RESEARCH ARTICLE

Cognitive Rehabilitation Approaches to Traumatic Brain Injury: A Review of Efficacy and Outcomes

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ABSTRACT

Cognitive rehabilitation is a critical component of intervention for many individuals with both short- and long-term impairments associated with traumatic brain injury (TBI). By focusing on major cognitive domains, emotional processing, and behavioral strategies, clinicians use cognitive rehabilitation to improve cognitive related functional outcomes, quality of life, and social relationships. Cognitive rehabilitation is traditionally divided into restorative and compensatory approaches, though increasingly combined approaches within the larger medical, multidisciplinary team are being incorporated and explored. Literature related to cognitive rehabilitation within the TBI population continues to be needed in order to assist clinicians in developing evidence-based intervention protocols and therapy plans. This paper details current approaches to cognitive rehabilitation and provides an updated review of the literature associated with the efficacy of cognitive rehabilitation. Reviewed evidence supports the use of cognitive rehabilitation to improve multiple cognitive domains, including attention, memory, executive function, and metacognitive skills. The long-term outcomes of continued cognitive rehabilitation services post-TBI are not as comprehensively documented as the relative short-term outcomes. The efficacy of cognitive rehabilitation is impacted by patient-specific variables, timing and intensity of treatment. This paper concludes with noted information related to the limitations of the current evidence of cognitive rehabilitation, including study design concerns, and reduced generalizability of the relevant research.

Keywords: cognitive rehabilitation, traumatic brain injury, restorative approach, compensatory strategies, efficacy, evidence-based practice

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Introduction

Traumatic brain injury (TBI) is a leading cause of morbidity and mortality worldwide, affecting millions annually[1]. A TBI can cause damage to the brain as a result of various external and/or internal forces, such as direct impacts causing bleeding or ischemia, rapid acceleration or deceleration changes, or penetration of an object through the skull[2]. Widespread effects on physical and/or cognitive abilities, emotional processing, and/or changes impacting behavior and social relationships may persist in the short- or long-term, depending on the injury type and the severity level[3,4]. Moderate-severe TBI, defined by a Glasgow Coma Scale[5] rating of 12 or less, is associated with numerous cognitive sequelae, which may include difficulty with memory, attention, executive functions, understanding literal or figurative language, using appropriate words to express oneself, analyzing situations, and making appropriate decisions[6-10]. The effects of these difficulties are myriad and may impact daily living, participation in meaningful activities, employment, and education; which in turn may negatively impact quality of life and result in withdrawal from social activities[11,12].

The rehabilitation process aims to maximize functional return to previous life participation endeavors by reducing disability burden that may inhibit these activities[12]. Cognitive rehabilitation is an essential component of the comprehensive rehabilitation needed for many TBI survivors[13]. Participation in rehabilitation is vital for recovery and aims to reduce the cognitive and behavioral effects of TBI while improving functional outcomes, autonomy, and overall quality of life[14,15]. When cognitive rehabilitation programs are used, recovery of cognitive functions occurs at a faster pace, specifically in the early stages[16,17].

Ideally, cognitive rehabilitation is a series of therapeutic activities that are systematic, have functional relevance, and are individualized to the patient, their needs, and their acquired deficits[18,19]. Within the scope of these activities are cognitive abilities that may impact quality of life, return to work, level of independence, and social interactions. Cognitive rehabilitation focuses on maintaining or improving areas of cognition such as memory, visuospatial abilities, attention, executive functioning, social communication, and language[20,21]. Within these cognitive domains, rehabilitation tasks may specifically be related to sustained attention training, errorless learning tasks, pragmatic language skills, meta-cognitive strategies, and problem solving skills[22]. Effective cognitive rehabilitation programs often include repeated stimulation, cognitive strategy instruction, external cognitive aids, and assistive technologies[23]. The greatest improvements in cognitive function have been reported to occur when a combination of these areas are targeted[23-25]. This multifaceted approach to cognitive rehabilitation is most effectively carried out by an interdisciplinary team[22].

An interdisciplinary approach is the integration of people across disciplines and impairment domains working collaboratively for the benefit of the patient. This may also be referred to as multidisciplinary, comprehensive, holistic, neurobehavioral, neurorehabilitative, or integrated approaches. In cognitive rehabilitation, this team typically includes speech-language pathologists (SLPs), physical therapists (PTs), occupational therapists (OTs), recreational or vocational therapists, nurses, physicians, and social workers. The level of interdisciplinary collaboration may depend on the setting and client needs. The Inpatient Rehabilitation Facility (IRF) environment offers a unique opportunity for the provision of high-intensity, high-collaboration care in the early stages of TBI recovery. As has previously been demonstrated in stroke research, there is emerging evidence that early intensive rehabilitation is associated with better neurological outcomes in TBI[26]. Often the collaborative efforts of the SLP, PT, and OT working together to provide cognitive rehabilitation to a client, can address specific cognitive targets related to their discipline's goals, including those relevant to communication, mobility, and self-care, respectively[27-29]. This type of interdisciplinary intervention thereby allows each discipline to focus on metacognitive and emotional regulation skills, and target new or re-learning that may be generalized across activities of daily living and community re-entry[27].

Cognitive Rehabilitation Approaches to TBI

Cognitive rehabilitation has historically been divided into restorative and compensatory approaches and is adapted to an individual's premorbid abilities and current level of impairment[14,30]. *Restorative approaches*, also called *direct approaches*, aim to target neuroplasticity through therapeutic learning tasks and relevant neurological correlates. Restorative approaches aim at directly targeting the cognitive disturbances following a TBI, focusing on reinforcing, strengthening, or re-establishing previously learned patterns of behavior with the goal of recruiting surrounding neural structures to take over damaged functions[12,22,23]. Inherent to this process is neural reorganization and relearning of specific functions that were affected by TBI[31,32]. Indeed, the use of restorative approaches in rehabilitation has been shown to lead to an increase in functional activity of

neural networks in the brain[33]. This approach targets specific cognitive domains and incorporates standardized cognitive tasks that increase in difficulty as rehabilitation (and progress) continues[12]. For example, to target memory, intervention techniques may include activities such as word lists and paragraph listening[34]. Overall, it may be beneficial to pair restorative approaches of treatments targeting specific skills to improve performance/function in a small subset of areas[23]. Unfortunately, evidence continues to emerge that improvements in a singular trained task, such as word lists, are confined to this task and demonstrate poor generalizability to functional outcomes[35,36].

While focusing on a single cognitive domain may result in more standardized treatment and facilitate short-term outcomes related to a specific goal, this narrow treatment approach may result in slower progress and long-term gains; and furthermore, has limited ability to generalize skills to unfamiliar tasks across different settings or environments[37]. Increasingly, cognitive rehabilitation is now addressing multiple cognitive domains during a single treatment session or activity. Choosing a broader cognitive focus during therapy sessions may be most beneficial to develop skills that rely on multiple cognitive aspects to complete a task, such as planning a graduation party for a loved one, or reading social cues while at a dinner party[23]. Research has demonstrated that the incorporation of a variety of cognitive faculties and varying of cognitive tasks and skills increases generalization of these learned behaviors, allows for strategies to be developed beyond the rehabilitation session, and facilitates the massed practice needed for neural connections to form and strengthen[37].

In addition to direct approaches for cognitive rehabilitation in TBI, another traditional and common approach is a *compensatory approach*. Compensatory strategies do not aim to directly target the neural connections, but instead use both internal and external compensatory mechanisms to recompense for an impaired function. For example, acquired memory impairment is often targeted by training compensatory strategies, such as writing down information or using an assistive device[12,22]. In a study, by Storzbach et al[38], examining the use of compensatory cognitive training on veterans with TBIs, many participants reported fewer cognitive difficulties when using compensatory cognitive strategies. Participants in this study also showed significant improvements on neurocognitive tests of attention, learning, and executive functioning, which were all targeted in rehabilitation using compensatory strategies. Using compensatory mechanisms has been demonstrated to lead to more effective and functional ways to process information[39].

Beyond the dichotomy of direct versus compensatory approaches, cognitive rehabilitation has more recently been divided into intervention hierarchies with slightly different methodologies. In their analysis of the efficacy of cognitive rehabilitation after TBI, Julien and colleagues[40] review other approaches with similar, yet distinct characteristics. In addition to *external aid training* (similar to compensatory strategy training), these intervention approaches detail methods similar to restorative training: *cognitive training*, which was defined as repetitive exercises without any explicit mention of metacognitive strategy training; and *integrative cognitive intervention*, which explicitly combined the training of cognitive functions and metacognitive strategies. Finally, the investigators identified the use of *combined approaches*, which incorporated cognitive rehabilitation with another intervention, such as pharmacotherapy or a medical intervention.

Regardless of treatment approach, the overall focus of cognitive rehabilitation should be on the provision of contextualized treatments targeting functional skills. This context should be relevant to the way the individual lives, works, and studies to maximize applicability and carryover of treatment techniques beyond the rehabilitation session to everyday, functional activities[23]. Trained cognitive strategies can facilitate behavioral change over time with consistent use[38]. Treating clinicians should develop cognitive rehabilitation plans that consider the treatment target, potential aims and outcomes associated with the intervention, the evidence/research behind the approach or method that is being considered, and specific details related to frequency and anticipated time length of treatment.

Efficacy of Cognitive Approaches

Multiple review studies have been conducted in the past five years to update evidence-based clinical recommendations for the most effective practices of cognitive rehabilitation [6-11,41,42]. Collectively, these studies provide practicing clinicians with levels of recommendations based on strong evidence from the literature (practice standards), to areas with lesser evidence (practice guidelines and practice options).

The INCOG 2.0 Guidelines for Cognitive Rehabilitation Following Traumatic Brain Injury[6-11,42] provide a series of important updates regarding such clinical practice guidelines, specifically relevant to post-traumatic amnesia, attention/processing speed, executive function, social communication, and memory. These guidelines

provide a summary of Level A, B, and C evidence across the aforementioned cognitive domains and provide strong support for the use of metacognitive strategy training and environmental modification in the cognitive rehabilitation of TBI. This includes (although is not limited to) use of Time Pressure Management Training (TPM) to promote attention and processing speed[43]; use of metacognitive strategy and goal management training in rehabilitation of executive dysfunction[44]; and use of external and environmental aids to mitigate acquired memory impairment[45].

In a scoping review by Julien et al[40], investigators evaluated the efficacy of cognitive rehabilitation using 3 main criteria: outcome measure used, internal validity of the reviewed study, and statistical analysis of the study. Results indicated that multiple cognitive domains including executive function, attention, memory, communication, and social cognition could be improved with cognitive rehabilitation, and that individual sessions using an integrative cognitive approach were used most commonly in their included studies. This study also provides information related to frequency and length of cognitive rehabilitation intervention. Across the included studies, most intervention was distributed with 3 or more sessions per week, over a 1 to 3-month period.

In the study by the ASHA Guideline Development Panel[23], authors found that interventions with the highest levels of efficacy were ones that used repeated stimulation, hierarchical training, cognitive strategy instruction, and/or external cognitive aids as the primary cognitive rehabilitation approach, or a combination of these approaches. Additionally, these authors found that a combination of restorative and compensatory strategies used in rehabilitation were more efficacious and provided better outcomes on both acute and post-acute stages of recovery[23].

Importance of Functional Outcomes

The efficacy of cognitive rehabilitation is often measured through specific cognitive domain improvement; however, it is vitally important to consider functional outcomes when assessing treatment efficacy. This may include functional improvements in various activities of daily living, improved quality of life, improved social relationships or emotional regulation, and/or ability to return to work/school. Currently, rehabilitation of moderate to severe TBI remains biased toward participation in activities of daily living (ADLs); however, cognition has a vital role to play in functional return to instrumental activities of daily living (IADLs), particularly in the generally younger inpatient rehabilitation population[10]. This may directly impact a TBI survivor's ability to live independently, return to work, and engage in the community[22].

According to Königs et al[46], early, intensive neurorehabilitation care promotes better functional recovery in patients with moderate to severe TBI. As such, interventions and rehabilitation focused on specific cognitive measures should be aimed towards working on functional aspects of daily living and improvement of functional outcomes[22]. Importantly, treatment interventions should be highly contextualized to reflect the individual's premorbid pursuits or goals in order to maximize functional outcomes[47]. These improvements can result in self-reported increase in quality of life for individuals with TBI[48].

Continued completion of rehabilitation services post-TBI may affect long-term outcomes as well, though the literature in this area is not as comprehensive compared to short-term outcomes. The chronic impact of TBI on outcome and quality of life have been documented in the research[49,50], though the evidence is sparse for how many people with TBI continue to utilize rehabilitation services in the years following injury, and even less studies are dedicated to continued participation in cognitive rehabilitation. Ruet et al[49], followed up with individuals 8 years post-TBI, noting that persistent impairments continued to interfere with social integration and participation in the community. Future studies may aim to capture if or how cognitive rehabilitation is being utilized in the long-term post injury to target persistent impairments such as these.

Factors Impacting Efficacy and Outcomes

Taken collectively, the literature delineates several factors that likely impact the efficacy of cognitive rehabilitation, and subsequently the outcomes achieved as a result of intervention. These variables may be related to patient-specific factors, timing of service delivery, or intensity of service delivery. Patient-specific variables are typically related to the individual's demographics, personality, and severity and location of TBI. Poorer outcomes were more frequently reported in those who sustained a TBI at an older age[51], which may be a predictor of outcomes as well. Younger individuals with deficits following a TBI tend to have better improvements, lower impairment-based outcomes, and higher likelihood of returning home [52,53]. Higher education levels were reported to result in better outcomes long-term[49]. Participation in social events and in functional activities is similarly influenced by demographics, age and sex, and severity of TBI[54].

Timing of therapy can additionally influence the speed of changes and recovery seen. The impairments of the injury can affect the composition, intensity, and duration of rehabilitation[55]. Studies have shown that time post-injury plays a role in functional outcomes. It was found that those who were six months to 1-year post injury tended to have better functional outcomes and increased gains for living independently compared to those who were further post-onset of injury[56,57]. As such, rehabilitation should begin as early as possible and continue past the acute stage of recovery, while continuing to work towards functional improvement and attainable and meaningful goals[23].

High-intensity rehabilitative training started soon after initial injury has proven to be effective in maximizing recovery in rat models, although the ideal "time window" of initiating these services remains somewhat elusive[58]. Similarly, intensive cognitive rehabilitation is an effective form of intervention and effective in improving functional outcomes. Turner-Stokes et al[59], found that intensive rehabilitation leads to earlier gains and shorter hospital stays in working age adults with an acquired brain injury, especially in those with severe TBI[59,60]. As such, inpatient rehabilitation, performed at a high intensity and ideally in the early recovery stages, is a critical piece of maximizing rehabilitative efforts and outcomes, especially in moderate-severe TBI associated with disorders of consciousness[61].

Limitations of Evidence

The most common limiting factors associated with cognitive rehabilitation efficacy are related to the heterogeneity of the TBI population and study design issues, both of which can lead to reduced generalizability of relevant research. The heterogeneity of the population is a common limiting factor within studying this population. This is based on a variety of factors, including those that are specific to the injury itself (i.e. TBI location, severity and extent of injury, and cascade of neurological or other medical events that may follow the initial injury); but, are also noted in individual factors (i.e. age, premorbid cognitive level of function, education level, psychiatric history, socioeconomic status). This variability in the TBI population makes results from relevant studies difficult to generalize to the public at large given the lack of standard control.

Study design issues were also commonly noted limitations within this review. For example, treatment approaches often varied, and timing of intervention was not consistent. Other methodological concerns include frequently small sample sizes, and treatment study designs that lacked the blinding of investigators[11]. Furthermore, different outcome measures and scales used to report comparable information were used across studies making it difficult to report this data and potentially creating a "washing out" effect[23]. Examples of various outcome measures used in the literature were standardized neuropsychological tests, behavioral self-report questionnaires, or neuroimaging results. Cicerone et al[41], note the importance and need for using a complete outcome measure when researching the effectiveness of cognitive rehabilitation. This would include a standardized assessment, self- or caregiver-report, and ecological assessment. An ecologically valid assessment as part of a complete, functional outcome assessment would more closely represent daily life tasks. Poor attrition rates in long-term follow-up have also been reported, resulting in sparse data regarding the lasting effects of intervention, improvement or resolution of symptoms, and impact of intervention on return to work/school/community[49]. These limitations impact the generalizability of relevant data to the practicing cognitive rehabilitation clinician.

Cognitive rehabilitation efficacy and outcomes may also be influenced by factors yet to be fully elucidated by the current research. Several studies have shown the efficacy of cognitive rehabilitation in populations other than TBI and explore other treatment approaches that are beneficial in targeting associated cognitive rehabilitation; however, these have yet to be replicated in the TBI population. Moreover, the appropriate frequency and intensity of cognitive rehabilitation has yet to be established by the literature, as well as length of treatment, or effectiveness of group vs. individual sessions. Other studies have demonstrated techniques that may have applications to cognitive rehabilitation, but not yet being fully utilized by practicing clinicians. For example, Martinez-Molina and colleagues[62] showed the effectiveness of music therapy in the TBI population to increase executive functioning skills and McDonald et al[63] described the improvement of memory and attention changes associated with pharmacotherapy. Furthermore, Pink et al[64] report on the use of repetitive transcranial magnetic stimulation following TBI and its impact on rehabilitation. Future studies that integrate a variety of combined approaches, such as these and others, are needed to evaluate their potential use within the realm of cognitive rehabilitation.

Conclusions

Cognitive rehabilitation continues to be a vital component of TBI care and management. The team

approach to treatment can be used to both restore and compensate for cognitive, behavioral, and emotional sequelae of TBI. Therapy approaches aim to improve neural connections, specific cognitive domains, functional outcomes, and overall quality of life. The long-term consequences of TBI that many patients face after injury, may dissipate to a certain degree after rehabilitation, though many are left to continuously adapt and cope with residual symptoms. The multidisciplinary rehabilitation team needs additional evidence pertaining to cognitive rehabilitation in order to optimize treatment plans that are both cost-effective and tailored to the individual with TBI. Although current research continues to support the efficacy of cognitive rehabilitation, more high-quality studies are needed, especially ones that guide future treatment combinations, include specific and ecologically valid outcome measures, include frequency and length of treatment, and consider the heterogeneity of the TBI population.

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