Traumatic Brain Injury: From Impact to Recovery

Understanding how brain injury can affect symptoms, walking, and rehabilitation

Executive Summary

A traumatic brain injury occurs when an external force disrupts normal brain function. Depending on its severity and the areas of the brain affected, a TBI can impact movement, balance, thinking, memory, emotions, sensory function, and sleep. The effects vary considerably from person to person, and recovery can range from relatively quick improvement to persistent difficulties requiring long-term rehabilitation.

Walking and balance may also be affected by traumatic brain injury. Changes may include slower walking speed, shorter steps, reduced stability, and greater difficulty navigating obstacles or walking while performing another task. Therefore, treatment and rehabilitation often involve a combination of medical care, physical therapy, balance and gait training, and other therapies tailored to the individual. Newer technologies, such as wearable sensors and biofeedback, may help assess and support recovery during everyday movement.



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1. The Brain and How It Is Protected

The brain is well protected, but sudden forces can still affect its function.

The brain is the control center of the nervous system. It regulates movement, sensation, thinking, memory, emotions, and many of the body's automatic functions. Although different areas of the brain contribute to different tasks, they work together continuously to enable us to interact with our surroundings and perform everyday activities.

The brain is protected by several layers. The skull forms a hard outer shell, and protective membranes called meninges surround the brain. Cerebrospinal fluid cushions the brain and reduces the impact of minor movements and collisions.

Despite this protection, the brain can still be injured when the head is exposed to strong or sudden forces. During rapid acceleration, deceleration, or rotation, the brain can move within the skull. This movement can stretch or damage brain tissue and disrupt communication between different areas of the nervous system [1,2].

The effects of an injury depend on factors such as the strength and direction of the force, which areas of the brain are involved, and the injury's severity. Since the brain contributes to many different functions, traumatic brain injury can affect more than just movement [2,3].

2. What Happens During a Traumatic Brain Injury

A sudden force can affect the brain in different ways.

A traumatic brain injury occurs when an external force disrupts the brain's normal function. This can result from a direct blow to the head, rapid acceleration or deceleration, rotational movement, or penetrating injury [2, 4].

The initial force can directly damage brain tissue. In some cases, the injury is more localized; for example, one area of the brain may be bruised or there may be bleeding. In other cases, the force is distributed more widely throughout the brain, stretching or damaging the long nerve fibers that connect different brain regions [4, 5].

These changes are often described as the primary injury, meaning the damage that occurs at the moment of the trauma. However, the effects of a traumatic brain injury do not always stop there. In the hours and days following the injury, processes such as swelling, reduced blood flow, inflammation, and changes in brain cell metabolism can further stress brain tissue. These later changes are referred to as secondary injury.

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Therefore, the type and severity of damage can vary considerably from person to person. Some injuries mainly affect one region of the brain, while others interfere with communication across several brain networks. This variation helps explain why traumatic brain injury can lead to a wide range of physical, cognitive, sensory, and behavioral difficulties [4].

3. How Traumatic Brain Injury Can Affect the Body and Mind

The effects of a brain injury depend on which areas and networks of the brain are affected.

The brain is involved in many different functions, including movement, sensation, attention, memory, emotion, behavior, and communication. Since traumatic brain injury affects different areas and connections within the brain, resulting difficulties vary widely from person to person [4, 6].

Some people experience mainly physical or movement-related problems, such as weakness, poor coordination, dizziness, balance issues, or changes in walking. Others may have greater difficulty with thinking and attention, including memory problems, slower information processing, and difficulty concentrating.

Traumatic brain injury can also affect sensory function. Changes in vision, hearing, touch, or body position awareness may make it harder to understand what is happening around you or respond accurately during movement. Emotional and behavioral changes may also occur, including irritability, anxiety, reduced motivation, and changes in mood [6, 7].

These difficulties do not always occur separately. For instance, a person with reduced balance, slower reactions, and difficulty dividing attention may find walking much more challenging, even if their muscle strength is relatively intact. Therefore, the effects of traumatic brain injury often result from several interacting changes rather than a single impairment.

The severity and duration of these problems also vary. Some people recover relatively quickly, particularly after a mild injury, while others experience persistent difficulties requiring longer-term rehabilitation [4, 6].

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4. Common Symptoms and Impairments After Traumatic Brain Injury

Traumatic brain injury can affect physical function, thinking, emotions, and sleep.

The symptoms of a traumatic brain injury can vary greatly from person to person. These symptoms depend on factors such as the injury's severity, the affected areas of the brain, and the person's overall health. Some symptoms appear immediately, while others become more noticeable over the following hours or days [4,8].

Physical symptoms

Physical symptoms may include headaches, dizziness, nausea, fatigue, sensitivity to light or noise, and balance or coordination problems. Some individuals may also experience weakness, altered sensation, visual disturbances, or movement difficulties [4, 8].

These physical changes can affect everyday activities such as standing, walking, climbing stairs, and moving safely through busy environments.

Cognitive symptoms

Traumatic brain injury can also affect thinking. Common difficulties include reduced attention, slower information processing, memory problems, and difficulty planning or completing complex tasks [6, 7].

A person may therefore have difficulty following a conversation, remembering new information, concentrating in a noisy environment, or performing several tasks at once.

Emotional and Behavioral Changes

Changes in mood and behavior are common after a traumatic brain injury. Some individuals experience irritability, anxiety, depression, emotional instability, or reduced motivation.

These changes may occur alongside physical and cognitive symptoms and influence social interactions, work performance, relationships, and participation in everyday activities.

Sleep and Fatigue

Sleep disturbances and fatigue are frequently reported after traumatic brain injury. People may have difficulty falling or staying asleep, sleep at unusual times, or feel unrefreshed despite adequate time in bed [8, 9].

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Fatigue can also exacerbate other symptoms. For instance, balance, concentration, and walking performance may deteriorate when a person is tired.
The combination of these symptoms can vary considerably from person to person. One person may experience mainly headaches and dizziness, while another may have more pronounced problems with attention, balance, or mood. This variability is one reason why traumatic brain injury assessment and rehabilitation need to be adapted to the individual.

5. How Traumatic brain injury Can Change Walking and Balance

Changes in balance, coordination, attention, and movement control can affect the way a person walks.

After a traumatic brain injury, walking can become slower, less steady, or more difficult in changing environments. These changes can occur after a mild, moderate, or severe traumatic brain injury, though the type and severity of gait impairment varies considerably from person to person. [10].
People with traumatic brain injury may walk more slowly, take shorter steps, or exhibit greater side-to-side movement while walking. These difficulties can become more noticeable when walking over obstacles, with the eyes closed, or in situations that require greater balance and attention [11].

Balance and Postural Control

Maintaining balance while walking requires the nervous system to integrate information from vision, the inner ear, and sensory receptors in the body. A traumatic brain injury can interfere with one or more of these systems, making it harder to maintain stability or respond quickly to changes in the environment.
For some individuals, these balance difficulties can persist even after other symptoms have improved. Research following concussions has identified changes in balance and gait beyond the early stages of recovery 12].

Walking While Doing Something Else

Everyday walking rarely happens in isolation. We may walk while talking, looking for directions, carrying an object, or thinking about something else. This is known as dual-task walking because the person is performing two tasks at the same time: walking and another task.

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After a traumatic brain injury, it can be more difficult to divide attention between walking and another task. Studies have found that people with concussions or traumatic brain injuries may walk more slowly or exhibit greater changes in their walking patterns during dual-task conditions [10, 13].

This is important because a person may appear to walk relatively normally in a quiet clinical environment, yet experience greater difficulty in busy or demanding situations. Tasks such as turning, avoiding obstacles, or walking and talking simultaneously may therefore provide additional information about how walking is affected after traumatic brain injury [10,11].

Gait Changes Are Not Caused by One Problem

Walking difficulties after traumatic brain injury do not necessarily result from muscle weakness alone. Balance problems, reduced coordination, dizziness, sensory changes, slower reactions, and attention difficulties can all influence gait.

For this reason, gait assessment after traumatic brain injury often considers several aspects of walking rather than a single measurement. Together, walking speed, step length, balance, turning, variability, obstacle negotiation, and dual-task performance can provide a broader picture of how a person moves [10].

6. How Traumatic Brain Injury Is Diagnosed and Classified

Clinical assessment helps determine how seriously the brain has been affected and whether further testing is needed.

A traumatic brain injury diagnosis is made based on information about how the injury occurred, the person's symptoms, and the results of a neurological examination. To understand how the brain has been affected, clinicians may assess alertness, memory, orientation, movement, vision, balance, and other neurological functions [4,14].

Describing Injury Severity

Traumatic brain injury is commonly described as mild, moderate, or severe. One of the most widely used tools is the Glasgow Coma Scale, which evaluates eye opening, verbal responses, and motor responses. Scores of 13–15 are generally classified as mild TBI, 9–12 as moderate traumatic brain injury, and 3–8 as severe traumatic brain injury.

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Other information that can help describe the injury includes whether the person lost consciousness and whether they experienced post-traumatic amnesia. Post-traumatic amnesia is a period after the injury during which the person may have difficulty forming new memories or remembering what happened [4, 15].

However, these categories do not tell the whole story. Two people with the same initial severity classification may experience very different symptoms and recovery patterns. For this reason, traumatic brain injury is increasingly assessed using a combination of clinical findings, imaging, and other information rather than relying on a single score [14].

The Role of Brain Imaging

Brain imaging may be used when there is concern about bleeding, swelling, a skull fracture, or another type of structural injury. Computed tomography (CT) is commonly used in the early stages because it is fast and can identify injuries that may require urgent treatment [16].

Magnetic resonance imaging can provide more detailed images and may detect some injuries that are less visible on CT scans. It can be useful when neurological symptoms persist despite an initial normal or inconclusive scan [16].

It is important to note that a normal brain scan does not necessarily mean that no traumatic brain injury has occurred, especially after a mild injury. Therefore, diagnosis relies on the overall clinical picture rather than imaging alone.

7. Treatment and Rehabilitation After Traumatic Brain Injury

Treatment focuses on protecting the brain early and helping people regain function during recovery.

Immediately after a traumatic brain injury, treatment depends strongly on the severity of the injury. Mild injuries may mainly require observation, symptom management, and a gradual return to normal activities. More severe injuries can require hospital monitoring, treatment of bleeding or swelling, and in some cases surgery [4,17].

An important goal during the early stages is to prevent additional damage to the brain. This may involve maintaining adequate oxygen and blood flow, monitoring pressure within the skull, and treating complications that could interfere with recovery [17].

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Rehabilitation and Recovery

Once a person is medically stable, rehabilitation can address remaining difficulties. Since traumatic brain injury can affect movement, thinking, communication, balance, and behavior, rehabilitation often requires the collaboration of several healthcare professionals [18].

Physical therapy can help improve strength, balance, coordination, endurance, and walking ability. Treatment may include balance exercises, gait training, treadmill walking, obstacle negotiation, and practice with everyday movements, such as standing up, turning, and climbing stairs [18,19].

For individuals with dizziness or balance problems, vestibular rehabilitation may be used as well. This type of therapy includes exercises that help the nervous system adapt to changes affecting balance, vision, and head movement [20].

Cognitive, occupational, and speech therapy address difficulties with attention, memory, communication, planning, and everyday activities. Therefore, the type and intensity of rehabilitation depend on each person's individual symptoms and goals [18].

Supporting Walking During Recovery

Since walking requires balance, coordination, attention, and sensory information, gait rehabilitation may need to address multiple issues simultaneously. Training can progress gradually from simple walking tasks to more challenging activities, such as turning, stepping over obstacles, changing speed, or walking while performing another task [19].

Technology is increasingly being used to support this process. Wearable sensors can measure characteristics such as walking speed, step timing, symmetry, and balance during rehabilitation or everyday activities. Virtual reality, biofeedback, and other technology-assisted approaches are also being investigated as ways to provide additional practice and feedback during recovery [21].

Recovery after traumatic brain injury varies considerably between individuals. Therefore, rehabilitation focuses not only on improving impairments, but also on helping each person regain independence and participate fully in everyday life.

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