

Head trauma and current rehabilitation approaches

Abstract

Traumatic Brain Injury (TBI) is a serious neurological condition that can affect individuals of all age groups and impair cognitive, motor, sensory, and psychosocial functions. This study discusses current physiotherapy and rehabilitation approaches following TBI from a multidisciplinary perspective. Early intervention during the rehabilitation process supports neuroplasticity and enhances recovery potential; innovative technologies such as Virtual Reality, robotic systems, Transcranial Magnetic Stimulation and tDCS are integrated with conventional practices. The recovery of sensory, balance, gait, speech, and cognitive functions is targeted, while telerehabilitation increases accessibility. Furthermore, psychological-emotional support and individualized therapy plans are among the key elements determining rehabilitation's success. The study aims to evaluate holistic and up-to-date TBI practices with the support of the literature.

Traumatic Brain Injury (TBI) is a serious neurological condition that can affect individuals of all age groups and impair cognitive, motor, sensory, and psychosocial functions. This narrative review, conducted in 2025, examines current physiotherapy and rehabilitation approaches following TBI within the context of international scientific literature from a multidisciplinary perspective. Early intervention during the rehabilitation process supports neuroplasticity and enhances recovery potential; innovative technologies such as Virtual Reality (VR), robotic systems, Transcranial Magnetic Stimulation (TMS), and transcranial Direct Current Stimulation (tDCS) are integrated with conventional practices. Rehabilitation interventions target the recovery of sensory, balance, gait, speech, and cognitive functions, while telerehabilitation improves accessibility to rehabilitation services. Furthermore, psychological and emotional support, along with individualized therapy plans, are among the key factors determining rehabilitation success. This review aims to provide a comprehensive evaluation of contemporary TBI rehabilitation practices based on the international scientific literature.

Keywords: traumatic brain injury, rehabilitation, physiotherapy

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Introduction

Head trauma is a clinical condition resulting from an external force causing damage to the head or brain tissue. These injuries, also referred to as Traumatic Brain Injury (TBI), can lead to temporary or permanent structural and/or functional impairments in brain tissue. TBI is characterized by altered levels of consciousness, neurological deficits, and reductions in cognitive, behavioral, and physical functions.¹

Head trauma is a clinical condition resulting from an external force causing damage to the head or brain tissue. Traumatic brain injury (TBI) may lead to temporary or permanent structural and functional impairments of the brain. Depending on the severity and location of the injury, individuals may experience alterations in consciousness, neurological deficits, and impairments in cognitive, behavioral, sensory, and physical functions.¹ These consequences can substantially affect functional independence, participation in daily activities, and overall quality of life.

The rehabilitation of individuals with TBI is a complex process requiring a comprehensive, multidisciplinary, and individualized approach. Physiotherapy plays an important role in addressing motor impairments, postural control, balance, mobility, and functional limitations. In addition, cognitive, communication, and psychosocial difficulties require coordinated interventions involving different rehabilitation disciplines. Evidence-based rehabilitation guidelines emphasize the importance of individualized treatment goals, functional activities, compensatory strategies, and consideration of patients' personal and environmental circumstances.^{2,3}

Conventional rehabilitation approaches, including therapeutic exercises, balance training, gait rehabilitation, and task-oriented interventions, remain important components of TBI management. Alongside these interventions, technological developments have introduced additional therapeutic opportunities, including virtual reality, robotic-assisted rehabilitation, transcranial magnetic stimulation, transcranial direct current stimulation, and telerehabilitation. Although these technologies offer potential opportunities to complement conventional rehabilitation, their effectiveness may vary depending on the intervention, clinical characteristics, and targeted outcomes. Furthermore, contemporary rehabilitation approaches increasingly emphasize cognitive rehabilitation, patient-centered treatment planning, and long-term functional participation.^{2,4}

Given the multidimensional consequences of TBI and the expanding range of rehabilitation interventions, a comprehensive evaluation of current approaches is important for clinical practice. Therefore, this narrative review, conducted in 2025, aims to discuss conventional and emerging physiotherapy and rehabilitation strategies following TBI from a multidisciplinary perspective. Particular attention is given to motor and sensory recovery, balance and gait rehabilitation, cognitive and communication functions, technology-assisted interventions, telerehabilitation, and psychosocial support. By integrating findings from the international scientific literature, this review seeks to provide an overview of contemporary rehabilitation practices and highlight the importance of individualized, holistic rehabilitation planning.

Classification

TBI is classified based on clinical evaluation using the Glasgow Coma Scale (GCS) (Istanbul Faculty of Medicine Neurology Department, 2022):⁵⁻⁷

Traumatic brain injury (TBI) is commonly classified according to injury severity using the Glasgow Coma Scale (GCS), which assesses three neurological responses: eye opening, verbal response, and motor response. The total GCS score ranges from 3 to 15, with lower scores indicating greater impairment of consciousness. Based on this assessment, TBI is traditionally categorized as mild (GCS 13–15), moderate (GCS 9–12), or severe (GCS 3–8) (Maas et al., 2017; National Institute for Health and Care Excellence [NICE], 2023).

In addition to GCS scores, TBI severity can be evaluated using the duration of loss of consciousness (LOC), post-traumatic amnesia (PTA), and neuroimaging findings. These parameters provide complementary information regarding the extent of neurological injury and potential functional consequences. However, the relationship between initial injury severity and long-term functional outcomes is complex, and clinical assessment should consider multiple factors rather than relying solely on GCS scores.^{7,8}

Mild Traumatic brain injury (GCS 13–15): Mild TBI is generally characterized by a GCS score of 13–15, loss of consciousness lasting less than 30 minutes, and post-traumatic amnesia lasting less than 24 hours. Patients may experience transient confusion, headache, dizziness, fatigue, and difficulties with attention or memory. Conventional neuroimaging findings may be normal, particularly in uncomplicated cases. Although many individuals recover within weeks, some experience persistent physical, cognitive, emotional, or behavioral symptoms that may require further evaluation and rehabilitation.^{7,9}

Moderate traumatic brain injury (GCS 9–12): Moderate TBI is associated with a GCS score of 9–12 and may involve loss of consciousness lasting between 30 minutes and 24 hours, with post-traumatic amnesia typically lasting between 1 and 7 days. Patients may present with neurological deficits, impaired balance and coordination, cognitive dysfunction, and limitations in daily activities. Structural abnormalities, including intracranial hemorrhage or cerebral contusions, may be identified through neuroimaging. Functional outcomes vary considerably depending on injury characteristics, associated complications, and individual patient factors. Multidisciplinary rehabilitation is often required to address motor, cognitive, and psychosocial impairments.^{7,8}

Severe traumatic brain injury (GCS 3–8): Severe TBI is characterized by a GCS score of 3–8 and is frequently associated with prolonged loss of consciousness exceeding 24 hours or post-traumatic amnesia lasting more than 7 days. These injuries may result in substantial neurological impairment and serious complications, including increased intracranial pressure, cerebral edema, and brain herniation. Survivors may experience persistent motor, sensory, cognitive, behavioral, and communication difficulties, leading to significant limitations in functional independence. Rehabilitation generally requires a prolonged, individualized, and multidisciplinary approach involving physiotherapy, occupational therapy, cognitive rehabilitation, and psychosocial support.^{7,8}

Although the GCS provides a standardized method for assessing the initial severity of TBI, it should not be considered an independent predictor of long-term rehabilitation outcomes. Comprehensive assessment should incorporate neurological findings, neuroimaging

results, cognitive and behavioral functions, physical impairments, and the patient's functional status. Furthermore, factors such as age, comorbidities, injury mechanism, and rehabilitation needs should be considered when developing individualized treatment strategies. Understanding the severity and clinical characteristics of TBI is essential for establishing realistic rehabilitation goals, selecting appropriate interventions, and optimizing functional recovery.

Other classifications of TBI

TBI can be classified not only according to the Glasgow Coma Scale but also based on different characteristics. According to the type of injury, TBI is categorized as **closed** or **open**, depending on whether the integrity of the dura mater is preserved. Regarding anatomical distribution, **focal TBI** refers to injuries or bleeding confined to specific regions, while **diffuse TBI** (e.g., diffuse axonal injury) affects the brain more globally. Based on the mechanism of trauma, **penetrating TBI** involves disruption of the skull integrity, whereas **non-penetrating TBI** occurs without skull penetration. Finally, in terms of timing, **primary injury** refers to the direct damage occurring during trauma, while **secondary injury** includes processes such as hypoxia, edema, and infection that develop afterward.⁷

Epidemiology and etiology

Traumatic Brain Injury is a major global public health issue, affecting approximately 69 million people annually. The most common causes include falls, traffic accidents, physical assaults, sports injuries, and military conflicts. Specific populations are particularly at risk, including children aged 0–4, adults aged 15–24, and individuals over 65. The risk of TBI is higher in males than females, a difference attributed to behavioral, social, and occupational factors. In light of these data, it is critical to consider factors such as age, gender, and trauma mechanism in the prevention and management of TBI. Developing age- and risk-specific preventive strategies and strengthening early diagnosis and rehabilitation services are essential components in addressing TBI effectively.

Current physiotherapy and rehabilitation in traumatic brain injury

TBI is a complex clinical condition that can permanently impair motor, cognitive, and sensory functions. Therefore, the rehabilitation process following TBI requires a multidisciplinary approach, with physiotherapy serving as a core component. Physiotherapy interventions aim to enhance patients' functional independence, improve their quality of life, and support reintegration into society.

Rehabilitation approaches for traumatic brain injury

Early intervention and acute care

After a TBI, initiating the rehabilitation process as early as possible is a critical factor that enhances recovery potential. Early intervention particularly facilitates functional recovery by supporting neuroplasticity. Environmental stimuli and sensorimotor experiences shape the brain's capacity for reorganization following injury, and this process can be positively influenced through rehabilitation initiated within the first days.¹⁰

During the acute phase, the primary goals are to stabilize the patient's vital functions, prevent secondary brain injury, and monitor neurological status. Standardized tools such as the Glasgow Coma Scale (GCS) assess consciousness level and prognosis (Istanbul Faculty of Medicine Neurology Department, 2022).¹¹ Multidisciplinary

evaluations conducted within the first 14 days are crucial in guiding rehabilitation.⁶

According to the literature, physical therapy initiated during the acute phase has positively affected functional recovery and mortality rates.^{10,12} Therefore, close collaboration among physiotherapists, neurologists, neurosurgeons, and intensive care specialists is essential in the early management of TBI.

Physiotherapy

Physiotherapy and rehabilitation following head trauma require a multidimensional approach that addresses the patient's motor, sensory, cognitive, speech, and emotional functions. This process is grounded in multidisciplinary teamwork, where physiotherapists, speech therapists, occupational therapists, and psychologists collaborate to support the patient's functional independence. The literature emphasizes that neuroplasticity-enhancing methods based on repetitive exercises and virtual reality (VR) and robotic technologies improve motivation, participation, and long-term outcomes.^{13,14}

Improving motor functions

Among the strategies to improve motor control in individuals with head trauma, Bobath/Neurodevelopmental Treatment (NDT) techniques are noteworthy; these methods aim to relearn functional movement patterns. Innovative approaches such as robot-assisted exercises and music-supported therapy contribute to rehabilitating the upper extremities and trunk region. Additionally, **motor imagery** activates neural pathways without physical effort, supporting neuroplasticity.¹⁵

Balance and gait training

While classical methods (manual therapy, weight shifting, use of orthotics) remain fundamental in balance and gait rehabilitation, virtual reality (VR)-assisted exercises have proven highly effective in enhancing motivation, attention, and functionality. In addition, multimodal programs such as IBaR (Integrated Balance Rehabilitation) optimize postural control by integrating VR, vestibular-proprioceptive feedback, and robotic systems.¹⁴

Sensory training

Sensory rehabilitation aims to ensure synchronized functioning of the visual, proprioceptive, and vestibular systems. Individualized feedback using VR and sensor-based systems improves balance and postural control in this area. In particular, vibrational and haptic sensory stimuli enhance sensitivity and adaptive responses in individuals with traumatic injuries.¹⁶

Cognitive rehabilitation

Computer- or VR-based cognitive tasks significantly restructure attention, memory, and executive functions. These approaches target functions directly related to daily living skills, facilitating transfer to real-life situations. Moreover, when combined with non-invasive brain stimulation techniques such as Transcranial Magnetic Stimulation (TMS) and Transcranial Direct Current Stimulation (tDCS), cognitive programs have been shown to produce meaningful improvements in attention and planning abilities, particularly in individuals with moderate traumatic brain injury.^{17,18}

Speech therapy

Speech disorders (e.g., aphasia, dysarthria, and swallowing difficulties) are commonly observed following head trauma. Telerehabilitation has gained prominence in this domain, with

individualized remote assessment and therapy protocols offering reliable results even in home settings. Studies have documented consistent progress when speech therapies are shaped according to patient-specific goals.¹⁹

Current treatment approaches

Recently, neuromodulation techniques (such as TMS and tDCS), cellular therapies, brain-computer interfaces, and telerehabilitation have garnered increasing interest. Robotic systems supported by *serious games* and web-based gaming platforms have also gained attention. For example, a platform for upper extremity rehabilitation can be integrated with online games to break monotony, adapting in-game difficulty levels based on the patient's progress, thereby enhancing motivation.

Recently, virtual reality (VR) and neuromodulation combinations have become prominent; several studies report synergistic improvements in motor and cognitive functions when tDCS or TMS is applied alongside VR-based exercises.²⁰ All these methods are combined with motor and cognitive programs to enhance neuroplasticity. Especially after the pandemic, the rapid expansion of telerehabilitation has made multidisciplinary applications more flexible and accessible.^{13,17,18}

Psychological and emotional approaches

Mood disorders, anxiety, and social isolation are common following head trauma. VR-supported psychotherapy and Cognitive Behavioral Therapy (CBT) offer promising results in this area. VR allows for safe re-experiencing of trauma-related memories (exposure therapy) and enables the creation of socially interactive scenarios that support emotional regulation. Because these approaches strengthen the entire rehabilitation process, the involvement of psychologists and psychiatrists in the care team is essential.^{13,14}

The importance of a multidisciplinary approach

TBI rehabilitation requires the collaboration of various healthcare professionals, including physiotherapists, occupational therapists, speech and language therapists, neuropsychologists, and social workers. This multidisciplinary approach allows for the holistic management of patients' physical, cognitive, and psychosocial needs.

Neurological and functional impairments resulting from head trauma can significantly affect an individual's quality of life. Rehabilitation plays a fundamental role in minimizing these adverse effects.

- I. Enhances functional independence:** Accelerates return to activities of daily living such as walking, dressing, and eating.
- II. Supports neuroplasticity:** Stimulates neuroplasticity, promoting brain reorganization and enhancing the effectiveness of learning and recovery processes.
- III. Facilitates cognitive and psychosocial recovery:** Improves cognitive functions such as memory, attention, and planning; reduces depression and anxiety.
- IV. Prevents complications:** Helps prevent secondary problems such as spasticity, contractures, and pressure ulcers.
- V. Accelerates reintegration into society:** Contributes to the individual's return to social and occupational life.

The success of rehabilitation depends on multiple factors, including the severity of the injury, the patient's age, comorbid medical

conditions, and the timing of intervention. Therefore, a personalized and multidisciplinary approach is essential for each patient.^{21–27}

Conclusion

Physiotherapy and rehabilitation play a critical role in enhancing functional independence and improving the quality of life in individuals after traumatic brain injury (TBI). Evidence suggests that recovery following TBI occurs through neuroplasticity, which involves neural regeneration and functional reorganization. Early intervention, individualized treatment plans, and the integration of technological innovations can significantly enhance the effectiveness of rehabilitation. A patient-centered interdisciplinary healthcare team and well-guided family members should be actively involved at every stage of the process. However, the current literature reveals a lack of standardization and methodological limitations. Therefore, more comprehensive and high-quality research is needed to strengthen the evidence base and optimize clinical practice.

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Conflicts of interest

The author declares there is no conflict of interest.

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