Gait Training, Robotic-Assisted

Indexing Metadata/Description

- **Device/equipment:** Gait Training, Robotic-Assisted
- **Synonyms:** Robotic gait training; robot-assisted gait training; robot-aided gait training; electromechanical gait training; robotic-assisted step training; robotic locomotor training; robotic-assisted gait training
- **Area(s) of specialty:** Neurological rehabilitation, pediatric rehabilitation, orthopedic rehabilitation
- **Description/use:** A method of gait training using assistive technology that makes use of automated devices to move and exert mechanical forces on the body
  - Robotic-assisted gait training was developed to overcome disadvantages inherent in body-weight-supported treadmill training (BWSTT) used for restoration of gait following stroke, traumatic brain injury (TBI), spinal cord injury (SCI), and other neurological conditions\(^1\,^2\,^3\,^4\,^5\,^6\)
    - Without robotic assistance, two or three therapists are required to assist a patient’s gait during treadmill training
    - One therapist is required to manually place each affected leg, and another therapist assists lateral weight shifting and upright trunk positioning
    - The correct assistance of leg movements during the training is crucial. The most advantageous input to the spinal cord is only attained if the legs are moved in as normal of a gait pattern as possible
    - As therapists start to experience fatigue, the patient’s gait can become asymmetrical and the benefit of repetitive practice decreases
  - Robotic-assisted gait trainers are mechanized devices that enable the repetitive practice of physiological gait patterns without relying on therapists. Robots have the potential to deliver training more consistently because they do not fatigue, and can be used to quantify and control the variables associated with assistance more accurately than human therapists.\(^7\) Other advantages include:
    - Training can start earlier after trauma or neurological insult because the robotic devices generate more power than a human being
    - The duration of the training can be longer, allowing more opportunity for repetitive practice
    - Training is less costly, with only one therapist required
  - Robotic-assisted gait training involves the use of an exoskeleton device to improve motor coordination\(^6\,^8\)
    - The exoskeleton is an external structural mechanism with joints and links corresponding to those of the human body. These robots use joint trajectories of the entire gait cycle and provide uniform control along this trajectory\(^6\)
    - Alternatives to powered exoskeletons are devices that use movable footplates attached to the patient’s feet
    - Body weight support is an integral part of the training
  - Feedback about the quality of movement and extent of muscle activity is important for gait training. These are difficult for patients to assess themselves, especially if sensory, proprioceptive, or cognitive impairments are present
Therapists have less contact with patients during robotic-assisted gait training compared to manually assisted partial BWSTT. Therefore, they are less able to assess the patients' involvement.

- Muscle strength, muscle tone, and ROM of the lower limb might be measured by potentiometers and force transducers in some robotic devices.
- Online feedback about joint movement and force production can be provided.

Commercially available robotic gait machines include the Gait Trainer (GT) with variations referred to as GT I, GT II and MGT (for Mechanized Gait Trainer, Reha-Stim, Berlin, Germany), which control endpoint trajectories; the Lokomat (Hocoma Medical Engineering Inc, Zurich, Switzerland); the AutoAmbulator (HealthSouth, Birmingham, Alabama), which uses robotic exoskeletons and a treadmill; and the LOPES (Lower-extremity Powered ExoSkeleton, Laboratory Biomechanical Engineering, University of Twente, Enschede, the Netherlands), which is designed specifically for research.

Please see Clinical Review...Stroke: Gait Training; CINAHL Item Number: T708722 and Clinical Review...Traumatic Brain Injury: Gait Training; CINAHL Item Number: T709258 for more information specific to these conditions. See also the series of Clinical Reviews on spinal cord injury and cerebral palsy.

HCPCS codes: There are no specific codes for robotic-assisted gait training.

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
G-code Modifier | Impairment Limitation Restriction
---|---
CH | 0 percent impaired, limited or restricted
CI | At least 1 percent but less than 20 percent impaired, limited or restricted
CJ | At least 20 percent but less than 40 percent impaired, limited or restricted
CK | At least 40 percent but less than 60 percent impaired, limited or restricted
CL | At least 60 percent but less than 80 percent impaired, limited or restricted
CM | At least 80 percent but less than 100 percent impaired, limited or restricted
CN | 100 percent impaired, limited or restricted


Reimbursement: Robotic-assisted rehabilitation is generally considered experimental and investigational for stroke and for all other indications (e.g., neuromuscular diseases) due to insufficient evidence of its effectiveness.

Indications for device/equipment:

Robotic-assisted gait training is indicated for select patients with walking disabilities due to neurologic and orthopedic disorders, including:

- Stroke
- Paraplegia
- TBI
- Cerebral palsy
- Parkinson’s disease (PD)
- Multiple sclerosis (MS)
- Guillain-Barré syndrome
- Transverse myelitis
- Endoprosthesis surgery (e.g., total hip endoprostheses)
- Osteoarthritis
- Muscle weakness

The decision to use robotic versus manual PBWSTT is generally determined by clinical judgment of the therapist in agreement with the patient, taking into consideration the patient’s overground ambulation ability, trunk control, motor control, and spasticity.

- This decision should be based on clinical decision algorithms as well as financial feasibility.
- Both types of assistance have advantages and disadvantages and are indicated for different populations and at different times during recovery.
- To determine the method and device that is best to use with a given patient, the therapist must know the literature and the features of the devices in question.
- Manually assisted PBWSTT might be indicated for patients who can actively step on independently, whereas robotic assistance might be indicated for individuals with more deficits in walking.
– Robotic assistance is an appropriate treatment for patients with spasticity as it can detect patient output, give feedback, and can provide consistent stepping for long durations. Robotic-assisted gait training can be used in combination with functional electric stimulation, which has demonstrated greater benefits than utilizing robotic-assisted gait training alone. Manual assistance can more easily be combined with electrical stimulation, can be adjusted through each gait cycle, and provides patients the opportunity to self-manage aspects of their gait cycle rather than being completely passive.

**Guidelines for use of device/equipment**

› The Lokomat is a bilateral orthosis used along with a PBWSTT system that controls patient’s movements in the sagittal plane.
  - The patient is fitted with a weight-supporting harness that is placed around the hips and abdomen snugly enough to minimize upward slipping
  - The patient is wheeled via wheelchair onto the treadmill via a ramp
  - The harness is attached to the cables on the body weight support system
  - The patient is assisted to stand using a motor driven lift
  - The gait orthoses system is secured to the standing patient by straps. Hip and knee joints are integrated into the exoskeleton structure. The robotic force arms and robotic drive motor positions are adjusted based on femoral and tibial length measurements
  - When the patient is set up, the treadmill is started and the patient is lowered to the treadmill. Treadmill speeds range from 1 to 3.2 km/hr
  - Motorized actuators at the hips and knees are programmed to produce normal physiologic gait patterns and to reproduce normal kinematics of gait. A rubber foot lifter passively dorsiflexes the ankle during swing phase to assist clearance
  - The patient’s legs are moved with repeatable, predefined hip and knee trajectories

› AutoAmbulator
  - The patient is fitted with a hard-shelled harness that encloses the lower abdomen and trunk region with straps between the legs
  - Weight-bearing is through the pubis and ischial tuberosities
  - The patient is wheeled onto the treadmill via a ramp
  - The hard-shelled harness is attached to the overhead lift mechanisms
  - The articulated arms are locked into their operational positions. Each arm has motor driven pivot joints at the hip and knee
  - There is no integrated attachment to control for ankle plantar flexion and dorsiflexion. Ankle position might be set with an ankle foot orthoses or wrap bandage as required for limb clearance during swing
  - Trunk stability is provided by adjusting braces that attach to each side of the shell and to the treadmill frame
  - When the patient is set up, the treadmill is started and the patient is lowered to the treadmill. Treadmill speeds range from 0 to 2.4 km/hr

› Gait Trainer
  - Does not work in conjunction with a treadmill
  - Based on a crank and rocker gear system, it provides limb motion similar to an elliptical trainer
  - Consists of 2 footplates coupled to rockers
  - A modified parachute harness is fitted and the patient is assisted to standing with a manually operated crank arm attached to the overhead support line and pulley
  - The patient initially stands outside the device and is required to ambulate with or without assistance into the device and place feet in the footplates
  - The patient does not have to be fitted to an orthotic device so adaptation to different sized patients, including children, is possible
  - Due to the need for some ambulatory ability to get into the device, it might be more suitable for individuals with hemiplegia than individuals with paraplegia
  - In all devices, parameters are set according to the individual’s needs
  - During treatments the velocity is generally set to the maximum speed tolerated by the patient.
  - Usually about 50% of body weight is supported by the harness at first. During subsequent sessions support might be decreased in approximately 10% increments as tolerated without knee buckling or toe drag
  - Gait drive components are computer driven with a touch screen control interface
Contraindications/Precautions to device/equipment

- **Contraindications** *(2)*: See specific contraindications/precautions to examination and contraindications/precautions under Assessment/Plan of Care
  - Body weight greater than 300 lbs
  - Severe fixed joint contractures
  - Bone instability (nonconsolidated fractures, unstable spinal column, severe osteoporosis)
  - Skin lesions on the lower extremities or torso
  - Circulatory problems
  - Severe vascular disorders of the lower extremities
  - Cardiac contraindications to exercise
  - Severe cognitive deficits
  - Uncooperative or aggressive behavior
  - Mechanical ventilation
  - Extreme or uncorrected leg length discrepancy
  - Severe scoliosis
  - Hip, knee, ankle arthrodesis
  - Mobility restrictions due to inflammatory or infectious disorders (e.g., osteomyelitis)
  - Orthosis not adaptable to the patient’s body (lower limbs)

- **Precautions**
  - Precautions that apply to individual pathologies should be followed. Examples include:
    - Orthostatic hypotension
    - Autonomic dysreflexia
    - Bladder and bowel control problems
    - Decreased sensation
    - Increased muscle tone that interferes with the functioning of the machine *(10)*
    - Long-term access ports (e.g., colostomy, gastrointestinal tube) where the equipment might disrupt position or increase pressure at the site *(10)*
  - It is recommended that the therapist or caregiver perform skin checks before and after treatment to monitor skin integrity *(10)*
    - Skin-related adverse events have been reported *(27)*. Patients should be instructed to wear long cotton exercise pants and tall cotton socks and to inform the clinician of any discomfort or rubbing *(27)*
    - Training duration might need to be modified if skin breakdown occurs
  - Short training sessions with a high level of support are recommended initially *(2)*
    - Training duration should be increased gradually
    - There is a risk of excessive strain on ligaments, tendons, joints, and bones if training sessions are too long or too frequent
    - Patients might need to be reminded to progress slowly. It is not uncommon for patients to feel excited after the initial session, and to want more and longer sessions
  - It is recommended that clinicians receive specialized training prior to implementing robotic-assisted gait training *(10)*

Examination

- **Contraindications/precautions to examination**: Depend on the underlying condition for which this device is used
  - Contraindications
    - Deep vein thrombosis (DVT) – Therapist should stop evaluation immediately and contact physician if patient presents with signs of DVT
  - Complications associated with neurological conditions requiring precaution during examination might include:
    - Decreased bone density
    - Muscle atrophy
    - Soft tissue contractures
    - Decreased endurance
    - Heterotopic ossification
– Venous stasis
– Infection
– Pain
– Pre- and postoperative restrictions
– Agitation, emotional lability

› History

• History of present illness/injury for which the device is needed
  – Mechanism of injury or etiology of illness: Describe history of patient’s condition, including onset, progression, complications, and treatment. Document initial Glasgow Coma Scale score for TBI patients and initial ASIA Impairment Scale (AIS) score for SCI patients

• Course of treatment
  - Medical management: Describe emergency management, hospitalizations, surgeries, immobilization, and weight-bearing status as relevant to the condition
  - Medications for current illness/injury: Determine what medications clinician has prescribed; are they being taken? Are they effective? Medications commonly prescribed for neurological conditions include:
    - Seizure prevention medications (e.g., levetiracetam [Keppra], phenytoin [Dilantin])
    - Medications for spasticity (e.g., tizanidine [Zanaflex])
    - Antidepressants
  - Diagnostic tests completed: Depends on underlying condition. Diagnostic imaging results such as radiographs, MRI, ultrasound, and electromyographic (EMG) test results should be obtained when available
  - Home remedies/alternative therapies: Document any use of home remedies (e.g., ice or heating pack) or complementary therapies (e.g., acupuncture), what they are used for, and whether or not they help
  - Previous therapy: Document whether patient has had occupational or physical therapy for this or other conditions and what specific treatments were helpful or not helpful. Describe any gait training the patient has already completed

• Aggravating/easing factors (and length of time each item is performed before the symptoms come on or are eased)

• Body chart: Use body chart to document location and nature of symptoms

• Nature of symptoms: Document nature of symptoms (e.g., pain, spasticity, weakness, sensory impairment)

• Rating of symptoms: Where 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; document changes related to activity or fatigue

• Sleep disturbance: Document number of wakings/night

• Other symptoms: Document other symptoms patient might 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)

• Respiratory status: Any history of respiratory compromise or use of supplemental oxygen?

• Barriers to learning
  - Are there any barriers to learning? Yes__ No__
  - If Yes, describe ______________________

• Medical history
  – Past medical history
    - Previous history of same/similar diagnosis: Document history of same or similar diagnosis
    - Comorbid diagnoses: Ask patient about other 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 about other symptoms he or she might be experiencing

• Social/occupational history
  – Patient’s goals: Document what the patient hopes to accomplish with therapy and in general
  – Vocation/avocation and associated repetitive behaviors, if any: Does the patient attend school? If so, what grade level? Is the patient employed? If so, what is the nature of the work? Does the patient participate in recreational activities or sports? Are there any barriers to accessing the community?
Functional limitations/assistance with ADLs/adaptive equipment: (include limitations with self-care, home management, work, community leisure)

Living environment: 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?

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)

• Anthropometric characteristics
  – Document patient’s height, weight, and body mass index (BMI)
  – Robotic-assisted gait training is contraindicated when body weight is greater than 300 lbs. (135 kg)
  – Measure lower extremity length and girth
  – Robotic exoskeleton must be able to accommodate femur length measured from greater trochanter to knee joint line (must be 35-47 cm [13.75-18.5 inches] for Lokomat)
  – Individuals with a major difference (> 2 cm) in leg length might not be accommodated by robotic legs (Lokomat)

• Arousal, attention, cognition (including memory, problem solving): Assess orientation to name, place, time, and situation; attention; short- and long-term memory; and problem solving as indicated. Obtain neuropsychological testing results where available. Problems occurring in neurological conditions might include:
  – Poor memory
  – Poor attention and concentration
  – Poor decision making
  – Impulsivity
  – Emotional lability
  – Disorientation
  – Language and communication difficulties
    – Inability to speak
    – Inability to understand when spoken to

• Assistive and adaptive devices: Describe any assistive and adaptive devices that patient uses. Assess need for splints or orthoses (e.g., ankle-foot orthoses) as indicated

• Balance: Assess sitting and standing balance using a standardized test such as Berg Balance Scale or Pediatric Balance Scale where indicated

• Cardiorespiratory function and endurance: Monitor blood pressure, heart rate, respiratory rate, and/or oxygen saturation as indicated. The Borg Rating of Perceived Exertion (RPE) Scale might be used to assess exercise intensity

• Circulation: Check lower extremity pulses for signs of diminished circulation

• Functional mobility: Assess functional mobility using standardized tests such as the Rivermead Mobility Index, Timed Up and Go (TUG) test, FIM, or WeeFIM as indicated by patient’s condition

• Gait/locomotion: Perform a complete gait assessment as able
  – What is the patient’s current ambulatory status?
  – Results of several studies have suggested that robotic-assisted gait training yields greater improvements for patients who are nonambulatory than for patients who ambulate
  – Does the patient use assistive devices?
  – Note any compensatory strategies secondary to device use, such as forward trunk flexion with walker use or asymmetry with cane use
  – Observational gait analysis (OGA) such as Rancho Los Amigos OGA can be performed
  – Gait is divided into stance and swing phases and focus is on the cyclical movements occurring in gait cycle, noting asymmetries and deviations
  – 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
  – 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 might be made
  – 10-meter walk test (10MWT) can be used to measure gait speed
  – Dynamic Gait Index (DGI) – assesses overall dynamic gait function and fall risk
  – Walking Index for Spinal Cord Injuries, Second Edition (WISCI-II) – assesses the amount of physical assistance needed as well as devices required for walking following SCI
• **Joint integrity and mobility:** Assess passive ROM and joint stability as indicated  
  – Patients might be at risk for joint injuries due to abnormal gait patterns (e.g., knee hyperextension)

• **Motor function (motor control/tone/learning)**  
  – Assess muscle tone, coordination, and voluntary movement ability  
  – The Modified Ashworth Scale can be used to assess tone; the Spinal Cord Assessment Tool for Spasticity (SCATS) can be used to assess tone in patients with SCI\(^{13}\)  
  – Movement disorders might include abnormal timing and trajectory of limb movements  
  – Assess for presence of obligatory synergies, compensatory movement strategies, and selective voluntary muscle activation as indicated  
  - The Fugl-Meyer Assessment of Motor Recovery or Chedoke-McMaster Stroke Assessment can be used for assessment of motor control in poststroke or TBI patients  
  – Assess equilibrium and protective reactions  
  – Assess eye-head coordination as indicated  
  – Assess for cerebellar signs (e.g., intention tremor, dysdiadochokinesia, nystagmus) as indicated

• **Muscle strength:** Assess trunk and upper 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 might obscure strength deficits

• **Neuromotor development:** Use a standardized test such as the Peabody Developmental Motor Scales, Second Edition (PDMS-2) as indicated  
  – The Gross Motor Function Measure (GMFM) can be used to assess change in gross motor function in children with cerebral palsy

• **Observation/inspection/palpation** (including skin assessment): Assess for skin irritation or breakdown, particularly in areas that are in contact with the equipment (harness support and robotic orthoses)

• **Posture:** Assess body alignment for asymmetric posture in sitting, standing, and walking. Note asymmetry in weight-bearing. Assess spinal alignment and posture of head, neck, shoulders, trunk, pelvis, and lower extremities. Is the posture stooped (head forward and shoulders rounded)? Is the lumbar curve flattened or excessively lordotic?

• **Range of motion:** Assess bilateral lower extremity ROM and flexibility. Assess bilateral upper extremity, trunk and neck ROM as indicated

• **Reflex testing:** Assess deep tendon reflexes for asymmetry and hyper- or hyporeflexia as indicated. Assess for primitive reflexes in children with cerebral palsy and patients with neurological disorders

• **Self-care/activities of daily living** (objective testing): The Barthel Index might be used to assess ADLs

• **Sensory testing:** Assess bilateral upper and lower extremity light touch, temperature, and pinprick as indicated. Assess proprioception as indicated

### Assessment/Plan of Care

› **Contraindications/precautions:** See [Contraindications/Precautions to device/equipment](#) and [Contraindications/ precautions to examination](#), above  
  • **Patients for whom robotic-assisted gait training is indicated 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

› **Diagnosis/need for device/equipment:** Individuals with motor deficits making them unable to completely support their own weight and walk at physiological speeds might benefit from robotic-assisted gait training

› **Prognosis**  
  • Factors affecting prognosis for recovery of ambulation after stroke or TBI include severity of injury or impairment and ambulatory ability at start of rehabilitation  
  • **Prognosis for independent ambulation after TBI or SCI is poorer with increasing age**  
  • The most relevant prognostic factor for SCI patients is neurological status at initial examination.\(^{14}\) Prognosis for walking recovery after SCI is very good for patients classified as D (incomplete with muscle grade ≥ 3 in at least half of key muscles below the injury) on the ASIA Impairment Scale (AIS).\(^{14}\) Patients classified as A (motor and sensory complete)
at their first examination have a poor prognosis for functional walking. Motor incomplete (C) patients have a better prognosis for walking recovery than sensory incomplete patients (B)\(^{14}\).

- Prognosis for improving gait in patients with PD is uncertain. PD is progressive, and decline in motor function is expected within 5 to 7 years of diagnosis.
- The probability of walking without assistance 15 years after the diagnosis of MS has been reported to be about 60\%\(^{15}\).
  - A relapsing-remitting course and long inter-episode intervals in the early phase of the disease are associated with a better outcome\(^{15}\).

**Referral to other disciplines:** A multidisciplinary team might be involved in the care of patients with neurological disorders. Team members might include physiatrists, physical therapists (PTs), occupational therapists (OTs), orthotists, speech-language pathologists (SLPs), nurses, case managers, neuropsychologists, social workers, and vocational trainers/counselors.

**Treatment summary**

- Although robotic-assisted gait training has the potential to incorporate therapeutic principles such as task-oriented practice, repetition, and neuroplasticity, it should not be provided routinely in place of overground training\(^{16}\).
- Courses of robotic-assisted gait training are lengthy and expensive. Efficacy and cost-effectiveness have not yet been satisfactorily demonstrated.
- Overall training efficacy depends on several different parameters\(^{17}\).
  - Controversial results might reflect different methods used for enhancing activity during training interventions and protocols.
  - For example, protocols might include reducing body weight support, increasing treadmill speed, and/or reducing guidance force.

- A 2011 systematic review of the use of robotic devices for restoring walking function in adults with neurological disorders supports that gait training with robotic assistance is beneficial for improving walking function in individuals following stroke or SCI. There is limited evidence that robotic-assisted gait training is beneficial in populations of patients with MS, TBI, or PD\(^{1}\).
  - 14 RCTs and 16 nonrandomized controlled trials were analyzed.
  - A wide variety of neurological diagnoses, including stroke, SCI, MS, and TBI, were included. No literature on the effects of robotic-assisted gait training on patients with PD was found.
  - All studies used one of the following robotic devices: Lokomat, Gait Trainer (GT), or LokoHelp.
  - Initial evidence supports the effectiveness of robotic-assisted gait training, although its effect compared to other forms of locomotor training remains unclear.

- A 2013 Cochrane Review of electromechanical-assisted training for walking after stroke concluded that patients who receive electromechanical-assisted gait training in combination with physiotherapy after stroke are more likely to achieve independent walking than patients receiving gait training without electromechanical assistance\(^{2}\).
  - 23 trials involving 999 stroke patients were analyzed.
  - All trials that evaluated electromechanical- and robotic-assisted gait training plus physical therapy versus physical therapy (or usual care) for regaining or improving walking after stroke were included.
    - Trials of devices used in combination with functional electrical stimulation (FES) to the legs during gait training were also included.
    - Trials of the effectiveness of treadmill training were excluded.
  - Use of electromechanically assisted gait training devices in combination with physical therapy appears to increase the chance of regaining independent walking after stroke.
  - The devices were not associated with improvements in walking velocity or walking capacity.
  - Patients in the first 3 months after stroke and patients who cannot walk appear to benefit most from robotic-assisted gait training.

- A 2010 systematic review of the effectiveness of robotic-assisted gait training for persons with SCI reported that there was no evidence that robotic-assisted gait training improves walking function more than other locomotor training strategies\(^{3}\).
  - Two RCTs and 4 pre-experimental trials involving 43 patients with incomplete SCI between C3 and L1 were analyzed.
  - Five studies used the Lokomat and 1 used the LokoHelp.
  - Some improvements in function and activity were attained.
  - There is insufficient evidence to draw conclusions due to small sample sizes, methodological flaws, and the heterogeneity of training procedures.
- A need for well-designed RCTs was identified

- Improvements in walking speed\(^{(18)}\), reductions of freezing of gait (FOG), improved postural stability\(^{(20)}\), and spatio-temporal gait parameters have been reported to result from robotic-assisted gait training in patients with PD

- In an RCT conducted in Italy, 41 patients with PD were randomly assigned to robotic-assisted gait training or physical therapy that included joint mobilization and conventional gait training\(^{(18)}\)

  - Statistically significant improvements in walking speed and walking distance were found in the robotic-assisted group compared to the conventional treatment group

- Results of a single-blind RCT conducted in Italy did not show robotic-assisted training to be superior to conventional gait training with a treadmill in patients with PD\(^{(28)}\)

  - 30 participants were randomized to receive robotic gait training with a Lokomat or gait training on a treadmill for the same amount of practice time
  - Treatment was for 30 minutes 3 days per week for 4 weeks
  - The primary outcome measure was the 6MWT
  - Patients in both groups showed significant improvements in the distance covered in the 6MWT. The between-group difference was not significant

- Robotic-assisted gait training and traditional balance training were compared for treating postural instability and functional mobility in patients with PD\(^{(30)}\)

  - In an RCT in Italy, 66 patients with PD were assigned to robot-assisted gait training or balance training groups. Balance training focused on traditional interventions for postural reactions and coordination
  - All patients received 12 45-minute treatment sessions, three days a week for four weeks
  - Statistically significant improvements were seen in both groups using the BBS. However, robotic-assisted gait training was not found to be statistically superior to balance training for treatment of postural instability and functional deficits in people with PD

- Studies of the effectiveness of robotic-assisted BWSTT in MS are inconclusive

  - In a randomized crossover trial conducted in the United States, there were no differences in gait outcomes or Expanded Disability Status Scale (EDSS) scores between a group of MS patients receiving BWSTT with robotic assistance and one receiving BWSTT alone\(^{(19)}\)

    - Significant within subject improvements were obtained, suggesting that both treatments have the potential to reduce gait impairments in MS
    - Further studies are needed

  - In a randomized controlled trial of robotic-assisted gait training for patients with MS conducted in Switzerland researchers found that robotic-assisted gait training is no better than overground walking training for these patients\(^{(20)}\)

    - A total of 67 patients with MS with scores from 3.0 to 6.5 on the EDSS were randomized to walking or to robotic-assisted gait training, in addition to multimodal rehabilitation
    - Outcomes measured were walking speed, activity level, and quality of life
    - Quality of life improved in both groups
    - There were no significant differences between groups

- Robotic-assisted BWSTT was not different from unassisted BWSTT for improving quality of life in patients with MS, in a pilot study conducted in the United States\(^{(21)}\)

  - Thirteen individuals with MS and gait impairments were randomly assigned to receive robotic-assisted BWSTT or BWSTT alone for 6 biweekly training sessions, followed by the other intervention for 6 biweekly training sessions
  - Both types of BWSTT might improve quality of life in this population

- A systematic review and meta-analysis of 10 studies indicates that robotic-assisted gait training in patients with cerebral palsy improves walking speed and distance\(^{(33)}\)

  - 52 children with spastic diplegia participated in the study conducted in Poland

- A neurorehabilitation unit in Italy studied the effects of robotic-aided gait training combined with physical therapy in children with acquired brain injury (ABI)\(^{(21)}\)

  - 23 patients participated in 20 sessions of robotic-aided gait training and traditional manual physical therapy. Results from a pretest-posttest were compared demonstrating significant improvements in Gross Motor Function Measures (GMFM), 6MWT scores, gait analysis and ROM throughout the whole gait cycle. Significant improvements were minimal to none in a control group of children with ABI who participated in manual physical therapy only
Researchers in the United States studied predictors of recovery patterns in individuals trained with robotic gait training (Lokomat) post SCI.  

- 40 subjects post SCI who had spastic hypertonia at their ankles were randomly selected for participation.  
- Two recovery classes (high and low walking capacity) were identified for each of the control and intervention groups. High capacity demonstrated shorter TUG time, higher 10MWT speed, and longer 6MWT distances. Those assigned to the low walking capacity group scored poorer scores on the respective tests.  
- Maximal voluntary ankle torque of each participant was measured prior to initial treatment and use of Lokomat. Torque scores were found to predict the classification and assignment to the high and low walking capacity groups.  
- Subjects in the initial high capacity group showed significant improvement in speed and functional mobility. No significant change in endurance was seen in the high capacity group. Subjects in the low walking capacity group failed to demonstrate significant improvement.  
- Maximum voluntary torque might offer some predictability as to which patients will benefit from Lokomat training, thereby containing unnecessary expenses and effort.  

Intramuscular multichannel FES combined with robotic-assisted gait training was found to be feasible in a study conducted in the United States.  

- Intramuscular electrodes were placed in up to 8 paretic or paralyzed muscles of chronic stroke patients. FES patterns were created with a specialized computer program.  
- A Lokomat robotic assistance system was used.  
- Results indicate that the two technologies can be feasibly combined. Each technology had unique advantages and disadvantages.  
  - FES provides practice of swing phase and coordinated limb movements and stance phase hip, knee, and ankle balance control. Muscles had to be sufficiently strong to respond to the FES.  
  - The robotic device provided early training, and passively assisted swing phase hip and knee movements and stance phase hip, knee, and ankle position control, but restricted lateral weight shift and pelvic movements.  

A number of studies have reported that use of virtual reality as an adjunct to robotic-assisted gait training improves outcomes by increasing patient motivation and reducing patients’ passivity during training. Researchers in Switzerland who studied the effects of various forms of training, with and without virtual reality, on active participation of children during robotic-assisted gait training found that virtual reality-based training conditions enhance active participation.  

- Ten children with neurological disorders and 14 children without neurological disorders participated in the study.  
- All participants used the Lokomat in 4 different randomly assigned conditions intended to increase motivation: use of a virtual reality soccer game, use of a virtual reality navigation game, watching a movie, and using a therapist’s standardized instructions to promote active walking.  
- Among children with neurological disorders and healthy controls, the virtual reality conditions were more effective in initiating the desired active participation compared to the conventional training conditions.  
- Muscular effort assessed by surface EMG during randomly assigned training protocols was higher during tasks with virtual realities than during normal robotic-assisted walking conditions in another study in children conducted in Switzerland.  
- Nine children with gait disorders and 8 controls without gait disorders participated.  
- Children walked in a pediatric Lokomat.  
- The gaming aspect of virtual reality appears to keep children highly engaged during repetitive tasks.  
- The use of augmented feedback via interactive games requiring navigation through virtual environments during pediatric robotic-assisted gait training is associated with better outcomes than robotic-assisted gait training without augmented feedback, based on a case series conducted in the United States.  
- Outcomes of a case series of 4 children with spastic diplegia indicate that augmented feedback is associated with larger improvements in walking function, walking speed, and endurance.  
- The apparent lack of benefits of robotic-assisted gait training as compared to human-assisted training suggests a need for ongoing revision of gait-training robotic design.  

<table>
<thead>
<tr>
<th>Problem</th>
<th>Goal</th>
<th>Intervention</th>
<th>Expected Progression</th>
<th>Home Program</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tr>
<tr>
<td>Gait impairments</td>
<td>Increase independence in ambulation, increase gait speed</td>
<td><strong>Robotic-assisted gait training</strong></td>
<td>Frequency and duration of training sessions should be gradually increased. Body weight support can be decreased, speed of treadmill increased, and/or guidance force decreased as patient progresses</td>
<td>A home program with emphasis on skill carryover is recommended. Activities should target enhancing community participation in daily activity¹⁰</td>
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<tr>
<td>Decreased lower extremity strength and mobility</td>
<td>Maintain and increase lower extremity strength and mobility</td>
<td><strong>Robotic-assisted gait training</strong></td>
<td>Subacute stroke patients can be trained to increase their VO₂ and lower extremity strength using a robotic device during inpatient rehabilitation²⁶</td>
<td>As above A home program of lower extremity strengthening and ROM exercises should be provided</td>
</tr>
<tr>
<td>Decreased endurance</td>
<td>Increase endurance</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Risk factors:</td>
<td>Minimize risks</td>
<td><strong>Risk reduction strategies</strong></td>
<td>Increased independence in risk prevention</td>
<td>Educate patient and caregivers about risks</td>
</tr>
<tr>
<td>Falls</td>
<td></td>
<td>Regular skin inspection and monitoring of joint positions¹⁰</td>
<td></td>
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<tr>
<td>Skin breakdown at equipment contact</td>
<td></td>
<td>Educate patient and family about fall risks and fall prevention strategies</td>
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<td></td>
</tr>
<tr>
<td>Joint injuries due to abnormal gait patterns</td>
<td></td>
<td>Maintain and use equipment according to safety standards and manufacturers’ specifications</td>
<td></td>
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</tr>
</tbody>
</table>

See Description, Indications for device/equipment, and Guidelines for use of device/equipment, above

**Desired Outcomes/Outcome Measures**

- Desired outcomes and examples of outcome measures. Outcome measures vary depending on condition
  - Increased independence with ambulation
    - Walking endurance (6MWT)
    - Emory Functional Ambulation Profile
    - WISCI-II
    - FAC
- Increased gait speed
  - Walking velocity (10MWT or 15MWT)
- Improved patient/caregiver safety
  - DGI
- Improved balance
  - Berg Balance Scale (BBS), Pediatric Balance Scale
- Improved functional abilities
  - Rivermead Mobility Index
  - GMFM/PDMS-2
  - FIM, WeeFIM
  - Barthel Index
- Increased lower extremity muscle activation/strength
  - Manual muscle test (MMT) scores where appropriate
  - EMG

A systematic review of outcome measures of walking training using electromechanical and robotic devices in patients with stroke identified 45 scales used in studies published between 2000 and 2012\(^{(29)}\)

- The most commonly used outcome measures were FAC, 10MWT, Motricity Index, 6MWT, Rivermead Mobility Index, and Berg Balance Scale
- When classified by International Classification of Functioning, Disability and Health (ICF) domain, 18 scales were classified into body function, 24 scales into activity, and 3 into participation
- None of the most commonly used scales evaluated participation. It was noted that studies of the impact of electromechanical and robotic devices should consider the ultimate goal to be to improve the individual’s involvement in real-life situations (i.e., participation)

**Maintenance or Prevention**

- Maintain the highest achievable ROM, strength, and function of the affected limbs
- Maintain fitness level and participation in activities
- Prevent falls
  - Increase awareness of patient and family members of risk of falls

**Patient Education**

- The Web sites of commercially available robotic-assisted gait training provide information useful to patients and their families. Users should be made aware of their vested interest in promoting the technology. Proponents sometimes present this therapy as superior with little evidence provided\(^{(16)}\)

**Coding Matrix**

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

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

**References**


