Physical rehabilitation interventions in children with acquired brain injury: a scoping review

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ABBREVIATIONS

ABI	Acquired brain injury
FITT	Frequency, intensity, time, and type
ICF-CY	International Classification of Functioning, Disability and Health: Children and Youth
nTBI	Non-traumatic brain injury
TBI	Traumatic brain injury

AIM To synthesize the evidence about the characteristics (frequency, intensity, time, type) and effects of physical rehabilitation interventions on functional recovery and performance in daily functioning in children and young people with acquired brain injury (ABI), including traumatic brain injuries (TBI) and non-TBI, during the subacute rehabilitation phase.
METHOD Using scoping review methodology, a systematic literature search was performed using four databases. Articles were screened by title and abstract and data from eligible studies were extracted for synthesis.
RESULTS Nine of 3009 studies were included. The results demonstrated a variety of intervention characteristics: frequency varied between 1 and 7 days per week; time of intervention varied between 25 minutes and 6 hours a day; intervention types were specified in seven studies; and none of the included studies reported details of intensity of intervention. All studies reported positive results on the International Classification of Functioning, Disability and Health: Children and Youth (ICF-CY) levels of body function and activities after the intervention period, with study designs of included studies being cohort studies without concurrent controls (*n*=7) or case reports (*n*=2).
INTERPRETATION Inconsistency in results hampers generalizability to guide clinical practice. Physical interventions during subacute rehabilitation have potential to improve functional recovery with intervention characteristics as an important factor influencing its effectiveness. Future well-designed studies are indicated to gain knowledge and optimize rehabilitation practice in paediatric ABI and high-quality research including outcomes across all ICF-CY domains is needed.

Acquired brain injury (ABI) in children and young people is defined as brain insults acquired after the first life-year and includes both traumatic brain injuries (TBIs) and non-traumatic brain injuries (nTBIs) such as stroke, brain tumours, cerebral anoxia, and encephalitis.[1–3] ABI is the most common cause of death or disability among children and young people,[4] with an incidence of 180 to 825 per 100 000 for TBI[2,5] and 82.5 per 100 000 for nTBI.[6] Children and young people with ABI are a heterogeneous group with respect to types of injury, severity, age at the time of injury, levels of impairments, functional status, and consequences for participation in life situations.[7,8] The level of functioning in childhood can be classified according to the International Classification of Functioning, Disability and Health: Children and Youth (ICF-CY)[9] and encompasses body functions and structures, activities, and participation. In addition, both personal and environmental factors need to be considered as they play a key role in a child's daily functioning. Using the terminology of the ICF-CY, severe ABIs are associated with impairments of physical, cognitive, and social–emotional function resulting in daily activity limitations, participation restrictions, and reduced overall quality of life and well-being.[8,10]

Besides spontaneous recovery that may occur in the first months after onset of the brain injury, early rehabilitation services provided by an expert multidisciplinary team are crucial to treat the complex and multidimensional sequelae of ABI.[11–13] The first year after injury is considered critical in the rehabilitation process after a brain injury.[14] After the acute phase, children and young people with moderate to severe ABIs are often admitted to inpatient rehabilitation programmes for intensive therapies to regain their functional abilities with the goal of returning to their home and community.[8,15] During this subacute rehabilitation

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phase, the focus of rehabilitation treatment is directed towards recovery, as well as compensation for sustaining impairments, to regain functional ability and overall health. This recovery process happens while children and young people are in a constant state of development and learning new developmental skills.[16]

Rehabilitation programmes after ABI have great potential to improve functional recovery through experience-dependent neural plasticity.[17,18] Neural plasticity is 'the ability of the nervous system to change its activity in response to intrinsic or extrinsic stimuli by reorganizing its structure, functions, or connections'[19] and is considered to be the mechanism by which the damaged brain relearns by rehabilitation interventions.[20,21] Emerging evidence indicates that dosage of rehabilitation interventions is an important component of the principles of experience-dependent neural plasticity.[17,20] Dosage consists of the factors frequency, intensity, time, and type (FITT) of an intervention[22] and relates both to the ability and speed in the recovery process which, in turn, is associated with the degree of restoration of functional performance.[17,20] The FITT factors are recommended as a useful framework in reporting dosage of physical rehabilitation interventions.[23,24]

In adults, several systematic reviews have explored whether increased intensity of physical rehabilitation intervention improves functional outcomes after stroke.[25–27] Although there are no clear guidelines for best level of practice, the principle that increased intensity of intervention is helpful is widely accepted.[28–30] A recent systematic review in adults with moderate to severe TBI revealed that more intensive physical rehabilitation interventions (at least 20 therapy hours per week) promotes recovery of functional outcome compared with usual care.[31] The authors of the review concluded that more research is needed to determine the gain of early and intensive physical rehabilitation specifically in the younger population because they have greater potential for neural plasticity and functional recovery.

The translation to daily clinical practice in rehabilitation in children and young people with ABI has not yet been described in detail in the paediatric literature. In clinical practice, many questions remain about the content and effects of physical rehabilitation interventions in children and young people with ABI. Therefore, it is warranted to synthesize current knowledge about the effects of physical rehabilitation interventions on functional recovery and daily functioning in children and young people with ABI, as well as to identify gaps in the evidence to guide future research.

The objective of this scoping review is to map and synthesize the current evidence about the characteristics (according to the FITT factors) and effects (classified according to the ICF-CY) of physical rehabilitation interventions on functional recovery and performance in daily functioning in children and young people with ABI during the subacute rehabilitation phase.

What this paper adds

- A large variety of intervention characteristics, study populations, and outcomes was found.
- The use of frequency, intensity, time, and type factors is recommended for reporting the dose–response relationship.
- Intervention characteristics are important aspects to optimize physical rehabilitation.

METHOD

To address the objective of this scoping review, a multidisciplinary research team was formed with expertise in the fields of paediatric physical therapy (CGM, OV, RHHE), neuropsychology (IRR), and paediatric rehabilitation medicine (JWG). Before the review, a protocol was written using the Joanna Briggs Institute methodology for scoping reviews[32] and the methodological framework described by Arksey and O'Malley.[33] The following five steps were identified, discussed, and agreed by the research team: (1) identify the research question; (2) identify relevant studies; (3) study selection; (4) charting the data; and (5) collating, summarizing, and reporting the findings.

Identify the research question

This review aimed to answer the following research question: what is known about the characteristics (according to the FITT factors) and effects of physical rehabilitation interventions on functional recovery and performance in daily functioning in children and young people with ABI (TBI and nTBI) during the subacute rehabilitation phase?

Identify relevant studies

A search of the PROSPERO International Prospective Register of Systematic Reviews revealed no ongoing reviews in this topic area. A three-step search strategy was used.[32] An initial search of PubMed and Embase was conducted to identify relevant articles and keywords according to the population, concept, and context framework. Terms were deliberately kept broad and random checks of results were performed during the process of search strategy development to ensure all relevant literature was identified. No initial limits on publication date or language were applied. The checklist of the evidence-based guideline for Peer Review of Electronic Search Strategies (PRESS)[34] was applied to the final search strategy. Subsequently the search strategy was adapted to the individual database requirements for Embase, Cochrane Library, and PsychInfo. Finally, the snowball method was used to check whether the search strategy was complete. The literature search in PubMed, Embase, Cochrane Library, and PsychInfo was performed on 24th September 2020. Reference lists were screened for potentially relevant articles. The full electronic search strategy is detailed in Appendix S1 (online supporting information).

Study selection

The criteria for inclusion of studies in this review have been developed on the basis of the population, concept, and context framework.[32] Studies were included if: (1) study participants were children (1–12y) and young people (12–18y) diagnosed with ABI (moderate or severe TBI or nTBI); (2) the study focused on physical rehabilitation interventions, defined as all types of intervention with a primary focus on the physical aspect of functioning (e.g. physiotherapy interventions, occupational therapy interventions, sports therapies, robot-assisted therapies, physical activities during the day); and (3) the study focused on the subacute rehabilitation phase, defined as the phase directly after the acute or immediate treatment phase in hospital, when a patient is admitted to an inpatient or outpatient rehabilitation programme.

Studies were excluded if: (1) they were animal studies; (2) the study population had 50% or more adults (>18y); (3) at least 50% of the study population had a brain injury related to birth injuries or congenital disorders; (4) the time since injury was at least 1 year in more than 50% of the population; (5) the children and young people had concussion/contusion-related problems (mild TBI) or prolonged disorders of consciousness (interfering with their ability to actively participate in the physical rehabilitation programme); and (6) the studies were protocols, conference abstracts, commentaries, editorials, and concept papers. All identified records were collected and duplicates were removed. A pilot screening of the inclusion criteria was performed (CGM and IRR) on 25 random samples with sufficient agreement of 88%, and inclusion criteria were refined after group discussion.[32] Next, all identified articles were independently screened on title/abstract by two reviewers (CGM and IRR). Disagreements were resolved by consensus between the two reviewers. If disagreements persisted, the decision was made by a third reviewer (OV). If an article met the inclusion criteria on title and abstract, full texts were obtained and examined independently (CGM and IRR) for inclusion in the scoping review. At the end of the screening process an overall percentage of agreement was calculated.

Charting the data

Included articles were read in full by two reviewers (CGM and OV) with their background in paediatric physical therapy, exercise physiology, and paediatric rehabilitation. A data extraction template was tested to become familiar with the results; after group discussion it was refined to ensure all relevant results were extracted (Appendix S2, online supporting information). The two reviewers recorded details using a data extraction template of the study design, research questions and key findings, setting, population characteristics, study duration, intervention characteristics, outcome measurements, and mediating and moderating factors. Gross motor levels of included populations were reported, where applicable, according to the Gross Motor Function Classification System (GMFCS)[35] to increase comparability between included studies. Outcome measurements on the activity domain of the ICF-CY were categorized to the constructs of capacity (what a child can do in a standardized environment), capability (what a child can do in the daily environment), or performance (what a child actually does in the daily environment).[36] No formal assessment of methodological quality of the included studies was performed, because the aim of the scoping review was to map and synthesize the current evidence, regardless of quality.

Collating, summarizing, and reporting the findings

From the extracted data, key themes related to the population, concept, and context framework were discussed by all authors, summarized in tabular form, and are presented in a narrative, descriptive section that describes how results relate to the review questions.

RESULTS

Study selection and characteristics

The search identified 4073 articles. After removing duplicates and trials, 3009 articles were screened by title and abstract and 2921 articles were excluded (96% agreement). The remaining 88 articles were screened by full text and 79 articles were excluded because they did not meet the criteria. A total of nine articles were finally included and reviewed. The flow diagram of study selection is presented in Figure S1 (online supporting information).

A summary of the included studies is presented in Table 1. The articles were published between 2002 and 2017. The studies were conducted in inpatient[37–43] and outpatient rehabilitation settings[44,45] in Italy,[37,38,41] the USA,[39,42–45] and the Republic of Korea.[40] Seven articles were cohort studies without concurrent controls[37–43] and two articles were case reports.[44,45] A summary of funding sources of included studies is presented in Table S1 (online supporting information).

Participants' characteristics

Three studies included TBI exclusively,[41,42,44] five studies included a combination of TBI and nTBI (brain tumour and cerebrovascular diseases),[37–40,43] and one study included a male child with nTBI (arteriovenous malformation).[45] Age at the start of the intervention varied between 1 year and 19 years 10 months. Time since injury varied between 0 and 24 months (n=8 studies). Motor level of participants was reported in seven studies, of which five reported motor level equal to GMFCS levels[35] I to IV[37,38,43–45] (classification based on case description in two studies)[43,45] and two reported initiation of hand function (study focus on upper limb function).[40,41] The study populations of included studies were relatively small ($n \leq 12$) with the exception of two descriptive retrospective studies,[39,42] where details of the intervention were reported to a limited extent.

Intervention characteristics

Intervention characteristics were extracted according to the FITT factors.[23,46] Frequency varied from once a week to 7 days a week. None of the included studies reported

Table 1: Characteristics of included studies

Study	Participants				Intervention					Outcomes		
	n, diagnosis	Age (y:mo)	TSI (mo)	Motor level	Study duration (wks)	Frequency	Intensity	Time	Type	Body function	Activity	Participation
Biffi et al.[38]	*n*=4 3 TBI, 1 brain tumour *n*=10 typically developing controls	13:8±3:8 (range 9:2–18:11) Controls: 26:8±1:8	1.9–15.3	Equal to GMFCS level I	3	2/wk (5× total)	Not reported	30min	Exercises to improve walking and balance ability in engaging virtual reality environments on the GRAIL	Gait parameters ↑[a]	Not reported	Not reported
Biffi et al.[37]	*n*=12 8 TBI, 4 stroke	12:1±3:10	5.4±6.8	Equal to GMFCS levels I/II	3	4/wk (10× total)	Not reported	30min	Exercises to improve walking and balance ability in engaging virtual reality environments on the GRAIL	Gillette Gait Index ↑[b] Gait parameters ↑[a]	GMFM ↑[b] 6MWT ↑[b] FAQ ↑[b]	Not reported
Chen et al.[39]	*n*=811 114 nTBI, 336 TBI	nTBI: 8:7±5:2 (1–19:10) TBI: 11:1±5:4 (1–18:4)	nTBI: 3.2±13.8 (0–132.6) IQR: 0–38d TBI: 1.2±6.9 (0–92.7) IQR: 6–19d	Not reported	nTBI: 4.3±3.1 (0.7–17.6) TBI: 4.7±3.7 (0.7–20.7)	nTBI: 290±201 units of 15min in total TBI: 352±289 units of 15min in total	Not reported	TBI: 160min/d	OT, PT, SLT, and psychology combined	Not reported	WeeFIM ↑[b]	Not reported
Chong et al.[40]	*n*=8 TBI, brain tumour, CVD	13±2:10 (range 9–18)	Not reported	Residual hand function, able to move hand without assistance	4–6	2/wk (total 8.33±2.24)	Not reported	25min	Playing simple patterns on keyboard based on repeated movements of fingers	MIDI-test (velocity) ↑[a] GPST ↑	BBT ↑ JTHFT ↑	Not reported
Cimoulin et al.[41]	*n*=10 severe TBI *n*=10 typically developing controls	8:10–12:11 Controls: 7:4–13:7	8.4 (range 2.4–16.8)	MACS 2/3	10	7/wk (3× in rehab, 4× at home)	Not reported	3h/d	CIMT	3D kinematics ↑[a] AROM ↑[b]	GMFM ↑[b] Besta grip/ manipulation ↑[b] QUEST A/B ↑[b]	Not reported

Table 1. Continued

	Participants				Intervention					Outcomes		
Study	n, diagnosis	Age (y:mo)	TSI (mo)	Motor level	Study duration (wks)	Frequency	Intensity	Time	Type	Body function	Activity	Participation
Dumas et al.[42]	n=80 TBI	10:4±5	0.88±1.5	Not reported	9.1±12.5	159.5 units of 15min therapeutic exercise per inpatient stay (±167.6)	Not reported	PT mean 46.5min/day	PT: therapeutic exercises most frequently reported	Not reported	PEDI ↑	Not reported
Erdman and Pierce[44]	n=1 TBI	13	6	Equal to GMFCS level III	13	1/wk + daily home exercise	Not reported	45min sessions Home programme 5–10min/d	Horse riding Home exercise programme (sit–stand control, gait speed, and endurance)	Strength ↑ PGWBI	PBS ↑ Dynamic Gait Index ↑ GMFM-D/E ↑ Functional mobility (ambulation, transfers, distance, gait speed) ↑	Not reported
Karman et al.[43]	n=7 3 TBI, 2 CVA, 2 AVM	7:8–17:10	1–24 (n=6 <6)	Equal to GMFCS levels I–II: 3; III: 1; IV: 3[c]	2	Daily	Not reported	6h weekday + waking hours in weekend	CIMT	AAUTq ↑	AAUTa ↑ Changes in activities of daily living ↑	Not reported
Tappan[45]	n=1 AVM	16	7.5	Equal to GMFCS levels II/III[c]	11	3/wk	Not reported	3h/session of which 50min PT	PT: attention training and compensatory techniques in context of gait and balance training OT and SLT Cognitive rehab for attention impairments	Manual muscle strength test lower extremity ↑	Tandem gait and one-legged stance ↑	Not reported

[a]Partly significant. [b]Significant. [c]Classification based on case description in original article. 6MWT, 6-Minute Walk Test; AAUTa, Actual Amount of Use Test – amount of use; AAUTq, Actual Amount of Use Test – quality of movement; AROM, active range of motion; AVM, arteriovenous malformation; BBT, Box and Blocks Test; CIMT, constraint-induced movement therapy; CVD, cerebrovascular diseases; FAQ, Gillette Functional Assessment Questionnaire; GMFCS, Gross Motor Function Classification System; GMFM, Gross Motor Function Measure; GPST, Grip and Pinch Strength Test; GRAIL, Gait Real-time Analysis Interactive Lab; JTHFT, Jebson–Taylor Hand Function Test; LoE, level of evidence; MACS, Manual Ability Classification System; MIDI-test, Musical Instrument Digital Interface-test; nTBI, non-traumatic brain injury; OT, occupational therapy; PBS, Pediatric Balance Scale; PEDI, Pediatric Evaluation of Disability Inventory; PGWBI, Psychological General Well Being Index; PT, physiotherapy; PWBI, Psychological Well-Being Index; QUEST, Quality of Upper Extremities Skills Test; SLT, speech and language therapy; TBI, traumatic brain injury; TSI, time since injury; WeeFIM, paediatric version of the Functional Independence Measure.

details of intensity of intervention. Time of intervention varied between 25 minutes and 6 hours a day. Intervention types were specified in seven studies and included exercises on a treadmill with virtual reality environment,[37,38] gait and balance training,[45] keyboard playing,[40] constraint-induced movement therapy,[41,43] and hippotherapy.[44] Two studies described type of intervention in a global way (physiotherapy, occupational therapy, speech–language therapy).[39,42] The total study duration varied between 1 and 20 weeks.

Effects of interventions

All included studies reported positive effects on physical outcome parameters at the level of body function (seven of nine studies) and activities (eight of nine studies) according to the ICF-CY.[9] Of a total of 23 unique outcome measures used in included studies, 14 were uniquely related to the level of body function, eight were uniquely related to the level of activities, and one was related to both levels of body function and activities. Of the measurements on the activity level, five were related to capacity, two were related to capability and performance respectively. One study reported outcomes on the psychosocial domain.[44] None of the studies reported outcome measurements at the ICF-CY participation level. No negative results or adverse events were reported.

DISCUSSION

This scoping review summarizes the current evidence about the characteristics and effects of physical rehabilitation interventions in children and young people with ABI during the subacute rehabilitation phase. We discuss key themes related to the interventions, study populations, and outcomes, and identify knowledge gaps and directions for future research.

Intervention characteristics

Since dosage of rehabilitation interventions is an important component of the principles of experience-dependent neural plasticity,[17,20] we reflect on the FITT factors of the reported interventions in this review. First, it is striking that none of the included studies reported detailed information on the intensity of the intervention. Defining intensity, and reporting its details, is a well-known problem in rehabilitation research.[24,28] Intensity is often equated with duration of therapy intervention.[39,42] However, duration is not a valid proxy for the intensity of an intervention and therefore cannot be used to establish a dose–response relationship.[24] It is challenging to formulate one currency to define how much effort the body requires for a variety of physical rehabilitation interventions. Therefore, intensity should be defined by a scale that fits the type of intervention and the intended goal.[24]

Second, we found a lot of variation in frequency (1–7d per week) and time (25–360min per day). Owing to inconsistency in data in a relatively small number of included studies, it remains unclear how much practice is optimal during the subacute rehabilitation in children and young people with ABI. However, as physical rehabilitation is a process of motor learning and relearning, motor learning principles could guide the dosing of practice.[47] Motor learning principles state that practice should be meaningful and that greater amounts of practice increase learning, which corresponds to the principles of experience-dependent neural plasticity.[47–49] As these principles are supported with evidence in animals and adult populations, we argue that similar principles should be applied to children and young people with ABI. Moreover, on the basis of evidence in other populations, including cerebral palsy, it is important to maximize the opportunities for practice by extending therapeutic activities into meaningful activities during the day in combination with an adequate amount of rest and sleep (24h approach).[50–52] This should also be translated in opportunities for active involvement of parents/caregivers and others involved in the daily care of the child.[53] Empowering parents to actively engage in the intervention process offers many opportunities to extend therapeutic activities during daily meaningful activities.[54,55]

Third, regarding types of intervention, we found interventions targeting both gross motor and fine motor functioning. It is not surprising that types of intervention vary for children and young people with ABI as they depend on the needs of the child and family, influenced by the stages of recovery as well as by healthcare resources.[16,56] Biffi et al.[37,38] studied the effects of treadmill training with virtual reality in physical rehabilitation in children and young people using multisensory stimulation. They hypothesized that increased engagement would involve reward-related dopaminergic systems in the brain that, in turn, facilitate learning through long-term potentiation of neural connections.[57,58] Two of the included studies reported constraint-induced movement therapy as the intervention.[41,43] Following the principles of experience-dependent neural plasticity, the literature on constraint-induced movement therapy focusses on the optimal dose–effect relationship, in particular the intensity of practice. While the debate is ongoing, the dosage variables of constraint-induced movement therapy reported in the literature could be used as a starting point for other types of intervention.

In summary, from our review we identified functional training and virtual reality-based therapies as potential interventions for children and young people with ABI, but further research is needed to investigate their effectiveness in relation to the FITT factors.

Study population

The study populations of most included studies were relatively small ($n \leq 12$). Limited sample sizes are a common problem in intervention studies involving children and young people with ABI.[59] The two studies with larger study populations were of a descriptive nature and details of the intervention were limited.[39,42] In addition, the heterogeneity of the population with ABI is large.[52] We observed a substantial variation in aetiology, age, and time since injury in our data extraction. Chen et al.[39] reported the largest functional gains in children with TBI compared with those with nTBI. This corresponds with available evidence showing that aetiology is associated with gross motor recovery after ABI, with greater recovery potential after TBI than other forms of ABI.[7,52] Furthermore, the included studies showed a large variation in ages at the start of the intervention (range 1–19y). None of the studies reported a rationale for including children of a specific age. Chen et al.[39] reported that age seems to be an important moderating variable that influences the amount of functional gain during rehabilitation. Available evidence indicates that ABI at younger ages (<7y) is associated with worse outcome than injury sustained later in development.[10,60–63] It is assumed that older children have already learned most functional skills before their injuries and therefore take advantage of the available motor programmes in the brain. The timing of rehabilitation interventions of the included studies varied between the first day after diagnosis to more than 12 months after diagnosis. As experience-dependent neural plasticity is seen in the acute stages after injury, early rehabilitation is recommended to maximize recovery.[12,13]

In summary, the small sample size in combination with the heterogeneity of the studied populations with ABI hamper the interpretation and generalizability of the findings to inform clinical practice.

Outcome and interpretation

The included studies showed a wide variety of reported outcome measurements, with most outcomes reporting on the ICF-CY domains of body function and activities, and none on the participation domain. Of the 23 unique measurements, only the paediatric version of the Functional Independence Measure measures the construct of performance in daily activities, which is viewed as a meaningful rehabilitation outcome of the subacute inpatient rehabilitation phase.[64] The choice for intermediate outcomes at the body function and capacity/capability levels may be explained by the subacute rehabilitation phase and the inpatient rehabilitation setting in which the interventions focus on recovery in basic (motor) functions. Moreover, during their stay on the ward of a rehabilitation setting, children and young people have limited opportunities to experience everyday activities in their home environment; therefore participation in their usual context (home, school, and community) may be a longer-term goal rather than an anticipated outcome of the intervention. Nevertheless, it remains unclear whether applied interventions have significantly led to improved performance in daily life and participation. All domains of the ICF-CY (body function, activities, participation, and contextual factors) are intrinsically linked and it is often assumed that rehabilitation interventions ultimately have an impact on the participation level.[65] For future evaluation studies we stress the importance of selecting appropriate outcome measures across all domains of the ICF-CY of human functioning, and not to restrict them to body function and capacity/capability levels of activities.

While all included studies reported positive results on physical outcome measurements, we cannot draw any firm conclusions about the benefits of physical rehabilitation interventions in children and young people with ABI. A degree of recovery of function is typically seen in the subacute rehabilitation phase, but the extent to which physical rehabilitation interventions result in faster recovery or better functional outcome compared with usual care is disputed and remains unclear for children and young people with ABI.[52] Despite supporting evidence for intensive rehabilitation interventions in adults with ABI,[26,27,31] the application of higher-intensity rehabilitation interventions over lower-intensity ones in children and young people has not been investigated. Available research on the mechanisms of recovery of the injured brain affirm the potential for intensive physical rehabilitation programmes, specifically for children and young people.[20,31,66,67] This corresponds to the growing evidence from children and young people with a brain tumour.[68–70] Most of these children receive chemoradiation during the first year(s) after diagnosis, and therefore rehabilitation may be delayed. Nevertheless, studies have shown that higher intensities of physical exercise training after chemotherapy and/or radiation therapy have beneficial effects on brain structure and physical functioning in survivors of paediatric brain tumour,[68–70] which could be applied to other populations with ABI.[70] Together with the current evidence in the adult population, there is a base on which to build towards optimizing physical rehabilitation in children and young people with ABI.

Future research

The limited body of current evidence highlights the need for more high-quality research in children and young people with ABI. Future research with group designs should consider the moderating variable of age, which should lead to division into specific age-groups. Given the potential for intensive physical rehabilitation in the subacute rehabilitation phase, future studies should determine the optimal intervention characteristics to improve functional recovery and performance in daily functioning in children and young people with ABI. We recommend the use of FITT factors as a base for reporting dose–response relationships as well as the use of the Template for Intervention Description and Replication (TIDier) to improve the reporting and replicability of interventions.[71] This will force clinicians and researchers to be clear about the active ingredients of physical rehabilitation interventions and the underlying theoretical understanding.[72,73] We emphasize the need to adequately determine the intensity of the broad scope of physical rehabilitation interventions. We propose that the choice of outcome measurements should be an appropriate selection across all ICF-CY domains of human functioning, including performance levels of activities and participation. Since the use of randomized controlled studies is challenging in children and young people with ABI,[42,74] single-participant and case–control research designs may be considered, as they offer control through systematic measurement and implementation, often under conditions that reflect the complexity and practicality of everyday practice.[75] In addition, grounded theory-driven research such as that of Armitage et al.[76] could provide insights into how principles of experience-dependent neural plasticity and related physical rehabilitation intervention characteristics should be shaped for clinical practice in the rehabilitation of children and young people with ABI. This offers opportunities for involvement of patients and the public in future research projects for children and young people with ABI.[77]

CONCLUSION

This review has demonstrated that the current body of evidence about the characteristics and effects of physical rehabilitation interventions in children and young people during the subacute rehabilitation phase is limited. The large variety of the intervention characteristics according to the FITT factors, as well as small sample sizes, limited studies, and heterogeneity of studied populations with ABI, hamper interpretation and generalizability of the findings.

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SUPPORTING INFORMATION

The following additional material may be found online:

Figure S1: Flow diagram of search.

Table S1: Funding sources of included studies

Appendix S1: Search strategy.

Appendix S2: Data extraction form.

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