Occupational and Physiotherapy modalities used to support interdisciplinary rehabilitation after concussion

A Scoping Review

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REVIEW ARTICLE

OCCUPATIONAL AND PHYSIOTHERAPY MODALITIES USED TO SUPPORT INTERDISCIPLINARY REHABILITATION AFTER CONCUSSION: A SCOPING REVIEW

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Objective: **To identify and describe occupational and physiotherapy rehabilitation modalities used to support an interdisciplinary rehabilitation in adults (aged 16+ years) with concussion.**
Methods: **A scoping review methodology was used. Included studies were categorized according to Wade's elements of rehabilitation and the Danish White Paper definition of rehabilitation.**
Results: **Ten studies were included in this review, addressing: "assessment" (*n* = 9), "goal-setting" (*n* = 4), "training" (*n* = 10), and "social participation and discharge support" (*n* = 4). Interventions were delivered mainly by physiotherapists or an interdisciplinary team. In two studies occupational therapists were part of the interdisciplinary team. Randomized controlled trials more often addressed several of the rehabilitation elements using interdisciplinary intervention delivery. No studies specifically aimed their intervention at patients with acute or subacute concussion.**
Conclusion: **The therapeutic modalities identified were: (*i*) manual and sensory motor interventions; (*ii*) physical exercises; and (*iii*) management of, or coping with, symptoms. More research is needed on how to better support social participation and discharge or return to work in the rehabilitation process. In addition, interventions delivered in the acute phases of concussion need further exploration.**

Key words: commotio cerebri; mild traumatic brain injury; mTBI; concussion; post commotio syndrome; rehabilitation modalities.

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LAY ABSTRACT

Individuals with prolonged or persisting symptoms from a concussion often struggle to participate in activities of daily living, and their quality of life and work ability is affected. Interdisciplinary rehabilitation is recommended, and it is recognized that occupational and physiotherapy is important to support the interdisciplinary rehabilitation and promote recovery. However, this scoping review found that occupational therapists were seldom part of the interdisciplinary rehabilitation team. Furthermore, the physiotherapy and occupational rehabilitation modalities used consisted of manual or sensory motor interventions, physical exercise interventions, and management and coping. Only a few studies included social participation and discharge support as a part of the rehabilitation. No studies specifically aimed their intervention at preventing prolonged symptoms in patients with acute or subacute concussion.
There is a need for more research into how to better support social participation and discharge in the rehabilitation process. Also, interventions delivered in the acute phases of concussion need further exploration.

IMPLICATIONS FOR REHABILITATION

- Occupational and physiotherapy rehabilitation should, to a greater extent, focus on social participation and discharge support or return to work.
- Occupational and physiotherapy rehabilitation should also be aimed at acute or subacute concussion to prevent persistent symptoms.

INTRODUCTION

Each year, millions of people experience a concussion, also referred to as commotio cerebri or mild traumatic brain injury (mTBI). Concussion or mTBI can be defined as an acute neurophysiological event caused by a

blow to the head, neck or body that results in disruption of brain function (1). The main causes of concussion are motor vehicle collisions, falls, and high-velocity contact sports (2). The risk of concussion is twice as high for males as females and higher in teenagers and young adults than older subjects (3).

Incidence rates of concussion are recognized as underestimated, since many injuries are not registered and thus not diagnosed (4). Danish incidence rates of concussion correspond to international rates, estimated to be approximately 45 million a year, equalling 600 per 100,000 (diagnosed and undiagnosed) (5). A recent registry study from Canada found the highest rate of concussion ever reported: an incidence of 1.153 per 100,000 residents, or approximately 1.2% of the population experiencing a concussion per year (4). Experiencing a concussion has personal, medical, and societal costs, and the annual economic burden has been estimated to be US$ 400.000.000.000 worldwide (6).

Most patients with concussion experience spontaneous recovery after 7–10 days (7) or a gradual remission of symptoms within 2–4 weeks, but 34–44% experience prolonged symptoms at 3–6 months and 5–20% experience symptoms 12 months after injury (8–12). Individuals who experience prolonged concussion symptoms can be diagnosed with post-concussion syndrome (PCS), also often referred to as persistent post-concussion symptoms (PPCS). According to the World Health Organization International Classification of Diseases 10th Revision (WHO ICD-10) classification symptoms of PCS fall into three overarching categories: physical, emotional, and cognitive. Symptoms comprise a combination of the following symptoms: headache, dizziness, fatigue, irritability, insomnia, difficulty concentrating, impaired memory, and intolerance for stress or emotions (8, 9, 13).

Due to the above-mentioned deficits, individuals with PCS often struggle to participate in activities of daily living (ADL) (14) and experience difficulties in maintaining their social, professional, and physical levels of activity, leading to consequences for their quality of life and work ability (9). Results from a recent Danish study found that 19% of individuals with concussion reported a sick leave period of more than 1 month, and 2% had still not returned to work one year after the initial trauma (15). Most experts agree that concussion is divided into three phases: acute, sub-acute, and persistent phases. What is not consistent is description of the duration of each phase (3, 8, 14, 16, 17). In the current study PCS is defined to cover the situation in which symptoms persist for more than four weeks, which is in accordance with the definition used by the Danish National Guideline (9) and suggested by WHO (3), and the acute and sub-acute phases are defined as when symptoms persist for less than four weeks. This is important, as the emphasis of treatment should be placed differently according to the symptoms, phase and duration of concussion and PCS (17).

Previously, it was recommended that patients rest until total symptom resolution after concussion; however it is now well established that rest (cognitive and physical) is recommended for only 24–48 hours after concussion, and that gradually increasing preinjury activities as soon as tolerated is important (18), as longer periods of inactivity may have potential adverse consequences (18, 19). There is sufficient evidence to suggest that early controlled aerobic exercise is safe following a concussion and may speed recovery and prevent PCS (20–23). Furthermore, exercise allows individuals to feel less isolated and to participate more actively in everyday life during the recovery process (20, 23).

Occupational therapy (OT) and physiotherapy (PT) are increasingly recognized to support an interdisciplinary rehabilitation after concussion. Since dizziness is a highly reported symptom associated with concussion (24) and may be a predictor of prolonged recovery, therapists are beginning to incorporate vestibular rehabilitation therapy (8, 25, 26) and oculomotor rehabilitation (8, 25, 27) in their post-concussion treatment plan. Also, strength training for the neck and spine (8, 28), manual therapy, patient education, headache management (8, 29), and cognitive rehabilitation therapy are used to support rehabilitation after concussion (8).

In the recent Danish national clinical guideline for PCS rehabilitation, it is suggested that attention should be focussed on the level of expertise in referral of individuals to the most suitable rehabilitation modalities for their special course and symptoms, as well as the timing and onset of the rehabilitation process (9). As the majority of existing research has its focus on youth (30, 31) and elite sports populations (17, 32, 33) existing guidelines and recommendations are based primarily on studies targeting those populations. There is a lack of evidence aimed at the management of concussion in the general population or in recreational sport (34). Interdisciplinary rehabilitation is recommended to support individuals after concussion and research into rehabilitation after concussion has increased. Also, a variety of therapy modalities are identified in the literature. However, the specific contribution and timing of OT and PT, as well as descriptions of the content of these therapeutic modalities to support the interdisciplinary rehabilitation of concussion in the general population is unclear.

Therefore, the aim of this scoping review was to identify and describe occupational and physiotherapy rehabilitation modalities to support an interdisciplinary rehabilitation in adults (aged 16+ years) in the general population with concussion. This includes describing

the onset of concussion, therapeutic modalities delivered, setting and duration of therapeutic modalities, professions delivering the therapeutic modalities, outcome measures, and key findings.

MATERIALS AND METHODS

A scoping review design was used to identify and map existing evidence regarding OT and PT rehabilitation modalities used to support interdisciplinary rehabilitation in individuals in the general population diagnosed with concussion.

Scoping reviews include a range of study designs in both published scientific literature and grey literature and are appropriate for when the aim is to determine the scope or coverage of a body of literature on a given topic, beyond those related to intervention effectiveness (35). A scoping review is less likely to assess the quality of included studies, whereas a systematic review focuses on a well-defined question and a relatively narrow range of quality assessed studies are included (35). A scoping review is therefore useful to guide the process of identifying and mapping the body of existing literature on OT and PT rehabilitation modalities used to support individuals diagnosed with concussion. This scoping review followed Arksey & O'Malleys' 5-stage framework: 1: identifying the research question; 2: searching for relevant studies; 3: selecting studies; 4: charting the data; and 5: collating, summarizing, and reporting the results (36). Also, the methodological guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analysis extension for Scoping Reviews (PRISMA-ScR) were followed (37). An a *priori* protocol was developed for this scoping review and is available at the online Center for Open Science, https://osf.io/xvnst (https://doi.org/10.17605/OSF.IO/XVNST).

Stage one: identifying the research question

First, a research question that was broad, but still specific enough to answer, was identified (35): "What occupational and physiotherapy rehabilitation modalities exist to support an interdisciplinary rehabilitation in adult and young adult individuals in the general population after concussion?" This includes describing the onset of concussion, therapeutic modalities delivered, setting and duration of therapeutic modalities, professions delivering the therapeutic modalities, outcome measures, and key findings.

Stage two: searching for relevant studies

In the literature search the following electronic bibliographic databases were used: PubMed, Cumulated Index to Nursing and Allied Health Literature (CINAHL), and Allied and Complementary Medicine Database (AMED). In addition, grey literature was searched in Data Archiving and Network Services (DANS) and Google Scholar. The search was conducted in August 2021 with a 10-year restriction to publication date, and an updated search was performed in January 2023. The search terms and search strategy were customized for each database to ensure precision and accuracy. The search strategy included thesaurus terms (MeSH terms and subject headings) combined with free-text words. Examples of main search terms used are concussion, mTBI, commotio cerebri, symptom reductions, rehabilitation, physiotherapy, and occupational therapy (see Table SI). To maximize the search results, multiple sets of search terms were used. The search was performed until an overlap in the identified studies was observed (38). The literature search was performed with support from an experienced research librarian (see Table SI). All studies retrieved from the database searches were imported into Covidence (https://www.covidence.org), while grey literature was screened directly from the webpages and imported to Zotero (https://www.zotero.org). Applying the inclusion criteria (see below) all titles and abstracts were initially screened for relevance to the research question by two researchers (JDG, MNM) and non-relevant titles were removed. In case of disagreement consensus was reached through discussion and by involving the other author (HKE).

Stage three: selecting studies

The inclusion criteria for this scoping review were: occupational and physiotherapy rehabilitation modalities used to support individuals diagnosed with concussion; studies including individuals +16 years diagnosed with concussion; studies published between 2011 and 2022; and studies written in English, Danish, Swedish or Norwegian. Primary studies were included, e.g. randomized controlled trials (RCTs), case studies, pilot studies, feasibility studies; thus, systematic reviews were excluded, but the reference lists were hand-searched for relevant studies. The scoping review aimed to include studies targeting the adult population. However, since some studies included both adults and adolescents, the age limit was set to include the age +16 years to minimize the risk of excluding essential studies in the field of the adult population. Studies that included individuals crossing this age limit were included if the mean age of participants was +16 years, or if results were presented according to age. Literature with a primary focus on elite sports populations and veterans or military concussion with access to specialized rehabilitation was excluded, since the course of rehabilitation (early diagnosis, rehabilitation management and guidelines for early return to play)

(34) and recovery might differ substantially from the general population.

Furthermore, studies were excluded if the participants had other comorbidities affecting the brain (i.e. post-traumatic stress, whiplash, cognitive deficits, or earlier concussion events), if they only introduced the therapeutic modalities (e.g. study protocols), or if the primary focus was on pharmacology and medications.

Stage four: charting the data

The authors collectively determined which variables to extract from the included articles, with a view to answering the research question. This stage of charting the data was an iterative process, in which the authors continuously extracted data from the included articles and updated the data-charting form (38). The following variables were chosen: author, year, and country; objective and aim; study design; study population (numbers of participants, age, sex, concussion onset; content of the therapeutic rehabilitation modalities; context (rehabilitation setting, duration, and which professions deliver the rehabilitation modalities; outcome measures; and key findings (see Table I).

To define the concept of rehabilitation, the current study was inspired by the recently published Danish White Paper (WP) on the concept of rehabilitation (39) and Derrick Wade's framework (40) of what constitutes rehabilitation. The WP (39) defines rehabilitation as being aimed at persons who experience or are at risk of experiencing limitations in physical, mental, cognitive and/or social functionality in everyday life. The aim of rehabilitation is to enable a meaningful life with best possible activity and participation, management, and quality of life. Also, the WP explicitly emphasizes that people with the same diagnosis and deficits may have varying rehabilitation needs, thus special attention should be put on goal-setting and on the support needed from professionals during the rehabilitation period (39). The WP (39) and Wade's framework (40) supported a meaningful way of categorizing the different parts of the OT and PT modalities in relation to the concept of rehabilitation. Both studies suggest that the rehabilitation process should include the following elements: (*i*) assessment: identify and screen for activity limitations (cognitive- and motor skills) faced by the patient; (*ii*) goal-setting: establish the patient's goals and expectations, both short-term and long-term, especially regarding level of activity and/or participation; (*iii*) training: undertake the planned interventions (training cognitive skills, motor skills, motivation, and strategies to compensate for deficits); (*iv*) social participation and discharge support: provide structure, planning for maintenance of health, education, and communication (39, 40). Discharge in this study means any termination of intervention (e.g. consultation with the general practitioner, visit to the emergency department (ED), shorter/longer rehabilitation processes in different settings etc.). Education as intervention is elaborated to include knowledge about the disease, its causes, prognosis, treatments, and skills in relation to self-management. Education may also cover managing the emotional aspects of the illness (40, 41). When categorizing the target of PT and OT rehabilitation modalities of the included studies, the above-mentioned four elements were used (see Table II).

All authors independently extracted data from all included studies using the data-charting form and subsequently discussed and determined whether the approach to data extraction was consistent with the research question and aim.

Stage five: collating, summarizing, and reporting the results

In this stage the results were collated, summarized, and reported.

RESULTS

The literature search resulted in 482 records (database search and grey literature search), after 16 duplicates were removed. Thirty-one studies were included after title and abstract screening. However, three relevant studies were inaccessible, 13 studies were excluded after full text reading due to wrong study population, one was excluded since participants had experienced multiple concussions and specialized treatment, and four were excluded since the intervention was not provided by an OT or PT. Of the studies excluded on title/abstract, two of these were conference abstracts (42, 43), which lacked essential details on therapeutic modalities.

Thus, a total of 10 studies using OT and/or PT rehabilitation modalities aimed at concussed individuals in the general population were included in this scoping review. A flow-chart of the search strategy and selection process is shown in Figure 1.

General description of studies

The characteristics of the included studies are shown in Table I. One of the 10 included studies was published in 2013 (44), and the remaining studies were published between 2017 and 2022. Most studies were conducted in the Nordic countries (three in Denmark (15, 45, 46) and two in Norway (25, 47)), three in the USA (28, 44, 48), and two in New Zealand (29, 49). Regarding study design, three studies were retrospective chart reviews (28, 29, 44), three were RCTs (15, 25, 47), one an open-label parallel-group randomized trial (46), one

Table I. Summary of characteristics of the articles included in the present scoping review ($n = 10$)

Study number	First author, publication year, and country	Objective/aim of study	Study design	Study population	Content of the intervention	Rehabilitation setting, intervention duration and professions delivering the intervention modalities	Outcome measures	Key findings
1	Alsalaheen et al., 2013 USA (44)	To describe the vestibular rehabilitation exercise prescriptions provided to individuals after concussion.	Retrospective chart review	104 participants **Age:** Mean 24, SD 19 years **Sex:** 66 F/38 M **Concussion onset:** Median 58 days (range 6–1,149 days)	Computer-generated home exercise programme of vestibular rehabilitation exercises.	**Setting:** Tertiary vestibular rehabilitation clinic for vestibular rehabilitation (home) **Duration:** Median 33 days (range 7–181) Median 4 visits (range 2–13) **Professions:** Physiotherapists	Frequency counts of the most common exercise types. Exercise progression patterns examined.	Eye–head coordination exercises were the most prescribed exercise type, followed by standing static balance exercises, and ambulation exercises.
2	Christensen et al., 2020, Denmark (45)	To investigate the use of submaximal aerobic exercise and body awareness therapy, and the influence on symptoms in post-concussion syndrome (PCS) cases.	Collective case study	4 participants **Age:** >18 years **Sex:** Not reported **Concussion onset:** >12 months	Study A: A submaximal graded aerobic exercise intervention supplemented by postural correction of the cervical spine. Study B: A modified body awareness intervention with additional group feedback sessions.	**Setting:** Centre of rehabilitation **Duration:** Study A: 8 individual sessions/ twice a week over 4 weeks Home exercises: postural correction of the cervical spine up to three times daily Study B: 6 guided practices/twice a week over 3 weeks **Professions:** Not reported	Study A: Rivermead Post-Concussion Questionnaire (RPQ), interviews, Craniocervical Flexion Test (CCFT). Study B: Short Form-36v2 questionnaire	Both cases in Study A showed marked improvements in their RPQ scores, but only one showed improvement in the CCFT. In Study B, 1 case improved in RPQ score and in the mental component of SF-36v2, while the other case did not experience any significant change. All cases expressed positive associations with the interventions during the interviews.
3	Horstman et al., 2017, USA (28)	To assess the efficacy of a cervical spine stabilization exercise programme (CSEP) in physical therapy for people following a concussion.	Retrospective chart review	4 participants with neck pain **Age:** 16–25 years **Sex:** 3 F/1 M **Concussion onset:** From 1 week to 1 year	A cervical spine stabilization exercise programme including deep neck muscle stabilization training exercises performed with the patient in supine, prone, side lying, standing, or while seated on a dynamic surface.	**Setting:** A medical centre, physical therapy or catholic health system, partners in rehabilitation physical therapy. **Duration:** 3–8 weeks **Professions:** Physiotherapists	The Neck Disability Index (NDI), the visual analogue scale (VAS) for pain, and the Dizziness Handicap Inventory (DHI).	Between 20% and 100% improvement in the NDI scores, 22.2% and 100% improvement in DHI scores, and 60% and 100% improvement in VAS scores. All patients reported an improvement in functional ability after receiving treatment.
4	Hurtado et al., 2022, USA (48)	To evaluate the clinical response to the combination of conventional vestibular rehabilitation therapy and technology-enhanced visual desensitization home exercises among a group of individuals referred for vestibular rehabilitation after concussion.	Retrospective case series	23 participants **Age:** Mean 23.1, SD 12.4 years **Sex:** 56.5% F/43.5% M **Concussion onset:** Mean 109 days, SD 56 days, Range 14 – 270 days	A combination of conventional vestibular rehabilitation therapy (VTR) and a technology-enhanced visual desensitization customized home exercise programme (HEP). Daily HEP: During weekly in-person 1-hr sessions with the physical therapist. Conventional VRT: Individualized gaze stabilization, balance, and gait exercises. Technology-enhanced visual desensitization exercises: On-line videos designed to progressively provoke visual motion sensitivity. Prescribed at a twice-daily frequency, 7-days per week.	**Setting:** A tertiary balance centre located at a health centre **Duration:** Median of 4 in-person visits Treatment duration mean 6.9 weeks, SD 2.5 weeks **Professions:** Physiotherapist specializing in vestibular rehabilitation therapy	Self-report measures included Activities-specific Balance Confidence Scale (ABC), Dizziness Handicap Inventory (DHI), Visual Vertigo Analog Scale (VVAS), and Vestibular Rehabilitation Benefit Questionnaire (VRBQ).	Significant improvements in post-intervention on subjective and objective measures of dizziness and gait. The response to intervention was independent of preinjury migraine history but pre-injury depression/anxiety increased self-report of post-treatment anxiety. Concurrent treatment with medications did not influence response to treatment.

(*Continued*)

Table I. (Continued) Summary of characteristics of the articles included in the present scoping review ($n = 10$)

Study number	First author, publication year, and country	Objective/aim of study	Study design	Study population	Content of the intervention	Rehabilitation setting, intervention duration and professions delivering the intervention modalities	Outcome measures	Key findings
5	Kennedy et al., 2017, New Zealand (29)	To describe the cervical spine findings and outcomes of treatment in a series of patients with persistent post-concussion symptoms, and describe the clinical characteristics of a cervicogenic component when it is present.	Retrospective chart review	32 participants /21 included with a cervicogenic component **Age:** Mean 26.9, SD 11.9 years **Sex:** 17 F/15 M **Concussion onset:** <1 month: 5 1–3 months: 19 4–6 months: 3 More than 6 months: 3 Unclear: 3	Patients considered to have a cervicogenic component were recommended a course of physiotherapy treatment, typically including manual therapy, acupuncture and/or stability exercises.	**Setting:** Private physiotherapy practice **Duration:** Not reported/ Mean 2.9 sessions (range 1–12) **Professions:** Physiotherapists	Work status, patient specific functional scale, numerical pain rating scale, and the outcome of assessment.	Physiotherapy treatment of the cervicogenic component achieved improvements in function, and pain.
6	Kennedy et al., 2021, New Zealand (49)	To describe individual long-term outcomes of people with persistent symptoms following a concussion who received neck treatment as part of multidisciplinary concussion care. Secondarily to report how participants describe the outcomes of neck treatment.	Prospective case series	11 participants **Age:** Mean 36, SD 17 years **Sex:** 7 F/4 M **Concussion onset:** Mean 8 weeks, SD 12 weeks	A multidisciplinary assessment to confirm the diagnosis, evaluate the source(s) of symptoms, consider any barriers to recovery and develop an individual management plan. Receives basic support from a key worker (an occupational therapist or physical therapist) including education about concussion, advice on how to manage a graduated return to daily activities and case management. Other treatment varies based on the assessment findings, such as vestibular and/or oculomotor rehabilitation, neck treatment, return to work planning, medical management etc.	**Setting:** Multidisciplinary nationally funded concussion service provided by local contract holders. **Duration:** 3–6 sessions Mean 4.5 Treatment duration 1–9 weeks, Mean 3.2 weeks **Professions:** Neck assessment and treatment by physiotherapist and basic support by either an occupational therapist or physical therapist	Standard questionnaires (Rivermead Post-Concussion Symptoms Questionnaire, Neck Disability Index, dizziness handicap inventory), patient-reported measures of headache, dizziness and neck pain and participant descriptions of the effects of neck treatment	Grouped measures of post-concussion symptoms were further improved or sustained at 6 and 12 months. 10/11 participants reported neck treatment as a beneficial part of their care and described the effects on the neck, multiple symptoms and their overall recovery. Seven participants experienced recurrent headache, neck pain or dizziness at 6- or 12-month follow-up.
7	Kleffelgaard et al., 2019, Norway (25)*	To investigate the effects of group-based vestibular rehabilitation in patients with traumatic brain injury.	Randomized controlled trial	64 participants **Age:** Intervention: Mean 37.6, SD 12.3 years Control: Mean 41.2, SD 13.6 years **Sex:** Females **Concussion onset:** Intervention: Mean 3.9, SD 2.2 months **Control:** Mean 3.4, SD 1.9 months	Group sessions with guidance, individually modified vestibular rehabilitation, general exercises for muscle conditioning and strengthening, a home exercise programme, and an exercise diary. Guidance sessions were held at the beginning of session 1 and were based on the patients' experiences, reflections, and active participation. The psychological aspect of recovery was promoted by information, confidence building, education, and reorientation. Furthermore, peer support was encouraged, and the group members shared experiences and provided emotional and practical support to each other. Self-efficacy was facilitated through a focus on positive experiences, gaining control by interpretation of physical and emotional symptoms, and strengthening the patients' beliefs in their own ability to reach their goals.	**Setting:** Outpatient clinic at a University Hospital College **Duration:** Twice a week for 8 weeks (60–90 min). + 2–5 individually adjusted exercises, a home aerobic exercise programme and gradually increasing activity, such as walking, skiing, swimming etc. Frequency: 3–5 times a week **Professions:** Physiotherapists	Primary outcome: Dizziness Handicap Inventory. Secondary outcome: High-Level Mobility Assessment Tool. Other outcomes: Vertigo Symptom Scale; Rivermead Post-concussion Symptoms Questionnaire; Hospital Anxiety and Depression Scale; and Balance Error Scoring System.	At the first follow-up, statistically significant mean differences in favour of the intervention were found in the primary and secondary outcomes. At the second follow-up, no significant between-group differences were found. No significant between-group differences in the other outcomes were found at the 2 follow-ups.

(*Continued*)

Table I. (Continued) Summary of characteristics of the articles included in the present scoping review ($n = 10$)

Study number	First author, publication year, and country	Objective/aim of study	Study design	Study population	Content of the intervention	Rehabilitation setting, intervention duration and professions delivering the intervention modalities	Outcome measures	Key findings
8	Rytter et al., 2019, Denmark (15)	To compare the effectiveness of a specialized, interdisciplinary rehabilitation (S-REHAB) with standard care (STAND) for people with persistent post-concussive symptoms	Randomized controlled trial	89 participants **Age:** Intervention: 18–29 years: $n = 12$ 30–43 years: $n = 21$ 44 < years: $n = 12$ Control: 18–29 years: $n = 12$ 30–43 years: $n = 24$ 44 < years: $n = 8$ **Sex:** Intervention: 29 F/16 M Control: 30 F/14 M **Concussion onset:** > 6 months (mean time since injury 27–29 months)	Combination of individual and group-based neuropsychological treatment with exercise therapy and physiotherapeutic coaching (S-REHAB) divided into 2 modules Module 1: 12 weeks, 12–14 individual consultation sessions (1–2 h/week) with a neuropsychologist 24 h in group therapy (2 h/week) combining psychoeducation, small exercises and group conversations 33 h (2–3 h/week) of individual exercise training and coaching by a physiotherapist Module 2: 10 individual consultations (1 h/week) with a neuropsychologist 16 h of group work (1.5 h/week) combining group exercises and conversations 10.5 h (1 h/week) of individual exercise training and coaching with a physiotherapist 1 meeting with a case manager in participant's municipality 2 meetings with an existing or potential employer focusing on education and return to work. Compared with the usual treatment offered by the public municipality services. This could range from no treatment at all, to referral to individual, discipline-specific therapies.	**Setting:** Specialized post-acute outpatient hospital **Duration:** 22 weeks **Professions:** Interdisciplinary team (neuropsychologist/ physiotherapist/municipal case manager/existing or potential employer)	The Rivermead Post-Concussion Symptoms Questionnaire (RPSQ), The Headache Impact Test (HIT-6), Major Depression Inventory (MDI), Multidimensional Fatigue Inventory (MFI-20) and The Short Form (36) Health Survey (SF-36). Collected at baseline, post-treatment, and at 6-month follow-up.	The S-REHAB group showed a significant reduction in symptoms measured by RPSQ compared with the STAND immediately post-treatment and at follow-up. The S-REHAB groups also showed significant improvements regarding HIT-6 post-treatment and at follow-up, MFI-20 – dimension 'mental fatigue' post-treatment, MFI-20 – dimension 'reduced activities' at follow-up and SF-36 – dimension "social functioning" posttreatment.
9	Thastum et al., 2019 Denmark (46)	To evaluate the efficacy of the intervention "Get going After concussIoN" (GAIN) added to "Enhanced Usual Care" (EUC) in reducing PCS.	Open-label, parallel-group randomized trial	112 participants $n = 57$ for GAIN + EUC, $n = 55$ for EUC **Age:** 15–30, mean 22.9 years **Sex:** Intervention: 45 F/12 M Control: 44 F/11 M **Concussion onset:** 4–6 months	An interdisciplinary, individually tailored intervention based on gradual return to activities and principles from cognitive behavioural therapy. The programme covered 3 structured group sessions, up to 5 semi-structured individual sessions with an allocated therapist (occupational therapist/ physiotherapist) either in person or by telephone/video, and homework between each session. Compared with enhanced usual care (EUC)	**Setting:** Hospital **Duration:** 8 weeks for GAIN + EUC For EUC/control duration was flexible **Professions:** Interdisciplinary team (physiotherapists, occupational therapists, neuro-psychologist)	Primary outcome: Rivermead Post-concussion Symptoms questionnaire (RPQ) score from baseline to 3-months follow up. Secondary outcome: Illness-specific health-related quality of life measured by The Quality of Life after Brain Injury Overall Scale Supplementary outcomes: Subjective improvement measured by Patient Global Impression of Change.	Patients allocated to GAIN + EUC reported a significantly larger reduction of PCS than patients allocated to EUC. No adverse events were observed. Compared with EUC, GAIN + EUC was associated with a larger reduction of post-concussion symptoms at 3-month follow-up.

(*Continued*)

Table I. (Continued) Summary of characteristics of the articles included in the present scoping review ($n = 10$)

Study number	First author, publication year, and country	Objective/aim of study	Study design	Study population	Content of the intervention	Rehabilitation setting, intervention duration and professions delivering the intervention modalities	Outcome measures	Key findings
10	Vikane et al., 2017, Norway (47)	To evaluate the efficacy of a multi-disciplinary outpatient follow-up programme compared with follow-up by a general practitioner for patients being at-risk or sick-listed with persistent post-concussion symptoms 2 months after a mild traumatic brain injury.	Randomised controlled trial	151 participants **Age:** 16–55,median 35 years **Sex:** 59 F/92 M **Concussion onset:** 9–16 weeks	Multidisciplinary outpatient rehabilitation with individual contacts and a psycho-educational group intervention compared with follow-up by a general practitioner. The group interventions consisted of receiving education and addressing common problems in daily life after MTBI.	**Setting:** Outpatient rehabilitation clinic (intervention) vs general practitioner (control) **Duration:** One session per week over 4-weeks + individually tailored additional follow-ups during the first year **Professions:** Interdisciplinary team (general practitioner/ specialist in rehabilitation medicine/neuropsychologist/ occupational therapists/ physician/social worker/ nurse)	Primary outcome: Sustainable return-to-work first year post-injury. Secondary outcomes: Post-concussion symptoms, disability, the patient's impressions of change and psychological distress	Days to sustainable return-to-work was 90 in the intervention and 71 in the control group. The number of post-concussion symptoms was fewer in the intervention compared with the control group at 12 months. No group differences were observed for disability, patients' impression of change or psychological distress.

*The description of the intervention modalities used was described in a previous study by Kleffelgaard et al. (63).

SD = Standard Deviation, M = Male, F = Female, h = hour.

Table II. Described modalities presented according to Wade's framework (assessment, goal-setting, training, and social participation & discharge support)

	Alsalaheen et al., 2013 (44)	Christensen et al., 2020 (45)	Horstman et al., 2017 (28)	Hurtado et al., 2022 (48)	Kennedy et al., 2017 (29)	Kennedy et al., 2021 (49)	Kleffelgaard et al., 2019 (25)	Rytter et al., 2019 (15)	Thastum et al., 2019 (46)	Vikane et al., 2017 (47)
A: Assessment			–[b]							
• Programme customized to patient's impairments and functional limitations	×[a]						×			
• Clinical examination		×				×				
• Physical therapy assessment and customized home exercise program, and questionnaire				×						
• Assessment of cervical spine, patient history, prior conditions, symptom nature and behaviour, and physical findings by physiotherapist					×					
• Questionnaire and multidisciplinary assessment to confirm diagnosis, evaluate the source(s) of symptoms, consider any barriers to recovery.						×				
• Interview by clinical neuropsychologist, and questionnaire regarding socio-demographic background, health situation, and current post-concussive symptoms								×		
• Questionnaire, neurological examination, psychiatric interview									×	
• Interview about patient's history and participation in everyday activities and work, and neurological examination										×

(*Continued*)

Table II. (Continued) Described modalities presented according to Wade's framework (assessment, goal-setting, training, and social participation & discharge support)

	Alsalaheen et al., 2013 (44)	Christensen et al., 2020 (45)	Horstman et al., 2017 (28)	Hurtado et al., 2022 (48)	Kennedy et al., 2017 (29)	Kennedy et al., 2021 (49)	Kleffelgaard et al., 2019 (25)	Rytter et al., 2019 (15)	Thastum et al., 2019 (46)	Vikane et al., 2017 (47)
B: Goal-setting	–	–	–	–	–				–	
• Support towards active evaluation, self-monitoring, and self-regulation								×		
• Development of an individual treatment plan						×				
• Re-establishing structured routines in daily living, stepwise return-to-work, strategies to lessen the impact (memory aids), referral to other specialists or therapists										×
• Guiding sessions used to discuss questions regarding goal setting							×			
C: Training	×	×	×	×	×	×	×	×	×	×
Manual and sensory motor interventions										
• Balance and vestibular training	×			×			×			
• Oculomotor training				×			×			
• Stability/general exercises for muscle conditioning and strengthening			×		×		×			
• Manual therapy of neck and spine/osteopathic therapy					×					
• Postural correction of the cervical spine		×								
• Neck treatment (joint mobilization, specific exercises (e.g. posture, retraction, craniocervical control) and/or soft-tissue technique)						×				
• Acupuncture					×					
Physical exercise interventions:										
• Graded physical therapy								×	×	
• Physiotherapeutic coaching								×		
• Aerobic exercise		×					×			
Management and coping:										
• Body awareness therapy + short group feedback session		×								
• Education about concussion						×				
• Cognitive behavioural therapy								×	×	
• Individual contacts and a psycho-educational group intervention										×
• Group-based neuropsychological treatment								×		
• Additional follow-ups during the first year individually tailored to the individual's needs and problems										×
D: Social participation & discharge support	–	–	–	–	–		–			
• Development of an individual management plan and advise on how to manage a graduated return to daily activities and case management						×				
• Meeting with case manager in participant's municipality, and with an existing or potential employer								×		
• Intervention included a focus on the patient's gradual return to activities and principles from cognitive behavioural therapy.									×	
• Interview concerning the patient's history and participation in everyday activities and work, return to work										×

[a, b]"×" and "–" indicate presence or absence of the aspect in the study.

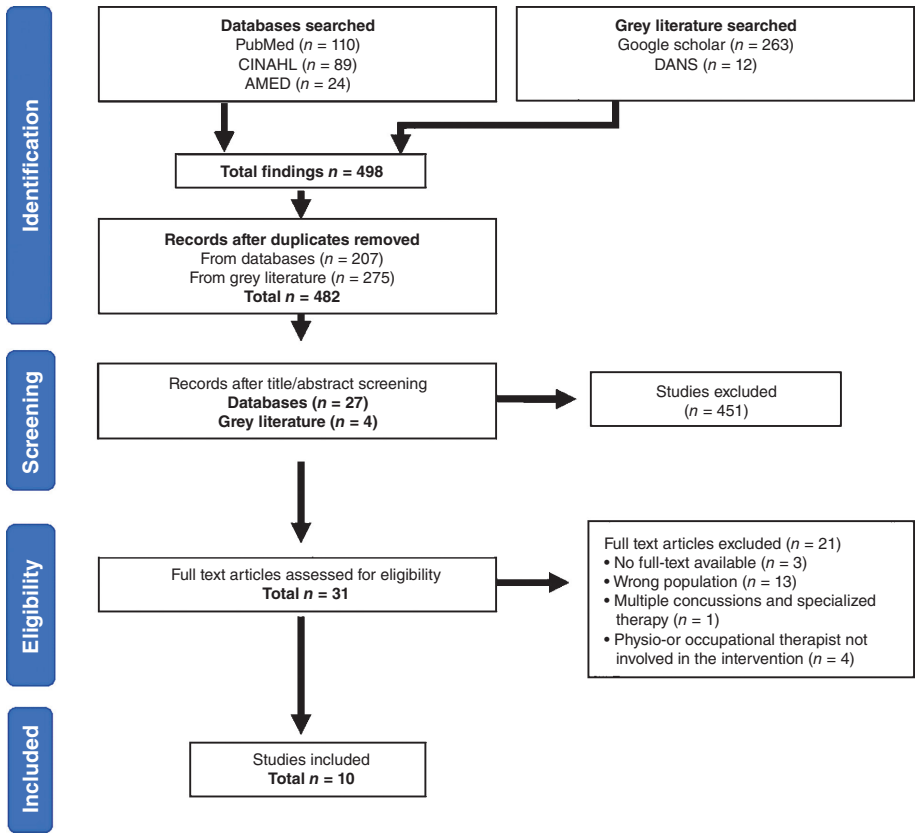

Fig. 1. Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) flow-chart of search strategy and selection process. AMED: Allied and Complementary Medicine Database; CINAHL: Cumulated Index to Nursing and Allied Health Literature; DANS: Data Archiving and Network Services.

a collective case study (45), and a retrospective (48) and prospective (49) case series.

The number of participants included in the studies ranged from four to 151, with half of the studies having more than 64 participants (15, 44, 46, 47), and the other studies having 11 (49), 23 (48), 32 (29), and four (28, 45) participants. Onset of concussion prior to rehabilitation start for the included patients were very different, ranging from weeks to years; 2–4 months (47–49), 2–6 months (46), more than 6 months (15), and ranging from a very broad time-period of between weeks to years (28, 29, 44, 45).

In one study the intervention was conducted at a private outpatient clinic (29), the remaining in outpatient clinics at either hospitals or universities. Six studies included group or individual home exercises (15, 25, 44–46, 48). In four studies (15, 25, 44, 45) home exercises were prescribed by a physiotherapist, who in two studies (15, 25) also adjusted and evaluated the performance of exercises to accommodate each participants' level, needs and goals. In the study by Thastum et al. (46) these were prescribed by an interdisciplinary team.

In Alsalaheen et al.'s study (44) participants performed vestibular exercises 1–3 times, in Christiansen et al.'s study (45) exercises were performed daily, and in Kennedy et al.'s study (49) neck treatment was recommended for a mean of 3.4 hours over a mean of 4.3 weeks. In Kleffelgaard et al.'s study (25) the intervention consisted of a group vestibular rehabilitation session twice a week for eight weeks, a home exercise programme, and an exercise diary. Also, Rytter et al. (15) included home-exercises, which were primarily performed in the local fitness centre in smaller groups. These exercises were aimed more broadly at increasing general activity level and muscle strength and were individually tailored. Thastum et al. (46) also included more general home exercises, such as walking and performing daily activities (e.g. reading, working with a computer, cleaning, going out with friends). Kleffelgaard et al.'s (25) home exercise programme consisted of a home aerobic exercise programme and more general home exercises, such as walking, biking or swimming, 3–5 times a week. Finally, participants in the study by Hurtado et al. (48) conducted daily vestibular home exercises combined with twice-daily online technology-enhanced visual desensitization exercises.

For most of the studies the duration of the intervention was in the range 3–8 weeks (25, 28, 45–48). The intervention durations in the remaining studies were

1–9 weeks (49), 22 weeks (15), 7–181 days (44), or not reported (29). Where reported, therapeutic rehabilitation modalities were delivered mainly by a PT (25, 28, 29, 44, 48, 49) or an interdisciplinary team (15, 46, 47) (i.e. PT, psychologist, OT, general practitioner, nurse specialist in rehabilitation medicine, medical specialist, physician, a municipality case manager, existing or potential employer). In two of these studies an OT was a part of the interdisciplinary team (46, 47). Finally, in one study the neck assessment and treatment were performed by a PT, and basic support (education about concussion, advice on how to manage a graduated return to daily activities and case management) was delivered by an OT or a PT (49). Key findings and outcome measures, which were very heterogeneous, are shown in Table I.

PT and OT rehabilitation modalities used to support an interdisciplinary rehabilitation

The described PT and OT rehabilitation modalities used are shown in Table II according to the four elements of the WP and Wade's framework of rehabilitation. Nine studies addressed "assessment" (15, 25, 29, 44–49), four "goal-setting" (15, 25, 47, 49), all studies "training", and four "social participation and discharge support" (15, 46, 47, 49). RCTs (15, 46, 47) and the prospective case series (49) more often addressed all or almost all elements of the WP and Wades framework and utilized interdisciplinary delivery of the intervention.

The studies describing "assessment" used one or two of the following tools for assessment; questionnaires (15, 46, 48, 49), interviews (15, 46, 47), and clinical (25, 29, 44, 48, 49), or neurological (46, 47) examinations of the patients. Where goal-setting was described, it was done by giving support towards active evaluation, self-monitoring, and self-regulation (15), by development of an individual treatment plan (49), by focusing on re-establishing routines in daily living and return-to-work (47), or by reviewing exercise diaries and discussing questions regarding goal-setting, progression, and the home exercise programme (25). The PT and OT rehabilitation modalities used in the included studies were categorized into three groups: "manual and sensory motor interventions" (25, 28, 29, 44, 45, 48, 49), "physical exercise interventions" (15, 25, 45, 46) (including home exercises (15, 25, 44–46)), and "management and coping" (15, 45–47, 49). Studies describing elements of social participation and discharge support, described elements as development of an individual management plan and advised on return to daily activities (49), meetings with municipality case manager and existing or potential employer (15), a focus on the patient's gradual return to all daily activities (46), and an interview concerning the patient's history and participation in everyday activities and work (47) (see Table II).

DISCUSSION

This scoping review has identified and described which OT and PT rehabilitation modalities are presented in the literature to support an interdisciplinary rehabilitation process in adults (aged 16+ years) in the general population after concussion. This included describing the onset, setting, duration, professions delivering the interventions, and the key findings.

The majority of the identified PT and OT rehabilitation modalities in the included studies addressed bodily functions, such as neck stability and vestibular training, and focussed less on coping and discharge support. However, four of the recent studies included in this scoping review (published after 2017), had an interdisciplinary approach and they included social participation and discharge support as part of their intervention elements. This might indicate a shift from focusing exclusively on rehabilitation on a bodily (function and structures) level to a more holistic approach, such as social participation support. Also, in accordance with the recommendations in the WP, collaboration with different sectors (i.e. health, social, employment, and education) may be necessary to meet the needs of the individuals in the general population struggling from concussion (39). However, only two studies (15, 47) in this scoping review described involvement of other sectors.

According to the Danish National guidelines (9) there is still a knowledge gap regarding when and where (and from whom) individuals with concussion and PCS should seek rehabilitation and on the rationale behind health professionals' different approaches. From our perspective a coordinated interdisciplinary approach is crucial, as concussion and PCS is a multifactorial and complex condition presenting very diverse symptoms. The interdisciplinary approach is also supported by Rytter et al. (8); however, their study was aimed at the persistent phases only. Furthermore, the rehabilitation modalities used should be based on symptoms, concussion onset, and duration (50); however, which modalities were used when and why was not discussed in the 10 studies included in this study.

This scoping review did not identify any studies that had specifically aimed at including patients at an early onset of concussion (acute or sub-acute phase of concussion where symptoms persist for less than four weeks), and only the three retrospective chart reviews and the retrospective case series included some patients at this early stage. However, it is well known that early controlled aerobic exercises following concussion is safe, may speed recovery, and prevent PCS (20–22, 27). Also, it is important to receive education,

reassurance, and strategy coaching early on to avoid prolonged rest that can lead to activity avoidance and persistent symptoms (17, 51). Targeting assessment and intervention at the acute and subacute phases of concussion in the general population might prevent PCS. This also aligns with the definition from the WP, which states that rehabilitation should be targeted at persons who experience, or are at risk of experiencing, limitations in their physical, mental, cognitive and/or social functionality and everyday life (39). In addition, it has been found previously that, in children and adolescents, active rehabilitation 2- or 3-week post-injury demonstrated lower symptom severity at follow-up compared with those starting 6 weeks or later (52) and that, in an adult population, early exercise prescription after concussion decreased the time to recovery (53).

One explanation of the scarce literature on PT and OT rehabilitation aimed at acute and subacute concussion could be that many people with concussion do not visit an ED or their general practitioner until symptoms have persisted for a longer time. Also, in some practice guidelines (17), referrals to interdisciplinary evaluation and treatment are recommended only if clients are at risk of poor prognosis (which should be assessed early), or experience symptoms that persist for longer than 4 weeks post-injury.

A brief search on studies aiming at interventions in the acute phase of concussion reveals that early interventions are delivered primarily by professionals other than OTs and PTs (34, 54–57). In a study by Moore (54), people attending an ED after experiencing acute concussion were met by a social worker whose intervention contained education about concussion-related symptoms, symptom management and coping. They found that patients who received this early intervention maintained their pre-injury levels of community functioning compared with the group receiving usual care, who experienced a significant decline in community functioning. Mistry & Rainar (34) suggest that acute assessment of the severity of concussion using validated prediction tools may help to identify individuals in need of individualized follow-up support to prevent prolonged symptoms. Dizziness, blurred vision, balance problems, orientation, and memory deficits were all mentioned as predictors for prolonged symptoms in their study. Also, clinically identifying the most severe symptoms may support a more targeted intervention (55). This may support that early assessment of concussion and symptoms and, when needed, an individualized and progressive exercise plan delivered by trained staff, may prove beneficial in decreasing PCS. Furthermore, it is essential that educational interventions in the acute phase are systematic and consistent with evidence, as supported by Rowe et al. (56) who discovered that most physicians in the ED did not follow the consensus guidelines when providing structured return to activity recommendations to patients. Nurse shortage and busyness in the ED and lack of standardized evidence-based material and procedures also hinder effective intervention of acute concussion (57). Another study found that adults with non-sport-related concussions are less likely to receive any written discharge instructions compared with concussed paediatric- and sport-related populations (58). Since sufficient education is necessary to achieve self-management (40) educational intervention in the acute phases may be essential for reducing PCS. Thus, it could be advised that people in the general population have early and easy access to evidence-based information on concussion and management, e.g. Bergman & Louis (57) found that an evidence-based and user-friendly booklet supported verbal discharge education in the acute phase of concussion. PTs and OTs could be valuable health professionals in developing procedures and materials to support acute interventions for concussion and in educating the interdisciplinary staff. Using formats other than brochures and booklets, such as webpages or mobile applications, might also be a strategy to ensure easy and timely access to relevant and evidence-based information on concussion and management. A Danish organization "*Hjernerystelsesforeningen*" (in English: The organisation for concussion) offers web-based information and educational materials on concussion and management building on updated evidence (www.hjernerystelsesforeningen.dk).

Prescribing progressive controlled home exercises is beneficial for recovery and quality of life (17, 31, 53). However, very little attention was given to this aspect in the included studies, and only one (48) of these which utilized home exercises argued that home exercises were an important supplement for rehabilitation after concussion.

The setting for most interventions was outpatient hospitals or university clinics with an intervention duration of 3–8 weeks. In the Scandinavian studies (15, 25, 45, 46) individuals were treated at public hospitals or outpatient hospital and clinics. In the American studies rehabilitation was conducted at a tertiary vestibular rehabilitation clinic (44), a tertiary balance centre at a health centre (48), and a medical centre of PT rehabilitation (28). This distinction might mirror the structure and organization of Scandinavian welfare societies in contrast to Anglo-American society structure.

The therapeutic rehabilitation modalities identified were mainly delivered by an interdisciplinary team or solely by PTs. OTs only participated in the rehabilitation process in two studies despite evidence for OTs' contribution in managing symptoms and facilitating gradual return to activities and work has shown to positively impact quality of life (46, 59). There may be several reasons for OTs being under-represented in the

included studies; however, a possible explanation may be that OTs more often get involved if the patient needs return-to-work support (60). However, the Canadian Association of Occupational Therapists recommend that OTs are involved earlier in the rehabilitation of concussion to support education, screening, and assessment, and to support prevention of disengagement from daily activities (61).

Strengths and limitations

A scoping review, rather than making analytical comparisons and pooling of data from primary sources, is concerned with collating and describing the available evidence, and presenting it in a clearly illustrated and summarized format. The strengths and limitations of this review will be discussed in that light.

Using the WP (39) and Wade's framework (40) supported a meaningful way of categorizing the different parts of the PT and OT modalities in relation to the concept of rehabilitation. However, frameworks and models may seem rigid, which does not reflect a flexible and fluent "real-life" rehabilitation. For example, assessment and goal-setting are not just elements of early rehabilitation, but rather done continuously throughout the entire rehabilitation process. Thus, our categorization of the included studies in relation to the framework, even though performed individually by all authors, might have been categorized differently by others. Furthermore, identifying PT and OT rehabilitation modalities in this review was challenging, as intervention components were seldom clearly described. Therefore, some important modality entities might have been lost in interpretation. The current literature search was limited to English, Danish, Norwegian and Swedish languages and selected databases; thus we cannot rule out that important knowledge published in other languages has been overlooked. Furthermore, although an inclusion criterion was set to include studies with individuals over the age of 16 years, some studies included individuals of ages crossing this age limit. To ensure that studies of relevance to the selected age group (+16 years) were not excluded, the current scoping review included studies in which the mean age of participants was +16 years, or subgroups if results were presented according to age. This will inherently mean that some of the participants in the current study have been younger. Lastly, when considering the current results, it should be taken into account that the current search was limited to PT and OT rehabilitation modalities only.

A strength of this study is that, to increase transparency, a study protocol was published before data extraction (62). Furthermore, two authors independently reviewed the titles and abstracts of the included records and the resulting list of studies were reviewed by the entire research team to ensure that they met inclusion and exclusion criteria. Lastly, data extraction was conducted, discussed, and verified by all researchers to strengthen validity and reliability.

Conclusion

In conclusion, this scoping review found that the PT and OT rehabilitation modalities used to support an interdisciplinary rehabilitation consisted of manual and sensory motor interventions, physical exercise interventions, and management and coping. In four of the 10 included studies social participation and discharge support was a part of the rehabilitation process. PTs were found to be engaged more often than OTs in the rehabilitation. The current scoping review did not identify any studies that specifically aimed to include patients at an early onset of concussion.

Perspectives

Future research should focus on how to better support social participation and discharge in the rehabilitation process, as these important elements were given very little attention in the included studies. Also, rehabilitation in the early stages of concussion needs further exploration with the aim of decreasing the prevalence of PCS. Acknowledging the strength of interdisciplinary concussion rehabilitation PTs and OTs could consider taking on greater responsibility for emphasizing the importance of early education, support of social participation and discharge in the interdisciplinary team.

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REFERENCES

1. Marshall S, Bayley M, McCullagh S, Velikonja D, Berrigan L, Ouchterlony D, et al. Updated clinical practice guidelines for concussion/mild traumatic brain injury and persistent symptoms. Brain Inj 2015; 29: 688–700. DOI: 10.3109/02699052.2015.1004755
2. Carroll LJ, Cassidy JD, Holm L, Kraus J, Coronado VG, WHO Collaborating Centre Task Force on Mild Traumatic Brain Injury. Methodological issues and research recommendations for mild traumatic brain injury: the WHO Collaborating Centre Task Force on Mild Traumatic

Brain Injury. J Rehabil Med 2004: 113–125. DOI: 10.1080/16501960410023877
3. Carroll LJ, Cassidy JD, Cancelliere C, Côté P, Hincapié CA, Kristman VL, et al. Systematic review of the prognosis after mild traumatic brain injury in adults: cognitive, psychiatric, and mortality outcomes: results of the international collaboration on mild traumatic brain injury prognosis. Arch Phys Med Rehabil 2014; 95: S152–S173. DOI: 10.1016/j.apmr.2013.08.300
4. Langer L, Levy C, Bayley M. Increasing incidence of concussion: true epidemic or better recognition? J Head Trauma Rehabil 2020; 35: E60–E66. DOI: 10.1097/HTR.0000000000000503
5. Pinner M, Børgesen SE, Jensen R, Birket-Smith M, Gade A, Østergaard Riis J. Consensus-driven guidelines regarding commotio cerebri. Videncenter for Hjerneskade; 2003. Available from: https://hjernerystelsesforeningen.dk/wp-content/uploads/2016/03/2003Pinner-mugge-konsensus.pdf
6. The World Bank. World Development Indicators database n.d. Available from: http://databank.worldbank.org/data/download/GDP.pdf
7. McCrea M, Guskiewicz KM, Marshall SW, Barr W, Randolph C, Cantu RC, et al. Acute effects and recovery time following concussion in collegiate football players: The NCAA concussion study. JAMA 2003; 290: 2556. DOI: 10.1001/jama.290.19.2556
8. Rytter HM, Graff HJ, Henriksen HK, Aaen N, Hartvigsen J, Hoegh M, et al. Nonpharmacological treatment of persistent postconcussion symptoms in adults: a systematic review and meta-analysis and guideline recommendation. JAMA Netw Open 2021; 4: e2132221. DOI: 10.1001/jamanetworkopen.2021.32221
9. Graff HJ. National clinical guideline for non-pharmacological treatment of prolonged symptoms after concussion. Dansk Center for Hjernerystelse; 2021.
10. Hiploylee C, Dufort PA, Davis HS, Wennberg RA, Tartaglia MC, Mikulis D, et al. Longitudinal study of postconcussion syndrome: not everyone tecovers. J Neurotrauma 2017; 34: 1511–1523. DOI: 10.1089/neu.2016.4677
11. Dikmen S, Machamer J, Temkin N. Mild traumatic brain injury: longitudinal study of cognition, functional status, and post-traumatic symptoms. J Neurotrauma 2017; 34: 1524–1530. DOI: 10.1089/neu.2016.4618
12. Smits M, Hunink MGM, van Rijssel DA, Dekker HM, Vos PE, Kool DR, et al. Outcome after complicated minor head injury. Am J Neuroradiol 2008; 29: 506–513. DOI: 10.3174/ajnr.A0852
13. ICD10Data.com. 2021 ICD-10-CM Diagnosis Code F07.81. Postconcussional syndrome. ICD10Data.com; 2021.
14. Cassidy JD, Carroll L, Peloso P, Borg J, von Holst H, Holm L, et al. Incidence, risk factors and prevention of mild traumatic brain injury: results of the WHO collaborating centre task force on mild traumatic brain injury. J Rehabil Med 2004; 36: 28–60. DOI: 10.1080/16501960410023732
15. Rytter HM, Westenbaek K, Henriksen H, Christiansen P, Humle F. Specialized interdisciplinary rehabilitation reduces persistent post-concussive symptoms: a randomized clinical trial. Brain Inj 2019; 33: 266–281. DOI: 10.1080/02699052.2018.1552022
16. Willer B, Leddy JJ. Management of concussion and post-concussion syndrome. Curr Treat Options Neurol 2006; 8: 415–426. DOI: 10.1007/s11940-006-0031-9
17. Ontario Neurotrauma Foundation. Guideline for concussion/mild traumatic brain injury & prolonged symptoms. Ontario: Ontario Neurotrauma Foundation; 2018.
18. Sawyer Q, Vesci B, McLeod TCV. Physical activity and intermittent postconcussion symptoms after a period of symptom-limited physical and cognitive rest. J Athl Train 2016; 51: 739–742. DOI: 10.4085/1062-6050-51.12.01
19. Howard Andrew, Schwaiger Tyler, Silverberg Noah, Panenka Will. Concussion management: time to give "brain rest" a rest 2018. DOI: 2022-01-10
20. Hattrup N, Gray H, Krumholtz M, Valovich McLeod TC. Early controlled exercise and timing of treatment following concussion: a critically appraised topic. J Sport Rehabil 2020; 29: 360–366. DOI: 10.1123/jsr.2019-0187
21. Lal A, Kolakowsky-Hayner A, Ghajar J, Balamane M. The effect of physical exercise after a concussion. Am J Sports Med 2018; 46: 743–752.
22. McLeod TCV, Lewis JH, Whelihan K, Bacon CEW. Rest and return to activity after sport-related concussion: a systematic review of the literature. J Athl Train 2017; 52: 262–287. DOI: 10.4085/1052-6050-51.6.06
23. Ritter KG, Hussey MJ, Valovich McLeod TC. Subsymptomatic aerobic exercise for patients with postconcussion syndrome: a critically appraised topic. J Sport Rehabil 2019; 28: 211–216. DOI: 10.1123/jsr.2017-0159
24. Maskell F, Chiarelli P, Isles R. Dizziness after traumatic brain injury: overview and measurement in the clinical setting. Brain Inj 2006; 20: 293–305. DOI: 10.1080/02699050500488041
25. Kleffelgaard I, Soberg HL, Tamber A-L, Bruusgaard KA, Pripp AH, Sandhaug M, 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: 74–84. DOI: 10.1177/0269215518791274
26. McIntyre M, Kempenaar A, Amiri M, Alavinia SM, Kumbhare D. The role of subsymptom threshold aerobic exercise for persistent concussion symptoms in patients with postconcussion syndrome: a systematic review. Am J Phys Med Rehabil 2020; 99: 257–264. DOI: 10.1097/PHM.0000000000001340
27. Worts PR, Burkhart SO, Kim J-S. A physiologically based approach to prescribing exercise following a sport-related concussion. Sports Med 2019; 49: 683–706. DOI: 10.1007/s40279-019-01065-1
28. Horstman J, Placanica J, Dinan E, Palmatier A, Lojacono M, Saviola K, et al. Cervical stabilization exercises in people with neck pain following concussion: a case series. Orthop Phys Ther Pract 2017; 29: 143–146.
29. Kennedy E, Quinn D, Tumilty S, Chapple CM. Clinical characteristics and outcomes of treatment of the cervical spine in patients with persistent post-concussion symptoms: a retrospective analysis. Musculoskelet Sci Pract 2017; 29: 91–98. DOI: 10.1016/j.msksp.2017.03.002
30. Dobney DM, Miller MB, Tufts E. Non-pharmacological rehabilitation interventions for concussion in children: a scoping review. Disabil Rehabil 2019; 41: 727–739. DOI: 10.1080/09638288.2017.1400595
31. Quatman-Yates C, Cupp A, Gunsch C, Haley T, Vaculik S, Kujawa D. Physical rehabilitation interventions for post-mTBI symptoms lasting greater than 2 weeks: Systematic review. Phys Ther 2016; 96: 1753–1763. DOI: 10.2522/ptj.20150557
32. Makdissi M, Schneider KJ, Feddermann-Demont N, Guskiewicz KM, Hinds S, Leddy JJ, et al. Approach to investigation and treatment of persistent symptoms following sport-related concussion: a systematic review. Br J Sports Med 2017; 51: 958–968. DOI: 10.1136/bjsports-2016-097470
33. Schneider KJ, Iverson GL, Emery CA, McCrory P, Herring SA, Meeuwisse WH. The effects of rest and treatment following sport-related concussion: a systematic review of the literature. Br J Sports Med 2013; 47: 304–307. DOI: 10.1136/bjsports-2013-092190
34. Mistry DA, Rainer TH. Concussion assessment in the emergency department: a preliminary study for a quality improvement project. BMJ Open Sport Exerc Med 2018; 4: e000445. DOI: 10.1136/bmjsem-2018-000445
35. Cronin P, Ryan F, Coughlan M. Undertaking a literature review: a step-by-step approach. Br J Nurs 2008; 17: 38–43. DOI: 10.12968/bjon.2008.17.1.28059
36. Arksey H, O'Malley L. Scoping studies: towards a methodological framework. Int J Soc Res Methodol 2005; 8: 19–32. DOI: 10.1080/1364557032000119616
37. Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, et al. PRISMA extension for scoping reviews

(PRISMA-ScR): checklist and explanation. Ann Intern Med 2018; 169: 467–473. DOI: 10.7326/M18-0850
38. Levac D, Colquhoun H, O'Brien KK. Scoping studies: advancing the methodology. Implement Sci 2010; 5: 1–9. DOI: 10.1186/1748-5908-5-69
39. Maribo T, Ibsen C, Thuesen J, Nielsen CV, Johansen CV, Vind AB. Whitebook on rehabilitation. Aarhus, Denmark: Rehabiliteringsforum Danmark; 2022.
40. Wade DT. What is rehabilitation? An empirical investigation leading to an evidence-based description. Clin Rehabil 2020; 34: 571–583. DOI: 10.1177/0269215520905112
41. Wade D. Rehabilitation – a new approach. Overview and part one: the problems. Clin Rehabil 2015; 29: 1041–1050. DOI: 10.1177/0269215515601174
42. Hove K, Roe M, Brown C, Mock E, Schulz L, Jones J. Implementation of biofeedback interventions for the treatment of adults with post-concussion syndrome. Am J Occup Ther 2020; 74: 7411505208p1-7411505208p1. DOI: 10.5014/ajot.2020.74S1-PO7725
43. Benson N, Davis J, Allen M, Fong A, Loewen J. Application of high intensity interval training in treating post concussion syndrome. Arch Phys Med Rehabil 2021; 102: e79. DOI: 10.1016/j.apmr.2021.07.707
44. Alsalaheen BA, Whitney SL, Mucha A, Morris LO, Furman JM, Sparto PJ. Exercise prescription patterns in patients treated with vestibular rehabilitation after concussion. Physiother Res Int J Res Clin Phys Ther 2013; 18: 100–108. DOI: 10.1002/pri.1532
45. Christensen T, Kyvsgaard M, Vindelev P, Joergensen S, larsson bodil wiberg. An active approach in the treatment of post-concussion syndrome – evidence-based practice in a collective case study. Preprints. Authorea 2020. DOI: 10.22541/au.159413746.69457665
46. Thastum MM, Rask CU, Næss-Schmidt ET, Tuborgh A, Jensen JS, Svendsen SW, et al. Novel interdisciplinary intervention, GAIN, vs. enhanced usual care to reduce high levels of post-concussion symptoms in adolescents and young adults 2–6 months post-injury: a randomised trial. EClinicalMedicine 2019; 17: 100214. DOI: 10.1016/j.eclinm.2019.11.007
47. Vikane E, Hellstrøm T, Røe C, Bautz-Holter E, Aßmus J, Skouen JS. Multidisciplinary outpatient treatment in patients with mild traumatic brain injury: a randomised controlled intervention study. Brain Inj 2017; 31: 475–484. DOI: 10.1080/02699052.2017.1280852
48. Hurtado JE, Heusel-Gillig L, Risk BB, Trofimova A, Abidi SA, Allen JW, et al. Technology-enhanced visual desensitization home exercise program for post-concussive visually induced dizziness: a case series. Physiother Theory Pract 2022; 38: 985–994. DOI: 10.1080/09593985.2020.1815259
49. Kennedy E, Chapple C, Quinn D, Tumilty S. Can the neck contribute to persistent symptoms post concussion? Long-term follow up from a prospective descriptive case series. J Man Manip Ther 2021; 29: 318–331. DOI: 10.1080/10669817.2021.1920276
50. Ontario Neurotrauma Foundation. Clinical practice guideline for the rehabilitation of adults with moderate to severe TBI. 2016 [cited 2022 Apr 05]. Available from: https://kite-uhn.com/brain-injury/en
51. van der Naalt J, Timmerman ME, de Koning ME, van der Horn HJ, Scheenen ME, Jacobs B, et al. Early predictors of outcome after mild traumatic brain injury (UPFRONT): an observational cohort study. Lancet Neurol 2017; 16: 532–540. DOI: 10.1016/S1474-4422(17)30117-5
52. Dobney DM, Grilli L, Kocilowicz H, Beaulieu C, Straub M, Friedman D, et al. Is there an optimal time to initiate an active rehabilitation protocol for concussion management in children? A case series. J Head Trauma Rehabil 2018; 33: E11–E17. DOI: 10.1097/HTR.0000000000000339
53. Leddy JJ, Haider MN, Ellis MJ, Mannix R, Darling SR, Freitas MS, et al. Early subthreshold aerobic exercise for sport-related concussion: a randomized clinical trial. JAMA Pediatr 2019; 173: 319–325. DOI: 10.1001/jamapediatrics.2018.4397
54. Moore M, Winkelman A, Kwong S, Segal SP, Manley GT, Shumway M. The emergency department social work intervention for mild traumatic brain injury (SWIFT-Acute): a pilot study. Brain Inj 2014; 28: 448–455. DOI: 10.3109/02699052.2014.890746.
55. Kontos AP, Collins MW, Holland CL, Reeves VL, Edelman K, Benso S, et al. Preliminary evidence for improvement in symptoms, cognitive, vestibular, and oculomotor outcomes following targeted intervention with chronic mTBI patients. Mil Med 2018; 183: 333–338. DOI: 10.1093/milmed/usx172
56. Rowe BH, Eliyahu L, Lowes J, Gaudet LA, Beach J, Mrazik M, et al. A prospective evaluation of the influence of an electronic clinical practice guidelines on concussion patients' future activities and outcomes. J Emerg Med 2018; 54: 774–784. DOI: 10.1016/j.jemermed.2018.02.013
57. Bergman K, Louis S. Discharge instructions for concussion: are we meeting the patient needs? J Trauma Nurs 2016; 23: 327–333. DOI: 10.1097/JTN.0000000000000242
58. Lane AD, Berkman MR, Verbunker D, Shekell T, Bouska M, Barnett L, et al. Retrospective chart analysis of concussion discharge instructions in the emergency department. J Emerg Med 2017; 52: 690–698. DOI: 10.1016/j.jemermed.2016.12.017
59. Finn C. An occupation-based approach to management of concussion: Guidelines for practice. Open J Occup Ther 2019; 7. DOI: 10.15453/2168-6408.1550
60. Chen J, Kouts J, Rippee MA, Lauer S, Smith D, McDonald T, et al. Developing a comprehensive, interdisciplinary concussion program. Health Serv Insights 2020; 13: 117863292093867. DOI: 10.1177/1178632920938674
61. Canadian Association of Occupational Therapists. Occupational therapy and concussion management. n.d. [cited 2022 Apr 05]. Available from: https://caot.ca/document/6994/CAOTBC_OTConcussionManagment_Final.pdf
62. Tricco AC, Lillie E, Zarin W, O'Brien K, Colquhoun H, Kastner M, et al. A scoping review on the conduct and reporting of scoping reviews. BMC Med Res Methodol 2016; 16: 15. DOI: 10.1186/s12874-016-0116-4
63. Kleffelgaard I, Soberg HL, Bruusgaard KA, Tamber AL, Langhammer B. Vestibular rehabilitation after traumatic brain injury: case series. Phys Ther 2016; 96: 839–849. DOI: 10.2522/ptj.20150095