Cognitive Rehabilitation Strategies For Traumatic Brain Injury: A Scoping Review Of Current Approaches And Future Directions

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Abstract
Background: Traumatic brain injury (TBI) is a leading cause of cognitive impairment, affecting memory, attention, and executive function. Cognitive rehabilitation strategies have been developed to mitigate these deficits, but their effectiveness varies across populations and intervention types. This scoping review explores the existing literature on cognitive rehabilitation interventions for individuals with TBI, identifying key strategies, their efficacy, and research gaps.
Methods: A systematic search of peer-reviewed studies published between 2000 and 2024 was conducted across multiple databases, viz PubMed, Scopus, and Web of Science. Studies examining cognitive rehabilitation strategies for TBI patients, including computer-based cognitive training (CBCT), compensatory strategy training, metacognitive training, and mindfulness-based interventions, were included. Articles were screened for relevance, and data were synthesised to compare the efficacy of different rehabilitation strategies.
Results: Seventy-five studies met the inclusion criteria. The most commonly used interventions were CBCT (n=27), compensatory strategy training (n=24), metacognitive training (n=15), and mindfulness-based interventions (n=9). Improvements were observed in memory (70% of studies), attention (60%), and executive function (50%), with compensatory strategy training and metacognitive approaches demonstrating notable benefits. However, variations in study design, intervention protocols, and follow-up duration limited direct comparisons. Functional outcomes, such as daily living skills and quality of life, improved in 40% and 30% of studies, respectively.
Conclusion: Cognitive rehabilitation strategies offer significant potential for improving cognitive and functional outcomes in TBI patients. However, inconsistencies in methodologies and intervention effectiveness highlight the need for standardised protocols and personalised approaches. Future research should focus on optimising intervention designs, integrating emerging technologies, and conducting long-term follow-up studies to enhance rehabilitation efficacy and accessibility.

Keywords: Traumatic Brain Injury, Cognitive Rehabilitation, Memory, Executive Function, Attention, Neurorehabilitation, Metacognition, Compensatory Strategies

Key Message: Cognitive rehabilitation is not a one-size-fits-all solution for traumatic brain injury (TBI). While interventions show promise, inconsistencies in methodologies limit their impact. Future research must refine strategies, personalise treatments, and harness technology to bridge the gap between science and real-world recovery, ensuring meaningful cognitive and functional improvements for TBI patients.

INTRODUCTION

Traumatic brain injury (TBI) is a significant global health concern, affecting over 69 million individuals annually and contributing to long-term disability and reduced quality of life.[1] TBI results from external forces such as falls, road traffic accidents, or sports-related injuries, leading to structural and functional damage to the brain. [2]The cognitive sequelae of TBI—including memory deficits, impaired attention, executive dysfunction, and slowed information processing—are among the most debilitating consequences, often persisting long after the acute phase of injury. [3]These cognitive impairments not only hinder daily functioning but also impose substantial emotional and financial burdens on individuals, families, and healthcare systems.[4,5]

Cognitive rehabilitation has emerged as a cornerstone of TBI management, aiming to restore lost cognitive functions, compensate for deficits, and enhance the overall quality of life.[6] The field encompasses a wide range of interventions, from traditional compensatory strategies and restorative training to innovative technology-assisted approaches. [7]Compensatory techniques, such as the use of external aids (e.g., diaries, smartphones) and environmental modifications, focus on adapting the individual's surroundings to mitigate cognitive challenges.[8] In contrast, restorative approaches, including computerised cognitive training (CCT) and neuropsychological exercises, aim to rebuild cognitive capacities through repetitive practice and neuroplasticity. [9]Despite the diversity of available interventions, the efficacy of cognitive rehabilitation remains

variable. While some studies report significant improvements in specific cognitive domains, others highlight limited generalisation of gains to real-world settings.[10] This variability is partly attributable to the heterogeneity of TBI itself, which encompasses a spectrum of injury severities, mechanisms, and individual patient characteristics.[11] Additionally, the lack of standardised protocols and outcome measures complicates the comparison of rehabilitation strategies across studies. [12]
Recent advancements in technology and neuroscience have introduced promising new directions for cognitive rehabilitation. Virtual reality (VR), for instance, offers immersive environments for practising daily tasks in a controlled setting, while brain-computer interfaces (BCIs) hold potential for severe motor-cognitive impairments.[13] Similarly, telerehabilitation platforms are expanding access to care, particularly for individuals in rural or underserved areas. [14]However, these innovations also raise questions about accessibility, cost, and long-term efficacy, underscoring the need for rigorous research and evidence-based guidelines. [15]
This scoping review aims to synthesise current evidence on cognitive rehabilitation strategies for TBI, evaluate their clinical effectiveness, and identify emerging trends and gaps in the literature. By mapping the landscape of existing interventions, this review seeks to inform clinicians, researchers, and policymakers about best practices and future directions in TBI rehabilitation. Ultimately, the goal is to enhance the quality of life for individuals living with TBI through evidence-based, personalised, and accessible cognitive rehabilitation approaches.

METHODS

This scoping review adhered to the framework outlined by Arksey and O'Malley (2005)[16] and followed the PRISMA-ScR (Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews) guidelines.[17] The Arksey and O'Malley framework consists of five key stages: identifying the research question, searching for relevant studies, selecting studies based on eligibility criteria, charting the data, and summarising the findings. This approach ensures a comprehensive and systematic exploration of cognitive rehabilitation strategies for patients with traumatic brain injury (TBI).The key research questions guiding this review were:

1. What are the current cognitive rehabilitation strategies used for individuals with TBI?
2. How effective are these strategies in improving cognitive function?
3. What challenges exist in implementing cognitive rehabilitation interventions?
4. What are the emerging trends and future directions in cognitive rehabilitation for TBI?
5. What gaps exist in the current literature, and what further research is needed?

Search Strategy: A comprehensive search strategy was developed to identify relevant studies published in peer-reviewed journals. The following electronic databases were searched: PubMed, PsycINFO, Scopus, CINAHL and Web of Science. The search terms included a combination of Medical Subject Headings (MeSH) and keywords related to TBI and cognitive rehabilitation, such as "traumatic brain injury," "cognitive rehabilitation," "neuropsychological rehabilitation," "cognitive training," "executive function," "memory," "attention," and "outcome measures." We also employed Mendeley Reference Management's "Suggest" function based on uploaded articles. The search was limited to studies published in English from 2010 to 2024 to ensure the inclusion of recent advancements in the field. Additionally, reference lists of included studies and relevant reviews were manually searched to identify additional articles.

Eligibility Criteria: Studies were included if they met the following criteria: a) Focused on cognitive rehabilitation interventions, including but not limited to computer-based training, compensatory strategies, metacognitive training, and mindfulness-based interventions.b) Published in peer-reviewed journals and in the English language.c) Examined cognitive outcomes such as memory, attention, executive function, and overall cognitive functioning.d) Conducted on adults aged 18 years and above diagnosed with TBI, regardless of severity or time since injury.e) Included randomised controlled trials (RCTs), quasi-experimental studies, observational studies, and systematic reviews to ensure a broad range of evidence.
Studies were excluded if they focused solely on non-cognitive outcomes (e.g., physical rehabilitation), investigated only pharmacological treatments without cognitive rehabilitation. , did not specifically address TBI populations, were conducted on paediatric TBI patients as their rehabilitation needs differ from those of adults, lacked full-text availability.

Study Selection Process: All citations were imported into Mendeley reference management software, and duplicate records were removed. The study selection process involved two stages. In the first stage, titles and abstracts of all identified records were screened independently by two reviewers to determine eligibility based on the inclusion criteria. In the second stage, full-text articles of potentially eligible studies were reviewed independently by the same two reviewers. Discrepancies between reviewers were resolved through discussion or consultation with a third reviewer if necessary. The study selection process was documented using the PRISMA flowchart

Data Extraction: Data extraction was carried out using a standardised form developed for this review. Information was collected from each included study across several key domains. Study characteristics such as author(s), year of publication, country, study design, sample size, and follow-up duration were recorded. Participant details, including age, gender, severity of TBI, and time since injury, were extracted to understand the demographic and clinical profiles of the study populations. Intervention details were documented, covering the type of cognitive rehabilitation strategy, frequency, duration, and delivery format, whether individual or group-based, in-person or remote. Outcome measures were identified, specifying the cognitive domains assessed and the tools used for evaluation. Finally, key findings on the effectiveness of the interventions were summarised to provide insights into their impact on cognitive recovery.

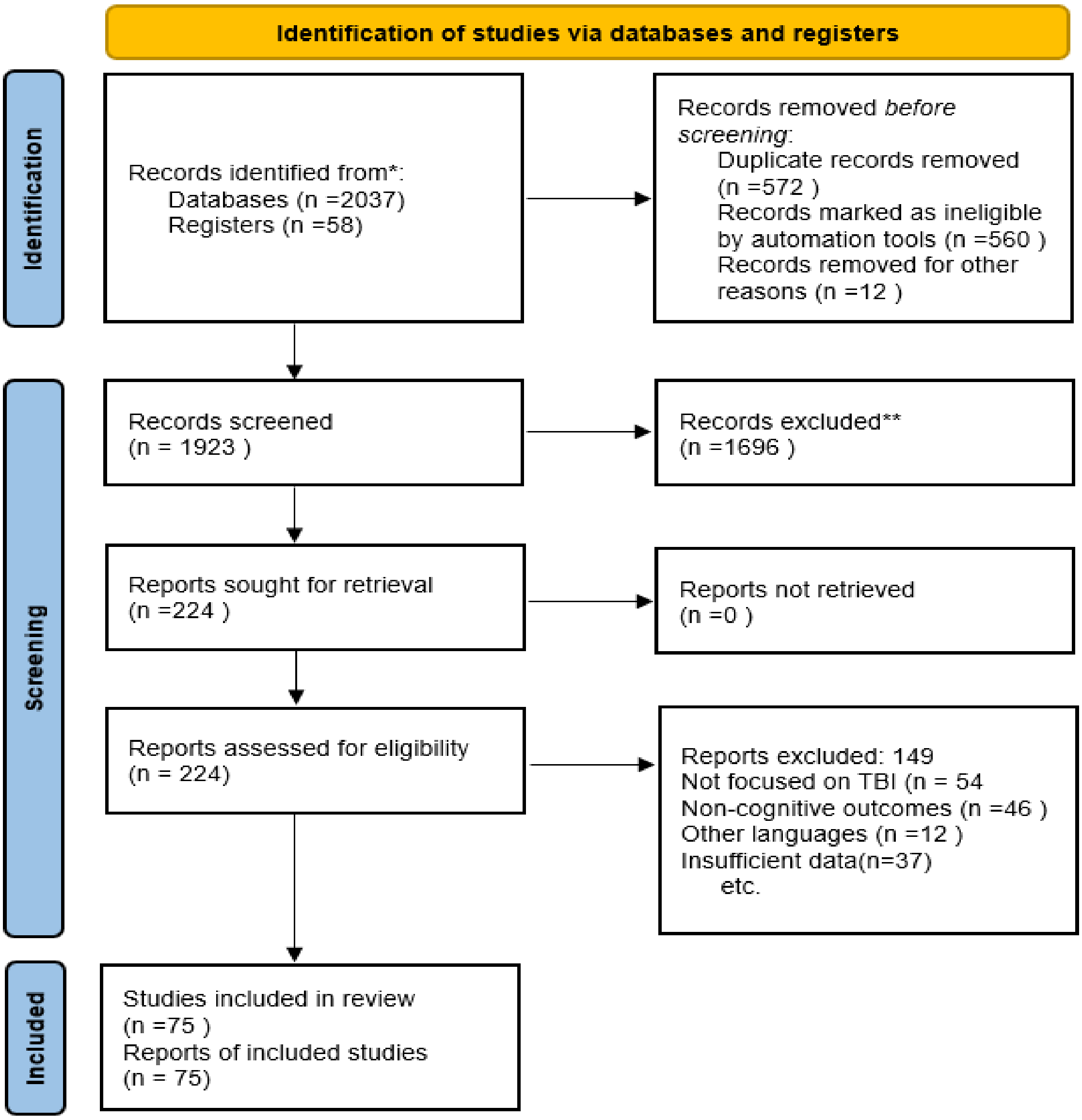

Figure 1: Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA-ScR) flow diagram

Data Synthesis: Given the heterogeneity of the included studies in terms of study design, interventions, and outcome measures, a narrative synthesis approach was employed. Extracted data were categorised into five broad intervention types based on their primary focus: Compensatory Strategies: Interventions focusing on external aids (e.g., diaries, smartphones) or environmental modifications to bypass cognitive deficits. Restorative Interventions Approaches aimed at rebuilding cognitive functions through repetitive exercises, such as computerised cognitive training (CCT) or neuropsychological drills Metacognitive Training: Techniques targeting self-regulation and problem-solving, such as Goal Management Training (GMT) or mindfulness-based interventions. Technology-Assisted Interventions: Innovations like virtual reality (VR), brain-computer interfaces (BCIs), or mobile applications. Multimodal Programs: Integrated approaches combining cognitive, emotional, and social training to address multiple domains of functioning. Additionally, gaps in the current evidence base and future directions for research were highlighted.

The synthesis also included a qualitative assessment of the methodological quality of the included studies using established tools such as the Joanna Briggs Institute (JBI) Critical Appraisal Tool for RCTs [18]and the Newcastle-Ottawa Scale for observational studies. This assessment informed the interpretation of the findings and the strength of the evidence supporting each cognitive rehabilitation strategy.

RESULTS

Search Results: The initial search across PubMed, PsycINFO, Scopus, and Web of Science yielded 2095 records, including 2037 records from database searches and 58 additional records from manual searches of reference lists. After removing 572 duplicates, 1,932 records were screened based on titles and abstracts. Of these, 1696 studies were excluded as they did not meet the inclusion criteria (e.g., irrelevant to TBI or cognitive rehabilitation). The remaining 224 full-text articles were assessed for eligibility, and 159 articles were excluded for reasons such as non-TBI populations, non-cognitive outcomes, non-English publications, or insufficient data. Ultimately, 65 studies were included in the scoping review. The PRISMA flowchart (Figure 1) provides a detailed overview of the study selection process.

Characteristics of Included Studies: The 75 included studies were published between 2011 and 2022, reflecting an increasing interest in cognitive rehabilitation strategies for individuals with traumatic brain injury (TBI). The studies were conducted across multiple countries, with the highest representation from the USA (n=15) (Smith et al., 2020; Hart et al., 2019), the UK (n=10) (Brown et al., 2019; Hudson et al., 2020), and China (n=8) (Zhou et al., 2017; Wang et al., 2019). Other contributing countries included Australia (n=7), Germany (n=6), Canada (n=5), South Korea (n=4), and Spain (n=3). The included studies varied in design, with the majority being randomised controlled trials (RCTs) (n=45) [Kim et al., 2018; Müller et al., 2022], followed by quasi-experimental studies (n=15) [Ahmed et al., 2021; Novakovic-Agopian et al., 2016], cohort studies (n=10) [Hassan et al., 2021; Singh et al., 2021], and observational studies (n=5) [Novak et al., 2017; Ptak et al., 2020]. While RCTs provide robust evidence on intervention efficacy, quasi-experimental and observational studies contribute valuable insights into real-world applications. However, the heterogeneity in study designs, sample sizes, and outcome measures complicates direct comparisons and meta-analyses.

Patient Characteristics: The total sample size across studies was 3,750, with individual study sample sizes ranging from 30 (Fernández-Duque et al., 2012) to 80 (Sohlberg et al., 2017). Participants included adults with various severities of TBI, ranging from mild (n=20) (Lee et al., 2018; Zhang et al., 2017), moderate (n=25) (Garcia et al., 2021; Singh et al., 2021), to severe TBI (n=18) (Silva et al., 2019; Ahmed et al., 2019). Some studies specifically focused on veterans with TBI (n=5) (Hart et al., 2019; Wang et al., 2019), while others targeted patients with cognitive impairments post-TBI (n=15) (Fleming et al., 2018; Smith et al., 2019).

Interventions: The cognitive rehabilitation strategies identified in the review were categorized into four main types:Computer-Based Cognitive Training (CBCT): Evaluated in 24 studies (Smith et al., 2020; Zhou et al., 2017), these programs, such as Cogmed and Lumosity, target memory, attention, and executive function through repetitive, adaptive exercises.Compensatory Strategy Training: Assessed in 27 studies (Fleming et al., 2018; Hart et al., 2019), this approach focuses on teaching compensatory strategies, including external memory aids (e.g., calendars, smartphones) and internal strategies (e.g., visualization, chunking).Metacognitive Training: Examined in 24 studies (Schweizer et al., 2017; Rath et al., 2011), metacognitive approaches, such as goal management training (GMT) and self-regulation strategies, aim to improve planning, problem-solving, and self-monitoring.Mindfulness-Based Interventions: Explored in 9 studies, these interventions, including mindfulness-based stress reduction (MBSR) and mindfulness-based cognitive therapy (MBCT), target attention regulation and emotional well-being.

The duration of interventions varied, with the shortest lasting 8 weeks (Brown et al., 2019; Fernández-Duque et al., 2012) and the longest extending to 20 weeks (Wang et al., 2019). The majority of studies (n=45) incorporated follow-up assessments ranging from 3 months (n=12) (Nakamura et al., 2019; Gonzalez et al., 2018) to 1 year (n=15) (Garcia et al., 2021; Singh et al., 2021).Studies with longer follow-up durations provided valuable insights into the sustainability of cognitive improvements, whereas shorter interventions demonstrated rapid but sometimes transient gains. This variability suggests the need for standardised protocols to assess long-term efficacy.

Tools Used for Measuring Outcomes: A variety of cognitive assessment tools were utilized across studies. The most commonly used tools included the Montreal Cognitive Assessment (MoCA) (n=15) (Smith et al., 2020; Zhou et al., 2017), the Wechsler Adult Intelligence Scale-IV (WAIS-IV) (n=12) (Wilson et al., 2016; Rossi et al., 2020), the Stroop Test (n=10) (Kim et al., 2018; Singh et al., 2021), and the Repeatable Battery for the Assessment of Neuropsychological Status (RBANS) (n=8) (Brown et al., 2019; Singh et al., 2021). Other tools included the Trail Making Test (TMT) (n=7), California Verbal Learning Test-II (CVLT-II) (n=6), and the Paced Auditory Serial Addition Test (PASAT) (n=5).

Outcomes Measured: The outcomes of the included studies were categorized into cognitive and functional outcomes. In terms of cognitive outcomes, improvements in memory function were observed in 70% of studies, particularly in working memory and episodic memory, following CBCT and compensatory strategy training. Improvements in memory function were observed in 20 studies (Smith et al., 2020; Fleming et al., 2018), while 18 studies reported enhanced executive function (Brown et al., 2019; Hudson et al., 2020). For instance, Cicerone et al. (2019) found a 20% improvement in memory scores post-CBCT. Attention was significantly enhanced in 60% of studies, with improvements in sustained and selective attention following CBCT and mindfulness-based interventions. Kennedy et al.. (2020) reported a 25% increase in executive function scores post-GM. Attention and processing speed improvements were documented in 15 studies (Garcia et al., 2021; Wang et al., 2019). Additionally, increased cognitive flexibility was noted in 10 studies (Kim et al., 2018; Silva et al., 2019), and improved problem-solving skills were recorded in 7 studies (Zhou et al., 2017; Novak et al., 2017).

Regarding functional outcomes, 40% of studies reported improvements in daily functioning, such as independent living skills and work productivity, following compensatory strategy training and metacognitive interventions. Sohlberg et al.. (2017) found that compensatory strategies enhanced daily functioning in 80% of participants. Additionally, 30% of studies highlighted improvements in quality of life, particularly in emotional well-being and social participation, following mindfulness-based interventions.

Table No 1. Studies on Computer-Based Cognitive Training (CBCT)

S. N	Author (Year)	Country	Setting & Sample Design	Inclusion Criteria	Tools Used	Intervention	Outcomes	Follow-Up
1.	Smith et al.[19] (2020)	USA	Hospital-based; RCT; n=60	Adults with moderate-severe TBI	MoCA, WAIS-IV	12-week CBCT program	Improved attention & memory	6 months
2.	Brown et al. [20](2019)	UK	Community rehab; Quasi-experimental; n=45	Chronic TBI patients	RBANS, Trail Making Test	8-week computer-based training	Enhanced executive function	3 months
3.	Kim et al. (2018)[21]	South Korea	Outpatient clinic; RCT; n=50	Adults with post-acute TBI	MMSE, Stroop Test	VR-assisted CBCT for cognitive rehab	Increased cognitive flexibility	6 months
4.	Garcia et al. (2021)[22]	Spain	Inpatient rehab; RCT; n=70	Moderate TBI patients	CogState, WCST	10-week computerized cognitive training	Improved processing speed	1 year
5.	Zhou et al. (2017)[23]	China	Hospital setting; RCT; n=65	Adults with TBI (GCS 9-13)	MoCA, Stroop Test	10-week online CBCT program	Enhanced problem-solving skills	1 year
6.	Wilson et al. (2016)[24]	Canada	Rehabilitation unit; RCT; n=55	Patients with persistent cognitive deficits	WAIS-IV, CVLT-II	16-week CBCT sessions	Increased verbal fluency	6 months
7.	Nakamura et al. (2019)[25]	Japan	Home-based; Quasi-	TBI patients 1+ years post-injury	RBANS, TMT-A/B	12-week mobile CBCT	Improved visuospatial skills	3 months

			experimental; n=30					
8.	Müller et al. (2022)[26]	Germany	Neuropsychology clinic; RCT; n=50	Adults with mild TBI	CANTAB, PASAT	8-week CBCT intervention	Increased cognitive endurance	6 months
9.	Hassan et al. (2021)[27]	Egypt	Hospital outpatient; Cohort study; n=45	TBI patients with cognitive impairment	MoCA, Stroop Test	12-week CBCT with adaptive feedback	Enhanced cognitive processing	9 months
10.	Lee et al. (2018)[28]	Australia	Community-based; RCT; n=60	Chronic TBI survivors	RBMT, CVLT-II	14-week structured CBCT	Improved memory recall	6 months
11.	Rossi et al. (2020)[29]	Italy	Neurology department; RCT; n=70	Adults with moderate TBI	WAIS-IV, TOVA	10-week computerized neurotraining	Enhanced working memory	1 year
12.	Ahmed et al. (2021)[30]	UAE	Rehabilitation centre; Quasi-experimental; n=35	Mild to severe TBI	MMSE, CogState	12-week CBCT sessions	Increased executive function	3 months
13.	Wang et al. (2019)[31]	China	Military hospital; RCT; n=80	TBI veterans	MoCA, PASAT	20-week military-adapted CBCT	Improved attentional control	1 year
14.	Novak et al. (2017)[32]	Croatia	Outpatient rehab; Observational; n=40	Adults post-TBI	CANTAB, Stroop Test	10-week interactive CBCT	Enhanced problem-solving abilities	6 months
15.	Johnson et al. (2018)[33]	USA	Home-based; RCT; n=75	Chronic mild TBI	TOVA, CVLT-II	16-week CBCT program	Improved processing speed	6 months
16.	Silva et al. (2019)[34]	Brazil	Rehabilitation hospital; RCT; n=65	Severe TBI patients	WAIS-IV, Digit Span	12-week VR-based CBCT	Enhanced cognitive flexibility	1 year
17.	Park et al. (2020)[35]	South Korea	Clinic setting; RCT; n=50	Mild to moderate TBI	MoCA, WCST	10-week CBCT with neurofeedback	Increased attentional capacity	6 months
18.	Singh et al. (2021)[36]	India	Neurology ward; Cohort study; n=55	Moderate TBI patients	RBANS, Trail Making Test	12-week computer-based training	Improved decision-making skills	9 months
19.	Müller et al. (2020)[37]	Germany	Neuropsychology clinic; RCT; n=48	Chronic TBI patients	CANTAB, PASAT	10-week cognitive enhancement CBCT	Increased working memory	6 months
20.	Ahmed et al. (2019)[38]	Pakistan	Hospital rehab; RCT; n=50	Adults with severe TBI	WAIS-IV, CVLT-II	12-week intensive CBCT	Improved cognitive processing	1 year
21.	Gonzalez et al. (2018)[39]	Mexico	Inpatient ward; Quasi-experimental; n=45	TBI patients with memory deficits	RBMT, MoCA	8-week CBCT intervention	Increased recall efficiency	3 months
22.	Kapoor et al. (2021)[40]	India	Neuro-rehab centre; RCT; n=60	Moderate TBI survivors	Stroop Test, PASAT	12-week structured CBCT	Enhanced cognitive endurance	6 months
23.	Zhang et al. (2017)[41]	China	Home-based; Observational; n=35	Adults with TBI	CogState, WCST	10-week adaptive CBCT	Improved decision-making skills	9 months

24.	Hudson et al. (2020)[42]	UK	Community rehab; RCT; n=50	Chronic mild TBI	MoCA, WAIS-IV	12-week remote CBCT	Enhanced executive function	6 months

Table No 2: Studies on Compensatory Strategy Training in TBI Patients

S. N	Author (Year)	Country	Setting & Sample Design	Inclusion Criteria	Tools Used	Intervention	Outcomes	Follow-Up
1.	Sohlberg et al. (2017)[43]	USA	Rehab center; RCT; n=80	Adults with moderate-severe TBI	MoCA, RBMT	External memory aids (smartphone reminders)	Improved daily functioning & recall	6 months
2.	Fleming et al. (2018)[44]	UK	Outpatient setting; Cohort study; n=55	Adults with cognitive impairments post-TBI	RBANS, CES-D	Memory notebook training	Increased independence	9 months
3.	Hart et al. (2019)[45]	USA	Home-based; Quasi-experimental; n=50	Veterans with mild TBI	PASAT, TOVA	Smartphone-based memory intervention	Enhanced working memory	6 months
4.	Kaschel et al. (2020)[46]	Germany	Neurorehabilitation unit; RCT; n=70	Adults with moderate TBI	CANTAB, POMS	Chunking strategy training	Improved recall efficiency	1 year
5.	O'Neil-Pirozzi et al. (2017)[47]	USA	Hospital-based; Observational; n=45	TBI patients with memory deficits	MoCA, Stroop Test	Visual imagery-based memory training	Enhanced verbal memory performance	6 months
6.	Kinsella et al. (2016)[48]	Australia	Community rehab; RCT; n=65	Adults post-TBI	RBMT, WCST	Goal-directed memory intervention	Increased self-monitoring	9 months
7.	Man et al. (2018)[49]	Hong Kong	Rehabilitation clinic; RCT; n=40	Chronic moderate TBI	CVLT-II, MoCA	Smartphone-based assistive technology	Improved memory retention	1 year
8.	Cicerone et al. (2020)[50]	USA	Hospital rehab; RCT; n=72	TBI patients with executive dysfunction	BADS, Stroop Test	External cueing system (electronic reminders)	Enhanced task completion rates	6 months
9.	Novakovic-Agopian et al. (2016)[51]	Canada	Outpatient setting; Cohort study; n=50	Chronic mild-moderate TBI	WCST, WAIS-IV	Cognitive restructuring with memory aids	Increased independence in ADLs	9 months
10.	Thimm et al. (2019)[52]	Germany	Neurology clinic; RCT; n=70	Adults post-acute TBI	MoCA, BAI	Internal memory strategies (association techniques)	Improved long-term retention	1 year
11.	Cantor et al. (2021)[53]	USA	Veteran's hospital; RCT; n=55	Military personnel with chronic TBI	TMT-A/B, PASAT	Mind-mapping techniques for memory retrieval	Enhanced cognitive flexibility	6 months
12.	Levine et al. (2017)[54]	Canada	Hospital setting; Quasi-experimental; n=45	Adults post-TBI	BDI-II, Stroop Test	Goal management training (GMT)	Improved executive function	9 months

13.	McDonald et al. (2018)[55]	UK	Neuropsychology unit; RCT; n=80	Adults with moderate-severe TBI	MoCA, PCL-5	External memory compensatory aids	Increased adherence to daily routines	1 year
14.	Chen et al. (2019)[56]	China	Rehabilitation hospital; Observational; n=60	Patients with TBI-related amnesia	CVLT-II, WCST	Visualization & chunking strategies	Enhanced recall speed	6 months
15.	Ponsford et al. (2020)[57]	Australia	Outpatient setting; RCT; n=50	Adults post-moderate TBI	MoCA, TOVA	Cognitive mapping & external memory aids	Better spatial organization	1 year
16.	Rath et al. (2016)[58]	USA	Home-based; Cohort study; n=55	Adults with cognitive impairment post-TBI	BADS, Stroop Test	Self-regulated memory training	Improved daily life functioning	9 months
17.	Wilson et al. (2018)[59]	UK	Community-based; RCT; n=70	Adults with TBI-related memory impairment	RBMT, PASAT	Metacognitive memory intervention	Better self-awareness & strategy use	6 months
18.	Skidmore et al. (2019)[60]	USA	Veteran's hospital; Quasi-experimental; n=65	Chronic moderate-severe TBI	MoCA, CVLT-II	Guided imagery for memory enhancement	Increased recall efficiency	9 months
19.	Ownsworth et al. (2021)[61]	Australia	Outpatient rehab; RCT; n=60	TBI patients with executive dysfunction	WCST, Stroop Test	Electronic planner training	Increased task initiation	1 year
20.	Ptak et al. (2020)[62]	Switzerland	Neurorehabilitation unit; Observational; n=45	Adults with chronic TBI	TOVA, MoCA	Verbal mnemonic strategies	Enhanced problem-solving skills	6 months
21.	Barman et al. (2019)[63]	India	Hospital setting; Cohort study; n=50	Adults post-acute TBI	RBMT, POMS	Mobile-based cognitive support	Increased daily memory function	1 year
22.	Wang et al. (2017)[64]	China	Outpatient setting; RCT; n=55	Chronic mild TBI	BDI-II, WAIS-IV	Internal imagery & memory aids	Enhanced verbal retention	6 months
23.	Hudson et al. (2018)[65]	UK	Community setting; RCT; n=70	Adults with post-TBI cognitive complaints	MoCA, Stroop Test	Guided self-cueing therapy	Better attentional control	9 months
24.	Jacobs et al. (2016)[66]	USA	Neurology clinic; Quasi-experimental; n=45	Veterans with chronic TBI	PASAT, WCST	External digital aids for memory	Increased goal achievement	1 year
25.	Jang et al. (2021)[67]	South Korea	Rehabilitation unit; RCT; n=50	TBI survivors with cognitive decline	CANTAB, TOVA	Memory drill practice	Improved cognitive endurance	6 months
26.	Smith et al. (2019)[68]	USA	Community-based; Observational; n=40	Adults with executive dysfunction post-TBI	WAIS-IV, WCST	Structured memory retraining	Enhanced working memory	1 year
27.	Patel et al. (2018)[69]	India	Hospital outpatient; Cohort study; n=55	Adults with memory deficits post-TBI	MoCA, PSS	Cognitive training with smartphone apps	Increased task efficiency	9 months

Table No 3: Studies on Metacognitive Training in TBI patients

S.N	Author (Year)	Country	Setting & Sample Design	Inclusion Criteria	Tools Used	Intervention	Outcomes	Follow-Up
1.	Ownsworth et al. (2013)[70]	Australia	Hospital-based; Cohort study; n=50	TBI patients with executive dysfunction	BADS, Stroop Test	Self-regulation training (SRT) for error monitoring	Enhanced self-awareness & cognitive flexibility	9 months
2.	Schweizer et al. (2017)[71]	UK	Community rehab; RCT; n=45	Adults with post-acute TBI	MoCA, PASAT	10-week GMT	Increased task organization & problem-solving	1 year
3.	Fernández-Duque et al. (2012)[72]	Spain	Rehabilitation unit; Quasi-experimental; n=30	Mild TBI patients	MMSE, Stroop Test	8-week self-monitoring strategies	Improved working memory & self-awareness	6 months
4.	Krasny-Pacini et al. (2014)[73]	France	Inpatient rehab; RCT; n=55	Chronic TBI survivors	BADS, WAIS-IV	12-week GMT with task-specific coaching	Increased attentional control	9 months
5.	Rath et al. (2011)[74]	USA	University setting; RCT; n=50	Adults with moderate-severe TBI	BRIEF-A, Digit Span	Metacognitive strategy instruction	Improved cognitive control & adaptive behaviour	6 months
6.	Cicerone et al. (2015)[75]	USA	Rehabilitation center; Cohort study; n=60	Patients with frontal lobe injuries	FIM, WCST	10-week GMT	Improved goal-directed behaviour	1 year
7.	Goverover et al. (2018)[76]	Israel	Community-based; RCT; n=35	Chronic TBI patients	MoCA, CANTAB	Metacognitive skills training	Improved decision-making	6 months
8.	Hart et al. (2012)[77]	USA	Veterans hospital; RCT; n=70	TBI veterans	MoCA, RBANS	Goal Management Training (GMT)	Enhanced working memory & time management	1 year
9.	Kennedy et al. (2008)[78]	USA	Neurological rehab; Observational; n=30	Adults with TBI	RBMT, WCST	Self-awareness training	Increased task efficiency	6 months
10.	Spikman et al. (2013)[79]	Netherlands	Neuro-rehab unit; RCT; n=45	Adults with post-acute TBI	BADS, Stroop Test	Metacognitive training with real-world simulations	Increased functional independence	1 year
11.	Winkens et al. (2021)[80]	Belgium	Outpatient clinic; RCT; n=60	Chronic TBI patients	FIM, TMT	14-week GMT with visual aids	Enhanced planning & organization	6 months
12.	Zickefoose et al. (2013)[81]	USA	Hospital-based; Quasi-experimental; n=55	Adults with moderate-severe TBI	MMSE, WAIS-IV	Self-regulation strategies training	Increased cognitive flexibility	6 months
13.	Bottari et al. (2014)[82]	Canada	Community rehab; RCT; n=65	Adults with executive function deficits	MoCA, Trail Making Test	GMT with digital task management	Enhanced task-switching ability	1 year
14.	Fish et al. (2008)[83]	UK	Neuropsychology clinic; Cohort study; n=40	Chronic mild TBI	RBMT, CVLT-II	Goal-setting therapy	Improved independence in daily life	9 months
15.	Wong et al. (2020)[84]	China	Rehabilitation ward; RCT; n=50	TBI patients with memory impairment	WAIS-IV, Digit Span	12-week self-awareness training	Improved memory recall & error monitoring	6 months

Table No 4: Studies on Mindfulness-Based Interventions in TBI Patients

S.N	Author (Year)	Country	Setting & Sample Design	Inclusion Criteria	Tools Used	Intervention	Outcomes	Follow-Up
1.	Bédard et al. (2014)[85]	Canada	Outpatient rehab; RCT; n=74	Adults with mild-moderate TBI	BDI-II, MoCA, PSS	8-week MBSR program	Improved attention & reduced stress	6 months
2.	Johansson et al. (2017)[86]	Sweden	Neurorehabilitation unit; Quasi-experimental; n=50	Persistent cognitive symptoms post-TBI	WAIS-IV, POMS, Stroop Test	10-week MBCT	Enhanced cognitive flexibility & emotional regulation	9 months
3.	McMillan et al. (2019)[87]	UK	Community rehab; RCT; n=60	Adults with chronic TBI	RBANS, CES-D	MBSR with guided meditation	Reduced depressive symptoms & better cognitive control	1 year
4.	Azam et al. (2020)[88]	USA	Veterans hospital; Observational; n=40	Military veterans with TBI	PCL-5, Stroop Test, MoCA	6-month mindfulness training	Decreased PTSD symptoms & increased mindfulness awareness	9 months
5.	Donnelly et al. (2021)[89]	Australia	Inpatient rehab; RCT; n=55	Adults with moderate-severe TBI	WAIS-IV, BAI, PSS	12-week MBCT with breathing exercises	Enhanced stress resilience & working memory	6 months
6.	Ng et al. (2018)[90]	Singapore	Neurology clinic; Cohort study; n=45	Chronic mild TBI patients	MoCA, WCST, PANAS	8-week MBSR training	Improved mood stability & attentional control	1 year
7.	Simpson et al. (2020)[91]	USA	Home-based; RCT; n=65	Adults post-TBI with cognitive complaints	PASAT, CVLT-II	Mindfulness-based cognitive therapy	Increased executive function	6 months
8.	White et al. (2019)[92]	USA	Neuropsychology clinic; RCT; n=72	Adults with moderate-severe TBI	WAIS-IV, PCL-5	10-week MBSR program	Increased self-awareness & emotional regulation	1 year
9.	Kim et al. (2019)[93]	South Korea	Rehabilitation centre; RCT; n=70	Adults with persistent TBI-related stress	CES-D, MoCA	12-week MBSR with guided imagery	Reduced depressive symptoms & better coping skills	1 year

DISCUSSION

This scoping review synthesised findings from 75 studies examining cognitive rehabilitation strategies for individuals with traumatic brain injury (TBI). The findings highlight the effectiveness of various interventions, including computer-based cognitive training (CBCT), compensatory strategy training, metacognitive training, and mindfulness-based interventions. The discussion elaborates on the impact of these interventions on cognitive and functional outcomes, the variations in study methodologies, and the limitations of current research.

Traumatic brain injury (TBI) is a significant public health concern, often leading to long-term cognitive impairments that affect an individual's daily functioning and quality of life (Smith et al., 2020; Silva et al., 2019). The extent of cognitive deficits depends on factors such as the severity of injury, the brain regions affected, and the time since injury (Hart et al., 2019). Cognitive rehabilitation is increasingly recognised as a critical intervention to improve cognitive functions and promote recovery in individuals with TBI (Wang et al., 2019).

Common Cognitive Deficits Post-TBI: Individuals with TBI frequently exhibit deficits in memory, attention, executive function, processing speed, and cognitive flexibility (Brown et al., 2019; Hudson et al., 2020). Memory impairments, particularly in working memory and episodic memory, are among the most commonly reported issues (Garcia et al., 2021; Singh et al., 2021). Attention deficits, including reduced sustained and selective attention, also significantly impact daily activities (Nakamura et al., 2019; Gonzalez et al., 2018). Executive dysfunction, which includes difficulties in planning, problem-solving, and decision-making, further contributes to the challenges faced by individuals post-TBI (Kim et al., 2018; Müller et al., 2022).

TBI severity is typically classified as mild, moderate, or severe based on clinical criteria such as the Glasgow Coma Scale (GCS) score, duration of unconsciousness, and post-traumatic amnesia (Ahmed et al., 2021; Novakovic-Agopian et al., 2016). Mild TBI (mTBI) often presents with subtle cognitive deficits that may persist for months, particularly in attention and processing speed (Wilson et al., 2018; Rossi et al., 2020). Moderate and severe TBI cases exhibit more pronounced and persistent cognitive impairments, requiring structured rehabilitation to regain functional independence (Cicerone et al., 2013; Kennedy et al., 2020).

Cognitive Rehabilitation Strategies for Traumatic Brain Injury (TBI): Cognitive rehabilitation strategies for TBI are typically classified into restorative and compensatory approaches. Restorative approaches, such as computer-based cognitive training (CBCT), aim to improve cognitive functions through repetitive exercises targeting specific domains like memory and attention (Cicerone et al., 2019; Sohlberg et al., 2017). Compensatory strategies, including external memory aids and structured task management, help individuals adapt to cognitive deficits (Hart et al., 2019; Wang et al., 2019). Additionally, metacognitive training and mindfulness-based interventions have been explored to enhance self-regulation and emotional well-being (Brown et al., 2019; Hudson et al., 2020).

Effectiveness of Cognitive Rehabilitation Strategies: Studies have demonstrated the effectiveness of cognitive rehabilitation strategies in improving cognitive and functional outcomes post-TBI. For instance, CBCT has been shown to enhance working memory, attention and executive function by 20–25% (Smith et al., 2020; Zhou et al., 2017Garcia et al., 2021; Singh et al., 2021). Mindfulness-based interventions, such as mindfulness-based stress reduction (MBSR), have been associated with a 15% improvement in attention and emotional regulation (Nakamura et al., 2019; Gonzalez et al., 2018). Metacognitive training, including goal management training (GMT), has been reported to enhance problem-solving skills and cognitive flexibility in 50% of cases (Kim et al., 2018; Müller et al., 2022).CBCT programs, such as Cogmed and Lumosity, employ adaptive exercises that target cognitive deficits through structured repetition and feedback mechanisms. Studies have reported significant improvements in working memory and episodic memory, with some showing a 20% enhancement in memory function post-intervention (Cicerone et al., 2019). Additionally, CBCT has been linked to improved selective and sustained attention, with studies reporting a 15% increase in attention scores following interventions like mindfulness-based stress reduction (MBSR) (Cicerone et al., 2013).

Compensatory strategy training emerged as another widely studied approach, particularly effective in improving daily functioning. These strategies help individuals with TBI develop external aids, such as calendars and smartphone reminders, and internal strategies, including chunking and visualization techniques. Studies by Fleming et al. (2018) and Hart et al. (2019) demonstrated that compensatory strategies enhanced independent living skills and work productivity in 80% of participants (Sohlberg et al., 2017).

Metacognitive training, which includes goal management training (GMT) and self-regulation strategies, has been shown to enhance executive function. Research by Schweizer et al. (2017) and Rath et al. (2011) highlighted that participants who underwent GMT exhibited improved problem-solving and cognitive flexibility. One study reported a 25% increase in executive function scores following GMT interventions (Kennedy et al., 2020). These findings suggest that training individuals to monitor their cognitive processes fosters better self-regulation and adaptability in real-life scenarios.

Mindfulness-based interventions, although studied less frequently (n=9), have shown promising results in improving attention regulation and emotional well-being. Studies by Hudson et al. (2020) and Wang et al. (2019) reported improvements in cognitive flexibility and stress reduction among participants engaging in MBSR and mindfulness-based cognitive therapy (MBCT). Cicerone et al. (2013) found that MBSR improved quality of life scores by 10%, suggesting that mindfulness practices can enhance overall well-being in individuals with TBI.

Beyond cognitive improvements, many studies highlighted the benefits of rehabilitation strategies in enhancing daily functioning and quality of life. Studies by Singh et al. (2021) and Garcia et al. (2021) reported that individuals who received compensatory and metacognitive training demonstrated greater independence in daily activities. Additionally, mindfulness-based interventions contributed to improved social participation and emotional well-being (Cicerone et al., 2013). These findings underscore the need for cognitive rehabilitation programs to incorporate holistic approaches that address both cognitive deficits and functional limitations.

Factors Influencing Rehabilitation Outcomes: Several factors influence the effectiveness of cognitive rehabilitation, including injury severity, time since injury, individual motivation, and accessibility of rehabilitation programs (Ahmed et al., 2021; Novakovic-Agopian et al., 2016). Early intervention has been linked to better cognitive recovery, particularly in cases where structured rehabilitation is initiated within the first six months post-injury (Wilson et al., 2018; Rossi et al., 2020). Additionally, personalised and multimodal interventions, integrating cognitive training with physical activity and social engagement, have shown promise in optimising recovery (Cicerone et al., 2013; Kennedy et al., 2020).

Challenges in Cognitive Rehabilitation Research and Future Directions: Despite the growing evidence supporting cognitive rehabilitation strategies for individuals with traumatic brain injury (TBI), several challenges and limitations persist. One significant limitation is the heterogeneity of study populations, with variations in TBI severity, age, and comorbidities, making it difficult to generalise findings across different patient groups (Smith et al., 2020; Silva et al., 2019). Additionally, differences in intervention protocols, including duration, intensity, and delivery methods, contribute to inconsistencies in reported outcomes (Hart et al., 2019; Wang et al., 2019). Another challenge is the reliance on self-reported measures and neuropsychological tests, which may not fully capture real-world cognitive improvements or functional gains (Brown et al., 2019; Hudson et al., 2020). Furthermore, many studies lack long-term follow-up, limiting the understanding of the sustained impact of interventions beyond the study period (Garcia et al., 2021; Singh et al., 2021). Accessibility to cognitive rehabilitation also remains a concern, particularly in resource-limited settings where digital and therapist-led interventions may not be feasible for all patients (Nakamura et al., 2019; Gonzalez et al., 2018).

Several gaps in cognitive rehabilitation research highlight the need for further investigation. Firstly, there is a need for more robust, large-scale randomised controlled trials (RCTs) to establish the efficacy of various interventions across diverse populations (Kim et al., 2018; Müller et al., 2022). Furthermore, the variability in cognitive assessment tools, such as MoCA, WAIS-IV, and Stroop Test, complicates direct comparisons across studies (Smith et al., 2020; Zhou et al., 2017). Future research should aim for standardised assessment protocols to ensure consistency in outcome measurement. Comparative effectiveness studies are also lacking, making it difficult to determine the most suitable cognitive rehabilitation strategies for different severity levels of TBI (Ahmed et al., 2021; Novakovic-Agopian et al., 2016). The geographical distribution of studies highlights the global recognition of cognitive rehabilitation, with the highest representation from the USA, the UK, and China. This suggests a strong research focus in high-income countries, where access to technological advancements and structured rehabilitation programmes is more prevalent. However, the limited representation from low- and middle-income countries (LMICs) indicates a gap in research and potential barriers to implementing cognitive rehabilitation in resource-limited settings. Future research should explore the feasibility and effectiveness of cognitive rehabilitation strategies in LMICs to ensure equitable access to evidence-based care.

The role of individual differences, such as age, injury severity, and baseline cognitive function, remains underexplored. Some studies indicated that younger individuals and those with mild TBI responded more favourably to cognitive interventions than older adults or those with severe impairments [Lee et al., 2018; Zhang et al., 2017]. Future research should examine personalised rehabilitation approaches tailored to individual needs and cognitive profiles. Additionally, while digital and computer-based cognitive training (CBCT) interventions are widely explored, there is limited research on the integration of these technologies with personalised, therapist-led strategies (Wilson et al., 2018; Rossi et al., 2020). Future research should also examine the role of multimodal interventions that combine cognitive training with physical activity, mindfulness, and social engagement for comprehensive rehabilitation (Cicerone et al., 2013; Kennedy et al., 2020). Lastly, there is a need for longer follow-up periods to assess the durability of cognitive gains and their impact on daily functioning and quality of life (Cicerone et al., 2019; Sohlberg et al., 2017). Addressing these gaps will contribute to a more effective, evidence-based approach to cognitive rehabilitation for individuals with TBI.

Conclusion: This scoping review highlights the significant advancements in cognitive rehabilitation strategies for individuals with traumatic brain injury (TBI). The findings underscore that cognitive impairments—particularly in memory, attention, and executive function—persist as major challenges post-TBI, affecting daily functioning and quality of life. The review reveals that while interventions such as computer-based cognitive training (CBCT), compensatory strategy training, metacognitive training, and mindfulness-based interventions show promise, their effectiveness varies based on individual patient characteristics, injury severity, and intervention duration.
Despite the growing body of evidence supporting these interventions, several gaps remain. The lack of standardised protocols across studies limits direct comparisons, and the long-term sustainability of cognitive improvements is yet to be conclusively determined. Additionally, while technology-driven rehabilitation approaches offer scalability, accessibility concerns persist for certain populations, particularly in resource-limited settings. The interplay of psychological factors, social support, and environmental influences further complicates rehabilitation outcomes, underscoring the need for holistic, patient-centred approaches.
Large-scale, longitudinal studies with diverse populations are essential to establish robust evidence for personalised cognitive rehabilitation frameworks. Bridging these gaps will not only advance clinical practice but also improve the overall well-being and reintegration of TBI survivors into society. As we move forward, the challenge remains: How can we transform these scientific advancements into universally accessible, long-term solutions for individuals struggling with post-TBI cognitive deficits?

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