Traumatic Brain Injury: Gait Training

Indexing Metadata/Description

› **Title/condition:** Traumatic Brain Injury: Gait Training
› **Synonyms:** Traumatic acquired brain injury: gait training; gait training: traumatic brain injury; brain injury, traumatic: gait training; concussion: gait training
› **Anatomical location/body part affected:** Brain and any or all body parts controlled by the affected area of the brain – can affect neurologic, psychiatric, cardiovascular, endocrine/metabolic, and gastrointestinal system
› **Area(s) of specialty:** Neurological Rehabilitation, Pediatric Rehabilitation; Geriatric Rehabilitation
› **Description:** Traumatic brain injury (TBI) is an alteration in brain function, or other evidence of brain pathology, that is caused by an external force. Secondary injury may develop during a period of hours to months after the primary injury

› **ICD-9 codes**
  • 850-854 traumatic brain injury
  • 907.0 late effects of intracranial injury

› **ICD-10 codes**
  • S06 intracranial injury
  • ICD-10-CA modification in Canada
  • S06.0 concussion
  • S06.1 traumatic cerebral edema
  • S06.2 diffuse brain injury
  • S06.3 focal brain injury
  • S06.4 epidural hemorrhage
    – ICD-10-CA modifications in Canada, 5th digit added for:
      - S06.40 (without loss of consciousness)
      - S06.41 (with brief loss of consciousness)
      - S06.42 (with moderate loss of consciousness)
      - S06.43 (with prolonged loss of consciousness with return to pre-existing level of consciousness)
      - S06.44 (with prolonged loss of consciousness without return to pre-existing level of consciousness)
      - S06.49 (with loss of consciousness of unspecified duration)
    - 6th digit added for:
      - 0 (without open intracranial wound)
      - 1 (with open intracranial wound)
  • S06.5 traumatic subdural haemorrhage
    – S06.50 (without loss of consciousness)
    – S06.51 (with brief loss of consciousness)
    – S06.52 (with moderate loss of consciousness)
    – S06.53 (with prolonged loss of consciousness with return to pre-existing level of consciousness)
    – S06.54 (with prolonged loss of consciousness without return to pre-existing level of consciousness)
- 6th digit added for
  - 0 (without open intracranial wound)
  - 1 (with open intracranial wound)
- S06.6 traumatic subarachnoid haemorrhage
- S06.7 intracranial injury with prolonged coma
- S06.8 other intracranial injuries
- S06.9 intracranial injury, unspecified

(ICD codes are provided for reader’s reference and not for billing purpose.)

› G-Codes
  • Mobility G-code set
    – G8978, Mobility: walking & moving around functional limitation, current status, at therapy episode outset and at reporting intervals
    – G8979, Mobility: walking & moving around functional limitation; projected goal status, at therapy episode outset, at reporting intervals, and at discharge or to end reporting
    – G8980, Mobility: walking & moving around functional limitation, discharge status, at discharge from therapy or to end reporting
  • Changing & Maintaining Body Position G-code set
    – G8981, Changing & maintaining body position functional limitation, current status, at therapy episode outset and at reporting intervals
    – G8982, Changing & maintaining body position functional limitation, projected goal status, at therapy episode outset, at reporting intervals, and at discharge or to end reporting
    – G8983, Changing & maintaining body position functional limitation, discharge status, at discharge from therapy or to end reporting
  • Carrying, Moving & Handling Objects G-code set
    – G8984, Carrying, moving & handling objects functional limitation, current status, at therapy episode outset and at reporting intervals
    – G8985, Carrying, moving & handling objects functional limitation, projected goal status, at therapy episode outset, at reporting intervals, and at discharge or to end reporting
    – G8986, Carrying, moving & handling objects functional limitation, discharge status, at discharge from therapy or to end reporting
  • Self Care G-code set
    – G8987, Self care functional limitation, current status, at therapy episode outset and at reporting intervals
    – G8988, Self care functional limitation, projected goal status, at therapy episode outset, at reporting intervals, and at discharge or to end reporting
    – G8989, Self care functional limitation, discharge status, at discharge from therapy or to end reporting
  • Other PT/OT Primary G-code set
    – G8990, Other physical or occupational primary functional limitation, current status, at therapy episode outset and at reporting intervals
    – G8991, Other physical or occupational primary functional limitation, projected goal status, at therapy episode outset, at reporting intervals, and at discharge or to end reporting
    – G8992, Other physical or occupational primary functional limitation, discharge status, at discharge from therapy or to end reporting
  • Other PT/OT Subsequent G-code set
    – G8993, Other physical or occupational subsequent functional limitation, current status, at therapy episode outset and at reporting intervals
    – G8994, Other physical or occupational subsequent functional limitation, projected goal status, at therapy episode outset, at reporting intervals, and at discharge or to end reporting
    – G8995, Other physical or occupational subsequent functional limitation, discharge status, at discharge from therapy or to end reporting

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Source: [https://www.cms.gov/](https://www.cms.gov/)

### Reimbursement
- Reimbursement for therapy will depend on insurance contract coverage. Observational gait analysis usually is covered; however, some insurance contracts specify restrictions for computer-based gait analysis.

### Presentation/signs and symptoms:
Symptoms vary according to the severity of the injury and stage of recovery.

#### Mild TBI
- Patients present with confusion, disorientation, loss of consciousness for less than 30 minutes, posttraumatic amnesia for less than 24 hours, or other transient focal neurological abnormalities.
- Patients may complain of memory loss, poor concentration, headaches, fatigue, irritability, dizziness, sleep disorders, and seizures. In most individuals with mild TBI, symptoms resolve over time.
- Athletic injuries make up a large proportion of mild TBIs. Return to contact sports, especially in children, is a contentious issue.
- Concussion is a subset of TBI. The terms mild TBI and concussion are often used interchangeably in the context of sports, particularly in the United States; however, an international conference consensus statement noted that others differentiate the terms.
  - The acute clinical symptoms of concussion tend to reflect a functional disturbance rather than a structural injury, so no abnormality is seen in neuroimaging studies.
  - Concussion results in a graded set of clinical symptoms that may or may not involve loss of consciousness.
  - Resolution of symptoms tends to follow a sequential course. Eighty percent to 90% of concussions resolve in 7–10 days. In some cases, symptoms may be prolonged.
  - Alterations in gait performance that persist after 10 days despite resolution of all aspects of the traditional clinical battery assessment were reported in study in the United States involving 21 individuals post-concussion.
  - Alterations in gait termination independent of gait velocity persisted, supporting a growing body of evidence that impairments in balance persist longer than indicated by clinical tests after concussion.

#### Moderate to severe TBI
- General symptoms may include loss of consciousness, profound confusion, agitation, combativeness or other unusual behavior, slurred speech, drowsiness, limb weakness, loss of coordination, loss of bladder or bowel control, persistent headache, nausea or vomiting, and seizures.
- Neuromuscular deficits may include dysphagia, abnormal muscle tone, decorticate or decerebrate rigidity, hyper-/hyporeflexia, motor control deficits such as monoparesis and hemiparesis, balance deficits, impaired ROM, limited endurance, and sensory deficits.
- Cognitive deficits may include amnesia, impaired attention, impaired problem solving, perseveration, and impaired executive functioning.
- Behavioral deficits may include apathy, disinhibition, aggression, and impulsiveness.
- Perceptual and communication deficits may also occur.
• In geriatric populations, symptoms may be subtle and not present until days after trauma

• Long-term complications
  – Decreased bone density
  – Muscle atrophy
  – Soft tissue contractures
  – Decreased endurance
  – Reduced physical activity
  – Heterotopic ossification
  – Venous stasis
  – Semimembranosus rupture with aggressive stretching or serial casting

• For more information and details on symptom classification, see
  – Clinical Review...Traumatic Brain Injury – Rancho Los Amigos Levels I, II, III; Item Number: T708761
  – Clinical Review...Traumatic Brain Injury – Rancho Los Amigos Level IV; Item Number: T708877
  – Clinical Review...Traumatic Brain Injury – Rancho Los Amigos Levels V and VI; Item Number: T708890
  – Clinical Review...Traumatic Brain Injury – Rancho Los Amigos Levels VII and VIII; Item Number: T708887

### Causes, Pathogenesis, & Risk Factors

#### Causes

- Falls (40%)
- Motor vehicle accidents (14%)
- Assault (10%)
- Child abuse (24% of TBI age 2 years and younger)
- Recreational activities (21% of pediatric TBI with peak seasons of spring/summer and peak ages of 10–14 years)

#### Pathogenesis

- Primary insult if due to direct mechanical damage and secondary insult if due to complex cellular and molecular processes that cause cerebral edema, ischemia, and apoptotic cell death
- Diffuse axonal injury
- Focal injury
- Hypoxic-ischemic injury
- Increased intracranial pressure (ICP)

#### Risk factors

- A history of head injury is a risk factor for sustaining another head injury
- Low socioeconomic status correlates with an increased risk for TBI, possibly as a result of increased exposure to high-risk occupations, personal violence, older vehicles, and substandard housing
- Child abuse
- Substance abuse
- Seizure disorder
- Attention-deficit/hyperactivity disorder (ADHD)
- Male sex
- Age; persons aged 0–4 years and 15–19 years have greater risk of TBI compared to other age groups
- Psychiatric history (e.g., depression, anxiety)
- Military service

### Overall Contraindications/Precautions

#### Concurrent injuries

- Fractures with or without external fixators
  – Ensure that weight-bearing restrictions are being adhered to during examination and treatment
  – Ensure that prescribed braces are used properly
- Other neurologic compromise (e.g., follow seizure precautions for patients with posttraumatic seizures)
Follow physician’s precautions and contraindications specific to gastrointestinal, genitourinary, dermatologic (e.g., open wounds), and cardiovascular injuries

Respiratory compromise is a precaution

– Ventilator status may contraindicate gait training

See specific Contraindications/precautions to examination and Contraindications/precautions under Assessment/Plan of Care

Examination

Contraindications/precautions to examination: When possible, the examination should be conducted in a minimally stimulating environment. The examination should be tailored for each individual patient with TBI. Monitor the patient’s emotional state and modify the examination accordingly

– Physical therapists (PTs) can help identify symptoms of hydrocephalus, which include worsening gait pattern, urinary incontinence, failing cognitive skills, and general lack of functional improvement

– Stop evaluation and contact physician immediately if patient presents with signs of deep vein thrombosis (DVT) or infection

– Respect patient’s reported level of pain

– Follow surgeon’s pre- and postoperative protocol if the patient has undergone any surgical procedures

History

History of present illness/injury:

Mechanism of injury or etiology of illness: Document cause and date of patient’s injury. What has been the course of recovery so far? Have there been any complications? What was the initial Glasgow Coma Scale (GCS) score? What was the length of coma, if any, and the length of any posttraumatic amnesia? What is the patient’s documented Rancho Los Amigos Level of Consciousness? Document any concomitant injuries

Course of treatment

Medical management

- Emergency management may include surgical intervention such as decompression of intracranial hematomas

- Depending on severity of injury, acute management may include ICP monitoring, mechanical ventilation, and mean arterial pressure monitoring

- Inpatient management may include DVT and pressure sore prevention measures and feeding interventions (e.g., percutaneous endoscopic gastrostomy [PEG] tube placement)

- Surgery may be performed to address complications or concomitant injuries (e.g., shunt placement, fracture fixation)

Medications for current illness/injury: Determine what medications clinician has prescribed; are they being taken? Medications commonly prescribed may include

- sedatives to minimize agitation

- seizure prevention medications (e.g., levetiracetam [Keppra], phenytoin [Dilantin])

- medications for spasticity (e.g., tizanidine [Zanaflex])

- medications for behavioral issues, including amantadine and methylphenidate for attention and concentration, carbamazepine and amitriptyline for aggressive behavior, and antidepressants

Diagnostic tests completed

- ICP monitoring

- Somatosensory evoked potentials (SSEPs) and electroencephalograms (EEGs) may be recorded during the acute phase

- Neuropsychometric testing

- Diagnostic imaging may include the following:

  - Radiographs

  - Computed tomography (CT)

  - Magnetic resonance imaging (MRI)

  - Positron emission tomography (PET)

  - Single-photon emission computed tomography (SPECT)

  - Functional magnetic resonance imaging (fMRI)

Home remedies/alternative therapies: Document any use of home remedies (e.g., ice or heating pack) or alternative therapies (e.g., acupuncture), what symptoms they are used for, and whether or not they help

- There is insufficient evidence for use of acupuncture in patients with TBI, but it may improve overall function(28)
- **Previous therapy**: Document what occupational or physical therapy the patient has had prior to presenting for gait training and his or her response
  - **Aggravating/easing factors** (and length of time each item is performed before the symptoms come on or are eased): Document factors known to increase agitation, including light, noise, and distractions. Presence of visitors and disruptions in schedule may also be factors
- **Body chart**: If appropriate, use a body chart to document location of symptoms
- **Nature of symptoms**: Document nature of symptoms (e.g., pain, fatigue, weakness, incoordination, spasticity)
  - **Rating of symptoms**: As appropriate, use a visual analog scale (VAS) or 0–10 scale to assess symptoms at their best, at their worst, and at the moment (specifically address if pain is present now and how much)
  - **Pattern of symptoms**: Document changes in symptoms throughout the day and night, if any (A.M., mid-day, P.M., night); also document changes in symptoms due to weather or other external variables
- **Sleep disturbance**: In acute phases of recovery from TBI, patients may have hypoarousal\(^2\) that manifests as fatigue and falling asleep mid-task.\(^2\) Patients may need frequent cues to stay awake during therapy sessions. In later stages patients may still have difficulty with sleep-wake cycles.\(^2\) Inquire about current sleep patterns, time to bed, time to sleep, times awake, rise time, and level of restfulness on wakening
- **Other symptoms**: Document other symptoms patient may be experiencing that could exacerbate the condition and/or symptoms that could be indicative of a need to refer to physician (e.g., dizziness, bowel/bladder/sexual dysfunction, saddle anesthesia). Dizziness is common after TBI
- **Respiratory status**: Document any respiratory compromise associated with injury, including use of mechanical ventilation or supplemental oxygen. Document any associated chest injuries, such as rib fractures or pneumothorax, and any history of pneumonia. Does patient have a history of respiratory conditions such as asthma or chronic obstructive pulmonary disease (COPD)? If so, how are they controlled? Smoking history?
- **Barriers to learning**
  - Are there any barriers to learning? Yes__ No__
  - If Yes, describe _________________________
    - Common barriers to learning after TBI include impaired memory, poor attention and concentration, poor decision making, impulsivity, and impaired language and communication
- **Medical history**
  - **Past medical history**
    - **Previous history of same/similar diagnosis**: A previous head injury is a risk factor for sustaining another head injury. Document any history of conditions that could affect gait, including musculoskeletal injuries, arthritis, and neurological conditions
    - Subdural hematomas are common after a fall or insult in older adults\(^1\)
    - **Comorbid diagnoses**: Ask patient about other current problems, including diabetes, cancer, heart disease, complications of pregnancy, psychiatric disorders, orthopedic disorders, etc.
    - **Medications previously prescribed**: Obtain a comprehensive list of medications prescribed and/or being taken (including over-the-counter drugs)
    - **Other symptoms**: Ask patient or caregiver about other symptoms the patient may be experiencing
- **Social/occupational history**
  - **Patient’s goals**: Document what the patient hopes to accomplish with therapy and in general. Goal setting seems to be a useful technique to influence motivation (e.g., the intensity of behavior) in brain-injured patients
    - Achieving independent gait is often a major goal of rehabilitation for patients with moderate to severe TBI\(^4\)
    - Therapists may need to caution patients about setting a goal of independent ambulation when injury severity and progress suggest it is unrealistic\(^20\)
  - **Vocation/avocation and associated repetitive behaviors, if any**: Does the patient work? If so, inquire about the nature of the work. Many patients will have difficulty returning to their previous level of employment, and may require vocational rehabilitation. Does the patient participate in recreational or competitive sports or activities? Inquire about social behaviors, including consumption of alcohol and habitual use of other substances
  - **Functional limitations/assistance with ADLs/adaptive equipment**: Does the patient require assistance with ADLs? Does the patient use assistive devices or adaptive equipment to complete ADLs? Is any assistive technology in use?
  - **Living environment**: What is the patient’s current living arrangement? Inquire about home, including stairs, number of floors in home, with whom patient lives, caregivers, etc. Identify if there are barriers to independence in the home; any
modifications necessary? What community resources are available; is the patient able to access them? The Community Integration Questionnaire can be used.

Relevant tests and measures: (While tests and measures are listed in alphabetical order, sequencing should be appropriate to patient medical condition, functional status, and setting)

- **Arousal, attention, cognition (including memory, problem solving):** Obtain neuropsychological testing results where available. Note patient’s orientation to person, place, and time. Level of cognitive functioning (LOCF) may be assessed using the Rancho Los Amigos LOCF Scale. See the Clinical Reviews on TBI at various Rancho Los Amigos LOCFs, referenced above, for more information. Common problems in this population include
  - poor memory
  - poor attention and concentration
  - poor decision making
  - impulsivity
  - disorientation
  - language and communication difficulties
    - Inability to speak
    - Inability to understand when spoken to

- **Assistive and adaptive devices:** Note all equipment being used, including wheelchair, ambulatory assistive devices, splints, and pressure-relieving cushions or mattresses
  - Assess for appropriateness, fit, and correct use of ambulatory assistive devices being utilized
  - Document any assistive technology to enhance cognitive functioning, including computers, memory aids, etc.
  - Document equipment used for performance of ADLs

- **Balance:** Clinical balance scales that may be used include the Berg Balance Scale and the Standing Balance Scale. The Berg Balance Scale has been reported to have a ceiling effect in chronic TBI. Lateral displacement of the center of mass (COM) is considered a measure of dynamic balance. This is usually tracked in 3 dimensions in gait analysis laboratories.

- **Cardiorespiratory function and endurance:** Patients with TBI tend to have reduced cardiorespiratory endurance
  - Oxygen saturation, blood pressure, and heart rate should be monitored during physical activity
  - 6-minute walk for distance test (6MWT) can be used to measure endurance

- **Circulation:** Patients may be at risk for DVT
  - Among rehabilitation patients, the ability to ambulate more than 100 feet is considered a milestone that must be reached to discontinue DVT prophylaxis
  - Assess for symptoms associated with DVT, including leg swelling, pain on palpation of calf or thigh, and Homan’s sign (calf pain with dorsiflexion of the foot)

- **Functional mobility** (including transfers, etc.)
  - The FIM or Rivermead Mobility Index may be used to assess functional mobility
  - The Functional Assessment Measure (FAM) includes functional mobility areas not covered in FIM
    - Addresses community access, reading, writing, safety, employability, and adjustment to limitations
  - The Timed Up and Go (TUG) test may be used

- **Gait/locomotion**
  - Where available, obtain results of computerized 3 dimensional (3D) gait analysis
    - Reflective markers are mounted on the skin at specific locations on the pelvis and lower limbs
    - Spatiotemporal, kinematic, and kinetic data are captured
  - Observational gait analysis (OGA) such as Rancho Los Amigos OGA is commonly performed
    - Gait is divided into stance and swing phases and focus is on the cyclical movements occurring in gait cycle, noting asymmetries and deviations
    - Note any compensatory strategies secondary to device use, such as forward trunk flexion with walker use or asymmetry with cane use
  - Observational gait analysis for adults with TBI has been reported to have relatively low accuracy
  - In a study of the accuracy of clinical visual observations of gait disorders following TBI, conducted in Australia, observer inaccuracy ranged from 30% to 50% for most kinematic variables
  - Kinematic and ground reaction force data during gait were collected and video recordings made. Some of the gait abnormalities apparent on these analyses were not detected by observational gait analysis.
- The most common gait abnormalities identified by computerized analysis were related to pelvic and trunk movement and to excessive knee flexion at initial foot contact.

- The key biomechanical abnormalities of gait after TBI are not yet fully determined. Descriptors such as hemiparesis and ataxia are often used, but the underlying biomechanical deficits causing these clinical pictures after TBI are not well established.

- Data from this study suggest that abnormal gait events in TBI occur independently of each other rather than in consistent patterns.

- Individuals with TBI were found to have multijoint gait abnormalities.

- Gait disorders associated with TBI were found to be classifiable into clinically relevant and distinct subgroups in a study conducted in Australia.(22)

- Classification was based on kinematic data of the pelvis and lower limbs.

- Data from 102 persons with TBI were analyzed.

- Statistical features related to movements of the pelvis, hip, knee, and ankle on the less affected leg were able to distinguish between and accurately classify most persons with TBI-related gait disorders into 1 of the following 6 distinct subgroups identified by clinical observation:

  - Spastic hemiparesis
  - Nonspastic hemiparesis
  - Ataxia/dyspraxia, unilateral
  - Spastic bilateral paresis
  - Nonspastic bilateral paresis
  - Ataxia/dyspraxia, bilateral

- Where 3D gait analysis data are unavailable, clinical measurement of parameters such as cadence, step length, stance time on the affected leg, and width of base of support may be made.

- 10-meter walk test (10MWT) – can be used to measure gait speed.(23)

- Results of a prospective reliability study involving 23 patients with TBI showed that the 10MWT is a reliable measure of gait velocity in adults with acute TBI for both self-selected pace and fastest pace.(23)

- Reduced gait speed is common after TBI(9)

  - Biomechanical factors such as reduced ankle power generation or reduced hip joint power generation appear to account for the reduced speed, rather than postural instability or increased caution(9)

- Dynamic Gait Index (DGI) – assesses overall dynamic gait function and fall risk.

  - The DGI is reported to predict falls better than the Berg Balance Scale or the Falls Efficacy Scale in TBI, but it does not correlate well with gait deviations detected with motion analysis.(21)

- The 3-D gait analysis measurements of medial/lateral displacement and velocity during dual-task walking regressed in adolescents with concussion after their return to activity, suggesting that monitoring needs to continue even beyond point of clinical recovery.(29)

- Based on a study conducted in the United States of 19 adolescents with concussion who returned to preinjury activity within 2 months.

- **Joint integrity and mobility:** Assess passive ROM and joint stability as indicated.

  - Patients may be at risk for knee hyperextension injuries due to abnormal gait pattern(4)

  - Patient may have concomitant musculoskeletal injuries

  - Assess the cervical spine as indicated. Symptoms such as dizziness or headaches may arise from cervical spine issues.

- **Motor function (motor control/tone/learning):** Assess muscle tone, coordination, and movement patterns.

  - Modified Ashworth Scale may be used to assess tone.

  - Fugl-Meyer Assessment of Motor Recovery or Chedoke-McMaster Stroke Assessment may be used for assessment of motor control(10)

    - Originally developed for poststroke hemiparesis population

    - Characteristic movement disorders include abnormal timing and trajectory of limb movements.

    - Assess equilibrium and protective reactions

    - Testing of neurological developmental sequencing may be indicated(11)

    - Assess eye-head coordination

    - Assess for cerebellar signs (e.g., intention tremor, dysdiadochokinesia, nystagmus).
- Patient may exhibit apraxia, which is a deficit in the ability to carry out skilled acts unrelated to deficits in motor power or mental capacity. There are several types:
  - Constructionsal apraxia – inability to put elements together to form a meaningful whole
  - Ideational apraxia – inability to plan even a simple action
  - Ideokinetic apraxia – loss of coordination between formation of ideas and motor activity; affected individuals can do certain things automatically but not deliberately
  - Motor apraxia – inability to perform fine motor acts
- Muscle strength: Assess trunk and lower extremity muscle strength using manual muscle testing (MMT) as appropriate
  - In presence of spasticity, MMT is not valid
  - Impaired motor control and abnormal muscle tone may obscure strength deficits
- Observation/inspection/palpation (including skin assessment): Symptoms of dysautonomia may be observed. These may include increased body temperature, tachycardia, tachypnea, and profuse sweating
- Perception: Patient may have visual and perceptual dysfunction. Common findings include oculomotor abnormalities, visual field deficits, and deficiencies in visual acuity
- Posture: Assess body alignment for asymmetric posture in sitting, standing, and walking. Note asymmetry in weight-bearing
- Range of motion: Assess active and passive ROM and flexibility of the lower extremities. Assess spine as indicated
- Reflexes: Assess deep tendon reflexes for asymmetry and hyper- or hyporeflexia
- Special tests specific to diagnosis
  - Use of discrete tasks (cognitive or performance) to measure balance and gait in a rehabilitation setting may not reflect the level of functional impairment patients with TBI will experience once they leave rehabilitation
  - Cognitive tasks have a detrimental effect on balance and postural stability
  - Mobility tests that incorporate dual-task conditions may be indicated to test walking while performing a secondary task. Times are noted under single- and dual-task conditions. Higher times indicate a higher risk of falls
    - Timed Up and Go (TUG) test, manual (TUG manual)
      - Patient instructed to stand up, walk 3 meters, turn around, and sit down
      - Secondary task would be carrying a cup of water
    - TUG test, cognitive (TUG cognitive)
      - Patient instructed to stand up, walk 3 meters, turn around, and sit down
      - Secondary task would be subtracting by 3 from a randomly selected number between 20 and 100
    - Multiple Tasks Test (MTT)
      - Patient to stand up, walk, turn around, and sit down
      - Additional tasks are added, such as avoiding obstacles, carrying an empty tray, carrying a loaded tray, low-light conditions
    - Walking and Remembering Test (WART)
      - Faster walking pace for 20 feet (12 inches wide)
      - Secondary task is “forward digit span task”
      - Examiner records walking time, number of steps off of path, and digit span recall
    - DGI and Functional Gait Assessment
      - Performance of walking with additional tasks, such as turning head or avoiding obstacles

Assessment/Plan of Care

- Contraindications/precautions
  - Patients with this diagnosis are at risk for falls; follow facility protocols for fall prevention and post-fall-prevention instructions at bedside, if inpatient. Ensure that patient and family/caregivers are aware of the potential for falls and educated about fall-prevention strategies. Discharge criteria should include independence with fall-prevention strategies
  - Clinicians should follow the guidelines of their clinic/hospital and what is ordered by the patient’s physician. The summary presented below is meant to serve as a guide, not to replace orders from a physician or a clinic’s specific protocols
- Diagnosis/need for treatment: Gait abnormalities due to motor, cognitive, and/or behavioral dysfunction secondary to TBI. Treatment is indicated for prevention of adverse effects associated with gait abnormalities, including falls, reduced aerobic fitness, and limited community access
Rule out: Other causes of altered gait and/or altered mental status, including musculoskeletal injuries, infection, toxicologic causes, and metabolic causes

Prognosis: Patients may improve for years. Prediction of outcome is difficult

- Poorer prognosis is associated with low GCS on admission, nonreactive pupils, old age, comorbidity, midline shift
- Increased duration of coma and posttraumatic amnesia are associated with poorer prognosis
- In a retrospective study, the majority of patients with severe TBI admitted to rehabilitation recovered independent ambulation within 3 months of injury
  - Patients who were not independently ambulating by 3 months post injury were found to have only a 13.9% chance of recovery
  - Recovery of ambulation is more likely in TBI patients who are young, are less dependent with ambulation at the start of rehabilitation, and have less severe injuries
- Researchers of a five-year follow-up conducted in the United States of patients with severe TBI showed that the greatest gains occurred in the first year, although significant recovery continued 2 years post injury
- Outcome measures included the Disability Rating Index, FIM cognitive and motor subscales, and Supervision Rating Scale
  - Gains made between 2 and 5 years were greater in cognitive than in motor domains
  - Improvements in cerebellar ataxia have been reported to be greatest within the first 6 months post injury; however, results of case studies conducted in the United States showed that persons with severe ataxia secondary to TBI may continue to improve many years after injury
  - Three and a half years after participating in locomotor training and trunk stabilization intervention, an adult who was not expected to become a functional ambulator was reported to be an independent community ambulator
  - Three individuals in a case series had improvements in ataxia 1 to 6 years after injury after participating in long-term multidimensional therapeutic programs that included rock climbing on an artificial climbing wall to decrease ataxia and promote participation

Referral to other disciplines: A multidisciplinary group of specialists may be involved in the care of patients with TBI, including physiatrists, PTs, occupational therapists (OTs), orthotists, speech-language pathologists (SLPs), nurses, case managers, neuropsychologists, and social workers. Vocational trainers/counselors may also be involved. Team members should ideally be specially trained in the cognitive and behavioral issues that are unique to TBI rehabilitation

Treatment summary

- Gait training methods commonly used for patients with TBI include parallel-bar walking with hand support, manual facilitation by therapist, use of gait assistive devices, treadmill walking with handrail support, and body-weight-supported treadmill training (BWSTT). Aquatic therapy (walking in water) can also be tried
  - Researchers of a study conducted in Australia comparing different gait training methods found that no single method of training is best for improving overall dynamic gait coordination after TBI
    - Seven alternative gait training methods were applied in randomized order to 17 study participants with acquired brain injury and 25 healthy control subjects
    - Training strategies included in the study were therapist facilitation, gait assistive devices, treadmill training, and four BWSTT variations (alone, with therapist assistance, with upper limb self-support, and with combined therapist assistance and upper limb self-support)
    - The movement of the COM (amplitude, timing, and steadiness) was analyzed
    - BWSTT with no other support or facilitation resulted in large COM displacements that were poorly timed within the gait cycle
    - The results of this study suggest that treadmill training with handrail support provides suitable task-specific training because it replicates the movement of the COM found in nonpathological gait. However, upper limb support may alter timing and variability of the gait cycle
  - BWSTT was compared to conventional overground gait training for 20 patients with chronic TBI in a randomized controlled trial conducted in the United States
    - Conventional gait training was found to be more effective than BWSTT for improving gait symmetry during overground walking in individuals greater than 6 years post TBI
Conventional gait training consisted of walking on level surfaces with whatever assistive device the PT determined was appropriate for 15 minutes 2 days per week. BWSTT was provided in 15-minute sessions, starting with 30% de-weighting at the fastest speed the subject could tolerate. Body weight support was decreased in increments over 3 months.

- Improvements in step width were obtained in both groups. No changes in velocity occurred in either group. Gait symmetry improved significantly more in the conventional gait training group.

- Results of a randomized controlled trial conducted in the United States comparing conventional physical therapy and physical therapy augmented with BWSTT in a population of inpatients with TBI of 2.8–4 months duration also did not support the hypothesis that BWSTT improves ambulation more than conventional physical therapy.

- Thirty-eight adults with TBI and significant gait abnormalities were randomized into 2 groups, one receiving standard physical therapy and the other receiving standard physical therapy supplemented by BWSTT twice per week. Standard therapy included neurofacilitation, isometric exercises, and assisted ambulation using gait belts and walking aids as indicated. The experimental group received BWSTT instead of the ambulation, keeping total physical therapy time equal for both groups.

- Outcome measures included the Functional Ambulation Category, Standing Balance Scale, Rivermead Mobility Index, and FIM.

- After 8 weeks, significant improvements were observed in both groups, but no differences were found between the treatment groups.

- A combined intervention of BWSTT and trunk stabilization exercises has been reported to be effective in improving gait and balance in a subject with severe ataxia secondary to TBI in a case study conducted in the United States.

- Relative contributions of each intervention could not be determined, and optimal intensity and duration are not known.

- Indications for use of BWSTT in TBI and its optimal usage are not fully established.

- Robotic-assisted treadmill training and manually assisted treadmill training are variations of BWSTT that are also used with patients with TBI.

- For more information on robot-assisted gait training, see Clinical Review... Gait Training: Robotic-Assisted; Item Number: T709290.

- Combined robotic-assisted gait training (RAGT) and PT may improve functional activities and gait pattern more than PT alone in adolescents and children with acquired brain injury (ABI).

- Based on a comparison study conducted in Italy of 23 patients with ABI who underwent 20 sessions of RAGT+PT and 20 patients who underwent PT only.

- Outcome measures were functional clinical scales and 3-D gait analysis.

- RAGT+PT patients who were ambulatory improved significantly in 6MWT, cadence, velocity and stride length as well as an increase in hip ROM during gait cycle.

- No differences in improvement in gait velocity, endurance, or Stroke Impact Scale scores were found between robotic-assisted treadmill training and manually assisted treadmill training in a randomized study conducted in the United States.

- Robotic-assisted gait training did result in greater improvement in symmetry of gait (step length).

- Sixteen patients with TBI participated.

- Gait training was for 45 minutes, 3 times per week for a total of 18 training sessions.

- Improvements occurred in both groups.

- Vestibular rehabilitation

- Vestibular physical therapy (VPT) has been reported to improve target following and dynamic visual acuity in individuals with blast-induced mild TBI in a study conducted in the United States.

- Treatment included exercises for the vestibulo-ocular reflex, the cervico-ocular reflex, and depth perception, and somatosensory balance exercises, dynamic gait, and aerobic function exercises. Vestibulo-ocular reflex, cervico-ocular reflex, and depth perception exercises were graded in difficulty based on velocity of head and object motion.

- Eighty-two patients with blast-induced balance disorder attended VPT for 1 hour twice weekly and were instructed to do the exercises at home on all other days.

- Target following and dynamic visual acuity returned to normal after 8 weeks of treatment. Gaze stabilization scores improved but remained below normal levels at the 8-week evaluation. A treatment period of 12 weeks was therefore suggested.
Mean DGI score was increased at 8 weeks, and all participants obtained the maximum DGI score of 24 after 12 weeks of VPT.

Virtual reality training

- Advancements in virtual reality technologies allow for training in complex environments that may be impossible or impracticable to create in the rehabilitation setting\(^{16}\).

Applications for movement disorders are being developed and include use of simulated environments to challenge patients during gait training.

Advantages over traditional gait training include the possibility of controlling duration, intensity, and feedback during treatment.

City and rural landscapes may be simulated, and lifelike scenarios such as street crossing, collision avoidance, and park strolling may be introduced.

In a study in Switzerland of virtual reality–based training for robot-assisted gait training in children, patients with neurological gait disorders and healthy control subjects both participated more actively with virtual reality–based training\(^{17}\).

- Ten children with neurological gait disorders, including 2 with TBI, and 14 children without gait disorders participated.
- Active participation is considered necessary for motor learning to occur.
- Further research is needed to determine whether an increase in active participation does in fact lead to better functional outcomes.

<table>
<thead>
<tr>
<th>Problem</th>
<th>Goal</th>
<th>Intervention</th>
<th>Expected Progression</th>
<th>Home Program</th>
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</thead>
<tbody>
<tr>
<td>Gait disturbances, slow walking speed, poor endurance, and dependence in ambulation</td>
<td>Improve gait pattern and walking performance</td>
<td><strong>Gait training</strong>&lt;br&gt;Methods include parallel bar walking, therapist-facilitated walking, treadmill walking, BWSTT, RAGT, walking with assistive devices, walking in water&lt;br&gt;A gait training program that uses a variety of techniques may be beneficial(^{6}) (See Treatment summary, above)</td>
<td>Walking exercises may be graded in difficulty by changing directions, walking with eyes closed, increasing speed, walking on soft or uneven surfaces, or climbing stairs(^{15})</td>
<td>Patient should be provided with instructions for a home walking program, with assistive devices if indicated, focusing on safety as patient progresses to community ambulation</td>
</tr>
<tr>
<td>Weakness and impaired motor control of trunk and lower extremities</td>
<td>Improve strength and motor control of trunk and lower extremities</td>
<td><strong>Therapeutic exercise</strong>&lt;br&gt;Lower-extremity progressive resistive exercises&lt;br&gt;Weight-bearing activities</td>
<td>Gradual progression of intensity of exercises should result in greater trunk and lower limb stability/control</td>
<td>Instructions for home program of strengthening exercises should be provided</td>
</tr>
<tr>
<td>Poor balance</td>
<td>Improve balance</td>
<td><strong>Therapeutic exercise</strong></td>
<td>Progression depends on severity of injury</td>
<td>Provide patient and family/caregivers with written instructions regarding functional activities that can be performed at home and correct use and/or of equipment</td>
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<td>Balance training</td>
<td>Initially patient may work on static balance in standing, progressing to dynamic balance and weight shifting with and without support</td>
<td>Vestibular training may be graded by increasing velocity of head movements (15)</td>
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<tr>
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<td>Vestibular rehabilitation</td>
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<tr>
<th>Cardiovascular deconditioning</th>
<th>Improve aerobic fitness</th>
<th><strong>Therapeutic exercise</strong></th>
<th>Progress each unique patient as indicated</th>
<th>Provide activities that patient and family can perform safely at home</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Walking – overground or treadmill</td>
<td>Aerobic exercise can be progressed by adjusting the time, speed, or distance</td>
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<td>Recumbent cycling, arm ergometry, and aquatic therapy are alternatives to walking that may be used to improve fitness (if safely tolerated)</td>
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<th>Impaired ROM/ potential for contractures</th>
<th>Improve ROM and resolution of contractures</th>
<th><strong>Therapeutic exercise</strong></th>
<th>Progress each unique patient as indicated</th>
<th>Functional activities using full available ROM</th>
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<tr>
<td></td>
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<td>Lower extremity ROM exercises</td>
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<td><strong>Therapeutic modalities</strong></td>
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<td></td>
<td>Manual joint mobilizations and stretching of tight tissues as indicated</td>
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<tr>
<th>Risk for falls</th>
<th>Decreased fall risk</th>
<th><strong>Fall prevention strategies</strong></th>
<th>Independence in fall prevention strategies, safe use of ambulatory assistive devices</th>
<th>Educate patient and family/caregivers about strategies and home modifications such as installation of grab bars, removal of obstacles, adequate lighting</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>Home modifications, proper use of ambulatory assistive devices</td>
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</table>
Desired Outcomes/Outcome Measures

- Desired outcomes and outcome measures
  - Improved patient and caregiver safety
  - Improved motor control
    - Modified Ashworth Scale, Fugl-Meyer Assessment of Motor Recovery
  - Improved balance
    - Berg Balance Scale, Standing Balance Scale
  - Improved functional mobility
    - FIM, FAM, Rivermead Mobility Index, TUG test
  - Improved performance of ADLs
    - Disability Rating Index
  - Increased tolerance to positions and activities
  - Increased independence with ambulation with or without assistive device
    - DGI, 6MWT, 10-meter walk test, 3-D gait analysis
  - Decreased level of supervision and assistance where appropriate

Maintenance or Prevention

- Prevent falls
  - Home hazard assessment and modification should include removing obstacles, installing transfer rails, and providing adequate lighting
  - Increase awareness of patient and family members of risk of falls
- Maintain the highest achievable ROM, strength, and function of the affected limbs
- Maintain fitness level and participation in activities
- Reduce risk of brain injury(1)
  - Appropriate use of helmets, seatbelts
  - Education of coaches, athletes, and parents about sport-related risk

Patient Education

- Website for caregivers of service members and veterans with moderate to severe TBI, http://www.dvbic.org/family-caregiver-curriculum
- BrainLine, a national multimedia project offering information and resources about preventing, treating, and living with TBI, https://www.brainline.org/video/caring-and-tbi-what-you-need-know
- Brain Injury Association of America, a brain injury advocacy organization, has useful information at their website, http://www.biausa.org/

Note

- Recent review of the literature has found no updated research evidence on this topic since previous publication on January 20, 2017

Coding Matrix

References are rated using the following codes, listed in order of strength:

- M Published meta-analysis
- SR Published systematic or integrative literature review
- RCT Published research (randomized controlled trial)
- R Published research (not randomized controlled trial)
- C Case histories, case studies
- G Published guidelines
- RV Published review of the literature
- RU Published research utilization report
- QI Published quality improvement report
- L Legislation
- PGR Published government report
- PFR Published funded report
- PP Policies, procedures, protocols
- X Practice exemplars, stories, opinions
- GI General or background information/texts/reports
- U Unpublished research, reviews, poster presentations or other such materials
- CP Conference proceedings, abstracts, presentation
References


