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Rehabilitation models

A scoping review

Alternative rehabilitation models and frameworks for clients with traumatic brain injury and orthopaedic trauma

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A joint initiative of

WorkSafe VICTORIA · TAC Transport Accident Commission · MONASH University

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EXECUTIVE SUMMARY

Background and Purpose

This evidence review was conducted to identify rehabilitation models and effective interventions for rehabilitating individuals with traumatic brain injury (TBI) and orthopaedic trauma. Additionally we sought to identify the characteristics of effective rehabilitation interventions. Rehabilitation following significant injury and trauma is traditionally delivered in a hospital inpatient setting. We wished to identify alternative models and interventions to inpatient rehabilitation.

It is intended that the findings from this evidence review will provide a better understanding of the different rehabilitation models and interventions available to the TAC to improve health and social outcomes for their clients through the development of a new Rehabilitation Strategy.

Method

We conducted a scoping review in two parts: 1) a website search for rehabilitation models and pathways of care in current national and international care guidelines; and 2) a database search for studies of rehabilitation interventions in the scientific literature. We identified nine rehabilitation models of care and 23 studies of rehabilitation interventions. Interventions were categorised into one of six delivery settings.

Findings

The key findings from the scoping review are:

- Rehabilitation models of care are underpinned by **flexible, multidisciplinary and evidence-based coordinated rehabilitation, delivered continuously across the rehabilitation journey and which engages patients.**
- Effective rehabilitation interventions are **commenced early, deliver continuous tailored care of the right intensity.**
- Comprehensive **multidisciplinary outpatient rehabilitation** is effective for clients with moderate to severe TBI.
- **Home-based post-acute rehabilitation** may be as effective as outpatient or inpatient rehabilitation for some clients with moderate to severe TBI.

Key Messages

Based on the available evidence and existing local and international models of care, the following areas may be considered in the development of the TAC's new Rehabilitation Strategy:

- Develop a rehabilitation model in partnership with hospital and community health providers. The model needs to be sufficiently flexible to be tailored to individual client need and to enable entry and re-entry across rehabilitation stages.
- Work collaboratively with health service providers to deliver coordinated rehabilitation services that are multidisciplinary, tailored and initiated early in the rehabilitation journey.
- Consider home-based post-acute rehabilitation for clients who sustain moderate to severe TBI and have a low risk of complications.
- Given the lack of available evidence on rehabilitation for orthopaedic trauma, the TAC could consult with a range of expert health professionals, organisations and consumers.

INTRODUCTION

This evidence review was conducted to identify different rehabilitation models and interventions that are effective at rehabilitating individuals with traumatic brain injury or orthopaedic trauma.

Rehabilitation aims to optimise functioning and reduce disability in individuals with health conditions such as those due to traumatic brain injury and orthopaedic trauma. Appropriate comprehensive rehabilitation following injury is associated with improved health and social outcomes for individuals, and economic benefits for health services, compensation schemes and society as a whole.[1] A wide range of rehabilitation models and interventions exist that vary, for example, according to setting, intensity, quantity and delivery timing.[2]

Injury type and patient characteristics play significant roles in the selection of rehabilitation setting and intervention. However other factors identified to influence rehabilitation include: availability and accessibility of community rehabilitation services, inpatient rehabilitation admission criteria, and discharge planning quality within the acute care setting.

Previous research has identified a number of challenges associated with rehabilitation. Specifically, acute bed pressures and compensable status have been found to increase the likelihood of rehabilitation being delivered in the inpatient setting compared to alternate (and potentially more appropriate) settings. Furthermore, inpatient rehabilitation for orthopaedic trauma in the post-acute phase has been associated with poorer self-reported patient outcomes among some TAC clients, in comparison to public patients not discharged to inpatient rehabilitation.

Identifying alternative effective rehabilitation models and interventions for individuals with traumatic brain injury and orthopaedic trauma will help ensure individuals receive comprehensive rehabilitation in the most appropriate setting to achieve optimal health and care outcomes. Specifically, identifying the features of effective rehabilitation models and interventions can inform the development and implementation of a new evidence-based rehabilitation strategy to achieve optimal outcomes for TAC clients.

Research Questions and Scope

The key research questions for this review, identified in consultation with the TAC, were:

1. What range of rehabilitation models or interventions for delivering rehabilitation services are reported?
2. How effective are rehabilitation models or interventions for improving patient outcomes?
3. What are the key characteristics of effective rehabilitation models or interventions?

This report was prepared by the ISCRR Evidence Review hub and presents a scoping review of the literature.

METHODS

This scoping review was undertaken in two parts: 1) a search for models and pathways of care in current national and international guidelines through a worldwide website search; and 2) a literature search for evaluation studies of models of care, care pathways or interventions in published scientific literature.

Literature Search

1. Rehabilitation models of care

A targeted search for current rehabilitation models of care was conducted in March 2017. One reviewer searched the Google website using a combination of the search terms: rehabilitation model of care, pathway of care, acquired brain injury, traumatic brain injury, and orthopaedic trauma. Additionally the websites of Australian state and international government health services were searched for guidelines and/or descriptions of rehabilitation models of care.

2. Rehabilitation interventions

A search for primary studies and systematic reviews of rehabilitation interventions was conducted in January 2017. One reviewer searched the Medline, EMBASE, CINAHL, PsychInfo, Cochrane Library, Scopus and Web of Science electronic databases using a combination of the search terms: low severity acquired brain injury/traumatic brain injury, orthopaedic trauma, lower leg fracture, trauma patient (population); rehabilitation, fast track, community based rehabilitation, care coordination, integrated care coordination, discharge planning, bundled payments (Intervention); mortality, morbidity, pain, postoperative complications, postoperative functional status, mobility, ability to perform activities of daily living, length of hospital stay, admission rates, return to work, independent living, discharge destination (Outcome). The search was restricted to English language peer-reviewed papers published since 1990.

All identified primary study and systematic review titles were screened independently by two reviewers. Papers were retained if they described a rehabilitation service and/or model of care, care pathway or intervention delivered to individuals following ABI or orthopaedic trauma. Following the initial screening process, full text articles were obtained and assessed for eligibility based on specific criteria developed a priori by the ISCRR Evidence Review team in collaboration with the TAC project sponsors. The inclusion and exclusion criteria are outlined below.

Population

Primary studies and systematic reviews were included for review if they included working-aged adults 18 to 65 years who had sustained an acquired brain injury (ABI) or orthopaedic trauma from any cause within the previous 12 months. Studies were excluded if at least 50% of the sample comprised youth aged <18 years or older adults > 65 years. We excluded orthopeadic injury due to osteoarthritis and other age-related causes. Orthopeadic injury and ABI due to degenerative and other non-traumatic causes were also excluded. Where studies included a range of injury conditions, they were retained if at least 50% of the sample had sustained an ABI or orthopaedic trauma. Individuals were required to have utilized acute care or rehabilitation services for their injuries.

Intervention

Evaluation studies of any rehabilitation service, model of care, or care pathway designed to reduce disability and promote community reintegration following ABI or orthopeadic trauma were included for review. Interventions could be delivered within a broader rehabilitation program and comprise one or more components delivered in one or more setting/s. Interventions or rehabilitation services

that commenced more than 12 months post-injury were excluded as such interventions targeted the chronic phase and were considered outside the scope of this review.

Outcomes

To be included for review the primary studies and systematic reviews were required to include at least one individual-level health-related outcome as a primary measure of an intervention's effectiveness. Specific primary outcomes could include: overall health, functioning, pain, return to work, independent living, quality of life, all-cause mortality, morbidity, and post-operative complications. Secondary outcomes could include: resource use (including length of hospital stay and readmission rates), level and extent of required care post-discharge, and carer burden. Primary studies and systematic reviews that included qualitative evidence were included. To be eligible for review systematic reviews were not required to include meta-analyses.

Classification of studies

The PRISMA flowchart (refer to Appendix 1) provides an overview of the study identification process conducted as part of the scientific literature search. Initially 2661 records were identified through the database searches and a further 18 records through scanning of reference lists of other papers. Following removal of duplicates, the titles and abstracts of 598 papers were reviewed manually. After the initial abstract and title screen, 173 papers were identified as potentially relevant. Full text papers were obtained and assessed for eligibility. One hundred and forty seven full text papers were excluded as they did not meet the inclusion criteria for this review. Twenty-four papers were retained for data extraction and synthesis. One reviewer systematically extracted information on study design, sample characteristics, intervention characteristics and study results for each included primary study and systematic review paper.

Quality assessment

We conducted a quality assessment of the scientific evidence as part of the second stage of the review. The quality of primary studies was assessed using the Effective Public Health Practice Project (EPHPP) Quality Assessment Tool for quantitative studies.[3] The EPHPP checklist assesses six domains of study quality: selection bias; study design; confounders; blinding; data collection; and dropouts. The tool produces an overall rating of study quality as strong, moderate or weak. Studies judged to have a strong level of quality have no weak ratings across the six key quality domains. Studies of a moderately strong quality have weakness in one quality domain, while those judged to be qualitatively weak have been judged to be weak in two or more domains.

The quality of systematic reviews was assessed using the Assessing the Methodological Quality of Systematic Reviews (AMSTAR) tool.[4] The AMSTAR appraises the methodological rigour of systematic reviews across 11 items. Systematic reviews received a score for each checklist item adequately addressed. No score was given for inadequately addressed items or where a judgement could not be made. Review papers could achieve a possible total score of 11. Systematic reviews that adequately addressed 9-11 checklist items were judged to be high quality. Moderate quality papers addressed five to eight items, while low quality papers addressed four or fewer items.

Quality appraisal of included studies was undertaken independently by two reviewers. In the case of disagreement consensus was reached through discussion.

Data synthesis

1. *Rehabilitation models of care*

Rehabilitation models of care are developed by health services and organisations to articulate pathways of care and guide the delivery of rehabilitation services. We identified the underlying

principles of models of care included for review based on descriptions within guideline documents and online descriptions published on government health service websites. We ordered the principles according to the frequency they were used to describe the different rehabilitation models. We considered as common principles of rehabilitation models of care those that were discussed in relation to two or more models.

2. Rehabilitation interventions

Rehabilitation interventions evaluated within the scientific literature were categorised according to the setting in which they were delivered. The categories were: inpatient, residential, outpatient, community, home-based, and continuous rehabilitation interventions. Continuous interventions were those that delivered rehabilitation across multiple settings.

RESULTS

1. *Rehabilitation models of care*

In this section we summarise the current rehabilitation models of care identified in the first stage of the review. A model of care is a comprehensive and broad design for the delivery of healthcare services informed by theory, evidence and defined standards.[5] A range of rehabilitation models of care exist which differ across organisations and countries. Of note, Victoria does not have existing state-wide models for rehabilitation related to general conditions or orthopaedic trauma. There is limited disparate information on specific models of care within the scientific literature.[6]

Table 1 below presents the nine identified rehabilitation models of care mapped against the nine most common key principles.

Table 1. Identified rehabilitation models of care mapped to the nine most common principles[1]

Model of care	Client centred	Equity of access	Evidence based	Interdisciplinary	Early intervention	Coordination	Continuity of care	Service integration	Family engagement
General									
NSW	●	●	●	●		●			●
United Kingdom	●		●	●	●	●	●	●	●
Specialist ABI/TBI									
NSW	●	●	●	●	●	●	●		●
Vic - Alfred hospital	●		●	●			●		●
SA 'Hub and Spoke'	●	●	●	●	●	●	●	●	●
The Nether-lands[2]									
UK Slinky model	●		●	●	●		●		
Canada[3]	●			●			●	●	●
Specialist Orthopaedic trauma									
SA	●	●	●	●	●	●	●		●

Note. [1]Listed principles represent those identified within publically available guidelines and/or literature and may not represent an exhaustive list of principles of any one Model of Care; [2]Details of the principles underlying the Netherlands rehabilitation model of care were not described; [3]Consistency of model of care principles across health organisations and provinces differs due to lack of national rehabilitation service.

Summary of Key Findings

We reviewed nine current rehabilitation models of care from Australian and international health contexts, including two models for the rehabilitation of general conditions, six models for ABI and one model for orthopaedic trauma. All of the models described are characterised by flexibility, in

recognition that individuals' rehabilitation journeys are unique and thus require an individualised approach to rehabilitation. Additionally, each of the models emphasise the need for entry, exit and re-entry across phases of care and over time. The most common principles across the models include: client-centred; interdisciplinary; patient and family engagement; continuity of care; and evidence-based. Coordination of care, or case management, is common to five different rehabilitation models. Recommendations as to the setting or profession best placed to undertake such a role is rarely articulated in documents describing these models. Home-based therapy was often considered appropriate for individuals unable to reasonably access outpatient or other local community-based services. Home-based rehabilitation does not appear to be a common delivery setting within the care pathways of the models described.

The South Australian rehabilitation model for ABI appears unique. It is notable for addressing rehabilitation needs across severity levels. The model describes a partnership approach across geographic regions to ensure equity of access, particularly across regional and rural locations.

The need to engage in evaluation research and contribute to the growing evidence base regarding rehabilitation effectiveness underpins a number of the models discussed. Of note, however, rehabilitation models do not appear to have been evaluated in the scientific literature. Therefore we do not know the impact of current rehabilitation models on client outcomes.

Detailed Findings

Key elements of each of the models are described below.

General rehabilitation models

New South Wales

The NSW state-wide rehabilitation model of care focuses on adult general rehabilitation (refer to Figure 1) with key consideration given to rehabilitation following stroke, orthopaedic trauma, reconditioning impairments and amputation.[7] According to this model, rehabilitation aims to restore functioning post illness/injury, regain pre illness/injury level of functioning, and develop functional ability to compensate for irreversible deficits in abilities.

The model promotes an *enablement* approach and aims to integrate assessment and care coordination to support continuity of care across settings. Case management is a key feature to support patients through their care journey and engage primary care and community services early in the rehabilitation process.

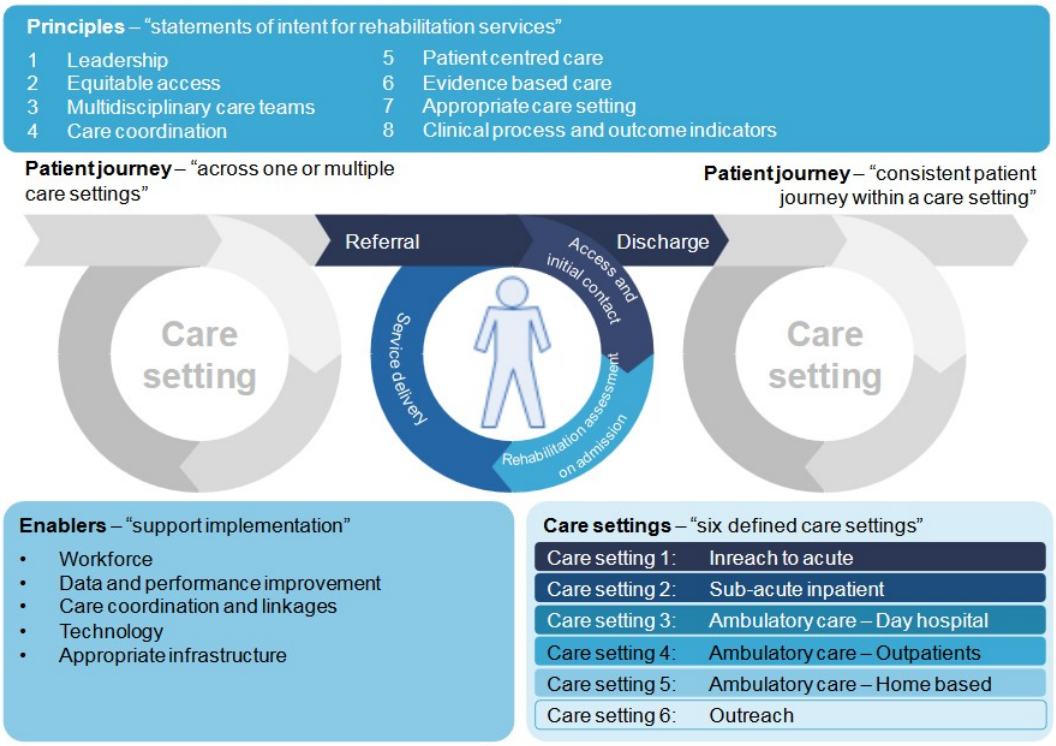

Fig 1. NSW Model of Care.[7]

United Kingdom

As Figure 2 shows, the National Health Service (NHS) model of rehabilitation services describes different phases of the rehabilitation pathway and the services required at each point.[8] The complex model was designed to be interpreted with flexibility according to patient need and rehabilitation pathway. The ability to transition between phases as well as exit and re-enter different phases across time as needed are dependent on strong networks and consistent dependable interprofessional communication.

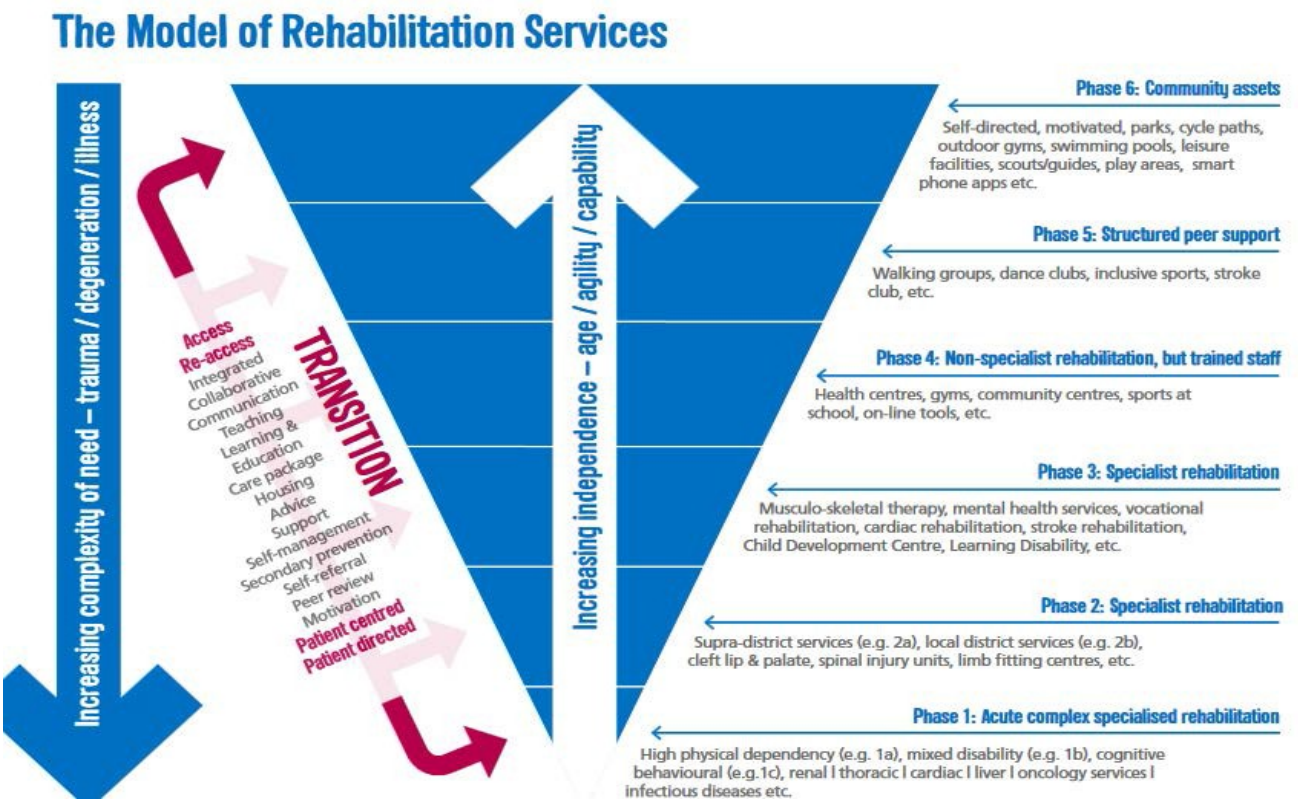

Fig 2. NHS Model of rehabilitation services.[8]

The NHS rehabilitation model is underpinned by 10 broad principles that were developed from service users' feedback and the scientific evidence. The principles of good rehabilitation services in England include: optimisation of patients' physical, mental and social wellbeing; patient and carer engagement; encouragement of hope and ambition and balance risk to maximise outcomes; use of individualised, goal-based approach to rehabilitation that is evidence-based; early and ongoing assessment and needs identification; support patient self-management; use of a range of interventions; use integrated multi-agency pathways; strong leadership and accountability with effective communication; and the conduct of research activities to contribute to the evidence base.[8]

Traumatic brain injury rehabilitation models

New South Wales

The NSW specialist model of care for brain injury rehabilitation describes a pathway of care for individuals who sustain a moderate to severe brain injury and are admitted to the state-wide Brain Injury Rehabilitation Program.[6]

The NSW specialist model of care is characterised by 11 key principles: equity of access, early intervention, needs-driven, goal-based, continuity of care, community rehabilitation, enablement, contextual-based care, participation-based care, family-centred care, and evidence-based care. ABI rehabilitation is provided across five phases: acute admission, inpatient services, transitional rehabilitation, community-based services and discharge. Care is provided across three settings:

- Specialist inpatient rehabilitation provides high level care for severe to very severe TBI.
- Transitional living programs provide intense rehabilitation focused on community reintegration and social participation. Therapy is delivered through individual and group sessions and incorporates client-centred goal planning and family engagement.
- Community based multidisciplinary services provide contextually based rehabilitation close to home. Case management is a core feature of service coordination and delivery.

A patient-centred approach enables entry, progression, exit and re-entry across care phases according to current need. Services are located across metropolitan, regional and rural NSW.

Victoria

The Alfred hospital in Melbourne established a state-wide evidence-based ABI rehabilitation service to provide comprehensive specialist rehabilitation for severe ABI across inpatient, outpatient and community settings.[9] The rehabilitation model that underpins the rehabilitation service at the Alfred was developed in 2014-15 in collaboration with ISCRR.[10] The key principles underpinning the Alfred's ABI rehabilitation program include: early transfer and discharge; comprehensive interdisciplinary care; evidence-based; person-centred; family/carer engagement; patient education; and continuity of care across service settings.[9]

South Australia

Specialist ABI rehabilitation is provided to South Australians through a state-wide 'Hub and Spoke' model system (see Figure 3) developed by the NSW Brain Injury Rehabilitation Program (BIRP).[11] The BIRP was established as a best practice model of specialised rehabilitation within the state of NSW. A partnership approach among hospital and community services across metropolitan, regional and rural South Australia enables patients to access specialist services in the most appropriate and accessible settings for timely rehabilitation. Within this model a single contact point provides screening, access and coordination of service delivery. The establishment of an ABI-specific interdisciplinary liaison/consultation service is key to provide case management, brokering of services, and communication among care providers, patients and families. This allows for integrated care pathways and seamless transfer among services and settings. Multidisciplinary intensive rehabilitation is initiated early in the acute phase and patients have access to specialist outpatient services in the post-acute phase.

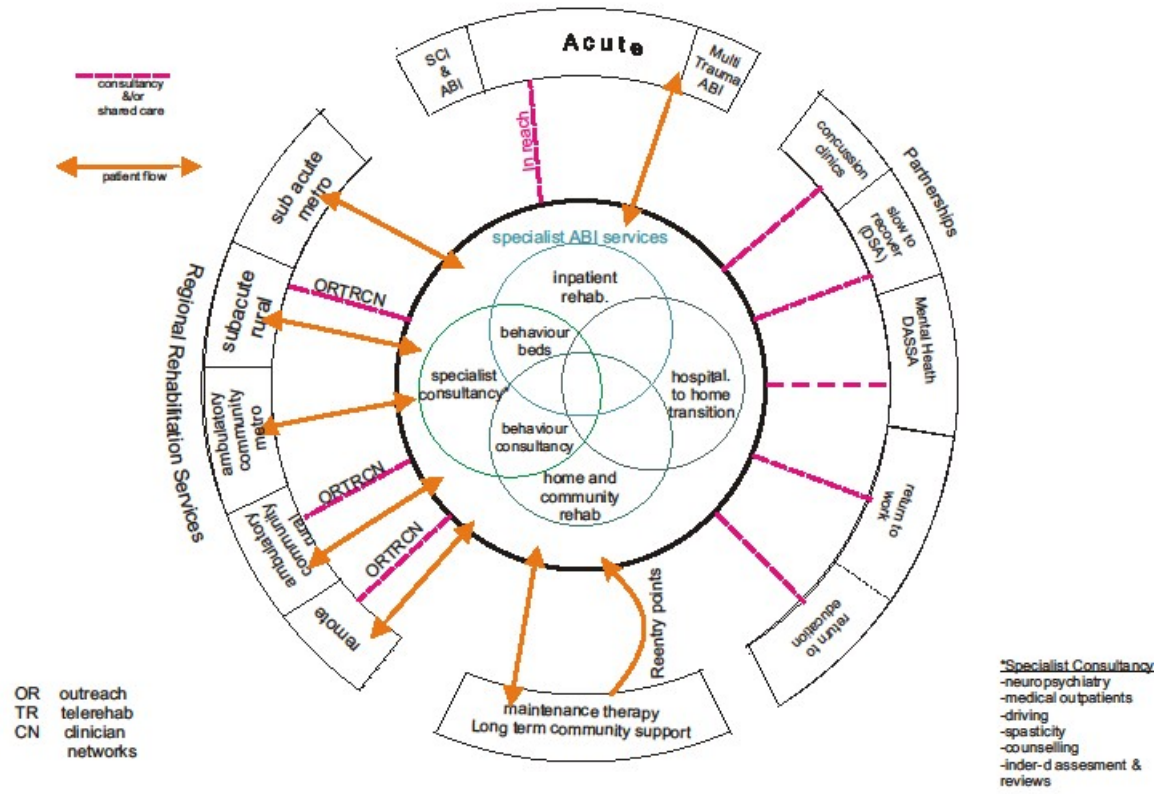

Fig 3. South Australian Brain Injury Rehabilitation Service: Hub and Spoke model.[11]

The Netherlands

TBI rehabilitation in the Netherlands is provided by national coverage of rehabilitation facilities, compulsory healthcare insurance that includes rehabilitation, and coverage of costs associated with long-term care.[12] The TBI care pathway varies according to injury severity. Most individuals who sustain a mild TBI are not referred to hospital and do not receive follow up care. Following a moderate to severe TBI in the Netherlands, individuals are admitted to a Level 1 trauma centre for acute medical management and determination of rehabilitation needs. Once patients are medically stable they are either discharged home or to inpatient rehabilitation, depending on need. Inpatient rehabilitation aims to restore functioning to enable early discharge. The estimated average inpatient length of stay is four months.[12] Approximately 90% of TBI patients are discharged from inpatient rehabilitation to home with outpatient rehabilitation for up to eight months. Outpatient rehabilitation focused on social integration includes recreational and vocational activities and addresses parental and marital issues.

Limited information could be sourced on TBI models of care in the Netherlands.

United Kingdom

The British Brain Injury National Clinical Guidelines developed a 'slinky' model to describe the phases of rehabilitation delivered within the United Kingdom (see Figure 4).[13, 14] This model emphasises flexibility of care and the ability for patients to enter and re-enter the care pathway across phases and at different times according to need. Seamless continuity of care is provided across four stages in hospital and community settings through information sharing and strong interprofessional communication.

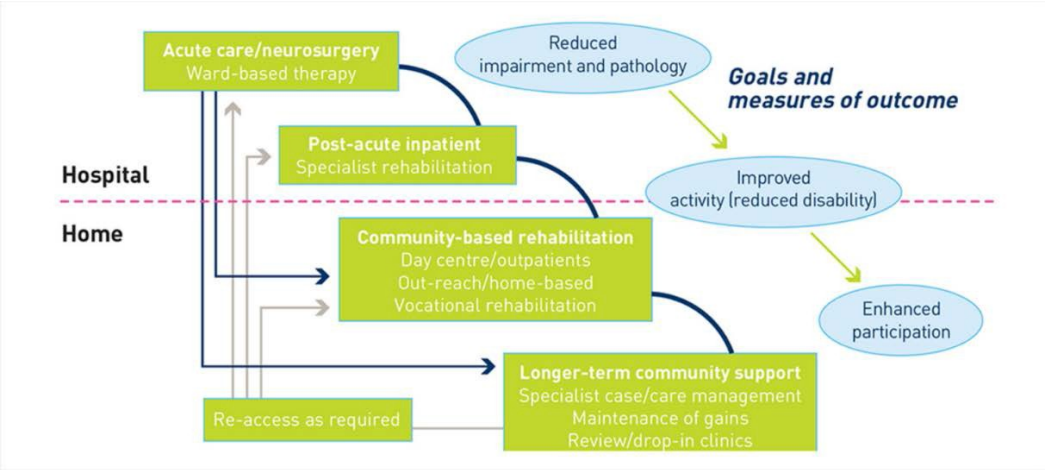

Fig 4. The Slinky model of rehabilitation.[14]

Canada

Canada does not have a national ABI rehabilitation system resulting in a wide variety of approaches to ABI rehabilitation across the country.[15] In general, interdisciplinary client-centred rehabilitation is provided for individuals with moderate to severe ABI, with continuity of care provided flexibly across inpatient and community settings. It appears that very limited rehabilitation is available for Canadians who sustain very severe injuries.[15]

The Toronto Rehabilitation Institute has been identified providing an exemplar pathway of care for ABI rehabilitation in Canada.[15] Within this institute, ABI rehabilitation begins in the emergency department. Once medically stabilised, patients with moderate to severe ABI are discharged home, with or without outpatient follow-up, or to inpatient rehabilitation. Post-acute rehabilitation is commenced 30-60 days post injury. While in inpatient rehabilitation, patients receive 3-5 hours of therapy each week day, return home on weekends, and remain in the program for, on average, 53 days.[15] Eighty percent of patients are discharged from inpatient rehabilitation to home. Community based rehabilitation is provided in a neurorehabilitation day hospital where patients receive therapy 2-3 times per week as needed. Therapy is multidisciplinary and includes physiotherapy, occupational therapy, psychiatry, neuropsychology, as well as vocational and driving assessments.

Of note, case management is not consistently provided across Canadian provinces and health services.[15]

Orthopaedic trauma rehabilitation model

We identified a single model of care specific to general orthopaedic trauma.

South Australia

The South Australian general orthopaedic trauma model of care outlines a pathway of care for simple orthopaedic trauma to one or more limbs, and pelvic or spinal injuries (refer to Figure 5).[16] Rehabilitation following spinal cord injuries, complex trauma to multiple body systems, or fragility fractures are outside the scope of this general model. Rehabilitation is delivered across five care phases: initial management, acute inpatient care, post-acute rehabilitation, community-based rehabilitation, and ongoing maintenance. A central tenet of the model is the provision of integrated multidisciplinary services that are client-centred and individualised. Entry, progression and exit across the phases are dependent on injury, patient and environmental characteristics. Coordination is a key feature of the pathway. However the model does not specify the most appropriate setting or

resource to fulfil this role. This could be a stand-alone role, combined with an existing role, or provided within a team approach within either a hospital or community setting.

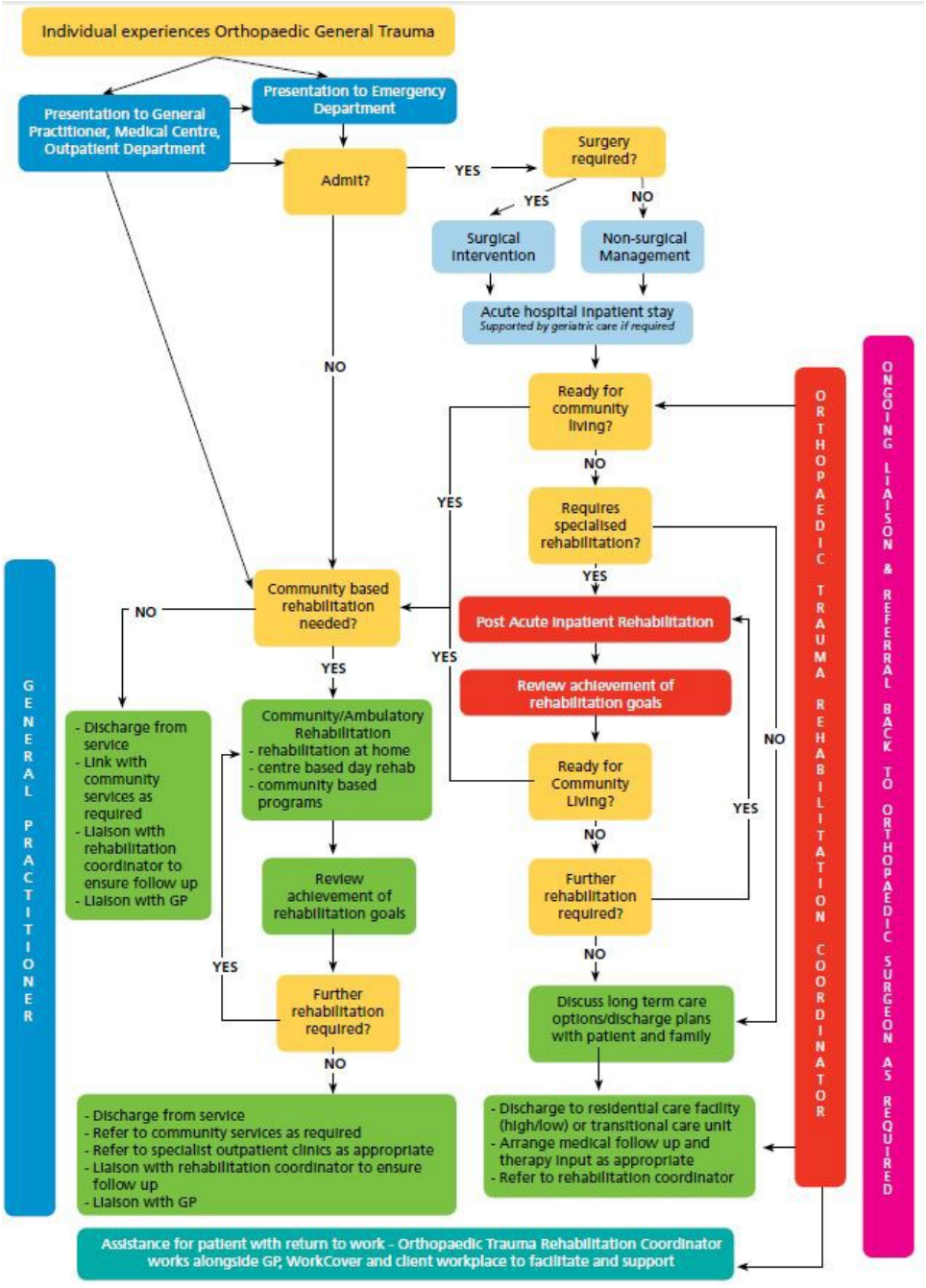

Fig 5. South Australian Model of care for general orthopaedic trauma.[16]

2. Rehabilitation Interventions

In this section we present the results of the literature search of rehabilitation interventions for TBI and orthopaedic trauma. Table 2 summarises the key rehabilitation interventions based on the description of interventions within reviewed studies.

Table 2. Characteristics of rehabilitation interventions

Intervention type (n interventions)	Case management	Integrated care	Supported discharge	Interdisciplinary	Patient/family engagement	Continuity	Individualised
Community (4)	2/4	1/4	1/4	4/4	2/4	0/4	3/4
Continuous (3)	2/3	2/3	2/3	3/3	0/3	2/3	3/3
Education (2)[1]	0/2	0/2	0/2	0/2	2/2	0/2	0/2
Inpatient (6)	1/6	3/6	0/6	5/6	2/6	0/6	2/6
Residential (1)	0/1	1/1	0/1	1/1	1/1	0/1	1/1
Outpatient (9)	3/9	3/9	0/9	7/9	3/9	4/9	6/9
Home-based (2)	0/2	0/2	0/2	0/2	2/2	0/2	2/2

Note. [1]Interventions considered in systematic reviews.

Summary of Key Findings

Overall, based on the evidence we reviewed, inpatient rehabilitation for moderate to severe TBI appears effective when commenced early, intensely delivered and tailored to patient need. Five of eight studies reviewed found outpatient rehabilitation to be effective for TBI. Effective outpatient interventions were comprehensive and multidisciplinary.

Four primary studies and one systematic review evaluated a range of community-based rehabilitation interventions for TBI. The limited evidence suggests that multidisciplinary community-based interventions can have a positive effect on short-term functional outcomes and health service use. Community-based rehabilitation was not found to be superior to residential rehabilitation in one primary study. Few studies have evaluated rehabilitation interventions delivered continuously across settings, however preliminary findings based on two diverse studies suggest it may be effective. Two studies provided support for home-based rehabilitation for moderate to severe TBI. Finally we identified no evidence in support of specialist rehabilitation and some evidence in support of low intensity educational interventions for mild uncomplicated TBI based on three systematic reviews.

Detailed Findings

Study characteristics

Twenty-four eligible papers were identified for review. These included 21 primary and three systematic review studies that were published between 1993 and 2016. Refer to Appendix 2 for primary study characteristics and Appendix 3 for systematic review characteristics. The majority of studies were conducted in America[17-23] and Canada[24-28], while three were published in Australia[29-31], two in Sweden[32, 33] and two in the United Kingdom[34, 35]. One paper each originated from Germany[36, 37], Norway[38], Japan[39] and China[40]. The study designs of the 21 primary studies, included cohort control[17, 18, 25, 30, 36, 38, 39], RCT[21, 22, 26, 28, 33, 40], and single sample designs[19, 20, 23, 27, 29, 31, 34, 37]. Of the studies that adopted a single sample design, Doig et al. used a repeated-measures cross-over design and Dow et al. conducted an outcome evaluation.

We assessed most primary studies as methodologically strong[21, 22, 26, 28, 30, 33, 40] or moderate[17-19, 23, 25, 27, 29, 34, 36-39, 41]. The impact evaluation conducted by Dow et al. was assessed as methodologically weak. Of the three systematic reviews included for review, two were assessed as being of moderate quality[24, 32] and the Cochrane review by Turner-Stokes et al.[35] as high quality.

Sample characteristics

Primary study sample sizes ranged from 14[29] to 1534[36] participants, with an average of 301 participants. All studies included male and female participants. Eight studies sampled working-aged adults 16 to 65 years[17, 21, 22, 26, 29, 30, 38, 39], while four studies sampled adults of any age [23, 25, 34, 36]. Zhu et al. sampled a wider age range of 12 to 65 years, and Dow et al. included participants aged 17 to 105 years with a sample mean age of 74 years.

Participants were recruited from acute[21, 22, 37, 40] or post-acute[18-20, 23, 25, 27, 29, 30, 34, 36, 39] rehabilitation settings. A further four studies recruited participants from hospital emergency departments[26, 28, 33, 38]. Cusick et al.[17] obtained their sample through a state-wide health service database. The recruitment sources used by Dow et al.[31] were not clearly described.

Within 19 studies, cohorts were exclusively patients who had sustained a TBI or an ABI. Of the six studies of patients with an ABI[27, 30, 34, 36, 39, 41], 28-85% of samples had sustained a TBI. Griesbach et al. evaluated the effectiveness of rehabilitation for 36 patients with TBI compared to eight patients with CVA. Of the studies of rehabilitation for TBI or ABI, injury severity levels included mild[24, 26-28, 32, 33], moderate to severe[17, 18, 21, 22, 25, 29, 30, 40], severe[37, 38], or a range of severity levels[19, 34, 36, 39-41]. The sample in Dow et al.'s study comprised patients with a range of general conditions, including 58% who required rehabilitation following orthopaedic surgery.

Interventions were commenced within three months[21, 26, 28, 30, 33, 37, 40], three to six months[22, 23, 25, 29, 34, 36, 39], or six to 12 months[17, 18] post-injury. The delivery timing of three interventions varied from 0 to more than 24 months[27], 38 to 9040 days[20] and less than three months to more than five years[19]. Four studies examined the impact which the timing of delivery had on patient outcomes[18-20, 38]. Dow et al. did not indicate the timing of rehabilitation delivery.

Rehabilitation interventions evaluated

Of the primary studies reviewed, five evaluated a single rehabilitation intervention compared to care as usual, two compared the effectiveness of an intervention to no treatment, and nine did not include a comparison treatment condition. A further three primary studies compared the delivery setting of a rehabilitation intervention. Three studies compared rehabilitation delivered in different settings. Paniak et al.[28] compared the effectiveness of an abbreviated severe TBI rehabilitation program to a single brief education session for mild TBI. Vanderploeg et al.[22] compared two specific post-acute inpatient therapies.

Interventions included inpatient[21, 22, 25, 38, 40], outpatient[18, 19, 23, 26, 29, 33, 36, 39, 41], community-based[17, 27, 30, 36], residential[30, 34], home-based[21, 29] and continuous[28, 31, 37] rehabilitation programs. Two studies compared rehabilitation delivered either in an inpatient[21] or outpatient[29] setting to a home-based

setting. Grill et al. evaluated a multi-component coordinated advisory program delivered within the community with home-based components.

Outcomes evaluated

Primary studies included one to four primary outcomes, and all studies included functional outcomes as primary measures of intervention effectiveness. Additional primary outcomes assessed include: return to work, independent living, quality of life, social participation, self-reported health, support needs, ADL performance and satisfaction, length of hospital stay, symptom improvement, discharge destination, and distress levels.

Evidence of the effectiveness of interventions

In this section we present a detailed synthesis of the evidence regarding the effectiveness of the six types of rehabilitation interventions for TBI or orthopaedic trauma. Appendix 4 provides a summary of the key findings.

Inpatient rehabilitation

Three of the six inpatient rehabilitation interventions evaluated in the primary studies we reviewed were found to be effective for moderate to severe TBI. Additionally one systematic review provided limited support for the effectiveness of inpatient rehabilitation based on two studies.[35] It appears that specialist inpatient rehabilitation for severe TBI that is commenced early, intensely delivered and tailored to patient need is most effective.

One primary study examined the impact that timing of delivery had on rehabilitation outcomes.[38] Comprehensive inpatient rehabilitation was commenced a median 12 days following severe TBI, was associated with a non-significantly shorter length of inpatient rehabilitation (median 29 days) and better functional outcomes 12 months later compared to either delayed (by 6-57 days) or no inpatient rehabilitation (OR 2.78, $p < .05$).[38] Early rehabilitation was provided within a dedicated section of an intensive care unit (ICU) and comprised comprehensive motor, sensory and facial therapy components for one hour and 45 minutes a day. A greater proportion of patients who received the early rehabilitation were living at home (81%) compared to the control patients (53%) at 12 months.

Domain-specific inpatient rehabilitation appeared to be effective but only when tailored to patient need. One RCT found that an 8-week cognitive rehabilitation intervention was no more effective when delivered in an inpatient versus a home setting.[21] Similarly, an RCT that randomised patients with moderate to severe TBI to receive either cognitive or physical rehabilitation within six months post-injury reported no significant differences between groups 12 months later.[22] Overall, 59% of the sample were living independently and 37% had returned to work at follow-up. Another functional neurorehabilitation intervention streamed patients to receive either physical- or cognitive-focussed treatment based on domain of greatest deficit. Streaming was associated with significantly better functioning at discharge compared to standard neurorehabilitation.[25] Patients who received neurophysical therapy had significantly greater motor function, and those who received neurocognitive therapy had reduced disability, on discharge compared to matched controls. Further neurophysical therapy was associated with a 13-day shorter length of stay compared to standard rehabilitation.

Finally, a small RCT compared the effectiveness of tailored multidisciplinary therapy delivered intensely (four hours per day) compared to standard delivery (two hours per day).[40] Therapy commenced a mean 22 days post-TBI and continued until either patients regained functional independence or six months had passed. Study findings indicated that a significantly greater proportion of patients who received intense therapy achieved functional independence (47%) and social integration (38%) at three months and were discharged compared to those who received standard therapy (19% and 14%, three month functional independence and social integration respectively). No significant differences at any other time to 12 months were noted. These findings

suggest that intense inpatient therapy is associated with earlier recovery than rehabilitation that is less intense.

Outpatient rehabilitation

Of the eight outpatient rehabilitation interventions evaluated, five were found to have beneficial effects.[18, 19, 23, 26, 39] In particular comprehensive outpatient rehabilitation programs appear most effective, particularly for moderate to severe TBI.

Two RCTs evaluated the effectiveness of outpatient rehabilitation for mild TBI and reported no overall beneficial effect.[26, 33] For example, a single outpatient appointment 14-21 days post mild TBI for patients with ongoing symptoms had no impact on quality of life or functioning at three months post-injury. Ghaffer et al. randomised 191 individuals within one week of sustaining a mild TBI to receive either tailored multidisciplinary treatment for up to six months or no treatment. The intervention consisted of ongoing assessment and treatment by an occupational therapist, neuropsychiatrist and rehabilitation physician, in addition to home-based support and referral to specialist services as needed. Overall there was no difference in pain and mental health symptoms between intervention and control groups at six months. However, among patients with pre-injury psychiatric conditions the intervention was associated with significantly reduced depressive symptoms at follow up.

A 6-week occupational therapy program was no more effective when delivered a median 5.7 months post TBI in an outpatient clinic compared to home-based delivery.[29] Therapy was goal-directed, structured and environment-focussed. This repeated measures cross-over study found that both therapy settings were associated with significant improvement in goal achievement, functioning and community reintegration 18 weeks after intervention end.

In contrast, comprehensive multidisciplinary outpatient rehabilitation was associated with significant functional improvement in three separate studies.[19, 23, 39] Group-based day treatment initiated within six months post-ABI led to significantly greater speech, cognitive function and social integration at treatment completion for 25 Japanese patients compared to 12 patients who received usual care. At treatment end (3-6months) 36% of intervention patients and 17% of controls had returned to work or study. Similarly, The Challenge Program (TCP), an American comprehensive post-acute rehabilitation program was associated with decreased disability (mean change score 2.71) and increased social integration ($p < .01$; m change score 3.0) from enrolment to treatment completion. However no further improvement in functioning or social integration was found at the 46 month follow up. This finding suggests that ongoing continuity of care within the community may be required for further sustained improvement. A larger study evaluated a comprehensive neurorehabilitation program. Treatment was initiated up to five years post-injury to 1274 patients with TBI of varying severity levels. Coordinated post-acute outpatient rehabilitation involved psychiatry, nursing, neuropsychology, physical therapy, occupational therapy and speech therapy, in addition to specialist referral as needed. Patients remained in the program for up to 74 weeks. Treatment was associated with significant functional improvement from baseline to treatment end ($p < .05$; $d = 1.24$). The majority (69%) of patients demonstrated clinically significant improvement at treatment end regardless of time since injury. However significantly greater improvement was made by patients who commenced treatment within three months post-injury, and this was most pronounced for patients with moderate-severe injury (ps <.001).

Community-based rehabilitation

Four primary studies[17, 27, 30, 36] and one systematic review[35] evaluated the effectiveness of diverse rehabilitation interventions delivered within the community. Multidisciplinary community-based interventions appear to positively impact functioning and decrease use of health service resources in the post-acute phase following TBI. However most evidence is limited to short term impact with few studies investigating the long-term effectiveness of community based rehabilitation.

Cusick et al. evaluated an American state-wide Brain Injury Medicaid Waiver program that provided access to 11 community-based rehabilitation services for individuals within six months post-injury. The program aimed to reduce the length of inpatient post-acute rehabilitation and prevent transition to residential care following moderate to severe TBI. Compared to matched controls, program participants demonstrated improved mental health and reduced alcohol use, but poorer social participation, at follow-up. Program participation was additionally associated with greater use of physical therapy and case management services, hospital readmission and residential stay compared to controls. Study authors did not clearly indicate the timing of follow-up or the average length of program participation.

An Australian study evaluated the effectiveness of community-based versus residential social integration programs for patients with moderate to severe ABI enrolled a mean 10 weeks post-injury.[30] Community-based rehabilitation was delivered 1-2 times per week in group and individual formats and program length varied up to six months. Participants demonstrated improved functioning six months after commencing rehabilitation; however no more superior to the improvement achieved by participants of a 7 week residential social re-entry program. Rehabilitation within the community was associated with significantly fewer hours of allied health service use (M = 2.8h, SD = 3.98) versus residential rehabilitation (M = 17.8h, SD = 2.34). Undertaking rehabilitation in the community was additionally associated with a higher rate of improved productivity at follow up (M = 3.94, SD = 2.18) compared to a residential setting (M = 2.58, SD = 1.68), p <.01.

An eight-week community-based Self-Management Program (SMP) for chronic mild TBI symptoms was found to increase performance and satisfaction in ADL over the study period (p <.001).[27] The majority (75%) of the sample (n = 53) achieved clinically significant improvement in performance. There was a trend for the program to have a positive effect on outcomes over the nine month follow up period. The SMP intervention comprised psychoeducation, goal-setting and occupational therapy delivered in person by an occupational therapist and, via telephone, by a psychologist. Time since injury varied across the sample, from 0-6 months (11%), 6-24 months (43%), to more than 24 months (41%). Study authors did not examine the likely impact that time since injury had on the effectiveness of the rehabilitation program.

Grill et al. evaluated a two-year coordinated advisory program delivered in a German community following discharge from inpatient ABI rehabilitation.[36] The multidisciplinary program comprised a range of components including: supported discharge; caregiver education, training and support; access to a telephone support service; and home nursing visits. The number of components patients received was dependent on functional status at program enrolment; patients with poorer functioning received a greater number of components than those with higher initial functioning. The community program was provided alongside standard outpatient rehabilitation and was compared to standard rehabilitation alone. Results indicated that, in comparison to standard care alone, addition of the advisory program was associated with increased functioning at program end (p <.001), and this was greatest among patients with higher initial functioning. Furthermore the community program was associated with an increased rate of hospital admissions, and this was highest among poorly functioning patients at baseline. Only 28% of the sample (n = 1534) had sustained a TBI, with the remainder had other specific ABIs. Effectiveness of the advisory program for TBI specifically not clear.

A systematic review of multidisciplinary rehabilitation for ABI considered three studies of different community-based programs, one of which focussed exclusively on stroke rehabilitation.[35] Review authors concluded there was limited evidence that community-based rehabilitation programs improved functional outcomes based on three studies of diverse programs.

Residential rehabilitation

Residential rehabilitation for TBI was considered in two primary studies[30, 34] and one systematic review[35]. The few residential rehabilitation interventions evaluated were diverse and we identified mixed evidence in support of such interventions for moderate to severe ABI.

Turner-Stokes et al. reviewed two primary RCTs of a 'therapeutic milieu' model of residential rehabilitation, whereby comprehensive neuropsychological group-based rehabilitation is provided in a residential setting.[35] The review found strong evidence of a positive effect (based on two studies) of the therapeutic model for moderate to severe ABI. Similarly, a retrospective cohort study evaluated the impact of a residential neurorehabilitation program for ABI. The majority (55%) of the 261 participants had sustained a severe TBI a median 20 weeks prior to program enrolment. The psychology-led multidisciplinary individualised program aimed to restore patient independence and community engagement. Patients remained in the program for an average 25.6 weeks (SD = 27.18). Results indicated that the residential program was associated with reduced support needs, as well as greater independence of living and occupational engagement at both program completion and six month follow-up compared to on admission (ps <.01). The proportion of the sample living independently in the community increased from 6% at admission to 28% at program discharge and 47% six months later. Eleven percent of the sample were in residential care at follow-up.

A seven-week transitional living program provided structured therapy focused on community re-entry for patients with moderate to severe ABI initiated a median 83 days (range 55 - 171) post-injury. The program was found to be no more effective than a community-based program in relation to functioning, support needs, and social participation at six months. Participants in the residential program demonstrated greater social integration and allied health service use compared to participants of the community-based program (ps <.01).

Continuous rehabilitation

Of the 22 primary studies reviewed, three evaluated continuous rehabilitation interventions that were delivered across multiple settings and rehabilitation phases.[28, 31, 37] It was difficult to draw conclusions as to the effectiveness of continuous rehabilitation programs owing to the diversity of the rehabilitation programs and their target patients.

A small observational study (n = 48) examined the impact that an early onset continuous rehabilitation for severe TBI had on functional outcomes one year post-injury.[37] Rehabilitation was provided across acute, subacute and postacute phases. Rehabilitation commenced in the ICU following medical stabilisation, with individualised sensory stimulation, physiotherapy, pharmacotherapy, and facio-oral therapy. Occupational, psychological and speech therapy were subsequently introduced as appropriate. Rehabilitation in the acute phase focused on restoring communication. Complex neurorehabilitation commenced in the subacute phase with daily multidisciplinary therapy of approximately four hours. Outpatient rehabilitation commenced at a mean 12 weeks post-injury and focussed on community reintegration. At 12 months the functional independence motor score was 86.2 and cognitive score was 33.2 indicating relative independence. With no baseline or control measure reported, it is difficult to determine the effectiveness of the continuous rehabilitation program on functional outcome. However the authors reported that 83% of patients were independent of care and 35% had returned to work at 12 months, suggesting restoration of functional independence.

Intense continuous rehabilitation does not appear to be effective for mild TBI. For example, an RCT evaluated the impact of an intense continuous rehabilitation versus a single education session for mild TBI on functional outcomes four months post-injury.[28] The intense intervention comprised an abbreviated 'Treatment As Needed' (TAN) rehabilitation model for severe TBI. TAN included a comprehensive multidisciplinary assessment followed by psychotherapy, physical therapy and/or specialist outpatient treatment as required. Results indicated no difference between TAN and the

minimal education session in functioning, community integration or vocational status across 12 months.

Dow et al. evaluated a unique Australian rehabilitation program.[31] The non-specialist program provided rehabilitation for neurological, musculoskeletal and geriatric conditions, and excluded complex specialist TBI, SCI and paediatric rehabilitation. The program was established through a collaboration of five health services within rural northern Victoria. Collaborative continuous care was provided through a system of shared governance, infrastructure and workforce. A program *Project Leader* provided overall management and coordination of the program across sites. *Rehabilitation Managers* located within each participating service served as key contacts and referral points. A notable aspect of the program was the involvement of community rehabilitation service staff in inpatient rehabilitation case conferences which enabled seamless continuity of care.

Of the 112 program participants within Dow et al.'s evaluation study, 58% received rehabilitation following orthopaedic surgery. Results of the preliminary outcome evaluation indicated that the unique continuous program was effective. In particular, program participants achieved a significant improvement in functioning from enrolment to discharge, with a Barthel Index mean change score of 26.5 points ($p < .001$). The mean length of inpatient stay was 13.8 days, 8.5 days lower than the state average. Most patients (65%) were discharged from inpatient rehabilitation to home, and only 16% discharged to residential care. Qualitative findings indicated a high level of satisfaction among program staff and patients. Noted benefits of the program included improved interprofessional communication and teamwork, as well as increased patient and caregiver engagement and improved patient access to local rehabilitation services.

Home-based and other rehabilitation

Home-based rehabilitation was evaluated in two primary studies.[21, 29] All three systematic reviews considered the effectiveness of low intensity interventions directed mainly at mild TBI.[24, 32, 35]

Two studies provide support for home-based rehabilitation following moderate to severe TBI. In the cross over study by Doig et al., occupational therapy delivered at home was as effective as outpatient-based delivery.[29] The home-based therapy was contextually based and focused on daily activities (i.e., shopping, preparing breakfast) relevant to patients' goals. While there was no difference in functional outcome across delivery settings, participants reported greater satisfaction with the home- than the clinic- based therapy. An RCT found no difference in 12 month vocational or functioning outcomes between an intense inpatient versus low-intense home-based eight week milieu-based cognitive neurorehabilitation program.[21] Home-based treatment emphasised recovery within a familiar setting and gradual resumption of regular physical and cognitive activity.[42] Weekly telephone contact was provided by a psychiatric nurse and included rehabilitation advice, support and, occasionally, referral to outpatient services. It is possible that familiarity of the home setting and applicability of rehabilitation to patients' usual routine may increase patient engagement in therapy and contribute to effectiveness. However, this possibility was not examined in either studies.

Limited low-intensity education-based interventions appear most effective for mild TBI. For example, a systematic review of 20 primary studies found a lack of evidence in support of pharmacotherapy or cognitive rehabilitation for mTBI.[24] Instead there was sufficient evidence from seven studies to support the provision of symptom information and reassurance for mild TBI. Similar conclusions were reported in review of 16 studies of varying quality.[32] Finally, a recent Cochrane review of multidisciplinary rehabilitation for ABI considered five RCTs targeting mTBI.[35] The Cochrane review authors concluded that there was no evidence in support of specialist rehabilitation for all patients with mild TBI, and limited support for symptom education and routine follow up of patients with mild TBI who experience post-traumatic amnesia for more than one hour.[35]

IMPLICATIONS OF FINDINGS

This evidence review identified that rehabilitation models and interventions for TBI, and potentially also for orthopaedic trauma, that are multidisciplinary and client-centred are more likely to be effective.

Specifically the evidence indicates that:

- Common principles of rehabilitation models of care are **flexibility, multidisciplinary, strong patient engagement, continuity of care** and **evidence-based**.
- **Early, intense and tailored post-acute inpatient rehabilitation** is effective for individuals with moderate to severe TBI.
- **Comprehensive multidisciplinary post-acute outpatient rehabilitation** is effective for individuals with moderate to severe TBI.
- **Home-based post-acute rehabilitation** may be as effective as outpatient or inpatient rehabilitation for some individuals with moderate to severe TBI.
- **Low intensity educational intervention** is effective for individuals with uncomplicated mild TBI.

Implications of these findings for the TAC in the development of the new Rehabilitation Strategy for its Supported Recovery client group are discussed below.

1. Rehabilitation models of care

Rehabilitation models of care across injury condition and geographic context described a flexible individualised approach to the delivery of rehabilitation services integrated across rehabilitation phases and settings. Common elements of existing models include: interdisciplinarity, patient engagement, continuity of care, and coordination.

The ABI model of rehabilitation for South Australia was identified as a stand-out model of care that crosses injury severity levels and describes an integrated partnership across geographic regions to ensure equity of access to regional and rural specialist health services.

Key considerations

- In developing a new TAC Rehabilitation model for the Supported Recovery group consider aligning this with the features of existing rehabilitation models, in particular the ABI model of rehabilitation for South Australia (especially the principles of flexibility, continuity of care and coordination).
- Funding a dedicated resource to tailor and coordinate rehabilitation services is critical.
- Consider commissioning research on rehabilitation following orthopaedic trauma, specifically examining the effectiveness of specific rehabilitation models of care following orthopaedic trauma.

2. Rehabilitation interventions

Most of the evidence reviewed relates to hospital-based inpatient and outpatient rehabilitation interventions for TBI, with more limited evidence for community, home-based, and continuous interventions. Except for a single methodologically weak study, this review did not identify evidence for the effectiveness of rehabilitation interventions for orthopaedic trauma.

The evidence indicates that inpatient rehabilitation for moderate to severe TBI that is commenced early in the acute phase, tailored to an individual's functional deficits and delivered intensely,

improves functional outcomes in the medium term (up to 12 months post-injury) and reduces inpatient length of stay.

Post-acute comprehensive multidisciplinary outpatient rehabilitation for moderate to severe TBI has been shown to improve functional outcomes in the medium-term. Ongoing continuity of care within the community will likely be required to achieve sustained long-term functional gains. Coordination of outpatient services to deliver comprehensive integrated rehabilitation is important.

There is no evidence that outpatient rehabilitation is an effective standard intervention for mild TBI. Individuals with pre-existing mental health and/or pain conditions who sustain a mild TBI may benefit from targeted outpatient rehabilitation to prevent the development of secondary conditions.[*43]

Home-based rehabilitation in the post-acute phase may be as effective as hospital-based (inpatient or outpatient) rehabilitation for some individuals with moderate to severe TBI, based on two moderate quality studies. Home-based interventions that are effective include goal-directed components and ongoing patient support through home visits or telephone contact. It is likely that familiarity of the home setting and applicability of rehabilitation to an individual's usual routine may increase therapy engagement and contribute to effectiveness. Home-based rehabilitation has been shown to be effective for other injury and illness conditions, for example joint replacement[44] and COPD.[45]

The evidence indicates that low-intensity education-based interventions delivered in the acute phase can prevent secondary complications and speed recovery time following mild TBI. Individuals who sustain a mild injury and have no pre-existing mental or physical health conditions will likely benefit from the routine provision of symptom information and reassurance.

Continuous rehabilitation

Despite limited evidence continuous rehabilitation interventions align with care pathways described in rehabilitation models and are potentially effective for moderate to severe TBI.

Preliminary evidence suggests that fully integrated continuous rehabilitation is successful when delivered through a collaborative partnership with shared resources among health services. Benefits of this broad intervention approach, based on a single study, may include improvements in health and functional outcomes, interprofessional communication and patient engagement, and reductions in inpatient length of stay and admissions to residential care facilities.

Key considerations

- Inpatient rehabilitation services for clients with moderate to severe TBI which are commenced early, tailored and intense are most promising.
- Consider offering targeted outpatient rehabilitation to clients with pre-existing conditions who sustain mild TBI to prevent secondary complications.
- Work collaboratively with health service providers to deliver coordinated outpatient rehabilitation services that are multidisciplinary and targeted to client needs.
- Consider home-based post-acute rehabilitation for clients who sustain moderate to severe TBI and have a low risk of complications.
- Adopt a model of continuous rehabilitation that involves hospital and community health providers. This model needs to be sufficiently flexible to be tailored to individual client need and to enable entry and re-entry across rehabilitation stages.

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[*] This is supported by the findings of ISCRR research report #173 *Early intervention after injury: A rapid review* undertaken in 2016 for the TAC.

- Examine opportunities to strengthen collaborations and partnerships with health service providers to deliver integrated and coordinated rehabilitation across settings.

Characteristics of effective rehabilitation

The evidence indicates four characteristics of effective rehabilitation interventions which are:

1. **Early** commencement of rehabilitation in the acute or sub-acute phase;
2. **Continuous** care delivery across rehabilitation phases and settings;
3. **Tailored** rehabilitation interventions targeting functional domains with greatest deficit; and
4. **Intensity** of rehabilitation matched to injury and individual characteristics. More severe injury and/or high risk of complications require intensely delivered rehabilitation; mild injury and low risk of complications require rehabilitation of a lower intensity.

The characteristics of effective interventions evaluated in the scientific literature align with the key principles of the rehabilitation models identified.

Limitations

We identified limited detailed information on rehabilitation models of care and no scientific evidence of the impact of models on patient outcomes. A detailed review of the effectiveness of rehabilitation models of care was beyond the scope of the current review.

Further, we identified as eligible for review only one primary study and no systematic reviews that evaluated rehabilitation interventions for orthopaedic trauma. The applicability of the findings and conclusions of this evidence review to TAC clients who sustain orthopaedic trauma is unclear.

CONCLUSION

There is substantial evidence in support of multidisciplinary client-centred rehabilitation approaches for improving health and social outcomes for TAC clients who sustain a TBI and, possibly also, an orthopaedic trauma. When developing an effective rehabilitation model, early initiation, continuity of care, tailoring of interventions, and appropriate delivery intensity are key considerations. Coordination is a key enabling factor of effective rehabilitation models and interventions. Of note, research on rehabilitation for transport accident-related orthopaedic trauma is lacking.

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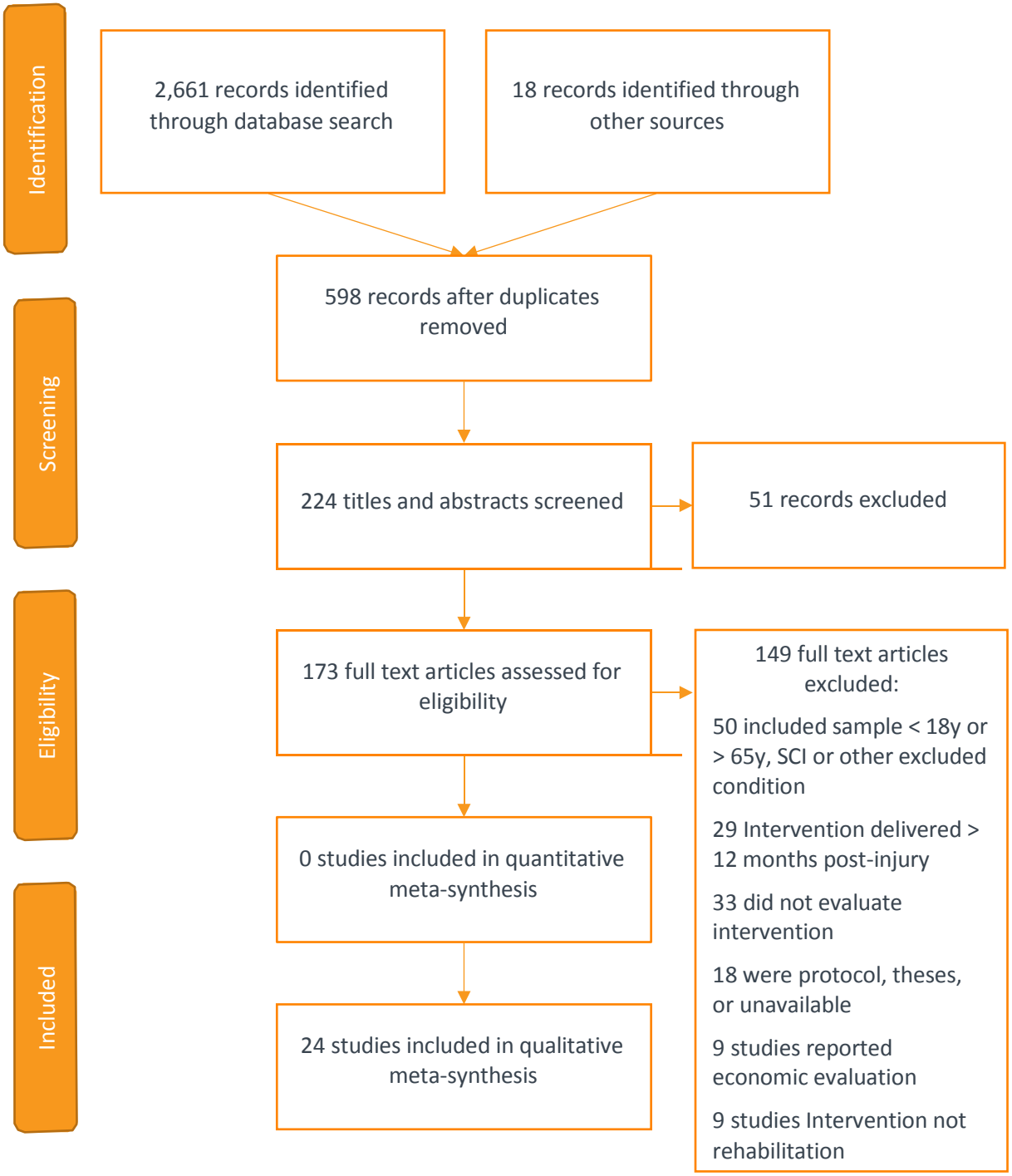
Appendix 1: PRISMA flow diagram depicting scientific evidence literature search



Appendix 2: Primary study characteristics

Study (year)	Country	Study design	Injury type (n; % male)	Inclusion criteria	Exclusion criteria	Rehabilitation Intervention (I), Control (C)	Post-injury Timing (T), Modality (M); Intensity (I); Setting (S)	Follow up	Primary (P) and secondary (S) outcomes	Intervention characteristics	Quality rating[1]
Andelic et al. (2012)	Norway	Prospective cohort control	Severe TBI (61; 77%)	16-55y; local resident; admission < 24h post injury; GCS 3-8; neuro-intensive care required > 4d; survived to 1y post injury	Serious comorbidities; history of psychiatric and AOD disorders	I: Early continuous inpatient rehabilitation C: Delayed broken specialist inpatient or no inpatient rehabilitation	T: median 12d (I); NR (C) M: Individual I: at least 2-3h/d S: Inpatient	1y	P: Functional level S: Disability, employment status, living situation	Inpatient	Moderate
Cullen (2013)	Canada	Retrospective case-matched cohort	Moderate - severe TBI (138; 64%)	18+y; moderate to severe TBI	Non-traumatic BI; history of psychiatric or degenerative neurological disorders	I: Functionally-based streaming neurorehab - physical vs cognitive C: traditional neurorehabilitation	T:42-88d M: Individual I: ~3h/d x 5d/w S: Inpatient	Discharge	P: Functional independence, disability level, LOS S: None	Inpatient	Moderate
Cusick et al. (2003)	America	Retrospective case-matched cohort	Moderate - severe TBI (132; 64%)	Referral to Medicaid; stable BI; rehabilitation potential; 16-65y; injured 1996-1999; referred < 6m post injury	non-traumatic BI; history of previous TBI	I: Medicaid waiver program C: No program participation	T: <6m M: Variable I: S: Community	NR	P: Symptom improvement S: None	Community-based	Moderate
Doig et al. (2011)	Australia	Single group cross-over	Moderate - severe TBI (14; 86%)	16-65y; recent inpatient discharge; TBI diagnosis; English language proficiency; availability of family member; occupational therapy program referral; consent provided	severe condition; history of psychiatric or neurologic condition; untreated AOD issue	I: Goal-directed occupational therapy delivered at home C: Intervention delivered in outpatient clinic	T: median 5.7m M: Individual I: 6 x 1h/w (home); 6 x 1h/w (outpatient) S: home vs outpatient	18w	P: Goal attainment S: Functioning; community integration, satisfaction with therapy	Outpatient	Moderate
Dow et al. (2010)	Australia	Impact evaluation	Range, 58% ortho (112, NR)	None	None	Non-specialist rural rehab	T: range, multiple entry points M: NR I: variable S: inpatient, outpatient	12m	P: LOS, discharge destination, functioning S: perceived barriers and enablers, client satisfaction S: None	Continuous	Weak
Ghaffer et al. (2006)	Canada	RCT	Mild TBI (191; 65%)	mTBI	major medical illness; < 16y, > 60y	I: Multidisciplinary treatment	T: < 1w M: Individual	6m	P: Post concussion symptoms,	Outpatient	Strong

						C: No treatment	I: variable as needed up to 6m S: outpatient		distress, cognitive function, psychosocial outcome S: None		
Griesbach et al. (2015)	America	Retrospective cohort	Moderate - severe TBI (36; 92%) or CV (8; 62%)	Ability to engage in rehabilitation; no benefit limitation from insurance carrier; TBI or CVA diagnosis; moderate to severe disability on admission	None	I: comprehensive post-acute rehab	T: mean 285d M: I: 6h/d x 5d/w S: outpatient	Mean 25m	P: disability level, functioning, community integration S: Cost effectiveness	Outpatient	Moderate
Grill et al. (2007)	America	Prospective cohort control	ABI, 28% TBI (1534; 59%)	18+y; discharged 1998-2003; ABI primary diagnosis;	lack of German language proficiency; refusal to participate	I: Coordinated advisory program + standard outpatient care C: standard outpatient care	T: mean 90d M: telephone, face-to-face, group, individual I: variable depending on discharge functional status S: community, home	2y	P: Functional independence, LOS S: Survival post-discharge	Community	Moderate
Hashimoto et al. (2006)	Japan	Cohort control	ABI (37; 72%)	near independence in ADL; have RTW/school goal; availability to attend clinic sessions	None	I: Comprehensive day treatment program C: Usual care	T: 97-152d M: group, face-to-face I: 2-4h x 2d/w x 3-6m S: outpatient	3-6m	P: Functional independence, community integration S: None	Outpatient	Moderate
Hayden et al. (2013)	America	Retrospective cohort	TBI (1274; 75%)	< 5y post injury, complete assessment at 3 times	None	I: Comprehensive post-acute rehabilitation	T: variable, <5y M: NR I: 6h/d x 5d/w x3-74w S: outpatient	Up to 74w	P: Functional status S: None	Outpatient	Moderate
Hopman et al. (2012)	Australia	Prospective cohort control	Moderate - severe ABI (38; 79%)	18-65y; admitted for rehab; ability to consent; English language proficiency; local resident	None	I_1: Community based I_2: Residential rehabilitation	T: 72-83d M: Individual, group, face-to-face I: ~1-2h/w x variable to 6m (community); 5d/wk x mean 7w (residential) S: community vs residential	6m	P: Functional status, participation S: Support needs, allied health service use	Community	Strong
Kendrick et al. (2012)	Canada	Retrospective case series	Chronic mild ABI, 85% TBI (53; 51%)	Diagnosis of non-progressive neurological condition; medically stable; able to identify rehab goals; comprehensive rehabilitation not required	None	I: Time limited community based program	T: variable M: Individual face-to-face, telephone I: 1 x 60-90min face-to-face, 8 x 30min telephone S: community	9m	P: ADL performance and satisfaction S: None	Community	Moderate
Lippert-Gruner et al. (2002)	Germany	Prospective observational	Severe TBI (48; 75%)	Severe TBI	Documented psychiatric history; previous TBI	I: Early-onset continuous rehabilitation	T: on medical stabilisation M: Individual face-to-face	12m	P: Functional outcome S: Occupational status, care needs	Continuous	Moderate

							I: ~ 3h/d (stage 1); ~4h/d to 12w (stage 2); variable (stage 3) S: ICU, inpatient, outpatient				
Malec et al. (1993)	America	Longitudinal cohort	ABI, 69% TBI (29; 69%)	Independent mobility; functional communication; sufficient memory for learning; continent; no imminent danger to self or others	None	I: Comprehensive-integrated post-acute rehab program	T: 38-9040d M: group I: 5h/d x mean 28w S: outpatient	12m	P: Independence, functional level, goal attainment S: None	Outpatient	Moderate
Matusevic et al. (2016)	Sweden	RCT	Mild TBI (173; 45%)	15-70y; ER presentation < 24h post injury; loss of consciousness < 30min, GCS 14-15	need for neurosurgery or ICU; other sig physical injury requiring surgery; ongoing psychiatric condition; previous mTBI <5y or mod/severe TBI; lack of Swedish language proficiency	Participants reporting >3 symptoms (n = 97) randomized to: I: Early follow-up intervention C: TAU	T: 14-21d M: individual face-to-face I: single session S: outpatient	3m	P: Limitations in ADL, health related QoL, sick leave S: None	Outpatient	Strong
Oddy & da Silva Ramos (2013)	United Kingdom	Multi-centre retrospective	ABI, 55% TBI (267; NR)	17+y; ABI; post-acute; primarily cognitive and/or challenging behavioural deficits requiring specialist support	> 1 admission in study period	I: Neurobehavioural rehab	T: median 20w M: NR I: median 20w S: residential	6m	P: support needs, independent living, engagement in occupation S: None	Residential	Moderate
Paniak et al.	Canada	RCT	Mild TBI (105; 44-47%)	Mild TBI	history of psychiatric treatment; mental retardation; lack of English language proficiency; history of moderate or severe TBI; mTBI in previous y; CNS disorder; pregnant female	I: Treatment as needed - abbreviated severe TBI rehabilitation model C: Single session brief education intervention	T: mean 12d M: face-to-face I: variable depending on discharge functional status S: community	12m	P: Functioning, community integration, vocational status S: None	Continuous	Strong
Salazar et al. (2000)	America	RCT	Moderate - severe TBI (120; 71%)	GCS <14; <3m post-injury; Rancho Los Amigos cognitive level 7; active military duty; availability of appropriate home setting with at least one responsible adult; able to ambulate	Mild TBI	Milieu-based cognitive rehab delivered I: inpatient C: home-based	T: mean 38d M: Individual face-to-face, telephone I: 1 x 30min/w x 8w (home); NR (inpatient) S: home, inpatient	12m	P: RTW, fitness for duty S: None	Inpatient	Strong

				independently; no prior severe TBI or other significant disability							
Sander et al. (2001)	America	Longitudinal cohort	TBI (34; 68%)	medically documented TBI; 16+y; consent provided	None	I: The Challenge Program (TCP) comprehensive-integrated post-acute rehab	T: mean 3m M: Individual, group face-to-face I: ~5h/d x mean 4.2m S: outpatient, community	2-5y post discharge	P: Functioning, community integration S: None	Outpatient	Moderate
Vanderploeg et al. (2008)	America	RCT	Moderate - severe TBI (360; 93%)	Moderate to severe non penetrating TBI < 6m; 18+y; active duty military officer; anticipated required length of acute rehabilitation >30d	Prior inpatient rehabilitation for current TBI; history of TBI, other neurologic, psychiatric, SCI, or MS condition	Interdisciplinary inpatient TBI rehabilitation + I_1:cognitive didactic therapy I_2: Functional experiential therapy	T: 20-60d M: individual, group fce-to-face I: 1.5-2.5h/d x 5d/w S: inpatient	1y	P: Independent living, RTW S: Functioning, QoL, psychosocial function	Inpatient	Strong
Zhu et al. (2007)	China	RCT	Moderate - severe TBI (68; 81%)	Moderate to severe TBI; 12-65y	severe medical disease or injury; pre-existing disability; default treatment or follow up; rapid recovery not requiring rehab; vegetative state	I: Intense 4h/d inpatient rehabilitation C: Standard 2h/d inpatient rehabilitation	T: < 6m (mean 22d) M: individual face-to-face I: 4h/d x 5d/w x variable to 6m (intervention); 2h/d x 5d/w x variable to 6m (control) S: inpatient	12m	P: Functional independence S: social integration, cognitive functioning	Inpatient	Strong

Notes. [1]Based on the Effective Public Health Practice Quality Assessment Tool[3]; LOS = length of stay; NR = not reported; Ortho = orthopaedic; QoL = quality of life; RCT = randomized controlled trial; TBI = traumatic brain injury

Appendix 3: Systematic review characteristics

Study (year)	Country	N databases searched (searched date range)	Inclusion criteria	Exclusion criteria	N included studies (date range) N participants	Target population	Intervention(s) evaluated	Quality rating[1]
Borg et al. (2004)	Sweden	3 (1980 - 2002)	Article addressed diagnosis, incidence, risk factors, prevention, prognosis, treatment and rehabilitation or economic costs of mTBI	Studies of diagnoses other than mTBI, non-human subjects, studies of n <10	16 (1987-2002) 2372	mTBI	Pharmacotherapy; home; homeopathy	Moderate
Comper et al. (2005)	Canada	6 (1980-2003)	study published 1980-2003; working age population; article described treatment for mTBI; treatment delivered < 5y post injury	case studies, case series	20 (1980-2003) 2147	mTBI	Pharmacotherapy; outpatient; home; other	Moderate
Turner-Stokes et al. (2015)	United Kingdom	8 (- 2015)	working age; ABI; RCTs or CCTs of multidisciplinary rehab	None	19 (1981-2012) 3480	ABI	Community; residential; outpatient; home	High

Notes. [1]AMSTAR quality rating[4]; ABI = acquired brain injury; mTBI = mild traumatic brain injury.

Appendix 4: Study findings

Study (year)	Primary outcome results	Secondary outcome results
	Primary studies	
Andelic et al. (2012)	Functional level: OR 3.25 (CI 1.08-9.87), p <.05	Disability: median score at 12m: 2.0 partial disability (I) vs 4.0 moderate disability (C) Employment status: % RTW at 12m: 39% (I) vs 27% (C) Living situation: % living at home: 81% (I); 53% (C); p < .05
Cullen (2013)	Functional independence Disability: ns LOS: ns	-
Cusick et al. (2003)	Symptom improvement: Program pts had better MH, alcohol use symptoms; greater service use: case m'ment, physical therapy, 2nd rehab admission, group home stay. Program pts had poorer outcome on 8 social participation variables	-
Doig et al. (2011)	Goal achievement overall sig ↑ across settings; Comparison of settings: goal achievement ns	Functioning: ns across settings Community integration: ns across settings Satisfaction: ↑ home setting (p <.05)
Dow et al. (2010)	Functioning: ↑ admission to discharge, p <.05 Discharge destination: 65% to home, 16% to residential care Mean LOS 14d (2-77, SD = 12)	-
Ghaffer et al. (2006)	Post-concussion symptoms: ns Distress: ns Cognitive function: ns Psychosocial outcome: ns	-
Griesbach et al. (2015)	Overall findings Disability level: ↑ admission to discharge, p <.05 Functioning: ↑ admission to discharge, p <.05 Community integration: 33% improved, 60% maintained living status and 43% maintained occupational status at mean 25m post discharge Impact of intervention timing: greater impact on functioning when program initiated within 1y; employment benefits and independent living sig improved when rehab initiated <3m; Impact of acute rehab: ↑ functioning among pts who received acute rehab, p <.05. No age difs in effectiveness of intervention	Cost effectiveness: ↓ in projected life care costs admission to discharge, p <.01.
Grill et al. (2007)	Functional independence: ↑ across 2y intervention period, p <.001, then slight ↓. Intervention effect greater for patients with higher initial functioning; no difference in functioning between controls and intervention pts with low initial functioning LOS: ↑ rate of days in hospital among intervention group, particularly those with initial functioning score less than 90	Survival: ns for high functioning patients; low functioning patients - ns in first 800 days, intervention assoc with sig lower mortality risk day 800-1200

Study (year)	Primary outcome results	Secondary outcome results
Hashimoto et al. (2006)	Functional independence: ↑ speech, cognitive function in intervention group, p <.05 Community integration: ↑ in intervention group, p <.05	-
Hayden et al. (2013)	Functional status: ↑ admission to discharge, p < .05 (ES d = 1.24) 69% of patients made clinically sig gains Impact of intervention timing, p <.001: Rehab more effective when initiated 0-3m post-injury (p<.001, mean dif 0.22-0.30) compared to all other groups to 5y; this effect larger among mod-severe TBI group	-
Hopman et al. (2012)	Functional status: ns Participation: overall ↑ for both groups at 8w, p <.05, improvement maintained w8 - 6m only for community group; ↑ productivity for community vs residential intervention (p <.01, ES = 1.0); ↑ social integration for residential vs community intervention (p <.01, ES = 0.86)	Support needs: ns Allied health service use: at 4w, residential group received mean 17.8h (SD = 2.34) vs community group mean 2.8h (SD = 3.98)
Kendrick et al. (2012)	ADL performance and satisfaction: ↑ from admission to discharge, p <.001; performance ratings higher than satisfaction ratings at each time point but satisfaction improved more than performance. 75% achieved clinically sig improvement in ADL performance, 85% ADL satisfaction	-
Lippert-Gruner et al. (2002)	Functional outcome: mean motor function score 86.2 (13-91), mean cognitive function score 33.2 (9-35) (no statistics reported) Prevalent neurological deficits at 12m: coordination (35%), behavior (29%), visual (21%)	Occupational status: 35% RTW at 12m Care needs: 83% independent of care at 12m
Malec et al. (1993)	Independence: ↑ independent living status admission to discharge, p <.01; 93% living without supervision at discharge vs 59% at admission; 86% independently at 1y follow-up ↑ RTW rate admission to discharge, p <.001, ns discharge to follow-up. Greater proportion of participants who began intervention <1y post-injury were in independent work placement at follow up compared to those who began >1y, p <.01 Functional level: ↓ disability level admission (m 19.3) to discharge (m 11.9), p <.001; early-intervention participants had lower final scores (m 8.0, SD = 5.6) than late intervention participants (m 14.2, SD = 8.0), p <.05 Goal attainment: early intervention group had higher goal attainment (m 4.8, SD = 2.3) than late intervention group (1.5, SD = 4.4), p <.05	-
Matusevic et al. (2016)	Limitations in ADL: ns dif between intervention and control groups Health-related QoL: ns difs between intervention and control groups; sig difs between intervention and non-randomised, and between control and non-randomised groups, p <.05 Sick leave: overall 9% report sick leave post injury	-

Study (year)	Primary outcome results	Secondary outcome results
Mellick et al. (2003)	Functional independence: sig group dif, p <.01; FIM score: discharged home (M = 89.9) > rehab to home with outpatient services (M = 87.0) > rehab to home (M = 85.0) > rehab to long term care (M = 54.6) > long term care (M = 54.0)	-
Oddy & da Silva Ramos (2013)	Support needs: ↓ support needs admission to 6m follow up, p <.001 Independent living: ↑ admission to follow up, p <.01; Proportion of sample living independently with partner/friend: 6% at admission, 28% at discharge, 47% at follow up; proportion in residential accom: 68% at admission, 14% at discharge, 11% at follow up Engagement in occupation: ↑ admission to follow-up, p <.001; proportion of sample engaged in no productive activity: 69% at admission, 36% at follow up	-
Paniak et al.	Functioning: ns group dif Community integration: ns group dif Vocational status: ns group dif	-
Salazar et al. (2000)	RTW: ns group dif Fitness for duty: ns group dif	-
Sander et al. (2001)	Functioning: ↓ in disability admission (M = 3.97, SD = 1.77) to discharge (M = 1.26, SD = 1.56), ns discharge to follow up Community integration: ↑ admission (M = 11.43, SD = 3.31) to discharge (M = 14.43, SD = 5.41), p <.01, ns discharge to follow up [n = 24]	-
Vanderploeg et al. (2008)	Independent living: ns group dif; 56% of cognitive and 62% of functional groups living independently at follow up RTW: ns group dif; 39% of cognitive and 35% of functional groups RTW	Functioning: cognitive functioning ↑ in cognitive group (M = 27.3, SD = 6.2) than functional group (M = 25.6, SD = 6.0), p =.01; motor functioning ns group dif QoL: ns group difs Psychosocial function: ns group difs
Zhu et al. (2007)	Functional independence: greater proportion of intervention participants achieved maximum independence score at 3m compared to controls, indicating independence in self-care and cog function (47% vs 19%, p =.01), ns group dif at 2m or 12m	Social integration: greater proportion of intervention participants achieved max integration score at 2m indicating return of normal social life (28% vs 8, p =.03) and 3m (38% vs 14%, p = .04), ns group difs at any other time Cognitive functioning: ns group difs across 12m
	Systematic reviews	
Borg et al. (2004)	No strong evidence for any non-surgical intervention; some evidence that early, limited, educational intervention and activation effective, routine provision of intensive assessment and treatment not beneficial	
Comper et al. (2005)	Limited evidence to support pharmacotherapy or cognitive rehabilitation for mTBI. Sufficient evidence to support early patient education initiatives based on 7 studies	
Turner-Stokes et al. (2015)	mABI with amnesia < 30min does not benefit from specialist rehabilitation; milieu-based residential programs effective for moderate to severe ABI, early rehabilitation began in the acute setting can lead to better outcomes for moderate to severe ABI	

Notes. mABI = mild acquired brain injury; mTBI = mild traumatic brain injury; ns = not statistically significant; RTW = return to work.