, and the intensity and volume of training.

- variation refers to the systematic process of altering one or more program variable(s) over time to enable the training stimulus to remain challenging and effective.

Strength training in novice and/or deconditioned individuals:

- Frequency: 2-3x week.
- Intensity: 60-70% 1-Repetition maximum (RM), 8–12 repetitions, 1-4 sets (for muscular strength) or 15–20 repetitions, ≥2 sets (for muscular endurance).
- Type: Target major muscle groups.

Muscle power training in novice and/or deconditioned individuals:

- Frequency: 2-3x week.
- Intensity: 1–3 sets per exercise using light to moderate loading (0–60% of 1RM for lower body exercises) with fast velocities for 3–6 repetitions, but not to failure.
- Type: multiple-joint exercises.

Muscle endurance training in novice and/or deconditioned individuals:

- Frequency: 2-3x week.
- Intensity: 10-15 reps with moderate to high volume and intentionally slow velocities.
- Type: Unilateral and bilateral multiple and single joint exercises.

An example of a muscle power training program in TBI (Williams et al., 2016; 2022; 2023):
Initial loads/resistance start low to facilitate high-velocity contractions. When the individual can consistently perform the exercises at high-velocity, the load/resistance can be progressively increased. Examples of ballistic exercises used in Williams et al. (2022) RCT to improve mobility: leg extension jumps on a 'leg sled' and calf raises on a 'leg sled', stair ascent and descent, reciprocal leg extension of a mini-trampoline, fast cyclical hip and knee flexion in standing. Images and training parameters can be found in Williams and Ada (2023).

Please see **Clinical question 3** in the Technical Report for the full evidence to decision framework that assisted with providing the recommendations for this clinical question.

References

American College of Sports Medicine. American college of sports medicine position stand. progression models in resistance training for healthy adults. *Med Sci Sports Exerc.* 2009 ;41(3): 687-708.

Carty C, van der Ploeg HP, Biddle SJ, et al. The first global physical activity and sedentary behavior guidelines for people living with disability. *J Phys Act Health*. 2021; 18(1): 86–93.

Cordner T, Egerton T, Schubert K, Wijesinghe T, Williams G. Ballistic resistance training: feasibility, safety, and effectiveness for improving mobility in adults with neurologic conditions: a systematic review. *Arch Phys Med Rehabil*. 2021; 102(4): 735-51.

Dorsch S, Ada L, Alloggia D. Progressive resistance training increases strength after stroke but this may not carry over to activity: a systematic review. *J Physiother*. 2018; 64(2): 84-90.

Garcia-Hermoso A, Cavero-Redondo I, Ramírez-Vélez R, et al. Muscular strength as a predictor of all-cause mortality in an apparently healthy population: a systematic review and metaanalysis of data from approximately 2 million men and women. *Arch Phys Med Rehabil*. 2018; (10): 2100-2113.e5

Hassett L, Moseley A, Harmer A. The aetiology of reduced cardiorespiratory fitness among adults with severe traumatic brain injury and the relationship with physical activity: a narrative review. *Brain Impair*. 2015; 17(1): 43–54.

Izzy S, Chen PM, Tahir Z, et al. Association of traumatic brain injury with the risk of developing chronic cardiovascular, endocrine, neurological, and psychiatric disorders. *JAMA Netw Open*. 2022; 5(4): e229478.

Jerome GJ, Boyer WR, Bustamante EE, et al. Increasing equity of physical activity promotion for optimal cardiovascular health in adults: a scientific statement from the American heart association. *Circulation.* 2023; 147: 1951-1962.

Olver JH, Ponsford JL, Curran CA. Outcome following traumatic brain injury: a comparison between 2 and 5 years after injury. *Brain Inj.* 1996; 10: 841–848.

Saunders DH, Sanderson M, Hayes S, et al. Physical fitness training for stroke patients. *Cochrane Database Syst Rev.* 2020; Issue 3. Art. No: CD003316.

Williams G, Hassett L, Clark R, et al. Ballistic resistance training has a similar or better effect on mobility than non-ballistic exercise rehabilitation in people with a traumatic brain injury: a randomised trial. *J Physiother*. 2022; 68(4): 262-268.

Williams G, Kahn M, Randall A. Strength training for walking in neurologic rehabilitation is not task specific: a focused review. *Am J Phys Med Rehabil.* 2014; 93(6): 511-522.

Williams GP, Schache AG, Morris ME. Mobility after traumatic brain injury: relationships with ankle joint power generation and motor skill level. *J Head Trauma Rehabil.* 2013; 28: 371–378.

Williams G, Ada L, Hassett L, Morris M, Clark R, Bryant A L, Olver J. Ballistic strength training compared with usual care for improving mobility following traumatic brain injury: protocol for a randomised controlled trial. *J Physiother.* 2016; 62(3) 164-164.

Williams, G and Ada L. The safety and accuracy of home-based ballistic resistance training for people with neurological conditions. *Physiother Theory Pract*. 2023; 39(9): 2015-2024.

Clinical question 4: Muscle strength training for children and adolescents with moderate to severe traumatic brain injury

Clinical question: Should structured **muscle strengthening** training compared to control be used for **children and adolescents** after moderate to severe traumatic brain injury?

Setting: Healthcare settings across the continuum of care:

- Inpatient, transition and outpatient rehabilitation settings
- Community settings (e.g., fitness centres, sporting fields, community centres)
- Home
- Schools

Perspective: Health systems

Critical outcomes of interest:

- Muscle strength
- Combined mobility

Important outcomes of interest:

- Walking capacity
- Balance
- Co-morbidities and mortality
- Body composition
- Physical activity

Key definitions:

- Children and adolescents: 5 to 17 years
- Muscle strengthening exercise: exercise that increases skeletal muscle strength, power, endurance, and mass (e.g., strength training, resistance training, or muscular strength and endurance exercises).

Clinical need for question

Children and adolescents experience reduced lower limb muscle strength following msTBI (Drijkoningen et al., 2015; Katz-Leurer et al., 2010; Katz-Leurer et al., 2009). Deficits in lower limb muscle strength after msTBI can impact the walking ability, balance, and co-ordination of children and adolescents. In a small group (n 19) of children and adolescents after msTBI, asymmetry in muscle strength was predictive of a poorer balance control and a more variable and asymmetric gait (Drijkoningen et al., 2015). This has negative implications for a child's or adolescent's engagement in physical activity (Katz-Leurer et al., 2010), which can impact their physical and psychosocial wellbeing (Sallis et al., 2000).

Types of strength training

Muscle strength reflects the maximum amount of force a muscle can produce, whereas muscle power reflects how quickly force can be generated or the rate of force production (Williams et al., 2016). *Progressive resistance strength training* is a type of muscle strengthening exercise where individuals exercise their muscles against some type of resistance that is progressively increased as their strength improves, and targets improving muscle strength. *Ballistic strength training* is another type of muscle strengthening exercise in which the muscles perform movement against resistance, but do so quickly, and targets improving muscle power.

Progressive resistance strength training has been shown to improve muscle strength in neurological populations, such as stroke and TBI, but these improvements do not carry over into improvements at the activity level (i.e., mobility) (Dorsch et al., 2018; Williams et al., 2014). To improve the capacity to perform activities that are limited by muscle weakness, such as walking and other high level mobility tasks, muscle groups involved in these tasks need to be able to contract with strength and speed (i.e., powerfully). Ballistic exercise training has shown to be safe and feasible in neurological populations (Cordner et al., 2021).

Summary of evidence

Indirect evidence:

There was no direct evidence to guide this judgement in children and adolescents in msTBI research. Thus, evidence for muscle strength training was drawn from the single RCT in adults with msTBI which had an inclusion criteria of ages 15 to 65 years old (Williams et al., 2022) and from the WHO physical activity and sedentary behaviour guidelines for people living with disability (Carty et al., 2021).

There was one single RCT that compared ballistic resistance training (e.g., leg extension jumps and calf raises on a 'leg sled') with non-ballistic exercise rehabilitation (e.g., balance exercises and lower limb stretching) (Williams et al., 2022). This study found that ballistic exercise training had a moderate effect on mobility in adults after msTBI but was no better (or worse) than non-ballistic exercise rehabilitation on measures of walking ability, or muscle strength (Williams et al., 2022). The non-ballistic exercise rehabilitation group was better than the ballistic exercise group on measure of balance (moderate certainty evidence).

The WHO guideline development group considered evidence for children without disability, and evidence for physical activity for children living with intellectual disability and children with attention deficit hyperactivity disorder (ADHD) (Carty et al., 2021). They found that evidence from children without disability could be extrapolated to children living with a disability for key favourable outcomes, including cardiorespiratory and muscular fitness, and mental health. They also found that there were improvements in physical function (low certainty evidence) in children with intellectual disability and improvements in cognition (moderate certainty evidence) in children with ADHD. Thus, the WHO physical activity and sedentary behaviour guidelines recommend that for children and adolescents (aged 5 to 17 years) living with a disability:

- Vigorous-intensity aerobic activities, as well as those that strengthen muscle and bone should be incorporated at least three days a week (*Strong recommendation, moderate certainty evidence*)

Please see **Clinical question 4** in the Technical Report for detailed study characteristics and meta-analyses that assisted with providing the evidence base for this clinical question.

Recommendations

	Type	Recommendation	GRADE/Quality
4		**Muscle strength training for children and adolescents with moderate to severe traumatic brain injury**	
4.1	**EBR**	For children and adolescents after moderate to severe traumatic brain injury, we suggest regular muscle strengthening play and/or exercise that is individually-tailored and across the continuum of care.	❖❖❖
We suggest the following Good Practice Points (GPP):			
4.2	**GPP**	Muscle strength training aims to achieve goals established collaboratively where the child's voice is at the centre.	
4.3	**GPP**	Assessment of muscle strength is conducted for school aged children prior to commencing strength training.	
4.4	**GPP**	For very weak muscles, strength training is set-up to make it as easy as possible to elicit muscle activity (e.g., reducing friction, reducing or removing gravity, working in mid-range, electrical stimulation and/or electromyographic biofeedback, and supported weight bearing) and high repetitions are encouraged.	
4.5	**GPP**	Muscle strength training dosage is prescribed according to American College of Sports Medicine guidelines.	
4.6	**GPP**	Health professionals consider the muscle groups involved, and their function, when developing muscle strength training programs to improve mobility and other functional tasks.	
4.7	**GPP**	Health professionals consider specificity of training (i.e., power vs strength vs endurance) when prescribing mode of muscle strength training.	
4.8	**GPP**	Muscle strength training is transitioned from health settings to community-based physical activity settings where appropriate.	

Justification

Rationale

Muscle weakness is a common impairment after msTBI which causes limitations in activities such as standing up and walking and will restrict participation in meaningful activities such as sport and play. Although there are no specific evidence of benefit or harm for children and adolescents living with msTBI, the WHO physical activity and sedentary behaviour guidelines (Carty et al., 2021) strongly recommend muscle and bone strengthening activities for children and adolescents living with a disability (with favourable outcomes on cardiorespiratory and muscular fitness, cardiometabolic health, bone health, cognitive outcomes, mental health, and adiposity). The WHO guideline group also considered evidence for improvements in physical function (low certainty for children living with an intellectual disability) and cognition (moderate certainty for children living with ADHD) (Carty et al., 2021). There were only two minor adverse events in the strength training trial in adults after msTBI. The WHO guidelines also suggest there are no major risks engaging in physical activity, including muscle strength training, for children and adolescents living with a disability. On the balance of desirable and undesirable effects, participating in muscle strength training, is probably favoured over the alternative (i.e., not participating in muscle strength training). There was good acceptability from multiple stakeholders, and it was feasible to deliver muscle strength training in both inpatient and post-rehabilitation settings. Implementation support will be needed, especially for health services and professionals working with children and adolescents with higher support needs and/or from other identified subgroups (e.g., children and adolescents living in regional or remote Australia).

Impact of clinical recommendation

We audited six services delivering rehabilitation to children and adolescents with msTBI across Australia. All services reported delivering muscle strength exercise and utilised a range of equipment to deliver muscle strength training, including tilt table (100% of services), handheld weights (83%), cuff weights (83%), resistance bands (83%), jump trainer (50%), weight machines (33%), suspension slings/springs (17%), and weighted vests (17%). However, there is variability between services in the equipment used for strength training and dosage provided. The implementation of the recommendations will likely improve consistent delivery of strength training programs that are safe and effective at improving critical and important outcomes.

Cost data and cost effectiveness data is not available from any studies in TBI for strength training. The Guideline Development Group estimated the resource requirements (costs) for this intervention to be moderate, with the costs likely dependent on the needs of the child or adolescent with msTBI. For example, whether a child or adolescent with msTBI can independently participate in strength training, or if they need one-on-one supervision or specific equipment to participate.

The American College of Sports Medicine (ACSM, 2009) provides the following recommendations for muscle strengthening training:

- The most important principles of strength training are progressive overload, specificity, and variation.
    - progressive overload is the gradual increase of stress placed upon the body during exercise training and can be achieved through progressing total repetitions and/or speed of repetitions, exercise intensity, training volume, and/or reducing length of rest periods.
    - specificity refers to the fact that the physiological adaptations to resistance training are specific to how training is prescribed, including the muscle actions involved, speed and range of movement, the muscle groups trained, energy systems involved, and the intensity and volume of training.
    - variation refers to the systematic process of altering one or more program variable(s) over time to enable the training stimulus to remain challenging and effective.

<u>Strength training in novice and/or deconditioned individuals:</u>

- Frequency: 2-3x week.
- Intensity: 60-70% 1-Repetition maximum (RM), 8–12 repetitions, 1-4 sets (for muscular strength) or 15–20 repetitions, ≥2 sets (for muscular endurance).
- Type: Target major muscle groups.

<u>Muscle power training in novice and/or deconditioned individuals:</u>

- Frequency: 2-3x week.
- Intensity: 1–3 sets per exercise using light to moderate loading (0–60% of 1RM for lower body exercises) with fast velocities for 3–6 repetitions, but not to failure.
- Type: multiple-joint exercises.

Muscle endurance training in novice and/or deconditioned individuals:

- Frequency: 2-3x week.
- Intensity: 10-15 reps with moderate to high volume and intentionally slow velocities.
- Type: Unilateral and bilateral multiple and single joint exercises.

An example of a muscle power training program in TBI (Williams et al., 2016; 2022; 2023):
Initial loads/resistance start low to facilitate high-velocity contractions. When the individual can consistently perform the exercises at high-velocity, the load/resistance can be progressively increased. Examples of ballistic exercises used in Williams et al. (2022) RCT to improve mobility: leg extension jumps and calf raises on a 'leg sled', stair ascent and descent, reciprocal leg extension of a mini-trampoline, fast cyclical hip and knee flexion in standing. Images and training parameters can be found in Williams and Ada (2023).

Please see **Clinical question 4** in the Technical Report for the full evidence to decision framework that assisted with providing the recommendations for this clinical question.

References

American College of Sports Medicine. American college of sports medicine position stand. progression models in resistance training for healthy adults. *Med Sci Sports Exerc.* 2009 ;41(3): 687-708.

ABS 2019. Microdata: National Health Survey, 2017–18. ABS cat. no. 4324.0.55.001. Findings based on detailed microdata analysis. Canberra: ABS.

Carty C, van der Ploeg HP, Biddle SJ, et al. The first global physical activity and sedentary behavior guidelines for people living with disability. *J Phys Act Health*. 2021; 18(1): 86-93.

Cordner T, Egerton T, Schubert K, Wijesinghe T, Williams G. Ballistic resistance training: feasibility, safety, and effectiveness for improving mobility in adults with neurologic conditions: a systematic review. *Arch Phys Med Rehabil*. 2021; 102(4): 735-51.

Dorsch S, Ada L, Alloggia D. Progressive resistance training increases strength after stroke but this may not carry over to activity: a systematic review. *J Physiother*. 2018; 64(2): 84-90.

Drijkoningen D, Caeyenberghs K, Vander Linden C, et al. Associations between muscle strength asymmetry and impairments in gait and posture in young brain-injured patients. *J Neurotrauma*. 2015; 32(17): 1324-1332.

Hardy LL, Merom D, Thomas M, Peralta L. 30-year changes in Australian children's standing broad jump: 1985-2015. *J Sci Med Sport*. 2018; 21(10): 1057-1061.

Jerome GJ, Boyer WR, Bustamante EE, et al. Increasing equity of physical activity promotion for optimal cardiovascular health in adults: a scientific statement from the American heart association. *Circulation.* 2023; 147(25): 1951-1962.

Katz-Leurer M, Rotem H, Keren O, Meyer S. Recreational physical activities among children with a history of severe traumatic brain injury. *Brain Inj.* 2010; 24(13-14): 1561-1567.

Katz-Leurer M, Rotem H, Keren O, Meyer S. The relationship between step variability, muscle strength and functional walking performance in children with post-traumatic brain injury. *Gait Posture*. 2009; 29(1): 154-157.

Ryan JM, Cassidy EE, Noorduyn SG, O'Connell NE. Exercise interventions for cerebral palsy. *Cochrane Database Syst Rev*. 2017; 6(6): CD011660.

Sallis JF, Prochaska JJ, Taylor WC. A review of correlates of physical activity in children and adolescents. *Med Sci Sport Exerc*. 2000. 32(5): 963-975.

Williams G, Hassett L, Clark R, et al. Ballistic resistance training has a similar or better effect on mobility than non-ballistic exercise rehabilitation in people with a traumatic brain injury: a randomised trial. *J Physiother*. 2022; 68(4): 262-268.

Williams G, Kahn M, Randall A. Strength training for walking in neurologic rehabilitation is not task specific: a focused review. *Am J Phys Med Rehabil.* 2014; 93(6): 511-522.

Williams GP, Schache AG, Morris ME. Mobility after traumatic brain injury: relationships with ankle joint power generation and motor skill level. *J Head Trauma Rehabil.* 2013; 28:371–378.

Williams G, Ada L, Hassett L, Morris M, Clark R, Bryant A L, Olver J. Ballistic strength training compared with usual care for improving mobility following traumatic brain injury: protocol for a randomised controlled trial. *J Physiother.* 2016; 62(3): 164-164.

Williams, G and Ada L. The safety and accuracy of home-based ballistic resistance training for people with neurological conditions. *Physiother Theory Pract*. 2023; 39(9): 2015-2024.

Clinical question 5: Mobility training for adults and older adults with moderate to severe traumatic brain injury

Clinical question: Should structured **mobility** training (i.e., gait, balance and function training) compared to control be used for **adults and older adults** after moderate to severe traumatic brain injury?

Setting: Healthcare settings across the continuum of care:

- Inpatient, transition and outpatient rehabilitation settings
- Community settings (e.g., fitness centres, sporting fields, community centres)
- Home

Perspective: Health systems

Critical outcomes of interest:

- Balance
- Combined mobility
- Walking capacity

Important outcomes of interest:

- Physical activity
- Co-morbidities and mortality
- Participation
- Quality of life

Key definitions:

- Adults: ≥ 18 years
- Older adults: ≥ 65 years
- Mobility exercise: Mobility is a broad term that is defined as the ability to move around and change positions, such as to stand up from sitting and to walk. Mobility exercise is the practice of these tasks, e.g., sit to stand exercises, walking on a treadmill or overground, reaching in standing to challenge balance.

Clinical need for question

Mobility limitations are common after msTBI, and it is common for individuals to be admitted to inpatient rehabilitation with mobility limitations. Typically, patients admitted to inpatient rehabilitation will improve while in rehabilitation, but some individuals live with some level of mobility limitation over their lifespan. For example:

- An Australian adult cohort study using prospectively collected clinical data over a 13-year period (2000 to 2013; n=613) found that on admission to inpatient rehabilitation, 27% of patients could stand up from a chair with equal weightbearing, 33% could stand with equal weightbearing, 26% could walk at ≥1 m/s independently, 37% could climb stairs, and 7% could run. On discharge this improved considerably; 65% could stand up from a chair with equal weightbearing, 73% could stand with equal weightbearing, 70% could walk at ≥ 1 m/s independently, 81% could climb stairs, and 33% could run (Wong et al., 2019).

- Improvements in physical function have also been shown in older adults with msTBI undertaking inpatient rehabilitation (Noel et al., 2023).
- Mobility limitations in people with msTBI can persist into the long-term, with a longitudinal follow-up of patients finding little change in mobility level for participants across a span of 10 years (Ponsford et al., 2014)
- Higher level mobility skills such as running and jumping are important for participating in social, leisure, and sporting activities. A long-term follow up of people living with msTBI found that around 75% of individuals did not resume their pre-injury activities (Ponsford et al., 2014).

Mobility training is often a focus of physiotherapy management and patient goals in rehabilitation, with a certain level of mobility required for the individual to be discharged home from hospital and to be safe walking in the community (Hassett, 2023).

Summary of evidence

Direct evidence:

Mobility training is the area of TBI physical rehabilitation with the most RCTs conducted. Many of the RCTs compare the same dose of different types of mobility training, while some compare an additional dose of mobility training.

For the critical outcome of balance, four RCTs compared virtual reality balance training with other balance interventions. Three of the four studies included participants >1-year post-injury and with high-level mobility problems. Interventions were prescribed to be performed for 15 to 60 minutes, three to five times per week for 4 to 12 weeks. There was uncertainty if virtual reality balance training improved balance more than other balance exercises (SMD: 0.27; 95% CI: -0.17 to 0.71; very low certainty evidence).

The Williams et al. (2022) RCT described under Clinical question 3 compared ballistic strength training to non-ballistic exercise rehabilitation. The non-ballistic exercise rehabilitation group was standardised and was delivered for one-hour, three times per week for 12 weeks (same amount as ballistic strength training group). The non-ballistic exercises included graded static and dynamic balance tasks progressed to ensure challenge, muscle stretching (calf, quads, hamstring, hip adductors), strength (seated-leg press), aerobic (60-80% HRmax up to 10mins on bike or arm ergometer), and gait training (10mins). Balance (timed single leg stance) at end of intervention favoured the non-ballistic exercise rehabilitation group (MD: 2 s; 95% CI: 3.7 to 0.3 s); moderate certainty evidence). The ballistic training group improved more than usual care group on combined mobility (HiMAT) and there was no difference between groups for walking speed.

For the critical outcome of combined mobility, four RCTs provided an additional mobility training dose to the intervention group compared to the control group. Overall, the analysis favoured additional dose, but there was uncertainty (SMD: 0.27; 95% CI: -0.17 to 0.71; very low certainty evidence). One RCT compared partial weightbearing training to. traditional physical therapy (no significant difference, very low certainty evidence) and another RCT compared additional group-based vestibular rehabilitation to usual multidisciplinary outpatient rehabilitation. The vestibular training provided significantly better improvements in combined mobility (HiMAT; MD: 6.4 points; 95% CI: 0.8 to 12 points; low certainty evidence).

There were no other findings favouring mobility training for the outcomes of walking speed and participation, and no studies measured physical activity or comorbidities and mortality. For most of the RCTs evaluating mobility training, most reported improvements in both groups from baseline to end of intervention. Collectively, these studies indicate that health professionals could use the interventions described above to improve mobility, although further high-quality research trials would help to confirm this recommendation, particularly including participants in the first six months after injury.

Indirect evidence:

The Australian and New Zealand Living Clinical Guidelines for Stroke Management were reviewed. They provide strong recommendations for retraining of sitting, standing up, standing balance, and walking, with suggestions of circuit class or treadmill training with or without body weight support to train these tasks. Weak recommendations are provided for virtual reality training, visual or auditory feedback, electromechanically assisted gait or standing training for stroke survivors with difficulty with standing balance. Weak recommendations were also provided for virtual reality training, electromechanically assisted gait training biofeedback, cueing of cadence, and electrical stimulation for stroke survivors with walking difficulty.

Please see **Clinical question 5** in the Technical Report for detailed study characteristics and meta-analyses that assisted with providing the evidence base for this clinical question.

Recommendations

	Type	Recommendation	GRADE/Quality
5		**Mobility training for adults and older adults with moderate to severe traumatic brain injury**	
5.1	**EBR**	For adults and older adults after moderate to severe traumatic brain injury, we recommend task-specific mobility training across the continuum of care.	❖❖❖❖ ⊕⊕⊕◯
We suggest the following Good Practice Points (GPP):			
5.2	**GPP**	Mobility training aims to achieve participation-level and activity-level goals established collaboratively.	
5.3	**GPP**	The setting and supervision requirements for adults with significant cognitive and/or behavioural impairments is considered to maximise participation in mobility training and the transfer of training to real life tasks.	
5.4	**GPP**	Virtual reality interventions and body weight support treadmill training (with or without robotics) may be used as options to train mobility.	
5.5	**GPP**	Mobility training is incorporated into weekly routines with key supports (e.g., family, friends, support workers) trained in facilitating this activity where appropriate.	
5.6	**GPP**	Mobility training incorporates motor learning principles of task-specific, repetitive, intensive practice.	

Justification

Reduced mobility is a common activity limitation after TBI which can reduce participation in everyday activities, as well as have negative physiological and psychological impacts. Mobility training is likely to have moderate positive effects on critical outcomes for individuals with msTBI including balance, combined mobility, and walking capacity. Indirect evidence from stroke strongly supports mobility training. In addition, motor learning principles of task-specific, repetitive, intensive practice (Carr and Shepherd, 2010) are recommended for acute brain injury and are likely to be important for adults and older adults with motor impairments from their msTBI. On balance, the likely desirable effects are moderate and undesirable effects such as adverse events are likely trivial (e.g., skin irritation, leg pain). The risk of musculoskeletal injuries because of participating in mobility training is likely no different to the risk posed to those without msTBI with appropriate supervision and programming (i.e., graded volume/intensity). We found good acceptability from multiple stakeholders and data from our audit of brain injury services in Australia indicated that it is a feasible intervention to deliver in inpatient and post-rehabilitation settings. Implementation support will be needed, especially for health services and professionals working with adults or older adults with higher support needs, such as significant cognitive and behavioural impairments, and/or from other identified subgroups (e.g., Aboriginal and Torres Strait Islander people).

Impact of clinical recommendation

We audited 21 services delivering rehabilitation to adults and/or older adults with msTBI across Australia. All services reported delivering mobility training, and used a range of equipment to do so, including up/down plinth (95%), walking track (86%), treadmill (100%), bodyweight support harness (62%), robotics (14%), virtual reality (14%), stairs (90%), trampette/mini trampoline (81%), walking frame (81%), walking stick (81%), ankle foot orthoses (95%), transfer belt (62%). However, there is variability between services in the equipment used and the outcome measures assessed. The implementation of the recommendations will likely improve consistent delivery of mobility training that is safe and effective at improving critical and important outcomes.

It should be considered that specific equipment and skills may be required to cater for the individual capabilities of adults and older adults with msTBI. But as highlighted by our stakeholder focus groups, these resources may be limited in some settings (e.g., in the community). National guidelines may support providers to deliver, and funders to fund, mobility training for those living in more regional, rural and remote areas that aren't as linked in with specialist brain injury services.

Cost data and cost effectiveness data is not available from any studies in msTBI for mobility training. The Guideline Development Group estimated the resource requirements (costs) for this intervention to be moderate, though this is likely dependent on the needs of the person with TBI. For example, whether an adult or older adult with msTBI can independently participate in mobility training, or if they need one-on-one supervision or specific equipment or setting to participate.

People with catastrophic injuries due to road traffic accidents or workplace accidents are covered for lifetime care and support by state insurance schemes. Mobility training, including access to resources such as health professionals, and assistive technology, may be funded by these insurance agencies if assessed as “reasonable and necessary” as per legislation. Adults with msTBI covered by the National Disability Insurance Scheme (NDIS) (< 65 years old) may have access to some funding to support their participation in mobility training if mobility training is identified as a goal by the patient. The provision of a national physical activity clinical practice guideline with recommendations for mobility training will likely support funding requests for funds to support effective mobility training.

Please see **Clinical question 5** in the Technical Report for the full evidence to decision framework that assisted with providing the recommendations for this clinical question.

References

Brown TH, Mount J, Rouland BL, et al. Body weight supported treadmill training versus conventional gait training for people with chronic traumatic brain injury. *J Head Trauma Rehabil*. 2005; 20(5): 402–415.

Canning CG, Shepherd RB, Carr JH, et al. A randomized controlled trial of the effects of intensive sit-to-stand training after recent traumatic brain injury on sit-to-stand performance. *Clin Rehabil*. 2003; 17(4): 355–362.

Corbetta D, Imeri F, Gatti R. Rehabilitation that incorporates virtual reality is more effective than standard rehabilitation for improving walking speed, balance and mobility after stroke: a systematic review. *J Physiother.* 2015; 61(3): 117-24.

Cuthbert JP, Staniszewski K, Hays K, et al. Virtual reality-based therapy for the treatment of balance deficits in patients receiving inpatient rehabilitation for traumatic brain injury. *Brain Inj*. 2014; 28(2): 181–188.

Esquenazi A, Lee S, Packel AT, Braitman L. A randomized comparative study of manually assisted versus robotic-assisted body weight supported treadmill training in persons with a traumatic brain injury. *PM R*. 2013; 5(4): 280-290.

French B, Thomas LH, Coupe J et al. Repetitive task training for improving functional ability after stroke. *Cochrane Database Syst Rev.* 2016; 11(11): CD006073.

Gil-Gómez JA, Lloréns R, Alcañiz M, Colomer C. Effectiveness of a wii balance board-based system (eBaViR) for balance rehabilitation: a pilot randomized clinical trial in patients with acquired brain injury. *J Neuroeng Rehabil*. 2011; 8: 30.

Handiru VS, Pilkar R, Suviseshamuthu ES, Yue G. Effects of Computerized Biofeedback-based Balance Intervention on the Muscle Coactivation Patterns during Dynamic Postural Control in Traumatic Brain Injury. *Annu Int Conf IEEE Eng Med Biol Soc.* 2022: 5144-5147.

Hassett L. Physiotherapy management of moderate-to-severe traumatic brain injury: invited topical review. *J Physiother.* 2023; 69(3): 141-147.

Howlett OA, Lannin NA, Ada L et al. Functional electrical stimulation improves activity after stroke: a systematic review with meta-analysis. *Archives of physical medicine and rehabilitation*. 2015; 96(5):934-43.

Hugues A, Di Marco J, Ribault S et al. Limited evidence of physical therapy on balance after stroke: a systematic review and meta-analysis. *PloS One.* 2019; 14(8): e0221700.

Kleffelgaard I, Lundgaard Soberg H, Tamber A, et al. The effects of vestibular rehabilitation on dizziness and balance problems in patients after traumatic brain injury: a randomized controlled trial. *Clin Rehabil*. 2019; 33(1): 74-84.

Laver K, Lange B, George S, et al. Virtual reality for stroke rehabilitation. *Cochrane Database Syst Rev* 2017; 11(11): CD008349.

Legg LA, Lewis SR, Schofield-Robinson OJ et al. Occupational therapy for adults with problems in activities of daily living after stroke. *Cochrane Database Syst Rev.* 2017; 7(7): CD003585.

Merhrolz J, Pohl M, Elsner B. Treadmill training and body weight support for walking after stroke. *Cochrane Database Syst Rev.* 2017; 8(8): CD002840.

Mohammadi R, Semnani AV, Mirmohammadkhani M et al. Effects of virtual reality compared to conventional therapy on balance poststroke: a systematic review and meta-analysis. *J Stroke Cerebrovasc Dis.* 2019; 28(7): 1787-1798.

Nascimento LR, Flores LC, de Menezes KKP et al. Water-based exercises for improving walking speed, balance, and strength after stroke: a systematic review with meta-analyses of randomized trials. *Physiotherapy.* 2020; 107: 100-110.

Noël F, Gagnon MP, Lajoie J, et al. Inpatient physical therapy in moderate to severe traumatic brain injury in in older adults: a scoping review. *Int J Environ Res Public Health*. 2023; 20(4): 3367.

Peirone E, Goria PF, Anselmino A. A dual-task home-based rehabilitation programme for improving balance control in patients with acquired brain injury: a single-blind, randomized controlled pilot study. *Clin Rehabil.* 2014; 28(4): 329–338.

Pollock A, Gray C, Culham E et al. Interventions for improving sit-to-stand ability following stroke. *Cochrane Database Syst Rev.* 2014; 5: CD007232.

Ponsford JL, Downing MG, Olver J, et al. Longitudinal follow-up of patients with traumatic brain injury: outcome at two, five, and ten years post-injury. *J Neurotrauma*. 2014; 13(1): 64–77.

Särkämö T, Huttula L, Leppelmeier J, et al. DARE to move: feasibility study of a novel dance-based rehabilitation method in severe traumatic brain injury. *Brain Inj.* 2021; 35(3): 335-344.

Stanton R, Ada L, Dean CM et al. Biofeedback improves performance in lower limb activities more than usual therapy in people following stroke: a systematic review. *J Physiother.* 2017;63(1):11-16.

Straudi S, Severini G, Sabbagh Charabati A, et al. The effects of video game therapy on balance and attention in chronic ambulatory traumatic brain injury: an exploratory study. *BMC Neurol.* 2017; 17(1): 86.

Sveistrup H, McComas J, Thornton M, et al. Experimental studies of virtual reality-delivered compared to conventional exercise programs for rehabilitation. *Cyberpsychol Behav.* 2003, 6(3): 245-249.

Tefertiller C, Ketchum JM, Bartelt P, et al. Feasibility of virtual reality and treadmill training in traumatic brain injury: a randomized controlled pilot trial. *Brain Inj.* 2022; 36(7): 898–908.

van Duijnhoven HJR, Heeren A, Peters MAM et al. Effects of exercise therapy on balance capacity in chronic stroke: systematic review and meta-analysis. *Stroke.* 2016; 47(10): 2603-2610.

Veerbeek JM, Van Wegen E, Van Peppen R. et al. What is the evidence for physical therapy poststroke? a systematic review and meta-analysis. *PLoS One.* 2014;9(2): e87987.

Williams G, Hassett L, Clark R, et al. Ballistic resistance training has a similar or better effect on mobility than non-ballistic exercise rehabilitation in people with a traumatic brain injury: a randomised trial. *J Physiother.* 2022; 68(4): 262–268.

Wilson DJ, Powell M, Gorham JL, Childers MK. Ambulation training with and without partial weightbearing after traumatic brain injury: results of a randomized, controlled trial. *Am J Phys Med Rehabil.* 2006; 85(1): 68–74.

Wong S, Hassett L, Liu J, et al. Physical outcomes for people admitted to an adult brain injury rehabilitation unit: a cohort study. In: ASSBI/NZRA Conference. New Zealand; 2019.

Zheng Q-X, Ge LI, Wang CC et al. Robot-assisted therapy for balance function rehabilitation after stroke: a systematic review and meta-analysis. *Int J Nursing Stud.* 2019; 95: 7-18.

Clinical question 6: Mobility training for children and adolescents with moderate to severe traumatic brain injury

- **Clinical question:** Should structured **mobility** training (i.e., gait, balance and function training) compared to control be used for **children and adolescents** after moderate to severe traumatic brain injury?

- **Setting:** Healthcare settings across the continuum of care:
  - Inpatient, transition and outpatient rehabilitation settings
  - Community settings (e.g., fitness centres, sporting fields, community centres)
  - Home
  - Schools

- **Perspective:** Health systems

- **Critical outcomes of interest:**
  - Balance
  - Combined mobility
  - Walking Capacity

- **Important outcomes of interest:**
  - Physical activity
  - Co-morbidities and mortality
  - Participation
  - Quality of life

- **Key definitions:**
  - Children and adolescents: 5 to 17 years
  - Mobility exercise: Mobility is a broad term that is defined as the ability to move around and change positions, such as to stand up from sitting and to walk. Mobility exercise is the practice of these tasks, e.g., sit to stand exercises, walking on a treadmill or overground, reaching in standing to challenge balance.

Clinical need for question

Children and adolescents commonly experience reduced mobility following msTBI. The recovery of mobility skills is important in supporting children's participation in their community (Bedell et al., 2004; Fragala et al., 2002). It is also important for participation in physical activity, which promotes social opportunities and has benefits for physical and psychological wellbeing (Sallis et al., 2000). While most children with msTBI regain the ability to walk independently, many experience ongoing mobility limitations due to impaired balance, speed, coordination, and fitness. These impairments impact a child's ability to perform high-level mobility skills (e.g., running, skipping, and hopping), which may restrict their participation in typical childhood sport and play (Kissane et al., 2015). When comparing high-level mobility in children with msTBI against healthy, age-matched controls, the mean HiMAT score for the TBI cohort was 36.1/54, compared to 45.6/54 in the healthy control group. This difference is indicative of significantly greater mobility limitations in children with msTBI (Kissane et al., 2015).

Summary of evidence

Direct evidence:

There are a limited number of studies investigating the effects of a mobility intervention on critical and important outcomes for children and adolescents after msTBI. We identified two RCTs (Baque et al., 2017; Katz-Leurer et al., 2009) and two NRSIs (Drijkoningen et al., 2015; de Kloet et al., 2012), though deKloet et al. (2012), Katz-Leurer et al. (2009) and Baque et al. (2017) included generally small samples sizes of a mix of traumatic and non-traumatic brain injured children and adolescents mostly above the age of 8-years.

In the Drijkoningen et al. (2015) NRSI, the effect of an 8-week home-based, computer-assisted, balance training intervention was investigated. The group, including 19 children with msTBI, improved from pre- to post-training on measures of balance. Similar findings were found in typically developing children who also participated in the intervention, but not in typically developing children who did not participate in the intervention (very low certainty evidence).

In a pre-post study design, de Kloet et al. (2012) investigated the effects of 12 weeks of goal-oriented Nintendo Wii training on physical activity and participation. Participants experienced an increase in time reported spent in physical activity, and intensity of activity, from pre- to post-intervention. Participants also reported participating in a greater diversity of recreational activities from pre- to post-intervention (very low certainty evidence).

For the two RCTs, Katz-Leurer et al. (2009) reported on the effects of six weeks of home-based, task-oriented exercise compared to a control group, while Baque et al. (2017) compared the effects of a 20-week, home-based, web-based, individually tailored, multimodal therapy intervention to a waitlist control. The Baque et al. (2017) intervention included 12 modules, including (1) gross motor tasks (sit-to stands, squats, lunges, aerobic, and balance tasks); (2) combined cognitive and visual perception activities; and (3) upper limb activities. While both studies measured combined mobility, the data could not be synthesised. The Katz-Leurer intervention group improved on the Timed Up and Go (TUG) test from pre- to post-intervention (change score = -1.6secs), while there was no change in the control group. The Baque et al. (2017) intervention group improved their mobility more than the control group, but there was uncertainty with this finding (MD: -0.5 s; 95% CI: -0.52 to 0.41 s; low certainty evidence). In addition, the Baque et al. (2017) intervention group improved their walking capacity (6MWT) more than the control group, though the between-group difference was non-significant (MD: 9 m; 95% CI: -17 to 35 m; low certainty evidence).

No studies measured the important outcomes quality of life or comorbidities and mortality.

Indirect evidence:

A consensus-based recommendation is provided from the Australian childhood stroke guidelines (2019): *"Goal-directed therapy incorporating motor learning principles (including task-specific, repetitive and intensive practice) should be considered to improve motor difficulties after childhood stroke."* While a pooled analysis across five systematic reviews investigating mobility training to improve gross motor function in children with cerebral palsy indicated a low risk of harms (Novak et al., 2019).

Please see **Clinical question 6** in the Technical Report for detailed study characteristics and meta-analyses that assisted with providing the evidence base for this clinical question.

Recommendations

	Type	Recommendation	GRADE/Quality
6		**Mobility training for children and adolescents with moderate to severe traumatic brain injury**	
6.1	**EBR**	For children and adolescents after moderate to severe traumatic brain injury, we suggest task-specific mobility training across the continuum of care.	❖❖❖ ⊕◯◯◯
We suggest the following Good Practice Points (GPP):			
6.2	**GPP**	Mobility training aims to achieve participation-level and activity-level goals established collaboratively where the child's voice is at the centre.	
6.3	**GPP**	The setting and supervision requirements for children with significant cognitive and/or behavioural impairments is considered to maximise participation in mobility training and the transfer of training to real life tasks.	
6.4	**GPP**	Mobility training is incorporated into weekly routines with key supports (e.g., siblings, friends, teachers, support workers, and parents) trained in facilitating this activity.	
6.5	**GPP**	Mobility training is performed when the child is and isn't fatigued to enable practice of mobility at different capacities.	
6.6	**GPP**	Mobility training is delivered within an interdisciplinary model to enable management of any psychosocial impairments and/or adjustments to injury that may impact on training.	
6.7	**GPP**	Mobility training incorporates motor learning principles of task-specific, repetitive, intensive practice.	

Justification

Reduced mobility is a common activity limitation for children and adolescents after msTBI that can reduce participation in everyday activities including school, sport, and recreation. As well as having negative physical consequences, this can limit social opportunities for children, negatively impacting their psychological wellbeing. Despite limited and low certainty evidence, mobility training may have positive effects on critical outcomes, such as combined mobility and walking capacity, for children and adolescents with msTBI. Motor learning principles of task-specific, repetitive, intensive practice (Carr and Shepherd, 2010) are recommended for acute brain injury and are likely to be important for children and adolescents with motor impairments from their msTBI. On balance, the likely desirable effects of mobility training are moderate and undesirable effects such as adverse events are likely trivial (e.g., skin irritation, leg pain). The risk of musculoskeletal injuries because of participating in mobility training is likely no different to the risk posed to those without msTBI with appropriate supervision and programming (i.e., graded volume/intensity). There was good acceptability from multiple stakeholders (including health professionals and adolescents and young adults living with msTBI, and family members of children with msTBI). Data from our audit of paediatric brain injury services in Australia indicated that it is a feasible intervention to deliver in inpatient and post-rehabilitation settings. Implementation support will be needed, especially for health services and professionals working with children and adolescents with higher support needs, such as significant cognitive and behavioural impairments, and/or from other identified subgroups (e.g., children and adolescents from Culturally and Linguistically Diverse communities).

Impact of clinical recommendation

We audited six services delivering rehabilitation to children and adolescents with msTBI across Australia. All services reported delivering mobility training, with all services reporting to have access to up/down plinths, treadmills, bodyweight support harness, stairs, trampette/mini-trampolines, and ankle foot orthoses. Other equipment less commonly reported to be used by the services include walking frames (5/6; 83%), walking sticks (4/6; 67%), transfer belt (4/6; 67%), walking track (4/6; 67%), and virtual reality (1/6; 17%). No services reported having access to or using robotics. It should be considered that specific equipment (e.g., overhead harness) and skills (e.g., movement analysis) may be required to cater for the individual capabilities of each child or adolescent living with msTBI. As indicated by our stakeholder focus groups, these resources may be limited in some settings (e.g., in the community), and as observed in the audit, there is variability between services in the equipment used and outcome measures assessed. The implementation of the recommendations will likely improve consistent delivery of mobility training that is safe and effective at improving critical and important outcomes.

National physical activity clinical practice guidelines may support providers to deliver and funders to fund mobility training for those living in more regional, rural and remote areas that aren't as linked in with specialist brain injury services.

Cost data and cost effectiveness data is not available from any studies in TBI for mobility training. The Guideline Development Group estimated the resource requirements (costs) for this intervention to be moderate, though this is likely dependent on the needs of the child or adolescent with msTBI. For example, whether a child or adolescent with msTBI can independently participate in mobility training, or if they need one-on-one supervision or specific equipment or setting to participate.

Children and adolescents with catastrophic brain injuries due to road traffic accidents may be covered by state insurance schemes (if they meet eligibility criteria) for lifetime care and support. Mobility training, including access to resources such as health professionals, and assistive technology, may be funded by these insurance agencies if assessed as “reasonable and necessary” as per legislation. Children and adolescents with msTBI who are covered by the National Disability Insurance Scheme (NDIS) may have access to some funding to support participation in mobility training if mobility training is identified as a goal by the patient. The provision of a national physical activity clinical practice guideline with recommendations for mobility training will likely support funding requests for funds to support effective mobility training.

Please see **Clinical question 6** in the Technical Report for the full evidence to decision framework that assisted with providing the recommendations for this clinical question.

References

Baque E, Barber L, Sakzewski L, Boyd RN. Randomized controlled trial of web-based multimodal therapy for children with acquired brain injury to improve gross motor capacity and performance. *Clin Rehabil.* 2017; 31(6): 722-732.

Bedell GM, Dumas HM. Social participation of children and youth with acquired brain injuries discharged from inpatient rehabilitation: a follow-up study. *Brain Inj.* 2004; 18(1): 65-82.

Carr JH, Shepherd RB, eds. Neurological rehabilitation. Optimizing motor performance. 2nd edition. Philadephia: Elsevier; 2010.

de Kloet AJ, Berger MAM, Verhoeven AMAJ, van Stein Callenfels K, Vliet Vlieland TPM. Gaming supports youth with acquired brain injury? a pilot study. *Brain Inj.* 2012; 26(7-8): 1021-1029.

Drijkoningen D, Caeyenberghs K, Leunissen I, et al. Training-induced improvements in postural control are accompanied by alterations in cerebellar white matter in brain injured patients. *NeuroImage Clin.* 2015; 7: 240-251.

Fragala MA, Haley SM, Dumas HM, Rabin JP. Classifying mobility recovery in children and youth with brain injury during hospital-based rehabilitation. *Brain Inj.* 2002; 16(2): 149-160.

Katz-Leurer M, Rotem H, Keren O, Meyer S. The effects of a 'home-based' task-oriented exercise programme on motor and balance performance in children with spastic cerebral palsy and severe traumatic brain injury. *Clin Rehabil;* 2009; 23: 714-724.

Kissane AL, Eldridge BJ, Kelly S, Vidmar S, Galea MP, Williams GP. High-level mobility skills in children and adolescents with traumatic brain injury. *Brain Inj.* 2015; 29(13-14): 1711-1716

Novak I, Morgan C, Fahey M, et al. State of the evidence traffic lights 2019: systematic review of interventions for preventing and treating children with cerebral palsy. *Curr Neurol Neurosci Rep.* 2019; 20(3): 1-21.

Sallis JF, Prochaska JJ, Taylor WC. A review of correlates of physical activity of children and adolescents. *Med Sci Sports Exerc.* 2000; 32(5): 963-975.

Victorian Subacute Childhood Stroke Advisory Committee. Guideline for the subacute management of childhood stroke — 2019.

Clinical question 7: Sport and physical recreation for adults and older adults with moderate to severe traumatic brain injury

Clinical question: Should **sport and physical recreation** compared to control be used for **adults and older adults** after moderate to severe traumatic brain injury?

Setting: Healthcare settings across the continuum of care:

- Inpatient, transition and outpatient rehabilitation settings
- Community settings (e.g., fitness centres, sporting fields, community centres)
- Home

Perspective: Health systems

Critical outcomes of interest:

- Social connection
- Participation
- Mood

Important outcomes of interest:

- Physical activity
- Co-morbidities and mortality
- Quality of life
- Cardiorespiratory fitness

Key definitions:

- Adults: ≥ 18 years
- Older adults: ≥ 65 years
- Sport: 'an activity involving physical exertion, skill and/or hand–eye co-ordination as the primary focus of the activity, with elements of competition where rules and patterns of behaviour governing the activity exist formally through organisations' (Pink, 2008).
- Physical recreation: 'an activity or experience that involves varying levels of physical exertion, prowess and/or skill, which may not be the main focus of the activity, and is voluntarily engaged in by an individual in leisure time for the purpose of mental and/or physical satisfaction' (Pink, 2008).

Clinical need for question

Meeting the physical activity guidelines (i.e., 150-300-min/week MVPA) is associated with a 19%–25% lower risk of all-cause mortality, cardiovascular disease, and non-cardiovascular disease mortality (Lee, et al., 2022). People living with msTBI generally have decreased participation in leisure and social activities after injury compared to pre-injury (Ponsford et al., 2014), and exhibit inadequate levels of physical activity (Hamilton et al., 2016; Wise et al., 2010; Reavenall et al., 2010). People living with msTBI experience higher rates of comorbid conditions, which are associated with higher rates of mortality (Izzy et al., 2022). The risk of social isolation, low mood, and reduced life satisfaction are heightened by physical inactivity (Schrempft et al., 2019).

Sport and physical recreation are physical activities suitable for people of all ages and abilities. Many adults and older adults with msTBI likely were participating in, or had previously participated in, sport and/or physical recreation prior to their injury and may wish to return to the same or a different type of sport and/or physical recreation post-injury. But due to their injury, they may need assistance from a health professional to identify appropriate activities and provide skill training in preparation to participate. Health professionals may also liaise with community sport and recreation providers to identify possible equipment and adaptations to encourage and enhance participation.

Summary of evidence

Direct evidence:

There were three RCTs and two NRSIs that reported on sport and/or physical recreation for adults with msTBI. The interventions investigated were tai chi, yoga, and a mixed sport and physical activity program. Of the seven outcomes identified as critical or important in this clinical practice guideline, four (i.e., social connection, participation, comorbidities and mortality, and cardiorespiratory fitness) were not measured in any of the included studies.

Sport and physical recreation had a small but uncertain effect on mood. For two RCTs, we pooled the data on the immediate effect that sport and physical recreation had on mood. The meta-analysis indicated the intervention had a small, non-significant reduction on depression (SMD: -0.22; 95% CI: -1.25 to 0.81; I2 = 73%; very low certainty evidence). In a NRSI of a sport and physical recreation intervention, participants allocated to the intervention experienced a small, but non-significant reduction, in depression compared to control participants (MD: -0.26 points; 95% CI: -0.74 to 0.23 points; very low certainty evidence). There was no clear long-term effect of sport and physical recreation on mood (MD: 1.10 points 95% CI: -4.31 to 6.51 points; very low certainty evidence).

One NRSI measured the effect of a sport and physical recreation intervention on time in sedentary behaviour, which might be considered as a proxy measure of physical activity (i.e., less time in sedentary behaviour = more time spent physically active). Participants allocated to the sport and physical recreation intervention reported less sedentary behaviour compared to control participants at end of intervention (MD: -104 mins/day; 95% CI: -195.27 to -12.73 mins/day; very low certainty evidence).

Quality of life was measured at end of intervention in one RCT and two NRSIs. In the RCT, participants allocated to the intervention improved their quality of life compared to control participants, though the CIs and small sample size (i.e., n=18) indicate uncertainty and suggest imprecision around the estimate of effect (SMD: 0.50; 95% CI: -0.44 to 1.45; very low certainty evidence). In the two NRSIs, participants allocated to the intervention improved their quality of life compared to the control participants (SMD: 0.61; 95% CI: 0.18 to 1.05; very low certainty evidence).

Indirect evidence:

In a Cochrane review, including two RCTs and 79 participants, there was insufficient evidence to suggest yoga is an effective intervention for improving health outcomes after stroke (Lawrence et al., 2017). However, a systematic review including 21 studies and 1,293 participants found Tai Chi can have positive effects on walking ability, balance, and mobility in people with stroke (Lyu et al., 2018).

Please see **Clinical question 7** in the Technical Report for detailed study characteristics and meta-analyses that assisted with providing the evidence base for this clinical question.

Recommendations

	Type	Recommendation	GRADE/Quality
7		**Sport and physical recreation for adults and older adults with moderate to severe traumatic brain injury**	
7.1	**EBR**	For adults and older adults after moderate to severe traumatic brain injury, we suggest participation in sport and physical recreation across the continuum of care considering their personal preference and capability.	❖❖❖ ⊕◯◯◯
We suggest the following Good Practice Points (GPP) and Precautionary Points (PP):			
7.2	**GPP**	Health professionals consider what sport and/or physical recreation the adult enjoyed and participated in prior to their brain injury when developing their rehabilitation program. Pre-injury activities may be a facilitator or may cause distress if physical, cognitive, or behavioural impairments restrict participation.	
7.3	**GPP**	Health professionals consider all aspects of the inclusion spectrum when suggesting options for sport and/or physical recreation.	
7.4	**GPP**	Health professionals establish relationships and work with external service providers to facilitate access and opportunities for their clients to participate in sport and/or physical recreation.	
7.5	**GPP**	Health professionals support the adult to facilitate participation in sport and/or physical recreation, including supporting preparation of funding requests, and identifying modifications, support, and adaptive or specialised equipment necessary to ensure the safety and appropriateness of the activity.	
7.6	**PP**	A knock to the head from sport participation may cause a second brain injury. Risk vs. benefit should be considered and discussed by the interdisciplinary team and advice provided to the adult and their family (if appropriate).	

Justification

Adults and older adults after msTBI experience low levels of physical activity, which is associated with higher rates of comorbid conditions and mortality, and often don't return to pre-injury leisure activities, including sport and recreation. Sport and physical recreation programs can provide opportunities to be physically active in a safe, social, and supportive environment. On the balance of small desirable and small undesirable effects (no serious adverse events reported, although this was not reported in all studies), and little uncertainty about the value of the main outcomes, participating in sport and physical recreation is probably favoured over the alternative. The cost of the required resources likely varies depending on the needs and wants of the adult after msTBI. We found good acceptability of the WHO physical activity and sedentary behaviour guidelines recommended levels of 150-300-min of moderate-vigorous physical activity from multiple stakeholders, but additional support/equipment may be needed to achieve this. It is likely feasible in rehabilitation and community-based settings when health professionals either deliver the intervention or work with external providers to deliver the intervention. Further work on implementation is needed to ensure suitability, acceptability, and effectiveness on delivering these interventions, particularly to those subgroups we have identified as needing additional support (e.g., adults and older adults with high support needs).

Impact of clinical recommendation

The inclusion of recommendations for sport and physical recreation are likely to increase health professionals' awareness of this intervention to consider for individuals who indicate an interest in participating in this type of physical activity. This intervention is not routinely delivered by healthcare services across Australia. Of the 21 adult services audited, only 10 (48%) services report delivering sport and physical recreation as part of their service. Referral out to community providers was also not routinely conducted. Of the 26 adult and paediatric brain injury services audited, 18 referred to community fitness centres, between 10-18 referred to various recreational groups, and between 1-7 to various sport programs.

Compared to the other interventions recommended in this guideline, the recommendation for sport and physical recreation will require the most support to implement change. This is in part because appropriate opportunities for sport and physical recreation may not be available in the community for health professionals to refer individuals with msTBI to, and thus pose a challenge for putting these recommendations into action.

An important aspect for health professionals when considering sport and physical recreation for their patients/clients is the inclusion spectrum, which places the inclusiveness of sport and physical recreation activities along a spectrum. The inclusion spectrum provides a range of options for how a person with disability can participate in sport and physical recreation activities depending on their needs, goals, and capabilities. Each element of the spectrum should be considered equally as important as the next, and ideally there would be activities on offer for all people with msTBI to choose from across all elements. A version of the Inclusion Spectrum was devised by the Australian Sports Commission (ASC). It includes six categories for how sport and/or physical recreation can be offered for people with a disability: no modifications, minor modifications, major modifications, primarily for people with disability, only for people with disability, non-playing role.

Cost data and cost effectiveness data is not available from any studies in TBI for sport and physical recreation. The cost of the required resources likely varies depending on the needs and wants of the person with msTBI. For example, if the person with msTBI can independently participate in a low-cost sport or physical recreation, such as walking, then the resource requirements are likely minimal. If, however, they need one-on-one supervision or specific equipment and/or setting to facilitate their sport or physical recreation e.g., ski equipment, and ski pass, then the resource requirements are likely larger.

Please see **Clinical question 7** in the Technical Report for the full evidence to decision framework that assisted with providing the recommendations for this clinical question.

References

Australian Bureau of Statistics: *Defining sport and physical activity, a conceptual model*. 2008, Canberra: Australian Bureau of Statistics.

Australian Institute of Health and Welfare. *Australian Burden of Disease Study: Impact and causes of illness and death in Australia 2018*. AIHW. 2021.

Blake H, Batson M. Exercise intervention in brain injury: a pilot randomized study of Tai Chi Qigong. *Clin Rehabil.* 2009; 23(7): 589-598.

Donnelly KZ, Baker K, Pierce R, et al. A retrospective study on the acceptability, feasibility, and effectiveness of loveyourbrain yoga for people with traumatic brain injury and caregivers. *Disabil Rehabil.* 2021; 43(12): 1764-1775.

Donnelly KZ, Linnea K, Grant DA, Lichtenstein J. The feasibility and impact of a yoga pilot programme on the quality-of-life of adults with acquired brain injury, *Brain Inj.* 2017;31(2): 208-214.

Gemmell C, Leathem JM. A study investigating the effects of tai chi chuan: Individuals with traumatic brain injury compared to controls. *Brain Inj.* 2006; 20(2): 151-156.

Hamilton M, Khan M, Clark R, et al., Predictors of physical activity levels of individuals following traumatic brain injury remain unclear: a systematic review. *Brain Inj*. 2016; 30(7): 819-828.

Hwang H-F, Chen C-Y, Chen S-J, et al. Effects of computerized cognitive training and tai chi on cognitive performance in older adults with traumatic brain injury. *J Head Trauma Rehabil*. 2020; 35(3): 187-197.

Izzy S, Chen PM, Tahir Z, et al. Association of traumatic brain injury with the risk of developing chronic cardiovascular, endocrine, neurological, and psychiatric disorders. *JAMA Netw Open*. 2022; 5: e229478.

Jerome GJ, Boyer WR, Bustamante EE, et al. Increasing equity of physical activity promotion for optimal cardiovascular health in adults: a scientific statement from the American heart association. *Circulation.* 2023; 147: 1951-1962.

Kiuppis F. Inclusion in sport: disability and participation. *Sport Soc.* 2018; 21(1): 4-21.

Lawrence M, Celestino Junior FT, Matozinho HHs, et al. Yoga for stroke rehabilitation. *Cochrane Database Syst Rev.* 2017; 12(12): CD011483.

Lee DH, Rezende LFM, Joh H-K, et al. Long-term leisure-time physical activity intensity and all-cause and cause-specific mortality: a prospective cohort of US adults. *Circulation.* 2022; 146(7): 523-534.

Lyu D, Lyu X, Zhang Y, et al. Tai chi for stroke rehabilitation: a systematic review and meta-analysis of randomized controlled trials. *Front Physiol*. 2018; 9: 983.

Pérez-Rodríguez M, García-Gómez S, Coterón J, et al. Physical activity and sport for acquired brain injury (PASABI): a non-randomized controlled trial. *Medicina*. 2021, 57(2): 122.

Quilico EL, Alaire C, Swaine BR, Colantonio A. Characteristics, outcomes, sex and gender considerations of community-based physical activity interventions after moderate-to-severe traumatic brain injury: scoping review. *Brain Inj.* 2022; 36(3): 295-305.

Quilico EL, Harvey WJ, Caron JG, Bloom GA. Interpretative phenomenological analysis of community exercise experiences after severe traumatic brain injury. *Qual Res Sport Exerc Health.* 2021; 13(5): 800-815.

Reavenall S, Blake H. Determinants of physical activity participation following traumatic brain injury. *Int J Ther Rehabil*. 2010; 17(7): 360-369.

Saunders DH, Sanderson M, Hayes S, et al. Physical fitness training for stroke patients. *Cochrane Database Syst Rev.* 2020; Issue 3. Art. No: CD003316. DOI: 10.1002/14651858.CD003316.pub7.

Schrempft S, Jackowska M, Hamer M, Steptoe A. Associations between social isolation, loneliness, and objective physical activity in older men and women. *BMC Public Health*. 2019; 19(1): 74.

World Health Organisation. *Global action plan on physical activity 2018–2030: more active people for a healthier world*. Geneva: World Health Organization; 2018

Wise EK, Mathews-Dalton C, Dikmen S, et al. Impact of traumatic brain injury on participation in leisure activities. *Arch Phys Med Rehabil*. 2010; 91(9): 1357-1362.

Clinical question 8: Sport and physical recreation for children and adolescents with moderate to severe traumatic brain injury

Clinical question: Should **sport and physical recreation** compared to control be used for **children and adolescents** after moderate to severe traumatic brain injury?

Setting: Healthcare settings across the continuum of care:

- Inpatient, transition and outpatient rehabilitation settings
- Community settings (e.g., fitness centres, sporting fields, community centres)
- Home
- Schools

Perspective: Health systems

Critical outcomes of interest:

- Social connection
- Participation
- Mood

Important outcomes of interest:

- Physical activity
- Co-morbidities and mortality
- Quality of life
- Cardiorespiratory fitness

Key definitions:

- Children and adolescents: 5 to 17 years
- Sport: 'an activity involving physical exertion, skill and/or hand–eye co-ordination as the primary focus of the activity, with elements of competition where rules and patterns of behaviour governing the activity exist formally through organisations' (Pink, 2008).
- Physical recreation: 'an activity or experience that involves varying levels of physical exertion, prowess and/or skill, which may not be the main focus of the activity, and is voluntarily engaged in by an individual in leisure time for the purpose of mental and/or physical satisfaction' (Pink, 2008).

Clinical need for question

The benefits of physical activity for children and adolescents are wide-ranging and well documented (Biddle et al., 2004). The WHO physical activity and sedentary behaviour guidelines recommend children and adolescents aged 5–17 years should accumulate at least 60 minutes per day of MVPA, on average, and incorporate vigorous-intensity aerobic activities as well as muscle and bone strengthening activities at least three days per week (WHO, 2020). Globally, children and adolescents have low levels of physical activity (Aubert et al.,2022), and children and adolescents with msTBI are even less physically active than their non-brain injured peers (Katz-Leurer et al., 2010). Low levels of physical activity can have negative consequences after msTBI, including physical deconditioning, compromised aerobic capacity, and functional impairment, and can lead to chronic health conditions later in life (Hamel et al., 2019).

Sport and physical recreation are physical activities suitable for people of all ages and abilities. It is likely that school aged children and adolescents with msTBI were participating in, or had previously participated in, sport and/or physical recreation activities prior to their injury and may wish to return to the same or a different type of sport and/or physical recreation post-injury. Sport and physical recreation also provide children and adolescents important opportunities to socialise with their peers. But due to their injury, they may need assistance from a health professional to identify appropriate activities and provide skill training in preparation to participate. Health professionals may also liaise with community sport and recreation providers to identify possible equipment and adaptations to encourage and enhance participation.

Summary of evidence

Direct evidence:

There was no direct evidence to guide this judgement in children and adolescents in msTBI research. Thus, evidence for sport and physical recreation was drawn from evidence in adults with msTBI (three RCTs and two NRSIs) and from the WHO physical activity and sedentary behaviour guidelines for people living with disability (Carty et al., 2021).

Indirect evidence:

For adults with msTBI, sport and physical recreation had a small, non-significant effect on mood, though there appears to be a slight indication that sport and physical recreation can improve mood in adults after msTBI. There was no clear long-term effect of the intervention on mood. A sport and physical recreation intervention may reduce time spent in sedentary behaviour and improve quality of life, though the evidence is limited and has a very low certainty. No studies in adults with msTBI measured social connection, participation, comorbidities and mortality, or cardiorespiratory fitness.

The WHO physical activity and sedentary behaviour guideline development group considered evidence for children living without disability, and evidence for physical activity for children living with intellectual disability and children with attention deficit hyperactivity disorder (ADHD) (Carty et al., 2021). They found that evidence from children living without disability could be extrapolated for key favourable outcomes, including cardiorespiratory and muscular fitness, and mental health. They also found that there were improvements in physical function (low certainty evidence) in children with intellectual disability and improvements in cognition (moderate certainty evidence) in children with ADHD. Thus, the WHO physical activity and sedentary behaviour guidelines recommend that children and adolescents (aged 5 to 17 years) living with a disability:

- should participate in at least an average of 60 minutes per day of moderate to vigorous intensity, mostly aerobic, physical activity, across the week *(Strong recommendation, moderate certainty evidence).*
- should participate in vigorous-intensity aerobic activities, as well as those that strengthen muscle and bone should be incorporated at least three days a week *(Strong recommendation, moderate certainty evidence).*

Please see **Clinical question 8** in the Technical Report for detailed study characteristics and meta-analyses that assisted with providing the evidence base for this clinical question.

Recommendations

	Type	Recommendation	GRADE/Quality
8		**Sport and physical recreation for children and adolescents with moderate to severe traumatic brain injury**	
8.1	**EBR**	For children and adolescents after moderate to severe traumatic brain injury, we suggest participation in sport and physical recreation across the continuum of care considering their personal preference and capability.	❖❖❖
We suggest the following Good Practice Points (GPP) and Precautionary Points (PP):			
8.2	**GPP**	Health professionals consider what sport and/or physical recreation the child or adolescent enjoyed and participated in prior to their brain injury when developing their rehabilitation program. Pre-injury activities may be a facilitator or may cause distress if physical, cognitive, or behavioural impairments restrict participation.	
8.3	**GPP**	Health professionals consider all aspects of the inclusion spectrum when suggesting options for sport and/or physical recreation.	
8.4	**GPP**	Health professionals establish relationships and work with external service providers to facilitate access and opportunities for their clients to participate in sport and/or physical recreation.	
8.5	**GPP**	Health professionals support the child or adolescent and their family to facilitate participation in sport and/or physical recreation, including supporting preparation of funding requests, and identifying modifications, support, and adaptive or specialised equipment necessary to ensure the safety and appropriateness of the activity.	
8.6	**PP**	A knock to the head from sport participation may cause a second brain injury. Risk vs. benefit should be considered and discussed by the interdisciplinary team and advice provided to the child or adolescent and their family.	

Justification

Children and adolescents after msTBI have high levels of physical inactivity, which can have negative consequences, including physical deconditioning, compromised aerobic capacity, and functional impairment, and can lead to chronic health conditions later in life. The WHO physical activity and sedentary behaviour guidelines strongly recommend children and adolescents (aged 5 to 17 years) living with disability to do at least an average of 60 minutes per day of moderate to vigorous intensity, mostly aerobic, physical activity, across the week. Participation in sport or physical recreation is an age-appropriate way for children and adolescents with msTBI to achieve some or all of WHO guideline recommendations, and socialise with their peers. On balance, only trivial or small undesirable effects are likely and potentially moderate desirable effects on critical and important outcomes. There was good acceptability from multiple stakeholders, although recognition that sport and physical recreation may not be a preference for all, and individual preferences should be considered. It is likely feasible in rehabilitation and community-based settings when health professionals either deliver themselves, or work with external providers to deliver, sport and physical recreation activities. Further work on implementation is needed to ensure suitability, acceptability, and effectiveness on delivering these interventions, particularly to those subgroups we have identified as needing additional support (i.e., children and adolescents with high support needs).

Impact of clinical recommendation

The inclusion of recommendations for sport and physical recreation are likely to increase health professionals' awareness of this intervention to consider for individuals who indicate an interest in participating in this type of physical activity. Sport and physical recreation activities are more commonly delivered or referred to by health professionals working in paediatric rehabilitation than adult rehabilitation. Of the 21 adult services audited, only 10 (48%) services report delivering sport and physical recreation as part of their service. For the six paediatric services, five (83%) reported providing sport and physical recreation. Referral out to community providers was also routinely conducted and was less likely for sport than physical recreation. Of the 26 services audited, 18 referred to community fitness centres, between 10-18 to various recreational groups, and between 1-7 to various sport programs.

Compared to the other interventions recommended in this guideline, the recommendation for sport and physical recreation will require the most support to implement change. Although paediatric health professionals are more likely to provide sport and recreation activities or refer to community-based activities, appropriate opportunities for sport and physical recreation need to be available in the community for health professionals to refer children and adolescents with msTBI to. But suitable services do not always exist, which poses a distinct challenge to putting these recommendations into action. School settings also have potential barriers to the implementation of the recommendations. The importance of physical activity interventions for children living with disabilities is not always seen as a priority, while health professionals may experience challenges in accessing children and adolescents in the school setting.

An important aspect for health professionals when considering sport and physical recreation for their patients/clients is the inclusion spectrum, which places the inclusiveness of sport and physical recreation activities along a spectrum. The inclusion spectrum provides a range of options for how a person with disability can participate in sport and physical recreation activities depending on their needs, goals, and capabilities. Each element of the spectrum should be considered equally as important as the next, and ideally there would be activities on offer for all people with msTBI to choose from across all elements. A version of the Inclusion Spectrum was devised by the Australian Sports Commission (ASC). It includes six categories for how sport or physical recreation can be offered for people with a disability: no modifications, minor modifications, major modifications, primarily for people with disability, only for people with disability, non-playing role.

Cost data and cost effectiveness data is not available from any studies in msTBI for sport and physical recreation. The cost of the required resources likely varies depending on the needs and wants of the person with msTBI. For example, if the person with TBI can independently participate in a low-cost sport or physical recreation, such as walking, then the resource requirements are likely minimal. If, however, they need one-on-one supervision or specific equipment or setting to facilitate their sport or physical recreation e.g., ski equipment, and ski pass, then the resource requirements are likely larger.

Please see **Clinical question 8** in the Technical Report for the full evidence to decision framework that assisted with providing the recommendations for this clinical question.

References

Australian Bureau of Statistics: *Defining sport and physical activity, a conceptual model*. 2008, Canberra: Australian Bureau of Statistics.

Aubert S, Barnes JD, Demchenko I, et al. Global matrix 4.0 physical activity report card grades for children and adolescents: results and analyses from 57 countries. *J Phys Act Health*. 2022; 19(11): 700-728.

Biddle SJ, Gorely T, Stensel DJ. Health-enhancing physical activity and sedentary behaviour in children and adolescents. *J Sports Sci*. 2004; 22(8): 679-701.

Carty C, van der Ploeg HP, Biddle SJ, et al. The first global physical activity and sedentary behavior guidelines for people living with disability. *J Phys Act Health*. 2021; 18(1): 86–93.

Hamel RN, Smoliga JM. Physical activity intolerance and cardiorespiratory dysfunction in patients with moderate-to-severe traumatic brain injury. *Sports Med*. 2019; 49(8): 1183-1198.

Jerome GJ, Boyer WR, Bustamante EE, et al. Increasing equity of physical activity promotion for optimal cardiovascular health in adults: A scientific statement from the American heart association. *Circulation.* 2023; 147(25): 1951-1962.

Katz-Leurer M, Rotem H, Keren O, Meyer S. Recreational physical activities among children with a history of severe traumatic brain injury. *Brain Inj.* 2010; 24(13-14): 1561-1567.

Kiuppis F. Inclusion in sport: disability and participation. *Sport Soc.* 2018; 21(1): 4-21.

McKinney J, Lithwick DJ, Morrison BN, et al. The health benefits of physical activity and cardiorespiratory fitness. *B C Med J*. 2016; 58(3): 131-137.

Ryan JM, Cassidy EE, Noorduyn SG, O'Connell NE. Exercise interventions for cerebral palsy. *Cochrane Database Syst Rev*. 2017; 6(6): CD011660.

World Health Organisation. *Global action plan on physical activity 2018–2030: more active people for a healthier world*. Geneva: World Health Organization; 2018.

World Health Organisation. *WHO guidelines on physical activity and sedentary behaviour.* Geneva: World Health Organization; 2020.

Clinical question 9: Overall physical activity promotion for adults and older adults with moderate to severe traumatic brain injury

Clinical question: Should **overall physical activity promotion** compared to control be used for **adults and older adults** after moderate to severe traumatic brain injury?

Setting: Healthcare settings across the continuum of care:

- Inpatient, transition and outpatient rehabilitation settings
- Community settings (e.g., fitness centres, sporting fields, community centres)
- Home

Perspective: Health systems

Critical outcomes of interest:

- Physical activity
- Social connection
- Behaviour change
- Quality of life
- Co-morbidities and mortality
- Participation
- Mood

Key definitions:

- Adults: ≥ 18 years
- Older adults: ≥ 65 years
- Overall physical activity promotion: Interventions that promote overall physical activity (incidental and planned), such as health coaching, pedometer programs, lifestyle/health and wellness programs.

Clinical need for question

Physical inactivity is a global health problem causing 5.3 million deaths per year and costing healthcare systems $53.8 billion worldwide in 2008 (Lee et al., 2012). Those who are most profoundly inactive account for a disproportionately high percentage of the deaths and healthcare costs that are attributable to physical inactivity, thus strategies which target those that are physically inactive are required.

People with msTBI are particularly inactive in the long-term, increasing the risk of preventable disease and compounding the primary effects of the TBI. A USA-based cohort study with 472 participants found that 55% of adults after msTBI did not meet physical activity guidelines, and this was worse for adults aged 45+ years (68%) (Pham et al., 2022). In a cohort of 160 people with msTBI, >80% of study participants had not returned to pre-injury leisure participation at 12-months post-injury, with pre-injury physical activity participation replaced by sedentary activity (i.e., watching television) (Wise et al., 2010). In a systematic review intended to identify predictors of physical activity post-TBI, Hamilton et al. (2017) reported the physical activity levels of the TBI participants in the six studies included in the review were below that required for general health maintenance.

The WHO Global Action Plan on Physical Activity (GAPPA) has set a target of a 15% relative reduction in the global prevalence of physical inactivity in adults and adolescents by 2030. To achieve this target, the GAPPA sets out 20 policy actions, with action 3.2 most pertinently recommending countries implement and strengthen physical activity assessment and counselling as part of universal health care. Thus, health professionals supporting adults and older adults after msTBI to identify and engage in activities that increase overall physical activity, and reduce time spent physically inactive, is critical to avoiding secondary complications and preventing the health risks associated with sedentary behaviour.

Summary of evidence

Direct evidence:

Two RCTs (Brenner et al., 2012; Driver et al., 2023), one crossover RCT (Bellon et al., 2015; Kolakowsky-Hayner et al., 2017 - two articles from the same study), and two NRSIs (Clanchy 2016; Driver 2016) reported on the effects of interventions characterised as activities that can increase overall participation in physical activity by adults after msTBI. Of the seven outcomes identified as critical or important in the physical activity clinical practice guideline, two (i.e., social connection and quality of life) were not measured, while behaviour change and composite mobility were measured, but the data was not reported for these outcomes in the included studies.

Clanchy et al. (2016) compares the effects of a12-week physical activity intervention (stage matched behaviour change activities, exercise prescription, community access facilitation and relapse prevention strategies) to a non-active control in 43 adults with acquired brain injury, including 21 people with msTBI. The intervention effectively increased adoption of physical activity (time in MVPA; MD: 13 min/day; 95% CI: 1 to 25 min/day), but the change was not maintained at follow-up. While Driver et al. (2016) reported on a quasi-experimental trial in which 47 people with brain injury (19 msTBI, 28 stroke) in a transitional outpatient setting were consecutively enrolled into an 8-week informational, social, and behavioural program aimed at facilitating increased activity for 6-months or a usual care control group (following six months). The intervention effectively increased the amount of time in MVPA more than control group (time in MVPA; MD: 24 min/week; 95% CI: 17 to 31 min/week), and this difference was maintained at follow up (time in MVPA; MD: 23 min/week; 95% CI: 17 to 30 min/week).

Data from these two NRSI were pooled to evaluate the immediate effect of physical activity promotion programs on physical activity data (device-based measure of time in MVPA in mins/day (Clanchy et al., 2016) and self-reported mins/week (Driver et al., 2016). The meta-analysis indicated the intervention had a large positive effect on physical activity (SMD: 2.66; 95% CI: 1.18 to 4.15; I2 = 84%; two studies, 90 participants; very low certainty evidence). The effect was maintained (though marginally reduced) at end of follow-up (SMD: 1.37; 95% CI: 0.28 to 2.46; I2 = 81%; two studies, 90 participants; very low certainty evidence).

In Driver et al. (2023), 54 people with msTBI were randomised to a 12-month Diabetes Prevention Program Group Lifestyle Balance for TBI (GLB-TBI) (a weight-loss intervention) or an attention control group. Using blood pressure as a proxy measure for comorbidities and mortality, there was no clear effect of the intervention on systolic blood pressure (MD: -1.20 mmHg; 95% CI: -9.73 to 7.33 mmHg; moderate certainty evidence). Bellon et al. (2015) and Kolakowsky-Hayner et al. (2017) report on a cross-over RCT (n=123), in which participants were randomised to a 12-week home-based walking programme or a nutrition coaching control group. Bellon et al. (2015) reported on 69 participants with TBI, including 45 with msTBI. There was no clear effect of the intervention on mood at end of intervention (MD: -3.11 points; 95% CI: -8.11 to 1.89points; very low certainty evidence). Kolakowsky-Hayner et al. (2017) reported an increase in physical activity, as measured by step counts, but there was no between group difference in steps/days (mean increase across the two groups = 1857 daily steps).

In the Driver et al., (2016) NRSI, there was a small positive effect of an overall physical activity promotion intervention on participation at end of intervention (MD: -4.49; 95% CI: -8.56 to -0.42; very low certainty evidence) and at end of follow-up (MD: -5.70; 95% CI: -9.36 to -2.02; very low certainty evidence).

Indirect evidence:

The WHO physical activity and sedentary behaviour guidelines for people living with disability (Carty et al., 2021) do not provide any specific evidence about the promotion of overall physical activity. They do suggest the following Good Practice Point for adults and older adults living with disability: *There are no major risks to adults living with disability engaging in physical activity when it is appropriate to the individual's current activity level, health status, and physical function; and when the health benefits accrued outweigh the risks.*

Please see **Clinical question 9** in the Technical Report for detailed study characteristics and meta-analyses that assisted with providing the evidence base for this clinical question.

Recommendations

	Type	Recommendation	GRADE/Quality
9		**Overall physical activity promotion for adults or older adults with moderate to severe traumatic brain injury**	
9.1	**EBR**	For adults and older adults after moderate to severe traumatic brain injury, we suggest the promotion of physical activity across the continuum of care.	❖❖❖ ⊕⊕○○
We suggest the following Good Practice Points (GPP):			
9.2	**GPP**	Physical activity is promoted with consideration of current public health physical activity guideline recommendations for adults and older adults living with disability.	
9.3	**GPP**	Health professionals initiate conversations with clients about a return to physical activity as early as possible, mindful of the potential for the early rehabilitation phase of recovery to be an opportune time to establish short and long-term goals, positive behaviours, and support systems.	
9.4	**GPP**	Pre-injury physical activity is assessed, and health professionals consider building on what the adult has done before (i.e., supporting a return to previous activity).	

	Type	Recommendation	GRADE/Quality
9.5	**GPP**	Key aspects of the promotion of overall physical activity include exploring the clients understanding of the benefits of physical activity, identification of goals, utilising evidence-based behaviour change techniques to support self-management, and implementing activities that broadly encourage physical activity.	
9.6	**GPP**	Health professionals seek to identify barriers to engaging in physical activity and implement strategies to support the uptake of physical activity.	
9.7	**GPP**	Physical activity is incorporated into weekly routines and key supports (e.g., family, friends, and support workers) are trained in facilitating opportunities for activity where appropriate.	

Justification

Physical inactivity is a critical problem leading to health complications secondary to brain injury and premature death. Adults and older adults living with disability from msTBI face multiple barriers to being physically active and may benefit from assistance from health professionals to overcome these barriers. The promotion of physical activity can improve physical activity levels and participation, however the certainty of evidence for these outcomes was very low. No adverse events occurred in two of the three RCTs; the third RCT reported adverse events, but these were deemed not related to the intervention by the study authors. The NRSIs reported on above did not report on adverse events.

On the balance of risk vs. benefit, interventions that promote overall physical activity are probably favoured. The promotion of overall physical activity probably increases equity by benefiting underserved populations and empowering disadvantaged populations, including the subgroups we have identified in this guideline needing further support. Promotion of physical activity within rehabilitation is feasible and needed to support adults with msTBI to overcome barriers and identify and navigate suitable and preferable community-based physical activity options beyond rehabilitation.

Impact of clinical recommendation

Tailored physical activity promotion interventions need to consider personal (i.e., levels of fatigue, physical conditioning, sensory sensitivity) and accessibility (i.e., appropriate equipment, safety and support, and environment) factors. Identifying opportunities for adults and older adults with msTBI to be physically active in a social environment, undertaking motivating, interesting, and enjoyable activities is likely important for long-term adherence to physical activity. Advice/input from a neuropsychologist or other relevant health professional may be required to assist with managing cognitive/behavioural impairment if necessary.

It is feasible for health professionals such as physiotherapists and exercise physiologists to promote physical activity within rehabilitation. We audited 21 services delivering rehabilitation to adults and/or older adults with msTBI across Australia. Fifteen services (71%) report assessing whether patients are meeting physical activity guidelines as a part of standard practice, though 86% report assessing their patient's physical activity levels. A high proportion (95%) of services report providing advice about the benefits of physical activity, while 81% and 90% discuss the physical activity guidelines and the type and dose of physical activity recommended, respectively, as standard practice. The implementation of the recommendations will likely improve consistent delivery of promotion of physical activity that is safe and effective at improving critical and important outcomes.

The clinical audit also identified barriers that services report limit their promotion of overall physical activity. The majority of services identified knowledge (58% of services) and skills (54%) as their main barrier to promoting physical activity to adults and older adults with msTBI. This would indicate that education and training would be a critical component of an implementation plan to effectively implement this recommendation into practice.

The Australian public health physical activity guidelines do not currently provide recommendations for adults and older adults living with disability. The WHO physical activity and sedentary behaviour guidelines for adults living with disability (Carty et al., 2021) recommend:

- 150-300 mins per week of moderate physical activity (or 75-150 mins of vigorous physical activity).
- Strength training at least twice per week involving major muscle groups.
- Functional balance and strength training on at least three days per week for older adults with disability.
- Limit the time being sedentary.

The WHO guidelines also provide good practice points that are very important for people with disability who are not able to reach the physical activity recommendations. They include that doing some activity is better than none, to start off slow and gradually increase (i.e., time and/or intensity of physical activity) with increasing tolerance, and seek the help of a health professional or physical activity expert if needed.

Costs data and cost effectiveness data is not available from any studies evaluating the promotion of overall physical activity in people with msTBI. The promotion of overall physical activity to adults after msTBI should include assessment of physical activity levels, providing information about the benefits of physical activity and meeting physical activity public health guidelines, collaboratively setting physical activity goals, and using behaviour change techniques to support physical activity uptake and maintenance. The resource requirements to promote overall physical activity are likely to be low cost and could be covered as part of standard care for health professionals. A reduction in population level physical inactivity is likely to be cost saving for health system.

Please see **Clinical question 9** in the Technical Report for the full evidence to decision framework that assisted with providing the recommendations for this clinical question.

References

Bellon K, Kolakowsky-Hayner S, Wright J, et al. A home-based walking study to ameliorate perceived stress and depressive symptoms in people with a traumatic brain injury. *Brain Inj.* 2015; 29(3): 313-319.

Brenner LA, Braden CA, Bates M, et al., A health and wellness intervention for those with moderate to severe traumatic brain injury: a randomized controlled trial. *J Head Trauma Rehabil*. 2012; 27(6): E57-68.

Carty C, van der Ploeg HP, Biddle SJ, et al. The first global physical activity and sedentary behavior guidelines for people living with disability. *J Phys Act Health*. 2021; 18(1): 86-93.

Clanchy KM, Tweedy SM, Trost SG. Evaluation of a physical activity intervention for adults with brain impairment: a controlled clinical trial. *Neurorehabil Neural Repair.* 2016; 30(9): 854-865.

Driver S, McShan E, Swank C, et al., Efficacy of the diabetes prevention program group lifestyle balance program modified for individuals with TBI (GLB-TBI): results from a 12-month randomized controlled trial. *Ann Behav Med*. 2023; 57(2): 131-145.

Driver S, Woolsey A. Evaluation of a physical activity behavior change program for individuals with a brain injury. *Arch Phys Med Rehabil*. 2016; 97(9 Suppl 3): S194-200.

Hamilton M, Khan M, Clark R, et al., Predictors of physical activity levels of individuals following traumatic brain injury remain unclear: a systematic review. *Brain Inj*. 2016; 30(7): 819-828.

Jerome GJ, Boyer WR, Bustamante EE, et al. Increasing equity of physical activity promotion for optimal cardiovascular health in adults: A scientific statement from the American heart association. *Circulation.* 2023; 147: 1951-1962.

Jones TM, Dear BF, Hush JM, et al. myMoves program: feasibility and acceptability study of a remotely delivered self-management program for increasing physical activity among adults with acquired brain injury living in the community. *Phys Ther.* 2016; 96(12): 1982-1993.

Lee, I.M.; Shiroma, E.J.; Lobelo, F.; et al., Effect of physical inactivity on major non-communicable diseases worldwide: an analysis of burden of disease and life expectancy. *Lancet*, 2012. 380(9838): 219-29.

Kolakowsky-Hayner SA, Bellon K, Toda K, et al. A randomised control trial of walking to ameliorate brain injury fatigue: a NIDRR TBI model system centre-based study. *Neuropsychol Rehabil*. 2017; 27(7): 1002-1018.

Michie S, Abraham C, Whittington C, et al. Effective techniques in healthy eating and physical activity interventions: a meta-regression. *Health Psychol*. 2009; 28(6): 690-701.

Morris JH, MacGilvray S, McFarlane S. Interventions to Promote Long-Term Participation in Physical Activity After Stroke: A Systematic Review of the Literature. *Arch Phys Med Rehabil.* 2014; 95(5): 956-967.

Pham T, Green R, Neaves S, et al., Physical activity and perceived barriers in individuals with moderate-to-severe traumatic brain injury; *PM&R.* 2022; 15(6): 705-714.

Quilico EL, Alaire C, Swaine BR, Colantonio A. Characteristics, outcomes, sex and gender considerations of community-based physical activity interventions after moderate-to-severe traumatic brain injury: scoping review. *Brain Inj.* 2022; 36(3): 295-305.

Saunders DH, Sanderson M, Hayes S, et al. Physical fitness training for stroke patients. *Cochrane Database Syst Rev.* 2020; Issue 3. Art. No: CD003316.

van der Ploeg HP, Streppel KRM, van der Beek AJ, et al. Successfully improving physical activity behavior after rehabilitation. *Am J Health Promot*. 2007; 21(3): 153-159.

World Health Organisation. Global action plan on physical activity 2018–2030: more active people for a healthier world. Geneva: World Health Organization; 2018

Wise EK, Mathews-Dalton C, Dikmen S, et al. Impact of traumatic brain injury on participation in leisure activities. *Arch Phys Med Rehabil*. 2010; 91(9): 1357-1362.

Clinical question 10: Overall physical activity promotion for children and adolescents with moderate to severe traumatic brain injury

Clinical question: Should **overall physical activity promotion** compared to control be used for **children and adolescents** after moderate to severe traumatic brain injury?

Setting: Healthcare settings across the continuum of care:

- Inpatient, transition and outpatient rehabilitation settings
- Community settings (e.g., fitness centres, sporting fields, community centres)
- Home
- Schools

Perspective: Health systems

Critical outcomes of interest:

- Physical activity
- Social connection
- Behaviour change
- Quality of life
- Co-morbidities and mortality
- Participation
- Mood

Key definitions:

- Children and adolescents: 5 to 17 years
- Overall physical activity promotion: Interventions that promote overall physical activity (incidental and planned), such as health coaching, pedometer programs, lifestyle/health and wellness programs.

Clinical need for question

Globally, children and adolescents have low levels of physical activity (Aubert et al., 2022). Children and adolescents after msTBI are even less physically active than their non-brain injured peers (Katz-Leurer et al., 2010). Low levels of physical activity can have negative consequences after msTBI, including physical deconditioning, compromised aerobic capacity, and functional impairment, and can lead to chronic health conditions later in life (Hamel et al., 2019). Several barriers to physical activity have been identified by children with disability onset during childhood, these include personal (e.g., fatigue and motivation) and environmental (inappropriate equipment and lack of professional support) barriers (Buffart et al., 2009).

Physical activity is associated with a 20%–30% lower risk in all-cause mortality and incidence of multiple chronic conditions (McKinney et al., 2016). The benefits of physical activity for children and adolescents are wide-ranging and well documented (Biddle et al., 2004). The WHO physical activity and sedentary behaviour guidelines indicate children and adolescents aged 5–17 years should accumulate at least 60 minutes per day of MVPA, on average, and incorporate vigorous-intensity aerobic activities as well as muscle and bone strengthening activities at least three days per week (Carty et al., 2021).

The WHO GAPPA sets out 20 policy actions to address physical inactivity, with action 3.2 most pertinently recommending countries implement and strengthen physical activity assessment and counselling as part of universal health care. Thus, health professionals supporting children and adolescents after msTBI to identify and engage in activities that increase overall physical activity, and reduce time spent inactive, is critical to avoiding secondary complications and preventing the health risks associated with physical inactivity.

Summary of systematic and narrative review evidence

Direct evidence:

There was no evidence to guide this judgement in children and adolescents in msTBI research. Thus, evidence for physical activity promotion was drawn from evidence in adults with msTBI (Clanchy et al., 2016; Driver et al.,2016) and from the WHO physical activity and sedentary behaviour guidelines for children and adults living with disability (Carty et al., 2021).

Indirect evidence:

Overall physical activity promotion had a large positive effect on levels of physical activity in adults after msTBI (low certainty evidence) (Clanchy et al., 2016; Driver et al.,2016). An overall physical activity promotion intervention may also improve participation in adults after msTBI, though the evidence is of very low certainty (Driver et al., 2016).

The WHO physical activity and sedentary behaviour guideline development group considered evidence for children without disability and evidence for physical activity for children living with intellectual disability and children with ADHD (Carty et al., 2021). They found that evidence from children without disability could be extrapolated for key favourable outcomes including cardiorespiratory and muscular fitness, and mental health. They also found that there were improvements in physical function (low certainty evidence) in children with intellectual disability and improvements in cognition (moderate certainty evidence) in children with ADHD.

Thus, the WHO guidelines recommend that children and adolescents (aged 5 to 17 years) living with a disability:

- should do at least an average of 60 minutes per day of MVPA (mostly aerobic) across the week (*Strong recommendation, moderate certainty evidence*)

Please see **Clinical question 10** in the Technical Report for detailed study characteristics and meta-analyses that assisted with providing the evidence base for this clinical question.

Recommendations

	Type	Recommendation	GRADE/Quality
10		**Overall physical activity promotion for children and adolescents with moderate to severe traumatic brain injury**	
10.1	**EBR**	For children and adolescents after moderate to severe traumatic brain injury, we suggest the promotion of physical activity across the continuum of care.	❖❖❖
We suggest the following Good Practice Points (GPP):			
10.2	**GPP**	Health professionals initiate conversations with the child or adolescent and their family about a return to physical activity as early as possible, mindful of the potential for the early rehabilitation phase of recovery to be an opportune time to establish short and long-term goals, positive behaviours, and support systems.	
10.3	**GPP**	Physical activity is promoted with consideration of current public health physical activity guideline recommendations for children and adolescents living with disability.	
10.4	**GPP**	Pre-injury physical activity is assessed, and health professionals consider building on what a child or adolescent has done before (i.e., supporting a return to previous activity).	
10.5	**GPP**	Health professionals consider promoting opportunities for their clients to engage in physical activity within a fun and social setting e.g., play, school activities, sport.	
10.6	**GPP**	Physical activity is incorporated into weekly routines and key supports (e.g., siblings, friends, teachers, support workers, and parents) are trained in facilitating opportunities for activity.	
10.7	**GPP**	Health professionals seek to discuss barriers and facilitators to engaging in physical activity with the child or adolescent and key supports and implement strategies to support the uptake of physical activity.	

Justification

Children and adolescents after msTBI are typically highly inactive, which can lead to impaired fitness, function, and chronic health conditions later in life. There is little condition- and population-specific evidence to inform this judgement. But the well-known benefits of physical activity to the broader population, including non-brain injured children and adolescents, apply to children and adolescents with msTBI. On balance, we suggest there are trivial undesirable effects and potentially moderate desirable effects on critical and important outcomes. There was good acceptability for the promotion of overall physical activity from multiple stakeholders. It is feasible to deliver physical activity promotion in both inpatient and post-rehabilitation settings, although implementation support will be needed, especially for health services and professionals working with children and adolescents with higher support needs, or from other identified subgroups requiring additional support (e.g., Aboriginal and Torres Strait Islander people).

On balance of risk and benefit, interventions that promote overall physical activity are probably favoured. The promotion of overall physical activity probably increases equity by benefiting underserved populations and empowering disadvantaged populations (i.e., children and adolescents with msTBI with low socioeconomic status). The promotion of overall physical activity within rehabilitation is feasible and needed to support children and adolescents with TBI and their families to overcome barriers and identify and navigate suitable and preferable community-based physical activity options beyond rehabilitation.

Impact of clinical recommendation

Physical activity promotion interventions should be tailored to consider personal (i.e., levels of fatigue, physical conditioning, sensory sensitivity) and accessibility (i.e., appropriate equipment, safety and support, and environment) factors. Identifying opportunities for children and adolescents with msTBI to be physically active in a social environment, undertaking motivating, interesting, and enjoyable activities is likely important for long-term adherence to physical activity. Advice/input from a psychologist or other relevant health professional may be required to assist with managing cognitive/behavioural impairment if necessary.

If children and adolescents can engage in an activity that promotes overall physical activity and enables them to participate alongside their peers, it is likely to be of value to them and their family. It is feasible for health professionals such as physiotherapists and exercise physiologists to promote physical activity within rehabilitation. Of the six paediatric services audited, it was standard practice in five services (83%) to assess their patients' physical activity levels as part of their role in broadly promoting physical activity, while three services (50%) reported assessing if current physical activity guidelines were being met as part of the patient's history taking. The implementation of the recommendations will likely improve consistent delivery of promotion of overall physical activity that is safe and effective at improving critical and important outcomes.

The audit also identified barriers that services report limit their promotion of physical activity. Two-thirds (66%) of services identified a lack of knowledge, skills, and time as barriers to promoting physical activity to children and adolescents with msTBI. This would indicate that education and training would be a critical component of an implementation plan to effectively implement this recommendation into practice.

The Australian public health physical activity guidelines do not currently provide recommendations for children and adolescents living with disability. The WHO physical activity and sedentary behaviour guidelines (Carty et al., 2021) recommends children and adolescents living with disability should:

- do at least an average of 60 minutes per day of MVPA (mostly aerobic) across the week.
- do vigorous-intensity aerobic activities, as well as muscle and bone strengthening activities at least three days a week.

The WHO guidelines also provide good practice points that are very important for people with disability who are not able to reach the physical activity recommendations. They include that doing some activity is better than none, to start off slow and gradually increase (i.e., time and/or intensity of physical activity) with increasing tolerance, and seek the help of a health professional or physical activity expert if needed. They also recommend that there are no major risks to children and adolescents living with disability engaging in physical activity when it is appropriate to an individual's current activity level, health status, and physical function; and the health benefits accrued outweigh the risks.

Cost data and cost effectiveness data is not available from any studies evaluating the promotion of overall physical activity in people with msTBI. The promotion of overall physical activity to children and adolescents after msTBI is suggested to include assessment of physical activity levels, providing information about the benefits of physical activity and meeting physical activity public health guidelines, collaboratively setting physical activity goals with the child and their family, and using behaviour change techniques to support physical activity uptake and maintenance. The resource requirements to promote overall physical activity are likely to be low cost and could be covered as part of standard care for health professionals. A reduction in population level physical inactivity is likely to be cost saving for health system.

Please see **Clinical question 10** in the Technical Report for the full evidence to decision framework that assisted with providing the recommendations for this clinical question.

References

Aubert S, Barnes JD, Demchenko I, et al. Global matrix 4.0 physical activity report card grades for children and adolescents: results and analyses from 57 countries. *J Phys Act Health*. 2022; 19(11): 700-728.

Biddle SJ, Gorely T, Stensel DJ. Health-enhancing physical activity and sedentary behaviour in children and adolescents. *J Sports Sci*. 2004; 22(8): 679-701.

Buffart LM, Westendorp T, van den Berg-Emons RJ, et al. Perceived barriers to and facilitators of physical activity in young adults with childhood-onset physical disabilities. *J Rehabil Med*. 2009; 41(11): 881-885.

Carty C, van der Ploeg HP, Biddle SJ, et al. The first global physical activity and sedentary behavior guidelines for people living with disability. *J Phys Act Health*. 2021; 18(1): 86-93.

Clanchy KM, Tweedy SM, Trost SG. Evaluation of a physical activity intervention for adults with brain impairment: a controlled clinical trial. *Neurorehabil Neural Repair.* 2016; 30(9): 854-865.

Driver S, McShan E, Swank C, et al., Efficacy of the diabetes prevention program group lifestyle balance program modified for individuals with TBI (GLB-TBI): results from a 12-month randomized controlled trial. *Ann Behav Med*. 2023; 57(2): 131-145.

Driver S, Woolsey A. Evaluation of a physical activity behavior change program for individuals with a brain injury. *Arch Phys Med Rehabil*. 2016; 97(9 Suppl 3): S194-200.

Hamel RN, Smoliga JM. Physical activity intolerance and cardiorespiratory dysfunction in patients with moderate-to-severe traumatic brain injury. *Sports Med*. 2019; 49(8): 1183-1198.

Katz-Leurer M, Rotem H, Keren O, Meyer S. Recreational physical activities among children with a history of severe traumatic brain injury. *Brain Inj.* 2010; 24(13-14): 1561-1567.

Kemp BJ, Cliff DP, Batterham M, Parrish A-M. Socio-ecological predictors of non-organized physical activity participation and decline between childhood and adolescence. *J Sports Sci.* 2021; 39(2): 120-130.

McKinney J, Lithwick DJ, Morrison BN, et al. The health benefits of physical activity and cardiorespiratory fitness. *B C Med J*. 2016; 58(3): 131-137.

Rossi C, Sullivan SJ. Motor fitness in children and adolescents with traumatic brain injury. *Arch Phys Med Rehabil.* 1996; 77(10): 1062-1065.

Ryan JM, Cassidy EE, Noorduyn SG, O'Connell NE. Exercise interventions for cerebral palsy. *Cochrane Database Syst Rev*. 2017; 6(6): CD011660.

World Health Organisation. *WHO guidelines on physical activity and sedentary behaviour.* Geneva: World Health Organization; 2020.

SECTION FOUR:
Dissemination, implementation, surveillance and evaluation

BRIDGES

Brain Injury: Developing Guidelines for Physical Activities

Dissemination, implementation, surveillance, and evaluation

Dissemination

The initial plan for dissemination of the *Australian Physical Activity Clinical Practice Guideline for people living with moderate to severe traumatic brain injury* is targeting health professionals (particularly physiotherapist, exercise physiologists and rehabilitation specialists) who are the main intended audience. The guideline will then be disseminated to other key stakeholders, namely people living with moderate to severe TBI and their families, support workers, funders of physical activity interventions (e.g., NDIS, icare NSW), community-based physical activity providers, advocacy organisations, and policy makers. Dissemination materials specific for each stakeholder group are planned if funding is secured. See Table 1 for more detail of the dissemination plan.

Table 1: Dissemination plan:

Target audience	Purpose	Method	Person Responsible	Timeframe	Cost
Health Professionals	Increase awareness of guideline	Conference presentations	Chair, co-chair, and steering group members	December 2024 (one national, two international abstracts submitted)	Funded through funds held by Chair.
	Increase knowledge of guideline of Australian health professionals likely to implement guidelines	Send final guideline documents via email to health professionals engaged in guideline development projects (i.e., clinical audit) across Australia; health professional organisations (e.g., Australian Physiotherapy Association)	Chair, co-chair, and steering group members	July 2024	Nil required

Target audience	Purpose	Method	Person Responsible	Timeframe	Cost
	Increase awareness of guideline by health professionals, public health researchers, and practitioners in physical activity	Peer-reviewed open-access journal publications	Chair, co-chair, and steering group members	Two journal publications complete (Johnson et al., 2023; Haynes et al., 2023). At least three more planned by December 2023.	Funded through funds held by Chair and/or no cost journals.
		Social media (i.e., Twitter/X)	Chair, co-chair, and institute social media accounts	Timed with conference presentations and journal publications	Nil required
People living with msTBI	Increase awareness of guideline	Link to final guideline document distributed via social media, emails, and newsletters from consumer organisations	Chair, co-chair, and consumer organisation partners: Brain Injury Australia, Connectivity TBI, and Head Together for ABI.	July 2024	Nil cost
	Increase knowledge of physical activity options	Co-designed video case studies, online summaries of recommendations	BRIDGES Investigator team, including lived-experience investigators	July 2024-June 2025	Pending funding request

Target audience	Purpose	Method	Person Responsible	Timeframe	Cost
Other stakeholder groups (i.e., family members, support workers, physical activity providers, health professionals, funders)	Increase awareness of guideline	Link to final guideline document distributed via social media, emails, and newsletters from relevant consumer organisations (identified in guideline development work)	Chair, co-chair, and consumer organisation partners: Brain Injury Australia, Connectivity TBI, Head Together for ABI, and Guideline Development Group members	July 2024	Nil cost
	Increase knowledge of physical activity recommendations and ways to support people with msTBI to be active	Co-designed video case studies, online summaries of recommendation, online education resources	BRIDGES Investigator team	July 2024-June 2025	Pending funding request
Relevant government sectors (all states and territories, and federal, e.g., Rehabilitation Network Agency for Clinical Innovation, NSW)	Increase awareness of guideline	Link to final guideline document for dissemination	Chair, co-chair, and steering group members	July 2024	Nil cost
All stakeholder groups	Widespread knowledge of guideline	Official in-person and online launch of guideline	Chair, co-chair, and steering group members	December 2024	Pending funding request

Implementation

Step 1: Development of clinical practice guideline using implementation science methods

We used implementation science methods (Bauer et al., 2015) to guide the development of the *Australian Physical Activity Clinical Practice Guideline for people living with moderate to severe traumatic brain injury*. This was to enable us to plan for implementation of the guideline from the early development stage. The guideline development and accompanying studies were conducted within the "Exploration" and "Preparation" phases of the Exploration Preparation Implementation Sustainment (EPIS) Framework as an overarching process framework to guide this work (Figure 1) (Aarons et al., 2011). Having a framework or theoretical model to guide implementation is essential to systematically and comprehensively identify and address factors that may facilitate or hinder implementation efforts.

The EPIS framework was chosen using the Dissemination and Implementation Models in Health Research and Practice webtool as the framework that best fits the purpose of the planned work. That is, to conduct the pre-implementation work for national guideline implementation. This framework is widely used in implementation research. Within the Exploration Phase, the needs of the target population are considered, the best evidence is identified and adaptations to fit the evidence for the population and the local context are considered. In the Preparation Phase the primary objective is to identify potential barriers and facilitators to implementation of the adapted evidence, consider any further needs for adaptation, and develop an implementation plan.

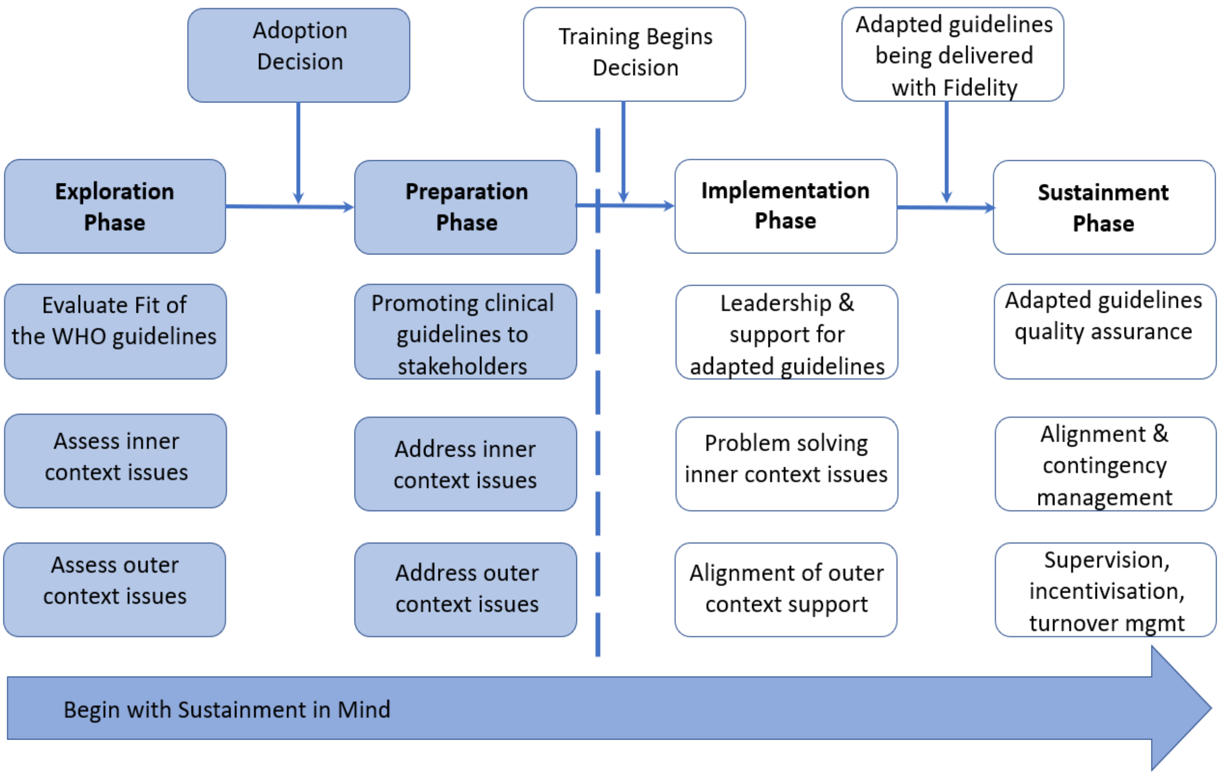

Figure 1: Proposed work for grant within EPIS Framework. Shaded aspects reflect the phases to be addressed.

Step 2: Identifying barriers and facilitators for implementation of the guideline

Barriers to implementation include system level barriers right along the continuum of care, particularly due to all the different parts of the system needing to work together (e.g., health, disability, education (for children and adolescents), and community sectors). Studies conducted within the BRIDGES project have been planning for implementation. The following barriers (and some facilitators) have been identified and will inform the implementation of the guideline.

<u>BRIDGES audit of brain injury health services</u>
Twenty-six services (20 adult, 5 paediatric, 1 all ages) across all eight Australian states and territories were included. Most services were based in metropolitan settings, four were based in regional/remote Australia. Physiotherapists and exercise physiologists were the main health professionals delivering physical activity interventions and considered this as central to their role. Most were delivering the types of physical activity recommended in the guideline (e.g., strength and mobility training), however *how* it was delivered often did not align with the guideline recommendations. Using the Capability, Opportunity, Motivation-Behaviour (COM-B) framework (Michie et al., 2011), we explored barriers influencing physical activity delivery reported by health professionals. We identified capability (limited knowledge and skills), opportunity (limited resources and time), and motivation (priority, habits, beliefs) barriers, indicating implementation support is needed to enable evidence-based care (see Table 2).

Table 2: Factors identified by the 26 brain injury health services across Australia as barriers to delivering different types of physical activity, categorised using the COM-B model of behaviour change.

Barriers using COM-B Framework	Behaviour: delivery and/or promotion of physical activity				
	Aerobic	Strength	Mobility	Sport & Recreation	Promotion PA
Capability					
-knowledge	12%	4%	4%	27%	58%
-skills	4%	8%	8%	8%	54%
Motivation					
-beliefs (intervention)	8%	0%	0%	8%	0%
-not a priority	35%	12%	0%	15%	12%
-habits	27%	19%	8%	15%	27%
-beliefs (safety)	35%	23%	15%	19%	0%
Opportunity					
-physical (resources)	62%	50%	42%	69%	31%
-physical (time)	50%	31%	15%	19%	35%
-social (not common practice)	8%	4%	0%	12%	8%

Facilitators: As part of the audit, we have collected resources, such as aerobic training policies and procedures, from health services across Australia. In preparation for implementation of the guideline we will be able to share these resources across sites for services to adapt to their local needs to support implementation of the physical activity clinical practice guideline recommendations.

BRIDGES qualitative research with people living with msTBI.

Several barriers/challenges were identified by people living with msTBI to engage in physical activity in the community post-discharge from inpatient rehabilitation.

These barriers will need to be considered as part of planning for the implementation of the guideline:

- Finding the right activity in the community for physical activity that meets the individuals' preferences and needs. Issues include msTBI often being considered an "invisible disability", adjusting to living with disability, accessibility of facilities and community provider knowledge about TBI (or disability more broadly).
- Identified transition from rehabilitation to community participation as challenging with more guidance needed. TBI being an acquired disability, the disability landscape is new for individuals with msTBI, thus information about options for physical activity in the community was identified as a need.
- Those individuals living with more severe TBI may need additional support to participate in physical activity. This may include transport to get to and from the activity, supervision of the activity, and adaptive equipment to participate in the activity.

BRIDGES stakeholders focus groups.

Focus groups were conducted with six stakeholder groups (people with msTBI, family members, support workers, community-based physical activity providers, health professionals, and service funders; n=36) to identify barriers likely to influence the ability of health professionals to prescribe physical activity for people with msTBI, particularly in community settings. Barriers were identified across all levels of the socioecological model (Bronfenbrenner, 1994): individual (e.g., "killer fatigue"); interpersonal (e.g., a siloed community of support); community (e.g., finding suitable community physical activity options); and policy (e.g., funding complexities), indicating the need to consider these when planning implementation support (see Figure 1).

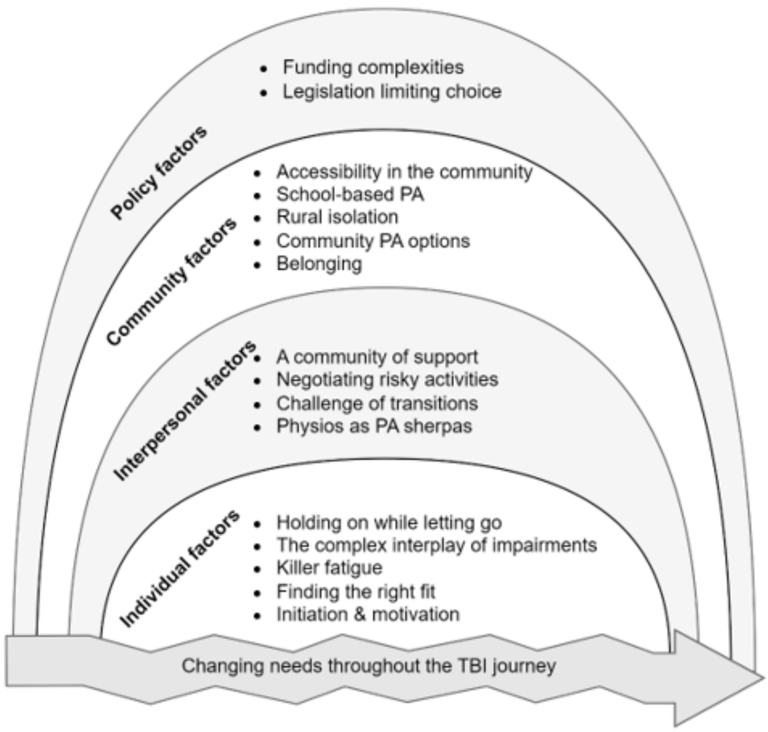

Figure 1: Influences on physical activity participation identified by stakeholders in research conducted for guideline development and planning for implementation.

Step 3: Additional planning for implementation for subgroups (pending funding request)

Our current guideline development work (predominantly conducted online) did not specifically subgroups identified as priority populations by Medical Research Future Fund (Aboriginal and Torres Strait Islander people with msTBI, people with msTBI from Culturally and Linguistically Diverse (CALD) populations, people with msTBI living in rural and remote Australia), where specific research principles (e.g., cultural sensitivity) and strategies are needed. In preparation for implementation, we aim to understand cultural considerations for brain injury rehabilitation and physical activity participation to ensure implementation plans (e.g., health professional training, resource development) are suitable and inclusive of priority populations. We also identified limited evidence or representation of people with msTBI with high support needs, children under 10 years and adults 65 years+, and people with msTBI from low socioeconomic backgrounds in our guideline development work. Further consultation with health services and qualitative work with these subgroups is planned to inform implementation of the guideline.

Step 4: Implementation plan (pending funding request)

A national implementation trial in planned to actively support the implementation of the guideline into clinical practice.

Implementation strategies are discrete methods or techniques used to support the implementation of an evidence-based intervention (Powell et al., 2015). We have selected implementation strategies described in the ERIC taxonomy (Powell et al., 2015) to address barriers to guideline implementation identified from our guideline development work. Guided by the COM-B framework (Michie et al., 2011) (which provides a mechanism to select strategies theoretically linked to a barrier), and based on empirical evidence, we have selected strategies that are effective at improving the professional practices of health professionals, and will be considered practical, feasible and acceptable to our stakeholders.

Develop an online resource hub (Implementation strategies: create a learning collaborative; develop and distribute educational materials; use advisory boards; promote network weaving).
Target audience: All stakeholder groups.
Barriers targeted: Capability, Opportunity and Motivation of health professionals; barriers across socioecological model (Figure 1).
Description: Following an international example in spinal cord injury (Hoekstra et al., 2020), the online hub will include the 'layered' presentation of educational and motivational information to meet diverse stakeholder needs. Our resources will be co-produced (Smith et al., 2023), acknowledging the essential input of the lived experience of msTBI. Stories of people with msTBI (including priority populations) participating in varied physical activities will be a key feature of the online hub as suggested by multiple stakeholders: *"...maybe if you could write some case studies or give some examples…if you could pick out different people, then you'd have different experiences or something like that. So just so that people could actually see … different ways of doing it*" (msTBI stakeholder). Our lived-experience investigators will guide creation of these stories in collaboration with videographer.
Management: A multi-stakeholder advisory committee will meet 3-6 monthly to review hub structure, content, and plan for sustainment.

Site implementation (Implementation strategies: prepare champions; conduct educational outreach visits; conduct ongoing training; capture and share local knowledge).
Target audience: Teams of health professionals.

Barriers targeted: Motivation (beliefs about interventions) and Capability (knowledge and skills).
Description: The intervention to be implemented is physical activity according to the 10 recommendations in the *Physical Activity Clinical Practice Guideline for people with msTBI*. Each recommendation has actionable good practice points (GPPs) for health professionals to put into practice. Implementation will be tailored to site training needs and provided onsite by members of the Guideline Leadership Group with content expertise (e.g., Guideline Chair Hassett; aerobic exercise). Online training resources will be developed with sites and shared to support ongoing training needs.
Management: A site implementation steering group will be established and will meet quarterly to oversee roll-out of site implementation across Australia.

Advocacy and policy (Implementation strategies: tailor strategies to address barriers).
Target audience: Government; community physical activity organisations.
Barriers targeted: Community and policy factors (see Figure 1).
Description: We will leverage this national project to seek opportunities to advocate for accessible community-based physical activity and contribute to policy discussions that support funding for evidence-based physical activity. Examples through our online hub may include accessibility checklists for community settings, stories highlighting inclusive community organisations and links to inclusive sporting organisations. Investigators with policy and advocacy expertise and our partner organisations will shape this work.
Management: Members of the Guideline Leadership Group with expertise in policy and advocacy (including from Brain Injury Advocacy groups) will meet quarterly to oversee this work.

Monitoring and evaluation

The following strategies have been planned for the monitoring and evaluation of physical activity delivery and promotion as part of rehabilitation in Australia:

Strategy 1: Audit tool to monitor change in practice of brain injury services:
The delivery and promotion of physical activity provided as part of rehabilitation across Australia can be monitored using the online audit tool developed as part of the BRIDGES project (see Appendix of Technical report). Baseline data has been collected from 26 brain injury health services across all states and territories of Australia to provide a current picture of practice and can be re-administered post-implementation to determine changes in practice due to the introduction of the guideline including specific strategies to implement the recommendations.

Strategy 2: Measurement of physical activity levels of people with msTBI:
Physical activity levels of people living with TBI are currently being collected as part of an online Discrete Choice Experiment survey online as part of the BRIDGES project. Physical activity is being measured using a brief physical activity questionnaire (see Appendix 4) developed specifically for the project based on brief surveys reported in the literature used in adults (Wald et al., 2018) and adolescents (Prochaska et al., 2021). It is yet to have psychometric testing of its appropriateness for people living with msTBI, which would be recommended prior to roll-out. If found suitable, the brief physical activity questionnaire for adults and children with msTBI can be embedded in services as part of the AUS-TBI national outcome data registry currently being planned.

Strategy 3: Evaluation of resources developed to support implementation:
Resources developed to address barriers to implementation (e.g., a website with case studies of different physical activity options) can be evaluated for their suitability, and website analytics can be monitored to evaluate use of resources.

Strategy 4: Routinely collected outcome measures across clinical sites:
Our audit of brain injury services identified a range of outcome measures used by clinical services to evaluate improvements from delivery and promotion of physical activity. Agreement on a core set of outcome measures and collection and sharing of de-identified data across multiple sites nationally will enable further evaluation of effectiveness of physical activity intervention in people with msTBI. See research priorities below regarding developing a core set of outcome measures.

Research priorities

With limited high-quality direct evidence to guide clinical practice for the delivery and

promotion of physical activity, there is a need for more rigorous studies across the five specific physical activity interventions covered in this guideline (aerobic exercise, strength training, mobility training, sport and physical recreation, promotion of physical activity). Deciding on priority questions should be conducted with key stakeholders, including people living with msTBI, to ensure that the most important questions are addressed first. Collaborations between consumer organisations, academics, and clinical services, and the creation and utilisation of learning healthcare systems where data can be collected and used for clinical and research purposes will also assist. Working in with other Medical Research Future Fund (MRFF) funded TBI mission projects, such as the AUS-TBI registry, may also assist with recruitment of individuals living with msTBI, sharing of data, and dissemination of research outputs.

Collaborations between specialist brain injury services both nationally and internationally is essential to enhance the collective capacity to recruit sufficient sample sizes to rigorously evaluate the effectiveness of physical activity interventions on individuals with msTBI on critical and important outcomes.

Based on the research conducted as part of the development of this guideline, areas where evidence was limited or non-existent included:

- There is an urgent need for rigorous studies that includes children and adolescents. Broader inclusion criteria may be needed in children, where the incidence of msTBI is smaller (e.g., acquired brain injury); however, participant demographic and injury data should be collected and individual participant data accessible so that data can be synthesised between studies.
- Given the increasing prevalence of msTBI in older adults, this is also a priority area. Studies in older adults often exclude people with cognitive impairments which may exclude people living with msTBI. Studies including older adults are needed to ensure the guideline recommendations for adults and older adults are suitable for this older age group.
- Studies conducted during inpatient rehabilitation are limited with most studies including people > 1-year post-msTBI. Further research in this setting will increase certainty of the amount and type of physical activity possible and guide recommendations to maximise rehabilitation outcomes.
- Consensus on a core set of physical outcome measures to be collected across brain injury services and within studies would improve our ability to compare results across services and studies and pool data for meta-analysis (Kirkham et al., 2019). Similar core sets already exist for psychosocial function in adults (Honan et al., 2019) and children (Wearne et al., 2020) with TBI.
- No data was identified informing resource requirements (costings) for delivering and promoting physical activity in health systems. Costing analysis studies to inform decisions

around costs of physical activity participation and cost effectiveness of physical activity delivery in brain injury health services are warranted.

Plans for updating this guideline

The BRIDGES Guideline Development Group recommends that the *Australian Physical Activity Clinical Practice Guideline for people living with moderate to severe TBI* be reviewed, assessed for the need to be updated, and new or modified recommendations developed, within five years of publication, or earlier if significant new research emerges warranting change.

Updating or adapting recommendations locally

The Australian Physical Activity Clinical Practice Guideline for people living with moderate to severe TBI has been informed by research studies conducted across the world and contextualised to Australian settings and people by the BRIDGES brain injury rehabilitation services audit, qualitative interviews and focus groups with people with lived experience, and stakeholder focus groups and interviews. Clinical trials based in Australia to address the current gaps in knowledge, and a national implementation research project, led by the BRIDGES team, are planned (pending funding), and will inform the update to the guideline, and its relevance to the Australian context, in coming years. Planning also includes supporting the development of local resources (e.g., policies and procedures, funding templates) to support implementation of guideline recommendations locally across Australian healthcare settings.

References

Aarons GA, Hurlburt M, McCue Horwitz S. Advancing a conceptual model of evidence-based practice implementation in public service sectors. *Adm Policy Ment Health* 2011; 38:4-23

Bauer MS, Damschroder L, Hagedorn HJ, Smith JL. An introduction to implementation science for the non-specialist. *BMC Psych*. 2015; 3(32).

Bronfenbrenner U. Ecological models of human development. *International Encyclopedia of Education, Vol 3, 2nd Ed. Oxford: Elsevier* 1994;1643-7

Honan CA, McDonald S, Tate R, et al. Outcome instruments in moderate-to-severe adult traumatic brain injury: recommendations for use in psychosocial research. *Neuropsychol Rehabil.* 2019; 29(6): 896–916.

Kirkham JJ, Gorst S, Altman DG, et al. Core Outcome Set-STAndardised Protocol Items: the COS-STAP Statement. *Trials*. 2019;20(1):116

Michie S, van Stralen MM, West R. The behaviour change wheel: A new method for characterising and designing behaviour change interventions. *Implement Sci.* 2011; 6(42): 1-11.

Wearne T, Anderson V, Catroppa C, et al. Psychosocial functioning following moderate-to-severe pediatric traumatic brain injury: recommended outcome instruments for research and remediation studies. *Neuropsychol Rehabil*. 2020; 30(5): 973–987.

Appendices

BRIDGES

Brain Injury: Developing Guidelines for Physical Activities

Appendix 1: Abbreviations and acronyms

2MWT	Two-minute Walk Test
6MWT	Six-minute Walk Test
10MWT	10-metre Walk Test
ABI	Acquired Brain Injury
ACSM	American College of Sports Medicine
ADHD	Attention deficit hyperactivity disorder
ADOLOPMENT	Adapt, adopt and/or develop de novo
AE	Adverse event
AMSTAR	A MeaSurement Tool to Assess systematic Reviews
AROC	Australian Rehabilitation Outcome Centre
ARR	Absolute risk reduction
BBS	Berg Balance Scale
BMI	Body Mass Index
Bpm	Beats per minute
BRIDGES	BRain Injury: Developing GuidElineS for physical activities
CALD	Culturally and Linguistically Diverse
CI	Confidence interval
COI	Conflict of interest
COM-B	Capability, Opportunity, Motivation-Behaviour
CP	Cerebral Palsy
DASS	Depression Anxiety Stress Scale
DCE	Discrete Choice Experiment
DOMS	Delayed onset muscle soreness
EMG	Electromyography
EP	Exercise physiologist
EPIS	Exploration Preparation Implementation Sustainment
EtD	Evidence -to -Decision
FAC	Functional Ambulation Category
FITT	Frequency, Intensity, Time, and Type
GAPPA	Global Action Plan on Physical Activity
GCS	Glasgow Coma Scale
GPP	Good practice points
GRADE	Grading of Recommendations Assessment, Development and Evaluation
HiMAT	High Level Mobility and Assessment Tool
HR	Heart rate
HR_{max} pred-adj	Age-predicted maximal heart rate
HRR	Heart rate reserve
ICP	Intracranial pressure
IQR	Interquartile range
LOS	Limits of Stability test
MET	Metabolic equivalent of task
MD	Mean difference
MitiiTM	Move It to Improve It training
MMT	Manual muscle test
MRFF	Medical Research Future Fund
msTBI	Moderate to severe traumatic brain injury
MVPA	Moderate-to-vigorous physical activity

NDIS	National Disability Insurance Scheme
NHMRC	National Health and Medical Research Council
NRSI	Non-randomised studies of interventions
OT	Occupational therapist
PICO	Population, Intervention, Comparison, and Outcome
POMS	Profile of Mood States
PP	Precautionary points
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
REDCap	Research Electronic Data Capture
RCT	Randomised controlled trials
RD	Risk difference
RoB	Risk-of bias
ROBINS-I	Risk of Bias in Non-randomised Studies- of Interventions
RWS	Rhythmic Weight Shift test
SAE	Serious adverse event
SD	Standard deviation
SF-36	36-Item Short Form Survey
SMD	Standardised mean differences
SoF	Summary of findings
SOT	Sensory Organisation Test
STS	Sit to stand
TBI	Traumatic brain injury
TUG	Timed Up and Go test
VO_2	Volume of oxygen
VO_2peak	Volume of oxygen uptake during peak exercise
WHO	World Health Organisation
WHR	Waist-to-hip ratio

Appendix 2: Glossary

Adults	**A person 18 years or older.**
Aerobic exercise	Activity in which the body's large muscles move in a rhythmic manner for a sustained period. Aerobic activity – also called endurance activity – improves cardiorespiratory fitness. Examples include walking, running, swimming, and bicycling.
AGREE II Tool	The Appraisal of Guidelines for Research & Evaluation (AGREE) Instrument is a tool that assesses the methodological rigour and transparency in which a guideline is developed. It was developed to address the issue of variability in guideline quality. The original AGREE instrument has been refined, which has resulted in the new AGREE II. (AGREE Collaboration, *Qual Saf Health Care*. 2003).
Balance Training	Static and dynamic exercises that are designed to improve an individual's ability to withstand challenges from postural sway or destabilizing stimuli caused by self-motion, the environment, or other objects.
Ballistic Training	A specific mode of resistance training which aims to increase the rate of force production (i.e., power generation) by muscle groups. Initial loads start low to facilitate high contraction velocities. When the individual can consistently perform the high velocity exercises, the load can be progressively increased.

Children and adolescents	Defined as a person between the age of 5 to 17 years as per the WHO Guidelines on Physical Activity and Sedentary Behavior for Children and Adolescents Living with Disability.
Consumer	A consumer is a person who uses (or may use) a health service, or someone who provides support for a person using a health service. Consumers can be patients, carers, family members or other support people (Australian Commission on Safety and Quality in Health Care.
Functional exercises	Exercises that can be embedded into everyday tasks to improve lower-body strength, balance, and motor performance. Examples include tandem and one-leg stands, squatting, chair stands, toe raises, and stepping over obstacles.
Inclusion Spectrum	The inclusion spectrum is about viewing inclusion in sport and physical recreation activities along a spectrum. A version of the Inclusion Spectrum was devised by the Australian sports Commission (ASC). It includes: **No Modifications** The sport or physical activity remains unchanged from the normal version for all participants. **Minor Modifications** Small changes are made to the normal sport or physical activity so that everyone can participate. **Major Modifications** Significant changes are made to the sport or physical activity so that everyone can participate. **Primarily for people with disability** A sport or physical activity designed with the specific needs of people with disability, but which allows participation of people without disability. **Only for people with disability** A sport or physical activity delivered exclusively for people with disability such as in competition (Inclusive Sport Design)
Mobility training	Mobility is a broad term that is defined as the ability to move around and change positions, such as to stand up from sitting and to walk. Mobility exercise is practice of these tasks, e.g., sit to stand exercises, walking on a treadmill or overground, reaching in standing to challenge balance.
Muscle strengthening training	Exercise that increases skeletal muscle strength, power, endurance, and mass (e.g., strength training, resistance training, or muscular strength and endurance exercises).
Older adult	Aged >65years
Overall physical activity promotion	Interventions that promote overall physical activity (incidental and planned), such as health coaching, pedometer programs, lifestyle/health and wellness programs.
Physical activity (PA)	Any activity involving bodily movement produced by skeletal muscles that requires energy expenditure.
Physical recreation	An activity or experience that involves varying levels of physical exertion, prowess and/or skill, which may not be the main focus of the activity and is voluntarily engaged in by an individual in leisure time for the purpose of mental and/or physical satisfaction
Sport	An activity involving physical exertion, skill and/or hand-eye coordination as the primary focus of the activity, with elements of competition where rules and patterns of behaviour governing the activity exist formally through organisations
Working Aged Adults	A person aged 15 to 65 years. This is often the inclusion criteria for adult brain injury services across Australia.

Appendix 3: Guideline Development Groups

Table 1: Guideline Steering Group

Name	Role	Affiliation
A/Prof Leanne Hassett	BRIDGES Chief Investigator	Sydney School of Health Sciences and Institute for Musculoskeletal Health, The University of Sydney, Sydney, Australia
Dr Liam Johnson	BRIDGES Postdoctoral Research Fellow	The University of Melbourne, Melbourne, Australia; Australian Catholic University, Melbourne, Australia
Dr Abby Haynes	Oversee BRIDGES qualitative research	Institute for Musculoskeletal Health, The University of Sydney, Sydney, Australia
Ms Sakina Chagpar	BRIDGES Research Officer	Institute for Musculoskeletal Health, The University of Sydney, Sydney, Australia
Ms Belinda Wang	BRIDGES Research Assistant	Institute for Musculoskeletal Health, The University of Sydney, Sydney, Australia
Ms Kerry West	BRIDGES Research Officer	Institute for Musculoskeletal Health, The University of Sydney, Sydney, Australia
Mr Daniel Cheung	BRIDGES Research Officer	Institute for Musculoskeletal Health, The University of Sydney, Sydney, Australia
Ms Pien Alferink	BRIDGES Research Student	Institute for Musculoskeletal Health, The University of Sydney, Sydney, Australia
Ms Ella Bracone	MPH Capstone Research Student	Sydney School of Public Health, The University of Sydney, Sydney, Australia

BRIDGES, BRain Injury: Developing GuidElineS for physical activities; MPH, Masters of Physiotherapy

Table 2: Guideline Leadership Group

Panel Member	Affiliation
A/Prof Leanne Hassett (Chair, BRIDGES Chief Investigator)	Sydney School of Health Sciences and Institute for Musculoskeletal Health, The University of Sydney, Sydney, Australia
Dr Liam Johnson (Co-chair, BRIDGES Postdoctoral Research Fellow)	Physiotherapy Department, The University of Melbourne, Melbourne, Australia; School of Behavioural and Health Sciences, Australian Catholic University, Melbourne, Australia
Professor Gavin Williams	Physiotherapy Department, Epworth Healthcare and The University of Melbourne, Melbourne, Australia
Professor Catherine Sherrington	Sydney School of Public Health and Institute for Musculoskeletal Health, The University of Sydney, Sydney, Australia
A/Prof Sean Tweedy	School of Human Movement and Nutrition Sciences, The University of Queensland, Brisbane, Australia
Dr Kelly Clanchy	School of Health Sciences and Social Work, Griffith University, Gold Coast, Australia
Professor Luke Wolfenden	School of Medicine and Public Health, University of Newcastle, Newcastle, Australia
Professor Anne Tiedemann	Sydney School of Public Health and Institute for Musculoskeletal Health, The University of Sydney, Sydney, Australia
Professor Adrian Bauman	Sydney School of Public Health, The University of Sydney, Sydney, Australia
Dr Catherine Carty	Munster Technological University, UNESCO Chair Manager, Kerry, Ireland
Professor Anthony Okely	School of Health and Society, University of Wollongong, Wollongong, Australia

Panel Member	Affiliation
Professor Zachary Munn	GRADE Centre, Adelaide, Australia
Dr Adam Scheinberg	Victorian Paediatric Rehabilitation Service, Melbourne, Australia
Ms Gabrielle Vassallo	No affiliation

BRIDGES, BRain Injury: Developing GuidElineS for physical activities; UNESCO, United Nations Educational, Scientific and Cultural Organization; GRADE, Grading of Recommendations Assessment, Development and Evaluation.

Table 3: Guideline Development Group

Panel Member	Role/Expertise	Affiliation
A/Prof Leanne Hassett	Project Chief Investigator, physiotherapist and academic member, clinical experience working age adults msTBI, research msTBI fitness & PA	Sydney School of Health Sciences and Institute for Musculoskeletal Health, The University of Sydney, Sydney, Australia
Dr Liam Johnson	Project Postdoctoral Research Fellow, exercise physiologist and academic member, exercise prescription neurological populations, research msTBI & stroke PA	Physiotherapy Department, The University of Melbourne, Melbourne, Australia; School of Behavioural and Health Sciences, Australian Catholic University, Melbourne, Australia
Professor Gavin Williams	Physiotherapist and academic member, clinical experience working age adults TBI, research TBI mobility & PA	Physiotherapy Department, Epworth Healthcare and The University of Melbourne, Melbourne, Australia
Professor Catherine Sherrington	Physiotherapist and academic member, research PA & mobility older adults & disability, guideline development	Sydney School of Public Health, Institute for Musculoskeletal Health, The University of Sydney, Sydney, Australia
A/Prof Sean Tweedy	Exercise physiologist and academic member, research PA & disability (high support needs), guideline development	School of Human Movement and Nutrition Sciences, The University of Queensland, Brisbane, Australia
Dr Kelly Clanchy	Exercise physiologist and academic member, research acquired brain injury PA transition program	School of Health Sciences and Social Work, Griffith University, Gold Coast, Australia
Professor Luke Wolfenden	Implementation scientist and academic member, PA guideline development	School of Medicine and Public Health, University of Newcastle, Newcastle, Australia
Professor Anne Tiedemann	Exercise physiologist and academic member, research PA and healthy ageing, WHO PA guideline development older adults	Sydney School of Public Health, Institute for Musculoskeletal Health, The University of Sydney, Sydney, Australia
Professor Adrian Bauman	Public health and academic member, PA policy and guideline development	Sydney School of Public Health, The University of Sydney, Sydney, Australia
Dr Catherine Carty	WHO representative and academic member, WHO disability guideline lead, human rights perspective	Munster Technological University, UNESCO Chair Manager, Kerry, Ireland
Professor Anthony Okely	Methodologist and academic member, PA guideline development	School of Health and Society, University of Wollongong, Wollongong, Australia

Panel Member	Role/Expertise	Affiliation
Professor Zachary Munn	Methodologist member	GRADE Centre, Adelaide, Australia
Dr Adam Scheinberg	Paediatric rehabilitation physician member, research paediatric rehabilitation	Victorian Paediatric Rehabilitation Service, Melbourne, Australia
A/Prof Grahame Simpson	Social worker, psychologist and academic member, research and clinical experience psychosocial rehabilitation working age adults with TBI	Ingham Institute for Applied Medical Research, Liverpool, Sydney Australia; Faculty of Medicine and Health, The University of Sydney, Sydney, Australia
Mr Nick Rushworth	Lived experience member and advocacy member	Brain Injury Australia, Sydney, Australia
Ms Gabrielle Vassallo	Lived-experience member, disability PA experience	No affiliation
Dr Abby Haynes	Academic member, qualitative research with lived experience members and clinicians	Institute for Musculoskeletal Health, The University of Sydney, Sydney, Australia
Mr Rhys Ashpole	Manager and case management experience for Lifetime Care and Support funding	icare NSW, Sydney, Australia
Ms Sakina Chagpar	Physiotherapist member, BRIDGES guidelines steering group	Institute for Musculoskeletal Health, The University of Sydney, Sydney, Australia
Ms Kerry West	Paediatric physiotherapist member, BRIDGES guidelines steering group	Institute for Musculoskeletal Health, The University of Sydney, Sydney, Australia
Ms Belinda Wang	Exercise physiologist member, BRIDGES guidelines steering group	Institute for Musculoskeletal Health, The University of Sydney, Sydney, Australia
Mr Domenic Denichilo	Physiotherapist member, working in regional and remote Australia and with Indigenous patients with TBI	Central Australia region, NT Health, Alice Springs, Australia
Ms Sarah Veli-Gold	Physiotherapist member, clinical experience in adult TBI, qualitative research in Indigenous population living with TBI, First Nations curriculum development university physiotherapy program.	Sydney School of Health Sciences, University of Sydney, Sydney, Australia
Mrs Sonia Hoppe	Physiotherapist member, experience community-based neurological rehabilitation including transition to community PA	School of Health and Rehabilitation Sciences, The University of Queensland, Brisbane, Australia
Ms Bhavini Whiteside	Physiotherapist member, clinical experience inpatient/transitional care and community adult rehabilitation	Liverpool Hospital Brain Injury Rehabilitation Unit, Liverpool, Sydney Australia
Mr Benjamin Sammut	Exercise physiology student and lived-experience member	No affiliation
Mr Nicholas Waters	Lived-experience member	No affiliation
Ms Francesca Brady	Lived-experience member	No affiliation
Mr Anthony Mamo	Lived-experience member	No affiliation
Mr Kieran Witts	Family of person with msTBI	No affiliation

Panel Member	Role/Expertise	Affiliation
Mrs Julie Witts	Family of person with msTBI	No affiliation
Ms Alexandra Edmonson	APA Chairperson NSW Disability Group, physiotherapist member	Institute for Musculoskeletal Health, The University of Sydney, Sydney, Australia
Mr Peter Mayhew	Provider community-based disability PA, lived-experience member	No affiliation
Ms Kate Heine	Head paediatric consumer organisation, advocacy, paediatric Physiotherapist member	Heads Together for ABI, Melbourne, Australia
Ms Sania Salim	Paediatric physiotherapist member, clinical experience paediatric rehabilitation	Royal Melbourne Childrens Hospital, Melbourne, Australia
Ms Olivia Beattie	Paediatric occupational therapist member, clinical experience paediatric rehabilitation	Royal Melbourne Childrens Hospital, Melbourne, Australia

msTBI, moderate to severe traumatic brain injury; PA, physical activity; WHO, World Health Organisation; UNESCO, United Nations Educational, Scientific and Cultural Organization; GRADE, Grading of Recommendations Assessment, Development and Evaluation; BRIDGES, BRain Injury: Developing GuidElineS for physical activities; NSW, New South Wales; NT, Northern Territory; APA, Australian Physiotherapy Association; ABI, acquired brain injury.

Appendix 4: Physical Activity Measurement

MEASUREMENT OF PHYSICAL ACTIVITY

Now we would like to ask you some questions about your pre-injury and current physical activity

(ADULT VERSION 18+)

Physical activity is any activity that increases your heart rate and makes you get out of breath some of the time. This may include sport, exercise, brisk walking or cycling for recreation or travel, or physical work that is part of your job.

Pre-injury physical activity history:

Think about a **typical** week just **before** you had your injury.

On average, how many days per week did you engage in physical activity that increased your heart rate and made you get out of breath some of the time?

0 days	1 day	2 days	3 days	4 days	5 days	6 days	7 days
☐	☐	☐	☐	☐	☐	☐	☐

On average, how many minutes per day of the days you were active did you engage in physical activity at this level?

0 mins/day	10 mins/day	20 mins/day	30 mins/day	40 mins/day	50 mins/day	60 mins/day	90 mins/day	120 mins/day	150 or greater mins/day
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

List up to three (3) of the most common types of physical activity you did for sport, exercise or recreation **before your injury** [only appear if "On average how many days per week did you engage in physical activity that increased your heart rate and made you get out of breath some of the time" ≥ 1 day]

Activity 1	
Activity 2	
Activity 3	

Current physical activity participation:

Think about a **typical** week for you **now**.

On average, how many days per week do you engage in physical activity that increases your heart rate and makes you get out of breath some of the time?

0 days	1 day	2 days	3 days	4 days	5 days	6 days	7 days
☐	☐	☐	☐	☐	☐	☐	☐

On average, how many minutes per day on the days you are active do you engage in physical activity at this level?

0 mins/day	10 mins/day	20 mins/day	30 mins/day	40 mins/day	50 mins/day	60 mins/day	90 mins/day	120 mins/day	150 or greater mins/day
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

How many days per week do you perform muscle strengthening exercises, such as bodyweight exercises or resistance training?

0 days	1 day	2 days	3 days	4 days	5 days	6 days	7 days
☐	☐	☐	☐	☐	☐	☐	☐

How many days per week do you perform activities that emphasise balance and functional strength training?

0 days	1 day	2 days	3 days	4 days	5 days	6 days	7 days
☐	☐	☐	☐	☐	☐	☐	☐

List up to three (3) of the most common types of physical activity you do for sport, exercise or recreation **currently** [only appear if at least one of the three days per week questions (1. physical activity that increases your heart rate, 2. muscle strengthening exercises, 3. balance and functional training)is ≥ 1]

Activity 1	
Activity 2	
Activity 3	

Now we would like to ask you some questions about your pre-injury and current physical activity *(Child version 10-17)*

Physical activity is any activity that increases your heart rate and makes you get out of breath some of the time.

This may include sport, exercise, playing with friends, or walking to school.

Some examples of physical activity are running, brisk walking or wheeling, rollerblading, biking, dancing, skateboarding, swimming, soccer, basketball, football, surfing, wheelchair rugby.

Think about a **typical** week just **before** you had your injury.

On average, how many days per week did you engage in physical activity that increased your heart rate and made you get out of breath some of the time?

0 days	1 day	2 days	3 days	4 days	5 days	6 days	7 days
☐	☐	☐	☐	☐	☐	☐	☐

On average, how many minutes per day of the days you were active did you engage in physical activity at this level?

0 mins/day	10 mins/day	20 mins/day	30 mins/day	40 mins/day	50 mins/day	60 mins/day	90 mins/day	120 mins/day	150 or greater mins/day
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

List up to three (3) of the most common types of physical activity you did for sport, exercise or recreation **before your injury** [only appear if "On average how many days per week did you engage in physical activity that increased your heart rate and made you get out of breath some of the time" ≥ 1 day]

Activity 1	
Activity 2	
Activity 3	

Current physical activity participation:

Think about a **typical** week for you **now.**

On average, how many days per week do you engage in physical activity that increases your heart rate and makes you get out of breath some of the time?

0 days	1 day	2 days	3 days	4 days	5 days	6 days	7 days
☐	☐	☐	☐	☐	☐	☐	☐

On average, how many minutes per day of the days you are active do you engage in physical activity at this level?

0 mins/day	10 mins/day	20 mins/day	30 mins/day	40 mins/day	50 mins/day	60 mins/day	90 mins/day	120 mins/day	150 or greater mins/day
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Over a typical or usual week, on how many days are you physically active for a total of at least 60 minutes per day?

0 days	1 day	2 days	3 days	4 days	5 days	6 days	7 days
☐	☐	☐	☐	☐	☐	☐	☐

How many days per week do you perform vigorous-intensity aerobic activities as well as those that strengthen muscle and bone?

0 days	1 day	2 days	3 days	4 days	5 days	6 days	7 days
☐	☐	☐	☐	☐	☐	☐	☐

List up to three (3) of the most common types of physical activity you do for sport, exercise or recreation **currently** [only appear if "On average how many days per week did you engage in physical activity that increased your heart rate and made you get out of breath some of the time" ≥ 1 day]

Activity 1	
Activity 2	
Activity 3	