3. Lower Extremity Motor and Mobility Rehabilitation

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3.1 Motor Recovery of the Lower Extremity Post Stroke

3.1.1 Brunnstrom Stages of Motor Recovery

The Seven Brunnstrom Stages of Motor Recovery (see table below for more details)

1. Flaccid paralysis. No reflexes.
2. Some spastic tone. No voluntary movement. Synergies elicited through facilitation.
3. Spasticity is marked. Synergistic movements may be elicited voluntarily.
4. Spasticity decreases. Synergistic movements predominate.
5. Spasticity wanes. Can move out of synergies although synergies still present.
6. Coordination and movement patterns near normal. Trouble with more rapid complex movements.
7. Normal.

Stages of Motor Recovery of the Chedoke McMaster Stroke Impairment Inventory (Gowland et al., 1993a)

Stages	Characteristics
1	**Flaccid paralysis is present.** Phasic stretch reflexes are absent or hypoactive. Active movement cannot be elicited reflexively with a facilitatory stimulus or volitionally.
2	**Spasticity is present** and is felt as a resistance to passive movement. **No voluntary movement** is present but a **facilitatory stimulus will elicit the limb synergies reflexively**. These limb synergies consist of stereotypical flexor and extensor movements.
3	**Spasticity is marked**. The **synergistic movements can be elicited voluntarily** but are not obligatory.
4	**Spasticity decreases.** Synergy patterns can be reversed if movement takes place in the weaker synergy first. Movement combining antagonistic synergies can be performed when the prime movers are the strong components of the synergy.
5	**Spasticity wanes** but is evident with rapid movement and at the extremes of range. Synergy patterns can be revised even if the movement takes place in the strongest synergy first. Movements that utilize the weak components of both synergies acting as prime movers can be performed.
6	**Coordination and patterns of movement can be near normal. Spasticity** as demonstrated by resistance to passive movement is **no longer present**. Abnormal patterns of movement with faulty timing emerge when rapid or complex actions are requested.
7	**Normal.** A "normal" variety of rapid, age appropriate complex movement patterns are possible with normal timing, coordination, strength and endurance. There is no evidence of functional impairment compared with the normal side. There is a "normal" sensory-perceptual motor system.

3.1.2 Factors that Predict Motor Recovery

Motor deficits post-stroke are the most obvious impairment (Langhorne et al. 2011) and have a disabling impact on valued activities and independence. Motor deficits are defined as *"a loss or limitation of function in muscle control or movement or a limitation of movement"* (Langhorne et al. 2011; Wade 1992). Given its importance, a large proportion of stroke rehabilitation efforts are directed towards the recovery of movement disorders. Langhorne et al. (2011) notes that motor recovery after stroke is complex with many treatments designed to promote recovery of motor impairment and function.

The two most important factors which predict motor recovery are:

1. Stroke Severity: The most important predictive factor which reduces the capacity for brain reorganization.
2. Age: Younger patients demonstrate greater neurological and functional recovery and hence have a better prognosis compared to older stroke patients (Adunsky, Hershkowitz, Rabbi, Asher-Sivron, & Ohry, 1992; Hindfelt & Nilsson, 1977; Marini et al., 2001; Nedeltchev et al., 2005).

Changes in walking ability and gait pattern often persist long-term and include increased tone, gait asymmetry, changes in muscle activation and reduced functional abilities (Pereira, Mehta, McIntyre, Lobo, & Teasell, 2012; Pizzi et al., 2007; Robbins, Houghton, Woodbury, & Brown, 2006; Woolley, 2001). Ambulation post stroke is often less efficient and associated with increased energy expenditure (Pereira et al., 2012). Hemiplegic individuals have been reported to utilize 50-67% more metabolic energy than normal individuals when walking at the same velocity (Woolley, 2001).

For mobility outcome, trunk balance is an additional predictor of recovery (Veerbeek, Van Wegen, Harmeling Van Der Wel, & Kwakkel, 2011). Non-ambulant patients who regained sitting balance and some voluntary movement of the hip, knee and/or ankle within the first 72 hours post stroke predicted 98% chance of regaining independent gait within 6 months. In contrast, those who were unable to sit independently for 30 seconds and could not contract the paretic lower limb within the first 72 hours post stroke had a 27% probability of achieving independent gait. The use of Biomarkers such as rTMS to determine integrity of the corticospinal tract is discussed in Chapter 2.

3.2 Assessments of Motor Recovery of the Lower Extremity and Mobility

3.2.1 Lower Extremity Rehabilitation Outcome Measures

There is a wide range of lower extremity rehabilitation outcomes measures which have been utilized. They can be categorized into broad categories listed below:

Lower Extremity Assessment and Outcome Measures

Category	Rationale	Individual Assessment Tools
Motor Function	These outcome measures covered gross motor movements and a series of general impairment measures when using the upper extremities	• Brunnstrom Recovery Stages • Chedoke McMaster Stroke Assessment Scale • Fugl-Meyer Assessment • Lindmark Motor Assessment • Lower Extremity Motor Coordination Test • Rivermead Motor Assessment

		• Sodering Motor Evaluation Scale • Upright Motor Control Test
Activities of Daily Living	These outcome measures assessed performance and level of independence in various everyday tasks.	• Ability for Basic Movement Scale Revised • Barthel Index • Frenchay Activities Index • Functional Independence Measure • Lower Extremity Functional Scale • Modified Barthel Index • Motor Assessment Scale • Nottingham Extended Activities of Daily Life • Stroke Impact Scale • Sunnaas Index
Spasticity	These outcome measures assessed changes in muscle tone, stiffness, and contractures.	• Composite Spasticity Index • Modified Ashworth Scale • Modified Tardieu Scale • Spasm Frequency Scale
Range of Motion	These outcome measures assessed a patient's ability to freely move their upper extremity through flexion, abduction, and subluxation movements for instance, both passively and actively.	• Active ROM • Minimal Elbow Extension Angle During Reach • Passive ROM
Proprioception	These outcome measures assessed sensory awareness about one's body and the location of limbs.	• Joint Position Sense Test • Kinesthetic Visual Imagery Questionnaire • Revised Nottingham Sensory Assessment
Global Stroke Severity	These outcome measures assessed the severity of one's stroke through a global assessment of a multitude of deficits a stroke survivor may experience.	• Hemispheric Stroke Scale • Modified Rankin Scale • National Institutes of Health Stroke Scale • Scandinavian Stroke Scale
Muscle Strength	These outcome measures assessed muscle power and strength during movements and tasks.	• Hand Grip Strength • Isokinetic Peak Torque • Manual Muscle Strength Test • Medical Research Council Scale
Functional Ambulation	These outcomes measures assessed ambulatory abilities during distance-based or timed walking exercises commonly.	• 10-Metre Walk Test • 25-Feet Walk Test • 2-Minute Walk Test • 30-Second Sit-to-Stand Test • 3-Meter Backward Walk Test • 3-Meter Walk Test • 50-Meter Walk Test • 5-Meter Walk Test • 6-Minute Walk Test • EU Walking Scale • Functional Ambulation Category • Gait Distance • Gait Speed • Locomotion Ability for Adults with Lower Limb Impairments Assessment

		• Modified Emory Functional Ambulation Profile • Walking Handicap Scale • Walking Speed
Balance 	These outcome measures assessed postural stability, and both static and dynamic balance.	• 30-Second Sit-to-Stand Test • Activities-Specific Balance Confidence Scale • Anteroposterior Center of Pressure • Balance Performance Monitor • Berg Balance Scale • Biodex Balance System • Brunel Balance Assessment • Burke Lateropulsion Scale • Community Balance and Mobility Scale • Four Square Step Test • Four Test Balance Scale • Functional Reach Test • Lateral Reach Test • Limit of Stability • Medial-Lateral Centre of Pressure • Mini Balance Evaluation Systems Test • Modified Functional Reach Tests • Modified Stairs Test • Overall Stability Test • Pedaling Unbalance • Performance-Oriented Mobility Assessment AKA Tinetti Balance Scale • Postural Assessment Stroke Scale • Postural Control and Postural Sway • Rate of Falls • Scale for Contraversive Pushing • Sitting Balance • Sit-to-Stand Test • Stabilometry Test • Stair Climb Test • Static Balance • Timed Up & Go Test • Tinetti Gait Scale • Trunk Control Test • Trunk Impairment Scale • Trunk Reposition Error
Functional Mobility 	These outcome measures assessed a person's ability to move around their environment, from one position or place to another, to complete everyday activities or tasks.	• Clinical Outcome Variable Scale • De Morton Mobility Index • Elderly Mobility Scale • Functional Independence Measure • Life Space Assessment • Modified Rivermead Mobility Index • Rivermead Mobility Index • Rivermead Motor Assessment • Short Physical Peformance Battery • Stroke Rehabilitation Assessment of Movement
Gait	These outcome measures assessed various phases of the gait cycle.	• Cadence • Double Limb Support Period • Dynamic Gait Index

		• Figure-8 Walk Test • Functional Gait Assessment • Gait Assessment and Intervention Tool • Gait Cycle Time • Single Limb Support Time • Stance Phase and Stance Symmetry • Step Length, Step Reaction Time and Step Test • Stride Length and Stride Width • Support Duration • Sway Area, Sway in Centre of Pressure. Sway Length and Sway Velocity • Swing Power and Swing Symmetry • Symmetric Weight Bearing • Tinetti Gait Scale • Turn Speed • Wisconsin Gait Scale

Levels of Evidence

Motor Function	ADLs	Spasticity	ROM	Propriocep-tion	Stroke Severity	Muscle Strength	Functional Ambulat.	Balance	Functal Mobility	Gait

3.2.2 Motor Function Outcome Measures

Brunnstrom Recovery Stages (BRS) (see above under Motor Recovery)

Is a measure of motor function and muscle spasticity in stroke survivors. The measure contains 35 functional movements which are done with the guidance of a clinician (e.g. should abduction, shoulder adduction, leg flexion/extension). These movements are evenly divided into 2 sections: upper extremity and lower extremity. Each movement is then rated on a 6-point scale (1=Flaccidity is present, and no movements of the limbs can be initiated, 2=Movement occurs haltingly and spasticity begins to develop, 3=Movement is almost impossible and spasticity is severe, 4=Movement starts to be regained and spasticity begins to decline, 5=More difficult movement combinations are possible as spasticity declines further. 6=Spasticity disappears, and individual joint movements become possible). This measure has been shown to have good reliability and concurrent validity (Naghdi, Ansari, Mansouri, & Hasson, 2010; Safaz, Ylmaz, Yasar, & Alaca, 2009).

Chedoke McMaster Stroke Assessment Scale

Is a measure of motor impairment and consists of an impairment inventory as well as an activity inventory. The score for the impairment inventory ranges from a minimum of 6 to a maximum of 42, with a higher score corresponding to less impairment (Gowland et al., 1993a). The maximum score for the activity inventory is 100, with a higher score corresponding to normal function (Gowland et al., 1993a) The assessment has demonstrated excellent test-retest reliability, inter-rater reliability, internal consistency, and validity (Gowland et al., 1993a).

Chedoke-McMaster Stroke Assessment Scale

Questions	Answer
What does it measure?	The Chedoke-McMaster Stroke Assessment Scale (CMSA) is a 2-part assessment consisting of a physical impairment inventory and a disability inventory. The impairment inventory is intended to classify patients according to stage of motor recovery while the disability inventory assesses change in physical function.
What is the scale?	The ***scale's impairment inventory has 6 dimensions***; shoulder pain, postural control, arm movements, hand movements, leg movements, and foot movements. ***Each dimension*** (with the exception of 'shoulder pain') is rated on a ***7- point scale*** corresponding to Brunnstrom's 7 stages of motor recovery. The ***disability inventory consists of a gross motor index (10 items) and a walking index (5 items)***. With the exception of a 2-minute walking test (which is scored as either 0 or 2), items are scored according to the ***same 7-point scale*** where 1 represents total assistance and 7 represents total independence.
What are the key scores?	The impairment inventory yields a total score out of 42 while the disability inventory yields a total score out of 100 (with 70 points from the gross motor index and 30 points from the walking index).
What are its strengths?	The use of Brunnstrom staging and FIM scoring increases the interpretability of the CMSA and may facilitate comparisons across groups of stoke patients. The CMSA is relatively comprehensive and has been well studied for reliability and validity.
What are its limitations?	Taking approximately 1 hour to complete, the length and complexity of the CMSA may make the scale less useful in clinical practice. As ***primarily a measure of motor impairment***, the CMSA should really be accompanied by a measure of functional disability such as the BI or the FIM.

Stages of Motor Recovery of the Chedoke McMaster Stroke Impairment Inventory (Gowland et al., 1993b)

Stages	Characteristics
1	***Flaccid paralysis is present.*** Phasic stretch reflexes are absent or hypoactive. Active movement cannot be elicited reflexively with a facilitatory stimulus or volitionally.
2	***Spasticity is present*** and is felt as a resistance to passive movement. ***No voluntary movement*** is present but a ***facilitatory stimulus will elicit the limb synergies reflexively***. These limb synergies consist of stereotypical flexor and extensor movements.
3	***Spasticity is marked***. The ***synergistic movements can be elicited voluntarily*** but are not obligatory.
4	***Spasticity decreases.*** Synergy patterns can be reversed if movement takes place in the weaker synergy first. Movement combining antagonistic synergies can be performed when the prime movers are the strong components of the synergy.
5	***Spasticity wanes***, but is evident with rapid movement and at the extremes of range. Synergy patterns can be revised even if the movement takes place in the strongest synergy first. Movements that utilize the weak components of both synergies acting as prime movers can be performed.
6	***Coordination and patterns of movement can be near normal. Spasticity*** as demonstrated by resistance to passive movement is ***no longer present***. Abnormal patterns of movement with faulty timing emerge when rapid or complex actions are requested.

7	***Normal.*** A "normal" variety of rapid, age appropriate complex movement patterns are possible with normal timing, coordination, strength and endurance. There is no evidence of functional impairment compared with the normal side. There is a "normal" sensory-perceptual motor system.

Fugl-Meyer Assessment (FMA)
FMA is an impairment measure used to assess locomotor function and control of the upper and lower extremities, including balance, sensation, and joint pain in patients poststroke. It consists of 155 items, with each item rated on a three-point ordinal scale. The maximum motor performance score is 66 points for the upper extremity section, 34 points for the lower extremity section, 14 points for the balance section, 24 points for sensation section, and 44 points each for passive joint motion and joint pain section, for a maximum of 266 points that can be attained. The upper extremity section consists of four categories (Shoulder/Elbow/Forearm, Wrist, Hand/Finger, and Coordination) and includes 23 different movements which evaluate 33 items. The items are scored on a 3-point rating scale: 0 = unable to perform, 1 = partial ability to perform and 2 = near normal ability to perform. The measure is shown to have good reliability and construct validity (Nilsson et al., 2001; Okuyama et al., 2018; Sanford, Moreland, Swanson, Stratford, & Gowland, 1993; Villan-Villan et al., 2018).

3.2.3 Activities of Daily Living Outcomes

Barthel Index (BI)
The Barthel Index is a measure of how well a stroke survivor can function independently and how well they can perform activities of daily living (ADL). The measure consists of a 10-item scale (e.g. feeding, grooming, dressing, bowel control). Possible total scores range from 0 to 100. This measure has been shown to have good reliability and validity in its full form (Gonzalez et al., 2018; C.-S. Park, 2018).

Modified Barthel Index (mBI)
The Modified Barthel Index is a measure of how well a stroke survivor can function independently and how well they can perform activities of daily living (ADL). The measure consists of a 10-item scale (e.g. feeding, grooming, dressing, bowel control). Possible scores range from 0 to 20. This measure has been shown to have good reliability and validity in its full form (MacIsaac et al., 2017; Ohura, Hase, Nakajima, & Nakayama, 2017).

Functional Independence Measure (FIM)
The FIM is an 18-item outcome measure composed of both cognitive (5-items) and motor (13-items) subscales. Each item assesses the level of assistance required to complete an activity of daily living on a 7-point scale. The summation of all the item scores ranges from 18 to 126, with higher scores being indicative of greater functional independence. This measure has been shown to have excellent reliability and concurrent validity in its full form (Granger, Deutsch, & Linn, 1998; Granger, Hamilton, Linacre, Heinemann, & Wright, 1993; Linacre, Heinemann, Wright, Granger, & Hamilton, 1994).

3.2.4 Spasticity Outcomes

Modified Ashworth Scale (MAS)

MAS is a measure of muscle spasticity for stroke survivors. The measure contains 20 functional movements which are done with the guidance of a trained clinician. These movements are evenly divided into 2 sections: upper extremity and lower extremity. Each movement is then rated on a 6-point scale (0=no increase in muscle tone, 1=barely discernible increase in muscle tone 1+=slight increase in muscle tone, 2=moderate increase in muscle tone 3=profound increase in muscle tone (movement of affected limb is difficult) 4=complete limb flexion/rigidity (nearly impossible to move affected limb)). This measure has been shown to have good reliability and validity (Blackburn, van Vliet, & Mockett, 2002; Merholz et al. 2005)

3.2.5 Stroke Severity

Modified Rankin Scale (MRS)
The MRS is a measure of functional independence for stroke survivors. The measure contains 1 item. This item is an interview that lasts approximately 30-45 minutes and is done by a trained clinician. The clinician asks the patient questions about their overall health, their ease in carrying out ADLs (cooking, eating, dressing) and other factors about their life. At the end of the interview the patient is assessed on a 6-point scale (0=bedridden, needs assistance with basic ADLs, 5=functioning at the same level as prior to stroke). This measure has been shown to have good reliability and validity (Wilson et al., 2002; Quinn et al. 2009).

National Institutes of Health Stroke Scale (NIHSS)
The NIHSS is a measure of somatosensory function in stroke survivors during the acute phase of stroke. This measure contains 11 items and 2 of the 11 items are passive range of motion (PROM) assessments delivered by a clinician to the upper and lower extremity of the patient. The other 9 items are visual exams conducted by the clinician (e.g. gaze, facial palsy dysarthria, level of consciousness). Each item is then scored on a 3-point scale (0=normal, 2=minimal function/awareness). This measure has been shown to have good reliability and validity (Heldner et al., 2013; Weimar, Konig, Kraywinkel, Ziegler, & Diener, 2004).

3.2.6 Functional Ambulation Outcome Measures

10-Metre Walk Test
The 10MWT is a measure used to assess walking speed, in which participants are asked to walk a distance of 10m in a straight line at maximum walking speed. The time taken to perform the task is recorded, and maximum walking speed is reported in m/s. The test is shown to have high interrater and intrarater reliability in stroke (Drużbicki et al., 2018).

2-Minute Walk Test
The 2MWT Is a measure of walking endurance in which participants are asked to walk at a comfortable pace between two defined points for two minutes. The walk is usually conducted along a straight path that is free of obstructions, and results are reported as a distance measure (in metres). The test is shown to have high inter- and intrarater reliability (Drużbicki et al., 2018; Hiengkaew, Jitaree, & Chaiyawat, 2012).

6-Minute Walk Test
The 6MWT is a measure of walking endurance, in which the distance walked by participants in a straight line within 6 minutes is reported. The test is proven to be valid and reliable in stroke (Fulk, Echternach, Nof, & O'Sullivan, 2008; Kwong & Ng, 2019).

6 Minute Walking Test (6MWT)

Questions	Answer
What does it measure?	The 6MWT is a functional walking which measures the distance that a patient can walk on a flat, hard surface in a period of 6 minutes. It is used to determine functional capacity in individuals with compromised ability.
What is the scale?	The 6MWT requires the patient to walk at the fastest speed over a period of 6 minutes. Walking is performed along a 30 m walking course. The subject is permitted to use a walking aid if required, with the use of the aid is kept consistent from test to test. Patient is allowed to rest during the course of walking.
What are the key scores?	The 6 MWT consists of the distance taken to walk within 6 minutes, in meters. Number of rest should also be recorded.
What are its strengths?	The 6MWT is quick and easy to administer, requiring no specialized equipment or training. As it usually reflects the submaximal aerobic capacity, thus it's more reflective in performance of ADLs compared to other functional walk test.
What are its limitations?	The 6 MWT is not suitable for use with those unable to ambulate. Stroke specific impairment, i.e. hemiparesis, spasticity, etc. may influence the distance walked.

Walking Speed (WS)

Walking Speed is a measure that simply evaluates how quickly a stroke patient can walk and compares that to an age-matched baseline score. This measure consists of the patient walking a set distance (usually 10-15m) with a trained clinician timing them. The patient's time is then compared to the average age-matched score in non-stroke patients. This measure has been shown to have good reliability and validity (Himann, Cunningham, Rechnitzer, & Paterson, 1988; Jordan, Challis, & Newell, 2007).

3.2.7 Balance Outcomes

Berg Balance Scale (BBS)

The BBS is a 14-item scale that measures balance ability and control while sitting and standing. Each item is ranked on a 4-point scale for a total score of 56. The measure is shown to have high interrater, intrarater, and test-retest reliability (Blum & Korner-Bitensky, 2008).

Berg Balance Score

Questions	Answer
What does it measure?	Quantitative assessment of balance in older adults (Berg, Wood-Dauphinee, Williams, & Gayton, 1989).
What is the scale?	14 items requiring subjects to maintain positions or complete movement tasks of varying levels of difficulty. Items receive a score of 0-4 based on ability to meet the specific time and distance requirements of the test. 0 = inability to complete the item; 4 = ability to complete the test independently.
What are the key scores?	Maximum score = 56. A score of less than 45 is indicative of balance impairment or risk of falling.
What are its strengths?	Measures a number of different aspects of balance, both static and dynamic. Requires little equipment or space and no specialized training.

	High levels of reliability even when test is administered by an untrained assessor. Particularly well suited to acute stroke rehabilitation, as the majority of patients do not obtain maximum scores on admission to rehabilitation. Often correlates well with functional mobility gains on rehabilitation.
What are its limitations?	Takes somewhat longer to administer than other balance measures and may not be suitable for the evaluation of active, elderly persons, as the item included are not sufficiently challenging for this group. As no common standards for interpretation of BBS scores exist, their relationship to mobility status and the requirement for mobility aides is not known. Decreased sensitivity in early stage post-stroke among severely affected patients as scale includes only one item relating to balance in the sitting position.

Timed Up & Go Test (TUG)

The TUG Test is a measure of the ability of a stroke patient to perform sequential motor tasks. This measure consists of 1 functional task which involves the patient standing up from a chair, walking 3 metres, turning around and sitting back down again. This task is then evaluated on a scale from 1 to 5 (1=normal function, 5=severely abnormal function). This measure has been shown to have good reliability and validity (Shumway-Cook, Brauer, & Woollacott, 2000; Steffen, Hacker, & Mollinger, 2002).

Timed Up and Go (TUG)

Questions	Answer
What does it measure?	The TUG is an objective measure of basic mobility and balance maneuvers that assesses an individual's ability to perform sequential motor tasks relative to walking and turning.
What is the scale?	The TUG requires subjects to stand up from a chair, walk a distance of 3 meters, turn around, walk back to the chair and seat themselves. The subject is permitted to use a walking aid if one is normally required and is allowed to walk through the test once before the timed session is undertaken.
What are the key scores?	The TUG score consists of the time taken to complete the test activity, in seconds.
What are its strengths?	The TUG is quick and easy to administer, requiring no specialized equipment or training. Timed scores are objective, straightforward, and more sensitive to change over time than ordinal measures (Whitney, Poole, & Cass, 1998a).
What are its limitations?	The TUG may not be suitable for use with cognitively impaired subjects; although verbal cueing during the test may eliminate this concern (Nordin, Rosendahl, & Lundin-Olsson, 2006; Rockwood et al., 2000). Because normative data is not available for the TUG, its primary use has been assessment of change within the individual (Thompson & Medley, 1995). Overall, the TUG is a limited measure that addresses relatively few aspects of balance and yields a narrower assessment than more comprehensive balance measures, such as the Berg Balance Scale (Whitney, Poole, & Cass, 1998b).

3.2.8 Functional Mobility

Clinical Outcome Variable Scale (COVS)
The COVS is a measure of functional mobility consisting of 13 mobility tasks, each scored on a 7-point scale. Overall scores range of a 13 at the lowest to 91 at the highest, with a higher score corresponding to better functioning (Garland, Willems, Ivanova, & Miller, 2003).

3.2.9 Gait Measures

Cadence
Cadence is a gait pattern that varies and is assessed through gait analysis ((Brandstater, de Bruin, Gowland, & Clark, 1983). Gait parameters after a stroke are associated with functional performance and recovery.

Gait Cycle Time
Gait Cycle Time is the time it takes from the heel strike of one foot until the heel strike of the same foot before the next step. It allows for a quantifiable assessment of the ambulation pattern in participants with neurological impairments post-stroke (Nadeau, Duclos, Bouyer, & Richards, 2011).

Stance Phase
The Stance Phase is the part of the gait cycle where a patient's one foot makes contact with the ground. It comprises approximately 60% of the gait cycle. This measure has been shown to have good reliability and validity. (Kozanek et al., 2009).

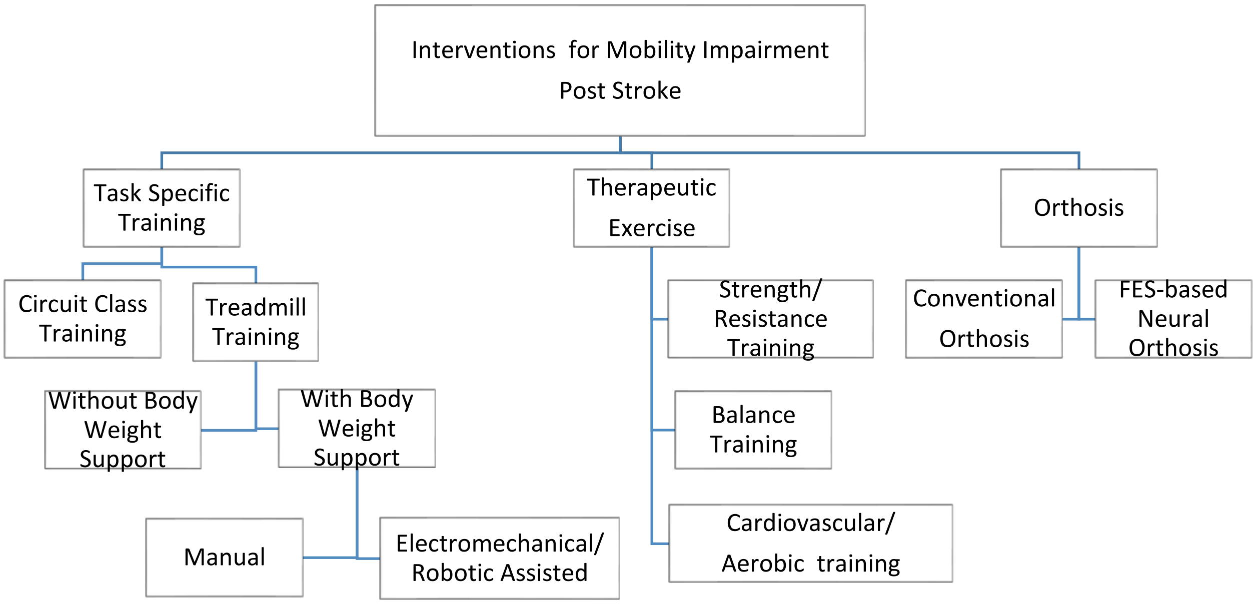
Stride Length
Stride Length is defined as the distance between two successive placements of the same foot. One stride length is the equivalent of two step lengths. Unlike step lengths, stride lengths should be very similar for both the right and left leg. This measure has been shown to have good reliability and validity. (Danion, Varraine, Bonnard, & Pailhous, 2003; Lewis, Byblow, & Walt, 2000).

3.3 Interventions for Mobility Impairment Post Stroke

Canadian Best Practice Guidelines: Update 2015 (Hebert et al., 2016) state that, *"Patients should engage in training that is meaningful, engaging, progressively adaptive, intensive, task-specific and goal-oriented in an effort to improve transfer skills and mobility (Evidence Level A)".* Regaining mobility, including the ability to walk independently and get up and down stairs, is the number one goal of most stroke patients. The majority of patients, including severe hemiplegics, still regain the ability to walk, albeit often times with great effort and the assistance of a cane or even someone else.

Figure 1. below outlines differing therapeutic treatments to improve mobility and gait, which are the principle functions of the lower extremities.

Figure 1. Different Rehab Therapeutic Approaches to Improve Gait and Mobility Post Stroke



3.3.1 Therapy Intensity

Kwakkel et al. (2004) conducted a meta-analysis, evaluating the benefit of augmented physical therapy, including 20 studies which had assessed many interventions: occupational (upper extremity), physiotherapy (lower extremity), leisure therapy, home care and sensorimotor training. After adjusting for differences in treatment intensity contrasts, augmented therapy was associated with statistically significant treatment effects for the outcomes of ADL and walking speed. Augmented therapy was found to be more effective when initiated within six months of the stroke.

The term, "intensity", most frequently refers to the frequency of repetitions within a given period of time, although more correctly, is defined as the amount of mechanical output of physical activity. However, such measurement is not usually possible within a clinical setting. Therefore, establishing a dose-response relationship is problematic in stroke rehabilitation. Many factors preclude the routine recommendation of standard amounts of therapy time an individual patient should receive, with many guideline recommendations regarding intensity and duration of therapy to reflect consensus by clinicians rather than research evidence (Foley et al., 2012). Therefore, it is extremely difficult to know how early therapy should be initiated post stroke or how much additional therapy would confer benefit. In a prospective cohort study, a relationship between lower limb exercise dose (mean daily number of exercise repetitions) and improved walking speed was found (Scrivener et al. 2012).

Kwakkel (2006) has demonstrated an association between effect size and additional treatment time, and Foley et al. (2012) have found that the total amount of occupational therapy (OT) time is a significant predictor of gains in functional independence measure (FIM) scores. Furthermore, researchers have reported that intensive practice of function-focused physiotherapy predicts greater than expected gains in mobility (Bode, Heinemann, Semik, & Mallinson, 2004), with a treatment time of 3 hours or longer being associated with greatest functional improvements (Wang et al., 2013).

Conclusions
Overall, there is strong evidence that early intensive therapy may improve gait and general motor function; there is conflicting high-quality evidence regarding the effect of augmented physical therapy on gait at follow-up.

3.3.2 Task-Specific Training

As discussed under Organized Stroke Care, stroke rehabilitation should be task-specific wherever possible and practical. Functional reorganization of cortex is greater for tasks that are meaningful to the animal; repetitive activity is not enough. Task-specific training has been shown to have longer-lasting cortical reorganization. Rehabilitation must be task specific, focusing on tasks which are important and meaningful to the patient. In stroke rehabilitation, task-specific training principle is practiced in mobility training and has been shown to improve gait speed and endurance. Task-specific training is performed via actual over-the ground walking and can be incorporated in circuit class therapy. A Cochrane review by French et al. (2016) found that repetitive task-specific training significantly improved walking distance (9 studies), functional ambulation (8 studies), and lower limb function (5 studies) for up to six months, regardless of stroke onset, treatment dosage, or intervention type. There are 20 RCTs examining task-specific training in the lower extremity post stroke.

Highlighted Study

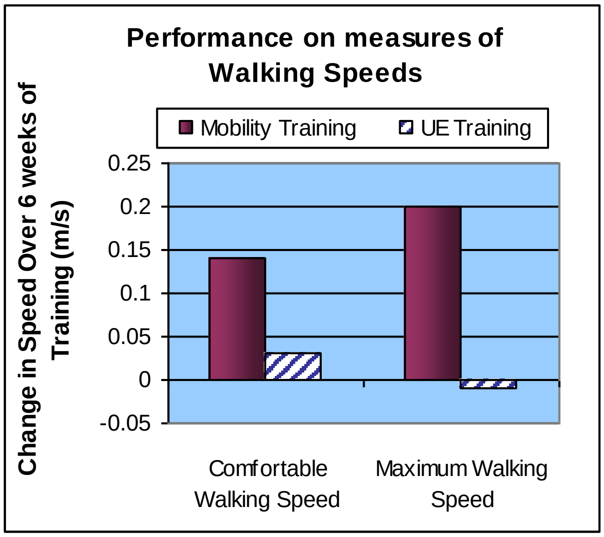
Van de Port IGL, Wevers LEG, Lindeman E, Kwakkel G. Effects of circuit training as alternative to usual physiotherapy after stroke: A randomised controlled trial. BMJ (2012); 344: e2072.		
RCT (PEDro=7) N_{start}=250 N_{end}=237 TPS=Chronic	E: Task-specific circuit training C: Conventional rehabilitation Duration: 90min/d, 2d/wk for 12 weeks	• 6-Minute Walk Test (+exp) • 5-Metre Walk Test (+exp) • Modified Stairs Test (+exp) • Timed Up & Go Test (-) • Rivermead Mobility Index (-) • Functional Functional ambulation Category (-) • Stroke Impact Scale (-) • Nottingham Extended ADL (-)
This large RCT showed that task specific circuit training was superior to standard outpatient therapy in improving gait post stroke.		

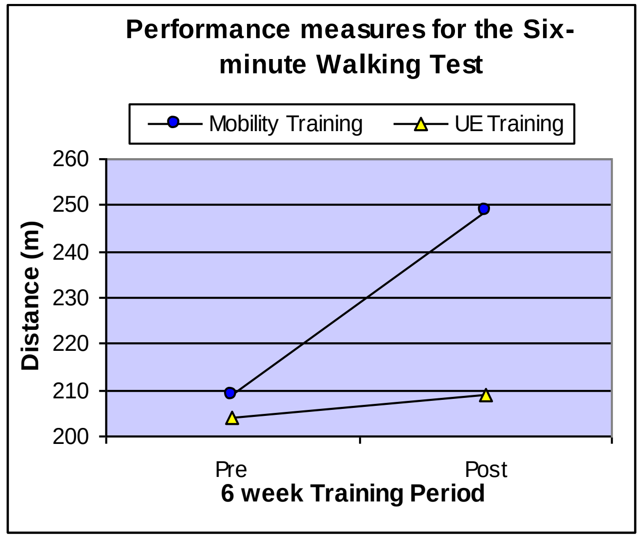
Highlighted Study

Dean et al. (2012). Exercise to enhance mobility and prevent falls after stroke: the community stroke club randomized trial. Neurorehabil Neural Repair (2012); 26(9):1046-1057.		
RCT (PEDro=7) N_{start}=151 N_{end}=133 TPS=Chronic	E: Community-based task-specific training for lower limb C: Community-based task-specific training for upper limb Duration: 30min/d, 4d/wk for 6wk	• 10-Metre Walk Test (+exp) • 6-Minute walk test (+exp)

Highlighted Study

Salbach NM, Mayo NE, Wood-Daphinee S, Hanley JA, Richard CL. A task-oriented intervention enhances walking distance and speed in the first year post stroke. A randomized controlled trial. Clinical Rehabilitation (2004); 18:509-519.		
RCT (PEDro=8) N_{start}=91 N_{end}=82 TPS=Chronic	E: Task-specific training, lower limb C: Task-specific training, upper limb Duration: 1hr/d, 5d/wk for 6wk	• 6-Minute Walk Test (+exp) • 5-Metre Walk Test (+exp) • Timed Up & Go Test (+exp) • Berg Balance Scale (-)
This study of community-dwelling stroke survivors found that a task-oriented gait training program increased walking distance and gait speed.		





Levels of Evidence for Task-Specific Training

Intervention	ADLs	Functional Ambulation	Balance	Functional Mobility
Bobath Concept Approach	**1a** **3 RCTs**	**1b** **1 RCT**	**1b** **1 RCT**	**1a** **2 RCTs**
Motor Relearning Programmes	**1b** **1 RCT**	**1b** **2 RCTs**	**1a** **3 RCTs**	

Conclusions

Task-specific training of the lower limbs may improve functional ambulation, balance and ADLs post stroke.

Further research is required to determine the efficacy of task-specific circuit training. The Neurodevelopmental Approach may improve ADLs when compared to conventional care.

3.3.3 Overground Walking

Overground gait training includes walking and related exercises with or without cueing from a physical therapist but does not include use of technology aids such as those used to administer body weight support (Pappas & Salem, 2009).

Highlighted Study

Gordon CD, Wilks R, McCaw-Binns A. Effect of aerobic exercise (walking) training on functional status and health-related quality of life in chronic stroke survivors: a randomized controlled trial. Stroke (2013); 44(4):1179-1181.		
RCT (PEDro=7) Nstart=128 Nend=116 TPS=Chronic	E: Aerobic training (overground walking) C: Massage Duration: 30min/d, 3d/wk for 12wk	• 6-Minute Walk Test (+exp) • Motricity Index (-)

Highlighted Study

Sandberg K, Kleist M, Falk L, Enthoven P. Effects of twice-weekly intense aerobic exercise in early subacute stroke: a randomized controlled trial. Arch Phys Med Rehabil (2016)2016; 97(8):1244-1253.		
RCT (PEDro=6) N_{start}=56 N_{end}=54 TPS=Subacute	E: Aerobic training (overground walking) C: Conventional rehabilitation Duration: 1hr/d, 5d/wk for 12wk	• 10-Metre Walk Test (+exp) • 6-Minute Walk Test (+exp) • Timed Up & Go Test (+exp)

Levels of Evidence for Overground Walking

Intervention	Functional Ambulation	Balance	Gait
Overground Walking	**1a 6 RCTs**	**1a 4 RCTs**	**1a 2 RCTs**

Conclusions

Overground walking may be beneficial for improving functional ambulation and gait but not balance.

3.3.4 Exercise Bike

Use of a cycle ergometer for stationary cycling has been used as a safe form of exercise training in those with challenges in maintaining balance and independent gait (Brown, Kautz, & Dairaghi, 1997). Cycling shares similar locomotor patterns with walking and is typically used for improving muscle strength, aerobic capacity, and to facilitate muscle control in the lower limbs (Kautz & Brown, 1998; Ozaki, Loenneke, Thiebaud, & Abe, 2015; Raasch & Zajac, 1999). Nine RCTs were found evaluating cycle ergometer training for lower extremity motor rehabilitation.

Highlighted Study

Jin H, Jiang Y, Wei Q, Wang B, Ma, G. Intensive aerobic cycling training with lower limb weights in Chinese patients with chronic stroke: discordance between improved cardiovascular fitness and walking ability. Disabil Rehabil (2012); 34(19):1665-1671.		
RCT (PEDro=4)	E: Aerobic training (cycle ergometer)	• 6-Minute Walk Test (+exp)

N_{start}=133 N_{end}=122 TPS=Chronic	C: Conventional rehabilitation Duration: 1hr/d, 5d/wk for 8wk	• Muscle strength (+exp) • Rivermead Mobility Index (-) • Berg Balance Scale (-) • Modified Ashworth Scale (-)

Highlighted Study

Mayo NE, MacKay-Lyons MJ, Scott SC, Moriello C, Brophy J. A randomized trial of two home-based exercise programmes to improve functional walking post-stroke. Clin Rehabil (2013); 27(7):659-671.		
RCT (PEDro=6) N_{start}=87 N_{end}=65 TPS=Chronic	E1: Home-based exercise program (cycle ergometer) E2: Home-based exercise program (overground walking) Duration: 30min/d, 5d/wk for 3wk	• 6-Minute Walk Test (-)

Levels of Evidence for Exercise Bicycle

Intervention	Motor Function	ADLs	Spasticity	Muscle Strength	Fnal Ambulat.	Balance	Functional Mobility	Gait
Cycle Ergometer	2 1 RCT	1b 3 RCTs	2 1 RCT	1b 2 RCTs	1a 6 RCTs	1b 1 RCT	2 1 RCT	1b 2 RCTs

Conclusions

Cycle ergometer training may be beneficial for improving motor function, balance and ADLs, but not beneficial for functional mobility, gait, spasticity and muscle strength.
The evidence is mixed for cycle ergometer training improving functional ambulation.

3.3.5 Treadmill Training in the Absence of Partial Body Weight Support

Treadmill training has been used as a form of task-specific training in rehabilitation, as it offers the opportunity for repetitive practice of complex gait cycles. Treadmill training without body weight support can be used when standard over-ground gait training is not available or appropriate. The evidence however, does not support treadmill training as necessarily more effective than standard gait training. In a review of nine trials, Polese et al. (2013) found that treadmill training without BWS significantly improved gait speed and walking distance long term when compared to conventional therapy, but was not superior to overground gait training.

Highlighted Study

Pohl M, Mehrholz J, Ritschel C, Ruckriem S. Speed-dependent treadmill training in ambulatory hemiparetic stroke patients. A randomized controlled trial. Stroke (2002); 33:553-558.		
RCT (PEDro=6) N_{start}=69 N_{end}=60 TPS=Subacute	E1: Speed dependent treadmill training E2: Treadmill training C: Neurodevelopmental techniques Duration: 6d/wk for 30min sessions over 2wk	E1 vs C: • 10-Metre Walk Test (+exp) • Cadence (+exp) • Stride length (+exp) • Functional Ambulation Category (+exp) E2 vs C: • 10-Metre Walk Test (+exp_2)

		• Cadence (+exp$_2$) • Stride length (-) • Functional Ambulation Category (+exp$_2$) E1 vs E2: • 10-Metre Walk Test (+exp) • Cadence (+exp) • Stride length (+exp) • Functional Ambulation Category (+exp)
This RCT demonstrated that structured speed-dependent treadmill training, where walking was increased with each session, resulted in significant improvements in many gait-related outcomes when compared to a less aggressive progressive treadmill training program or conventional gait therapy.		

Highlighted Study

Richards CL, Malouin F, Bravo G, Dumas F, Wood-Dauphinee S. The role of technology in task-oriented training in persons with subacute stroke: a randomized controlled trial. Neurorehabil and Neural Repair, (2004); 18(4):199-211.		
RCT (PEDro=6) N_{start}=63 N_{end}=51 TPS=Chronic	E: Treadmill training C: Conventional rehabilitation Duration: 1h, 5d/wk for 8wk	• Gait speed (-) • Fugl-Meyer Assessment (-) • Timed Up and Go test (-) • Barthel Index (-) • Berg Balance Scale (-)

Highlighted Study

Macko RF, Ivey FM, Forrester LW, Hanley D, Sorkin JD, Katzel LI et al. Treadmill exercise rehabilitation improves ambulatory function and cardiovascular fitness in patients with chronic stroke: a randomized, controlled trial. Stroke (2005); 36(10):2206-2211.		
RCT (PEDro=5) N_{start}=61 N_{end}=45 TPS=Chronic	E: Treadmill training C: Conventional rehabilitation Duration: 40min/d, 3d/wk for 24wk	• 6-Minute Walk Test (+exp) • 30-ft timed walk (-) • Walking Impairment Questionnaire (-) • Rivermead Mobility Index (-)
This RCT demonstrated that stroke patients undergoing treadmill training had improved gait function than low-intensity walking control.		

Highlighted Study

Park IM, Lee YS, Moon BM, Sim SM. A comparison of the effects of overground gait training and treadmill gait training according to stroke patients' gait velocity. J Phys Ther Sci (2013); 25(4):379-382.		
RCT (PEDro=8) N_{start}=102 N_{end}=98	E: Treadmill training C: Overground gait training Duration: 30min, 2/d for 5d	• 10-Metre Walk Test (-) • 6-Minute Walk Test (-) • Berg Balance Scale (-)

Levels of Evidence for Treadmill Training

Intervention	Motor Function	ADLs	Functional Ambulation	Balance	Functional Mobility	Gait
Treadmill Training	1b	1b	1a	1a	1b	1a

	1 RCT	2 RCTs	7 RCTs	5 RCTs	2 RCTs	6 RCTs

Conclusion
Treadmill training may improve functional ambulation, but may not impact balance, ADLs and motor function. The evidence is mixed for functional ambulation and gait.

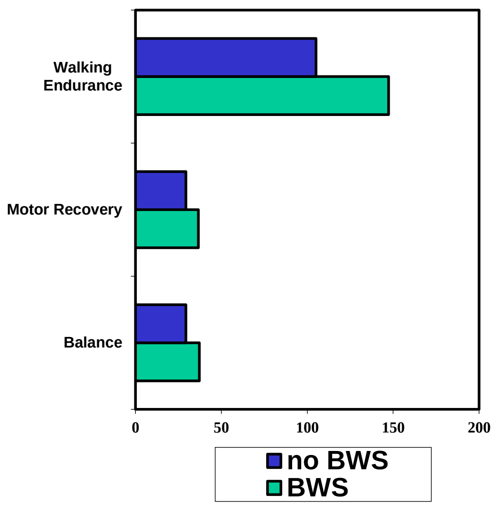
3.3.6 Partial Body Weight Support and Treadmill Training (PBWSTT)

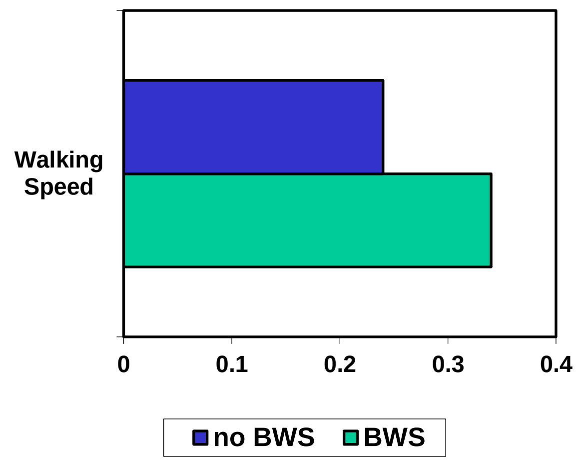
"Those who want to walk learn by walking" (Hesse, Werner, Von Frankenberg, & Bardeleben, 2003). Based on animal models whereby various motor activities, such as stepping, may be induced by brainstem and spinal cord with little cortical stimulus. The evidence of PBWS and treadmill training is mixed but the weight of the evidence is moving towards supporting PBWS. This is supported by the general trend towards task-specific therapies. Treatment does require equipment and is labour intensive. PBWSTT can be considered for patients with low ambulatory function especially when other mobility strategies are inappropriate or unsafe.

A Cochrane review evaluated 56 trials of treadmill training, either with or without BWS (Mehrholz, Thomas, & Elsner, 2017). Overall, treadmill training demonstrated significantly increased gait speed (+0.06m/s) and walking endurance (+14.2m) in the short term relative to other physiotherapy interventions, without increased risk of adverse events. However, treadmill training overall did not increase the odds of walking independently, and treadmill training with BWS did not improve gait speed or walking endurance. The authors concluded that independent walkers benefit most from treadmill training. Fifty-two RCTs were found evaluating treadmill training for lower extremity motor rehabilitation.

Highlighted Study

Visintin M, Barbeau H, Korner-Bitensky N, Mayo NE. A new approach to retrain gait in stroke patients through body weight support and treadmill stimulation. Stroke (1998); 29:1122-1128.		
RCT (PEDro=5) N_{start}=100 N_{end}=79 TPS=Subacute	E: Treadmill training with body weight support C: Treadmill training Duration: Not reported	• Berg Balance Scale (+exp) • Stroke Rehabilitation Assessment of Movement (+exp) • Walking speed (+exp)
This RCT was the key initial study supporting the concept that treadmill training with partial weight support results in improved gait performance. However, the training was very labour intensive.		





Highlighted Study

Ada L, Dean CM, Morris ME, Simpson JM, Katrak P. Randomized Trial of Treadmill Walking With Body Weight Support to Establish Walking in Subacute Stroke. The MOBILISE Trial. Stroke (2010); 41:1237-1242.		
RCT (PEDro=8) N_{start}=126 N_{end}=120 TPS=Acute	E: Treadmill training + Body weight support C: Overground gait training Duration: 45min/d, 5d/wk for 4wk	• Independent walking (+exp)
This RCT of BWSTT in the acute phase of stroke found that there was a non-significant trend towards improved walking compared to an active walking control at 6 months.		

Highlighted Study

LEAPS (Locomotor Experience Applied Post-Stroke) trial – Duncan PW, Sullivan KJ, Behrman AL et al. K Body-weight-supported treadmill rehabilitation after stroke. NEJM (2011); 364:2026-36.		
RCT (PEDro=7) N_{start}=408 N_{end}=NR TPS=Chronic	E1: Treadmill training + Body weight support, Early E2: Treadmill training + Body weight support, Late E3: Home-based exercise program Duration 90min/d, 3d/wk for 14wk	• Gait speed (-) • Walking independence (-) • Fugl-Meyer Assessment (-) • Berg Balance Scale (-) • Stroke Impact Scale (-)
This definitive large multicentred trial found that BWSTT was not superior to an active control, in this case home-based walking program, for higher functional walking level.		

Highlighted Study

MacKay-Lyons M, McDonald A, Matheson J, Eskes G, Klus MA. Dual effects of body weight supported treadmill training on cardiovascular fitness and walking ability early after stroke: a randomized controlled trial. Neurorehabil and Neural Repair (2013); 27(7):644-653.		
RCT (PEDro=8) N_{start}=50 N_{end}=47 TPS=Chronic	E: Treadmill training + Body weight support C: Conventional rehabilitation Duration: 1hr/d, 5d/wk for 6wk	• 6-Minute Walk Test (+exp) • 10-Metre Walk Test (-) • Berg Balance Scale (-) • Chedoke-McMaster Recovery Stages (-)

Highlighted Study

DePaul VG, Wishart LR, Richardson J, Thabane L, Ma J, Lee TD. Varied overground walking training versus body-weight-supported treadmill training in adults within 1 year of stroke: a randomized controlled trial. Neurorehabil and Neural Repair (2015); 29(4):329-340.		
RCT (PEDro=8) N_{start}=71 N_{end}=68 TPS=Chronic	E: Treadmill training + Body weight support C: Overground gait training Duration: 90min/d, 2d/wk for 6wk	• Gait speed (-) • 6-Minute Walk Test (-) • Functional Balance Test (-) • Activities-Specific Balance Confidence Scale (-) • Stroke Impact Scale (-) • Life Space Assessment (-)

Levels of Evidence for Partial Body Weight Support and Treadmill Training

Intervention	Motor Function	ADLs	Stroke Severity	Muscle Strength	Functional Ambulat.	Balance	Functional Mobility	Gait
Partial Body Weight Support Treadmill Training	**1b** **1 RCT**	**1b** **4 RCTs**	**1b** **2 RCTs**	**1b** **1 RCT**	**1b** **3 RCTs**	**1a** **9 RCTs**	**2** **1 RCT**	**1a** **6 RCTs**

Conclusions

Based on all RCTs, partial-body weight support treadmill training does not appear to improve ADLs, stroke severity with a mixed picture for gait and functional ambulation.

There is strong evidence that partial body weight support treadmill training may not improve gait or balance outcomes compared to conventional or other gait training interventions based on the most definitive trial, the LEAPs trial (Duncan et al. 2011).

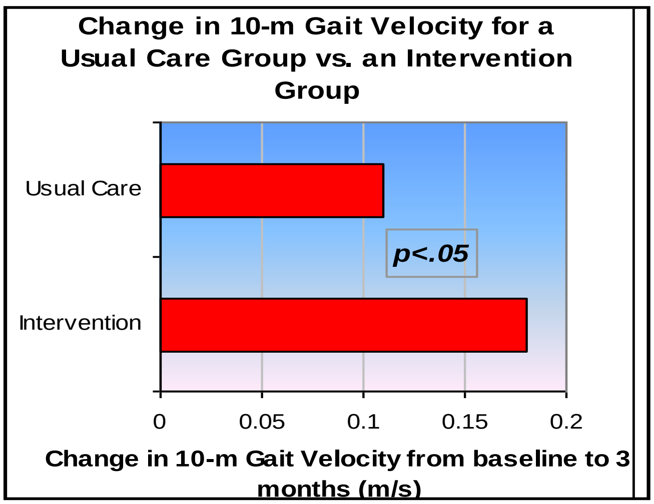
3.3.7 Physiotherapy Exercise Programs and Aerobic Training

In a meta-analysis of seven RCTs investigating individuals with chronic stroke, cardiorespiratory training was found to result in a moderate and statistically significant effect in improving walking endurance, but it was not associated with improved gait speed (Mehta et al., 2012). Similarly, a meta-analysis of 11 RCTs investigating individuals with acute stroke found improvements in walking endurance but not gait speed (Stoller, de Bruin, Knols, & Hunt, 2012). A systematic review of 25 studies revealed that aerobic exercise had a significant beneficial effect for measures of aerobic capacity and functional performance (endurance and speed), but not balance or functional independence (Pang, Charlesworth, Lau, & Chung, 2013a). Most recently, a Cochrane review examined 58 trials of physical fitness interventions, including aerobic training (28 trials), resistance training (13 trials), and mixed training (17 trials) (Bekele et al., 2016). Aerobic interventions demonstrated improvements in maximum gait speed, preferred gait speed, and walking endurance, while mixed interventions showed improved preferred gait speed and endurance. As well, aerobic and mixed interventions were associated with moderate improvements in disability.

Cardiovascular conditioning is increasingly being advocated for stroke patients. American Heart Association (2004)published exercise recommendations which included aerobic exercises as a means to improve sensorimotor function and help with secondary prevention of stroke. Patients with stroke should participate in an aerobic program following medical clearance. Based on the findings of their review, Pang et al. (2013b) recommended that patients engage in aerobic exercise of moderate to high intensity, 20-40 minutes per day, 3-5 days per week, to obtain improvements in aerobic fitness, maximal walking speed, and endurance.

Highlighted Study

Duncan P, Studenski S, Richards L, et al. Randomized clinical trial of therapeutic exercise in subacute stroke. Stroke (2003); 34:2173-2180.		
RCT (PEDro=8) N_{start}=100 N_{end}=92 TPS=Chronic	E: Home-based exercise program C: Conventional rehabilitation Duration: 90min/d, 3d/wk for 12wk	• 10-Metre Walk Test (+exp) • 6-Minute Walk Test (+exp) • Berg Balance Scale (+exp) • Functional Reach Test (+exp) • Fugl-Meyer Assessment (-) • Muscle strength (-)
This definitive large multicentred trial found that BWSTT was not superior to an active control, in this case home-based walking program, for higher functional walking level.		



Highlighted Study

Gordon CD, Wilks R, McCaw-Binns, A. Effect of Aerobic Exercise (Walking) Training on Functional Status and Health-related Quality of Life in Chronic Stroke Survivors A Randomized Controlled Trial. Stroke (2013); 44(4), 1179-1181.		
RCT (PEDro=7) N_{start} =128 N_{end} =116 TPS=Chronic	E: Aerobic training (overground walking) C: Massage Duration: 30min/d, 3d/wk for 12wk	• 6-Minute Walk Test (+exp) • Motricity Index (-)

Highlighted Review

Brazzelli M, Saunders DH, Greig CA, Mead GE. Physical fitness training for stroke patients. Cochrane Database of Systematic Reviews (2011), Issue 11. Art. No.: CD003316. DOI:10.1002/ 14651858. CD003316.pub4.
Methods 32 trials were included, patients were recruited in both the acute and chronic stages of stroke. Intervention were classified into 3 major groups: cardiorespiratory training vs usual care; resistance

training vs usual care; mixed training inclusive of both cardiorespiratory and resistance training method.

Results

In the cardiorespiratory training group, the walking speed (maximal speed and preferred speed) and walking capacity were significantly improved. However, cardiorespiratory training was not associated with reductions in disability as reflected by FIM.

This review examined 32 clinical trials looking at physical fitness training for stroke patients and found with cardiorespiratory training did improve walking speed and capacity but did not result in a reduction in disability.

When compared to less active/intensive interventions or conventional rehabilitation techniques, aerobic exercise demonstrated significant improvements in gait by overground walking. However, some trials failed to find significant improvements in balance associated with aerobic training, particularly those utilizing over ground walking. Exercise programs incorporating aerobic training were found to improve motor function, whether delivered in the community or at home. Comparing exercise programs using a cycle ergometer or over ground walking, Mayo et al. (2013) found both programs to be similarly effective. In addition, Olney et al. (2006) found that exercise programs improved gait and strength whether supervised or unsupervised. There was strong evidence cardiovascular training post-stroke improves level of physical fitness and gait performance; however, it did not result in additional improvement in ADL performance.

Levels of Evidence for Physiotherapy Exercise Programs and Aerobic Training

Intervention	Motor Function	ADLs	Spasticity	Muscle Strength	Fnal Ambulat.	Balance	Functal Mobility	Gait
Overground Walking					1a 6 RCTs	1a 4 RCTs		1a 2 RCTs
Cycle Ergometer	2 1 RCT	1b 3 RCTs	2 1 RCT	1b 2 RCTs	1a 6 RCTs	1b 1 RCT	2 1 RCT	1b 2 RCTs
Treadmill Training	1b 1 RCT	1b 1 RCT			1a 7 RCTs	1a 5 RCTs	1b 2 RCTs	1a 6 RCTs

Conclusions

Overground walking appears to improve functional ambulation and gait but not balance.

Cycle ergometer training may be beneficial for improving motor function, balance and ADLs, but not beneficial for functional mobility, gait, spasticity and muscle strength. The evidence is mixed for cycle ergometer training improving functional ambulation.

Treadmill training may improve functional ambulation, but may not impact balance, ADLs and motor function. The evidence is mixed for functional ambulation and gait.

3.3.8 Strength Training to Improve Mobility

Weakness has been defined as inadequate capacity to generate normal levels of muscle force (Miller, Garland, & Koshland, 1998). Gray et al. (2012b) found that individuals experience decreases in muscle fibre length and lean muscle mass post stroke. Neural input to the muscle are reduced, resulting in weakness and a decrease in muscle fibre length, which the fibres may adapt to if the muscle is not moved through the full range of motion (Gray, Juren, Ivanova, & Garland, 2012a). In contrast, Klein et al. (2013) did not find any significant differences in muscle volume or atrophy between the contralesional and ipsilesional limbs in relation to weakness. However, the authors reported lower levels of maximal voluntary contraction torque in the contralesional limb, which was associated with deficits in muscle activation and electromyographic amplitude. Twenty-eight RCTs were found evaluating strength and resistance training for lower extremity motor rehabilitation.

Highlighted Study

Moreland JD, Goldsmith CH, Huijbregts MP, Anderson RE, Prentice DM, Brunton KB, O'Brien A, Torresin WD. Progressive resistance strengthening exercises after stroke: a single-blind randomized controlled trial. Arch Phys Med Rehabil (2003); 84:1433-40.		
RCT (PEDro=6) N_{start}=133 N_{end}=106 TPS=Subacute	E: Progressive resistance training C: Training without resistance Duration: 30min/d, 5d/wk for 6wk	• 2-Minute Walk Test (-) • Chedoke-McMaster Stroke Assessment (-)
This RCT tested the benefit of two strengthening programs on gait. Unfortunately, strength training did not improve gait when compared to an exercise program which did not involve strength training. Although strength training has been shown to be helpful in studies, the benefit is by no means consistent.		

Highlighted Study

Mead GE, Greig CA, Cunningham I et al. Stroke: a randomized trial of exercise or relaxation. J Am Geriatr Soc 2007; 55:892-899.		
RCT (PEDro=8) N_{start}=66 N_{end}=66 TPS=Chronic	E: Progressive resistance training C: Relaxation Duration: 30min/d, 3d/wk for 12wk	• Timed Up-and-Go Test (+exp) • Rivermead Mobility Index (-) • Sit-to-Stand Test (-) • Elderly Mobility Score (-) • Functional Independent Measure (-)
This RCT showed that a strengthening program resulted in improved physical abilities, timed up and go and walking economy when compared to a relaxation exercise group.		

Highlighted Study

Cooke EV, Tallis RC, Clark A, Pomeroy VM. Efficacy of functional strength training on restoration of lower-limb motor function early after stroke: phase I randomized controlled trial. Neurorehabilitation and Neural Repair 2010; 24(1):88-96.		
RCT (PEDro=7) N_{start}=109 N_{end}=80 TPS=Chronic	E: Functional strength training C1: High-intensity physiotherapy C2: Low-intensity physiotherapy	<u>E vs C1/C2</u> • Walking Speed: (-) • <u>C1 vs C2</u> • Walking Speed: (+con_1) • Rivermead Mobility Index (-) • Knee flexion peak torque (-) • Knee extensor peak torque (-)
This multicentre RCT revealed that patients who received high-intensity conventional physiotherapy exhibited significantly greater improvements in gait speed compared to a lower-intensity control group, while patients who received FST did not demonstrate significantly greater improvements than the controls.		

Muscle strengthening as an intervention is designed to improve the force-generation capacity of hemiplegic limbs and enhance functional abilities. Several studies have provided evidence that resistive training for the lower limb can produce strength gains, although these gains may not translate into improved functional performance. For that reason, there is mixed evidence that strength training improves outcomes post stroke. Some of the studies were positive while others were not.

Levels of Evidence for Strength Training to Improve Mobility

Intervention	ADLs	Muscle Strength	Functional Ambulation	Balance	Functional Mobility	Gait
Strength and Resistance Training	**1b 2 RCTs**	**1a 6 RCTs**	**1a 7 RCTs**	**1a 9 RCTs**	**1a 4 RCTs**	**1a 7 RCTs**

Conclusions
Due to conflicting findings, it is unclear whether strength and resistance training for the lower limbs improves ADLs, muscle strength, functional ambulation and gait.
There was considerable heterogeneity in the type, duration, and intensity of strength/resistance interventions.
There is strong evidence that strength and resistance training for the lower limbs improves balance but not functional mobility.

3.3.9 Balance Training and Falls Prevention Post Stroke

Sit-to-Stand Training

Standing from a seated position is considered the most frequently performed functional task and is necessary for mobility (Alexander et al., 2000). Sit-to-stand training is a targeted and specific intervention aimed at improving this particular movement, as well as at improving balance and muscle strength (Tung, Yang, Lee, & Wang, 2010). Pollock et al. (2014) conducted a systematic review with 13 trials, finding that sit-to-stand interventions can improve sit-to-stand time and lateral symmetry but insufficient evidence to assess ability to sit-to-stand independently, peak vertical ground reaction forces, or functional ability.

Highlighted Study

Liu M, Chen J, Fan W, Mu J, Zhang J, Wang L., Zhuang J, Ni C. (2016). Effects of modified sit-to-stand training on balance control in hemiplegic stroke patients: a randomized controlled trial. Clin Rehabilitation 2016; 30(7):627-636.		
RCT (PEDro=7) N_{start}=50 N_{end}=50 TPS=Subacute	E: Sit-to-stand training with asymmetrical foot position C: Sit-to-stand training with symmetrical foot position Duration: 1hr/d, 3d/wk for 4wk	• Berg Balance Scale (+exp) • Dynamic balance (+exp) • Static balance (+exp)

Levels of Evidence for Sit to Stand Training

	Muscle Strength	Balance	Gait

Intervention			
Sit to Stand Training	1b 1 RCT	1b 1 RCT	1b 1 RCT

Conclusions

Sit-to-stand training may be beneficial for improving gait and muscle strength, but not balance.

Trunk Training

Trunk impairment is common after stroke and is directly associated with balance and gait (Jijimol, Fayaz, & Vijesh, 2013; Verheyden et al., 2006). Additionally, trunk control and balance while sitting are well known predictors in functional outcome and hospital stay after a stroke (Franchignoni, Tesio, Ricupero, & Martino, 1997; Verheyden et al., 2006). Trunk training targets the trunk or "core muscles", which include those supporting the lumbo-pelvic-hip complex (Hibbs, Thompson, French, Wrigley, & Spears, 2008). Nine RCTs were found evaluating trunk training for lower extremity motor rehabilitation.

Highlighted Study

Saeys W, Vereeck L, Truijen S, Lafosse C, Wuyts FP, Van de Heyning P. Randomized controlled trial of truncal exercises early after stroke to improve balance and mobility. Neurorehabil and Neural Repair 2012; 26(3):231-238.		
RCT (PEDro=7) N_{start}=33 N_{end}=33 TPS=Chronic	E: Trunk training C: Conventional rehabilitation Duration: *Not Specified*	• Trunk Impairment Scale (+exp) • Tinetti Test (+exp) • Four Test Balance Scale (+exp) • Berg Balance Scale (+exp) • Rivermead Motor Assessment (+exp) • Dynamic Gait Index (+exp)

Levels of Evidence for Trunk Training

Intervention	Motor Function	ADLs	Stroke Severity	Muscle Strength	Fnal Ambulat.	Balance	Functal Mobility	Gait
Trunk Training	1a 4 RCTs	2 2 RCTs	2 1 RCT	2 1 RCT	2 1 RCT	1a 5 RCTs	2 1 RCT	1b 2 RCTs

Conclusions

Both trunk training and enhanced trunk training may be beneficial for most lower limb rehab outcomes, in particular balance and motor function where the evidence is strong.

Balance Training

Improvement in balance has been identified as the strongest predictor of distance walked. There have been a large number of RCTs examining balance which have employed a number of therapy approaches. Trunk-specific balance training and balance-focused exercise programs have been shown to improve balance post stroke. Whole body and local vibration, thermal stimulation, and interventions involving feedback may not improve balance outcomes. It is unclear whether task-specific balance training programs and virtual reality training improve balance, gait and functional recovery post stroke.

Many different programs have been developed to improve general balance. Programs that focus on balance, stability, and mobility exercises improve balance outcomes more than regular physiotherapy (Allison & Dennett, 2007; Puckree & Naidoo, 2014; Tang et al., 2014), while those focused on weight shifting do not yield such improvements (Howe, Taylor, Finn, & Jones, 2005).

Trunk training describes various exercises and approaches aimed at improving trunk performance and functional sitting balance; a systematic review by Cabanas-Valdes (2013) identified 11 trials suggesting that trunk training may improve trunk performance and dynamic sitting balance.

Highlighted Study

Tang Q, Tan L, Li B, Huang X, Ouyang C, Zhan H, Pu Q, Wu L. Early sitting, standing, and walking in conjunction with contemporary Bobath approach for stroke patients with severe motor deficit. Topics in Stroke Rehabilitation 2014; 21(2):120-127.		
RCT (PEDro=9) N_{start}=48 N_{end}=48 TPS=Acute	E: Early sitting, standing, and walking C: Conventional rehabilitation Duration: *Not reported*	• Berg Balance Scale (+exp) • Stroke Rehabilitation Assessment of Movement (+exp)

A Cochrane review of seven trials by Barclay-Goddard et al. (2004) concluded that force platform biofeedback therapy (visual or auditory) can improve standing balance, but not functional balance. A more recent systematic review of 22 trials suggested that biofeedback therapy was superior to usual therapy or placebo at improving lower limb activities, both balance and gait (Stanton, Ada, Dean, & Preston, 2011a).

A systematic review found that the use of VR with postural training (6 studies) but not Wii Fit balance board (7 studies) significantly improved performance on the Berg Balance Scale and Timed Up and Go Test (Iruthayarajah, McIntyre, Cotoi, Macaluso, & Teasell, 2017).

Similar to virtual reality, balance trainers incorporate visual cues into balance exercises. These mechanical devices support patients as they move in both the horizontal and vertical planes.

Highlighted Study

Lee SH, Byun SD, Kim CH, Go JY, Nam HU, Huh JS, Jung TD. Feasibility and Effects of Newly Developed Balance Control Trainer for Mobility and Balance in Chronic Stroke Patients: A Randomized Controlled Trial. Annals of Rehabilitation Medicine 2012; 36(4):521-529.		
RCT (PEDro=8) Nstart=40 Nend= 40 TPS=Chronic	E: Balance training with Balance Control Trainer C: Conventional rehabilitation Duration: 1hr/d, 5d/wk for 4wk	• Berg Balance Scale (+exp) • Timed Up & Go Test (+exp) • Functional Ambulation Categories (+exp) • Modified Barthel Index (-)

Intervention	**Motor Function**	**ADLs**	**Stroke Severity**	**Muscle Strength**	**Functional Ambulation**	**Balance**	**Gait**

Balance Trainers	**1b 3 RCTs**	**1a 8 RCTs**	**2 1 RCT**	**1b 2 RCTs**	**1b 3 RCTs**	**1a 18 RCTs**	**2 2 RCTs**

Level of Evidence for Balance Training

Conclusions

Balance training does not appear to improve stroke severity, muscle strength or gait. The evidence is mixed for improvements in balance, ADLs, motor function and functional ambulation.

Balance Training and Risk of Falling

Patients experience a stroke are at a higher risk of falling with 25-39% of patients falling while on the stroke rehabilitation unit and 73% falling within 6 months of discharge form hospital. Several RCTs have exhausted the effectiveness of exercise programs in reducing falls while one study (see highlighted study below) actually studies a falls prevention study.

Highlighted Study

Batchelor FA, Hill KD, Mackintosh SF, Said CM, Whitehead CH. Effects of a multifactorial falls prevention program for people with stroke returning home after rehabilitation: A randomized controlled trial. Arch Phys Med Rehabil 2012; 93(9):1548-1655.		
RCT (PEDro=8) N_{start}=156 N_{end}=148 TPS=Chronic	E: Falls prevention program including home exercise, implementation of falls and injury risk minimization as well as education. C: Usual care Duration: 1hr/d, 3d/wk for 12mo	• Falls rate (-) • Falls risk (-) • Falls efficacy (-) • Balance (-) • Gait (-) • Strength (-) • Participation (-) • Activity (-)
This RCT found that a tailored multifactorial falls prevention program did not prevent falls more than usual care.		

Conclusion

Falls prevention programs may not reduce the rate of falls post stroke.

3.3.10 Caregiver Mediated Exercise Programs

Caregiver-mediated programs allow primary caregivers to assume responsibility for home-based exercise programs following patient discharge.

Highlighted Study

Wang TC, Tsai AC, Wang JY, Lin YT, Lin KL, Chen JJ, Lin BY, Lin TC. Caregiver-mediated intervention can improve physical functional recovery of patients with chronic stroke: a randomized controlled trial. Neurorehabil Neural Repair 2015; 29(1):3-12.		
RCT (PEDro=6) N_{start}=51	E: Caregiver-mediated exercise program C: Usual care	• 10-Metre Walk Test (+exp) • 6-Minute Walk Test (+exp)

N_{end}=51 TPS=Chronic	Duration: 90min/d, 5d/wk for 4wk	• Berg Balance Scale (+exp) • Barthel Index (+exp) • Stroke Impact Scale (+exp)

In individuals with chronic stroke, Wang et al. (2015) compared a personalized caregiver-mediated home-based program to a control group that only received physiotherapist visits. Their findings suggested that the program significantly more effective in improving gait and balance compared to controls. Furthermore, the results showed that there was no difference in the burden of the caregiver compared to the control group.

Levels of Evidence for Caregiver Mediated Programs

Intervention	ADLs	Balance	Functional Mobility
Caregiver Mediated Programs	**1a** **2 RCTs**	**1b** **1 RCT**	**1b** **1 RCT**

Conclusions
Caregiver-mediated programs may improve lower limb functional mobility, balance and ADLs.

3.3.11 Electromechanical and Robotic Assisted Mobility Training

Electro-mechanical and robotic-assisted therapy have gained much recent interest in stroke motor rehabilitation. Theoretically, robot-assisted therapies are able to provide alternative to labour-intensive therapist-assisted interventions, thus fulfil the stroke rehabilitation principles of high intensity and task specificity. However, the potential benefits have not yet been fully apparent in research and clinical practice; with studies showing mixed outcome results.

These devices are generally classified as either an "end-effector device" (i.e. patients are placed on foot plates that stimulate the stance and swing phases of gait) or an "exoskeleton device" (i.e. patients are outfitted with a programmable device that moves the hips and knees during gait). The most commonly studied end-effector device is the Gait Trainer, while the Lokomat is the most studied exoskeleton device (Mehrholz & Pohl, 2012b). There has also been recent focus on small modular robots designed for single joint use such as the ankle (Forrester et al., 2014). The main advantage of these devices over conventional gait training is that they can increase the number of repetitions performed and reduce the need for intensive therapist involvement, thereby increasing therapist productivity and accelerating patient recovery.

Electromechanical devices used for lower limb rehabilitation post-stroke

Electromechanical Devices	Description
End-Effectors • G-EO System • Gait Trainer I and II (GT I, GT II)	The G-EO system is a gait-trainer robotic device that provides a supportive harness and uses foot plates to simulate floor walking and also walking up and down stairs (Hesse et al. 2012).
	The GT II is a gait-trainer robotic device that offers body weight support through a harness and also endpoint feet trajectories through foot plates (Iosa et al., 2011).
Exoskeleton Systems • Lokomat • Walkbot • Hybrid Assistive Limb (HAL) • AutoAmbulator • LokoHelp	The Lokomat is a widely used exoskeleton device that features a treadmill, a dynamic body weight support system, and a motor-driven robotic orthosis (Bae, Kim, & Fong, 2016). The robotic orthosis is used to control gait pattern through adjusting gait speed, guidance force, and support from body weight (Bae et al., 2016).
	The Walkbot is a gait rehabilitation exoskeleton that features powered hip-knee-ankle joint drive motor design as well as a biofeedback platform (Kim et al., 2015).
	The HAL is a wearable robotic exoskeleton that supports participants in walking, standing, and performing other leg movements (Yoshikawa et al., 2018). The HAL detects bioelectrical signals generated by muscles and floor-reaction-force signals and responds to the user's voluntary movements instead of following a predefined motion (Yoshikawa et al., 2018).
	The AutoAmbulator is a gait rehabilitation exoskeleton that provides body weight support treadmill training with the assistance of a harness and robot arms. The robot arms have four degrees of freedom and control various aspects of the gait cycle (Fisher et al. 2011).
	The LokoHelp device is placed on top of a treadmill and is an easily installed or removed. It works through transmitting the treadmill movement to levers on either side of the device which then create movements that imitate stance and swing phases of gait (Freivogel, Schmalohr, & Mehrholz, 2009).
Exoskeleton Portable Devices • Stride Management Assist (SMA) • Anklebot • Bionic Leg	The Stride Management Assist (SMA) device is a robotic exoskeleton that provides assistance with high flexion and extension in each leg. This device uses neural oscillators and the user's Central Pattern Generator to generate assist torques during the gait cycle to regulate walking patterns (Buesing et al., 2015).
	The Anklebot is a robotic device consisting of a knee brace that is attached to a custom shoe (Forester et al. 2013). It is designed to strengthen the ankle and the lower extremity through adjusting the force applied depending on varying requirements (L. W. Forrester et al., 2013).
	The Bionic Leg device is a powered knee orthosis that uses sensors, accelerometers, and joint angle detectors to detect the user's movements and provide mechanical assistance (Stein, Bishop, Stein, & Wong, 2014).
Robotic Arm Control System	The gait-assistance robot is a robotic arm control system that includes 4 robotic arms, a full weight-bearing system, and a visual foot pressure biofeedback system (Nakanishi, Wada, Saeki, & Hachisuka, 2014). The four separate robotic arms provide the ability to

• Gait-Assistance Robot (GAR)	move the lower body automatically and independently (Ochi, Wada, Saeki, & Hachisuka, 2015). This device does not suspend a patient with a harness and thus promotes full body weight bearing while on a treadmill (Ochi et al., 2015).

In a systematic review of 18 trials, Mehrholz and Pohl (2012a) compared the effects of end-effector and exoskeleton devices as part of gait training after stroke. The authors found that end-effector device studies achieved significantly higher rates of independent walking at the end of the study period relative to studies involving exoskeleton devices, despite a significantly greater proportion of participants in the former studies having initial severe impairment. A recent Cochrane review examined 36 trials of electromechanical-assisted gait training in stroke rehabilitation (Mehrholz, Thomas, Werner, et al., 2017). Compared to gait training alone, the enhanced intervention significantly increased the odds of independent walking, but did not significantly increase gait speed or endurance. All devices were similar in terms of treatment effect, although there were significant differences between devices in their effect on gait. Additional analyses revealed that the intervention provided most benefit for patients who were non-ambulatory and/or in the acute phase of stroke.

Highlighted Review

Mehrholz J, Werner C, Kugler J, Pohl M. Electromechanical-assisted training for walking after stroke. Cochrane Database of Systematic Reviews 2007, Issue 4. Art. No.: CD006185. DOI: 10.1002/14651858.CD006185.pub2.

Methods
17 trials with 837 participants comprising of ambulators, non-ambulators and combination of both. Interventions include electromechanical and robotic -assisted devices (with or without electrical stimulation) with the addition of physiotherapy compared with physiotherapy or routine care only.
Results
Electro-mechanical assisted gait training in combination with physiotherapy increased the odds of becoming independent in walking (OR 2.21, 95% CI: 1.52 to 3.22). However, there is no significant increment in walking velocity or walking capacity.

This Cochrane Review of 17 trials found electromechanical assisted gait training in addition to physiotherapy increased the odds of walking independently when compared to PT or routine care alone; it did not increase gait velocity.

Highlighted Study

Pohl M, Werner C, Holzgraefe M, Kroczek G, Mehrholz J, Wingendorf J et al. Repetitive locomotor training and physiotherapy improve walking and basic activities of daily living after stroke: a single-blind, randomized multicentre trial (DeutscheGAngtrainerStudie, DEGAS). Clin Rehabil. 2007; 21(1):17-27.

RCT (PEDro=8) N_{start}=155 N_{end}=150 TPS=Acute	E: Gait Trainer GT I (Rehastim) C: Conventional rehabilitation Duration: 45min/d, 5d/wk for 4wk	• Functional Ambulation Category (+exp) • Barthel Index (+exp)

This RCT demonstrated stroke patients treated with PT and an electromechanical gait trainer were more likely to walk independently with an improved Barthel Index score than controls receiving PT equal to the amount of time spent in both PT and the gait trainer.

Highlighted Study

Schwartz I, Sajin A, Fisher I, Neeb M, Shochina M, Katz-Leurer M, Meiner Z. The effectiveness of locomotor therapy using robotic-assisted gait training in subacute stroke patients: a randomized controlled trial. PMR 2009; 1:516-523.		
RCT (PEDro=6) N_{start}=67 N_{end}=61 TPS=Subacute	E: Lokomat gait training C: Conventional rehabilitation Duration: 30min/d, 3d/wk for 6wk	• Functional Ambulatory Category (+exp) • NIH Stroke Scale (+exp) • Stroke Activity Scale (-) • Gait speed (-) • Gait endurance (-) • Stair climb (-)
This RCT found the patients who received additional Lokomat training to a physiotherapy gait training program were able to walk more independently than controls who received only the PT gait training.		

Highlighted Study

Morone G, Bragoni M, Iosa M, De Angelis D, Venturiero V, Coiro P, Pratesi L, Paolucci S. Who may benefit from robotic-assisted gait training? A randomized clinical trial in patients with subacute stroke. Neurorehabil Neural Repair 2011; *25:636–644*. **Morone G, Iosa M, Bragoni M, De Angelis D, Venturiero V, Coiro P, Riso R, Pratesi L, Paolucci S. Who may have durable benefit from robotic gait training: a 2-year follow-up randomized controlled trial in patients with subacute stroke? Stroke 2012; 43(4):1140-1142.**		
RCT (PEDro=6) N_{start}=48 N_{end}=43 TPS=Subacute	E: Gait Trainer GT II (Rehastim) and conventional gait training C: Conventional gait training Duration: 30min (2x/d), 5d/wk for 12wk	• Functional Ambulation Category (+exp) • Rivermead Mobility Index (+exp) • 6-Minute Walk Test (+exp) • 10-Metre Walk Test (-) • Motricty Index (-) • Ashworth Scale (-) • Rankin Scale (-) • Barthel Index (+exp)
This RCT found low impairment groups receiving robotic-assisted and conventional gait training improved more than control receiving conventional gait training alone for mobility and ADLs; high impairment groups both improved but there was no significant difference between the treatment and control groups suggesting that electromechanical gait aids work best for low impairment groups.		

Highlighted Study

Han EY, Im SH, Kim BR, Seo MJ, Kim MO. Robot-assisted gait training improves brachial–ankle pulse wave velocity and peak aerobic capacity in subacute stroke patients with totally dependent ambulation: Randomized controlled trial. Medicine 2016; 95(41).		
RCT (PEDro=5) N_{start}=60 N_{end}=60 TPS=Subacute	E: Lokomat gait training C: Conventional rehabilitation Duration: 90min/d, 5d/wk for 4wk	• Functional Ambulation Category (-) • Fugl-Meyer Assessment (-) • Berg Balance Scale (-) • Modified Barthel Index (-)

32 RCTs were found that evaluated lower limb robotics for motor rehabilitation up to mid July 2018 (Chapter 9, http://www.ebrsr.com/). The evidence is mixed regarding the effectiveness of end-effectors, alone or in combination with functional electrical stimulation, for lower limb rehabilitation following

stroke. The evidence is mixed regarding the effectiveness exoskeleton systems for lower limb rehabilitation following stroke. Portable exoskeleton devices are likely not effective for lower limb rehabilitation following stroke. Robotic arm control systems are likely not effective for lower limb rehabilitation following stroke. Lokomat training may be beneficial for lower limb rehabilitation following stroke but not in the acute phase. Canadian Best Practice Guidelines: Update 2015 (Hebert et al., 2016) have noted that, *"Electromechanical (robotic) assisted gait training devices could be considered for patient who would not otherwise practice walking. They should not be used in place of conventional gait training (Evidence Level A for Early and Late Rehab)".*

Levels of Evidence for Electromechanical Devices/Robotics for Mobility

Intervention	Motor Function	ADLs	Spasticity	ROM	Propriocep-tion	Stroke Severity	Muscle Strength	Fnal Ambulat.	Balance	Functal Mobility	Gait
End Effectors (Robotics)	**1a 3 RCTs**	**1a 6 RCTs**	**1b 1 RCT**				**1a 3 RCTs**	**1a 8 RCTs**	**1a 3 RCTs**	**1a 6 RCTs**	
Exoskeleton (Robotics)	**1a 8 RCTs**	**1a 6 RCTs**	**2 2 RCTs**	**2 1 RCT**	**1b 1 RCT**	**1b 1 RCT**	**1b 4 RCTs**	**1a 17 RCTs**	**1b 13 RCTs**	**1a 6 RCTs**	**1a 3 RCTs**

Conclusions

End effector robotics, using body weight support and moving foot plates, has been shown to improve functional ambulation and functional mobility and may help with motor function, ADLs, muscle strength and balance.

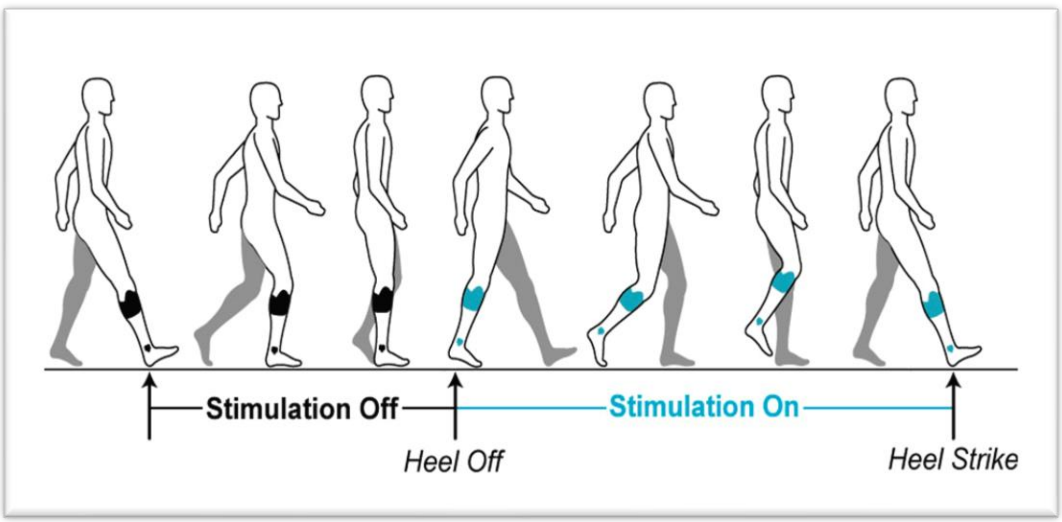
The Lokomat, or a similar exoskeletal system (e.g. LokoHelp, AutoAmbulator, Walkbot), may improve motor function, muscle strength, functional ambulation, balance and gait; it does not improve ADLs and functional mobility.

Specifically Lokomat training may be beneficial for lower limb rehabilitation following stroke while evidence is more mixed for exoskeleton devices being effective for lower limb rehabilitation following stroke.

3.3.12 Functional Electrical Stimulation/FES-Based Neural Orthosis for Gait Cycle

The integration of neuromuscular electrical stimulation with functional activity or training is referred to as functional electrical stimulation (FES) (Peckham & Knutson, 2005).

Use of the Ness L300® decreases spasticity, improves dynamic instability and creates a more normal gait pattern with chronic hemiparesis.



FES of the common peroneal nerve has been used to enhance ankle dorsiflexion during the swing phase of gait. Although weak ankle dorsiflexion with plantar flexion hypertonicity is typically corrected by an ankle foot orthosis, FES may be a suitable alternative for highly motivated patients who are able to walk independently or with minimal assistance.

There is growing evidence that FES combined with gait training improves hemiplegic gait. Systematic reviews (Kottink et al., 2004; Robbins et al., 2006) both showed a benefit for walking speeds. Two systematic reviews of RCTs found that FES was superior to training alone for improving functional mobility in both acute and chronic phases (Howlett, Lannin, Ada, & McKinstry, 2015; Pereira et al., 2012). There is strong evidence FES and gait retraining results in improvements in hemiplegic gait. Canadian Best Practice

Guidelines: Update 2015 notes that, *"FES should be used to improve strength and function (gait) in selected patients, but the effects may not be sustained (Evidence Level: Early – Level A; Late – Level A)."*

Highlighted Study

Daly JJ, Zimbelman J, Roenigk KL, McCabe JP, Rogers JM, Butler K et al. Recovery of coordinated gait: Randomized controlled stroke trial of Functional Electrical Stimulation (FES) versus no FES, with weight-supported treadmill and over-ground training. Neurorehabil Neural Repair 2011; 25(7):588-596.		
RCT (PEDro=7) N_{start}=54 N_{end}=47 TPS=Chronic	E: Gait training + Intramuscular FES C: Gait training Duration: 90min/d, 4d/wk for 12wk	• Gait Assessment & Intervention Tool (+exp)
This RCT demonstrated that intramuscular FES resulted in greater improvements in gait during a gait training program when compared to controls who did not have IM FES.		

Highlighted Study

Sheffler LR, Bailey S., Wilson RD, Chae J. Spatiotemporal, kinematic, and kinetic effects of a peroneal nerve stimulator versus an ankle foot orthosis in hemiparetic gait. Neurorehabil Neural Repair 2013; 27(5):403-410.		
RCT (PEDro=7) N_{start}=110 N_{end}=98 TPS=Chronic	E: Gait training + FES C: Gait training Duration: 1hr/d, 2d/wk for 12wk	• Modified Emory Functional Ambulation Profile (+exp) • Fugl-Meyer Assessment (-)

Highlighted Study

Kluding PM, Dunning K, O'Dell MW et al. Foot drop stimulation versus ankle foot orthosis after stroke: 30-week outcomes. Stroke 2013; 44(6):1660-1669.		
RCT (PEDro=5) N_{start}=197 N_{end}=162 TPS= Chronic	E: FES C: AFO Duration: 1hr/d, 5d/wk for 30wk	• 10-Metre Walk Test (-) • 6-Minute Walk Test (-) • Fugl-Meyer Assessment (-) • Timed Up and Go Test (-) • Berg Balance Scale (-)

Highlighted Study

Bethoux F, Rogers H, Nolan K et al. The effects of peroneal nerve functional electrical stimulation versus ankle-foot orthosis in patients with chronic stroke: A randomized controlled trial. Neurorehabilitation and Neural Repair 2014; 28(7): 688-697.		
RCT (PEDro=6) N_{start}=495 N_{end}=399 TPS=Chronic	E: FES C: AFO Duration: 45min/d, 5d/wk for 12wk	• 10-Metre Walk Test (-) • 6-Minute Walk Test (-) • Timed Up and Go Test (-) • Berg Balance Scale (-) • Modified Emory Functional Ambulation Profile (-) • Stroke Impact Scale (-)

Highlighted Study

Sheffler LR, Taylor PN, Bailey SN et al. Surface peroneal nerve stimulation in lower limb hemiparesis: effect on quantitative gait parameters. Am J Phys Med Rehabil 2015; 94(5):341.		
RCT (6) N_{start}=110 N_{end}=96 TPS=Subacute	E: Gait training + FES C: Gait training Duration: 1hr/d, 2d/wk for 12wk	• Gait speed (-) • Stride length (-) • Hip power (-) • Ankle power (-) • Cadence (-)

Given its ability to stimulate foot drop, FES has been compared to ankle foot orthosis (AFO) in terms of effectiveness in improving lower limb motor function. A total of 35 RCTs were found evaluating functional electrical stimulation for lower extremity motor rehabilitation up to July 2018 (Chapter 9, http://www.ebrsr.com/). Functional electrical stimulation may be beneficial for improving gait. The literature is mixed regarding functional electrical stimulation, alone or in combination with other techniques, for lower extremity rehabilitation following stroke.

Levels of Evidence for Functional Electrical Stimulation to Improve Gait

Intervention	Motor Function	ADLs	Spasticity	ROM	Muscle Strength	Functional Ambulation	Balance	Functional Mobility	Gait
FES	1a 7 RCTs	1a 6 RCTs	1a 4 RCTs	1b 1 RCT	1a 4 RCTs	1a 12 RCTs	1a 5 RCTs	1a 2 RCTs	1a 7 RCTs

Conclusions
Functional electrical stimulation may be a suitable adjunct for therapies targeting lower limb motor function post stroke.
FES has been shown to improve ADLs, muscle strength, functional ambulation and gait. It may help motor function and spasticity but does not improve balance and functional mobility more than conventional care.

3.3.13 Neuromuscular Electrical Stimulation

Neuromuscular electrical stimulation (NMES) is a technique used to generate muscle contractions in regions affected by hemiparesis by stimulating lower motor neurons involved in muscle movement through transcutaneous application of electrical currents {Monte-Silva, 2019 #157; ; Allen & Goodman 2014). A total of 9 RCTs were found that evaluated different NMES techniques up until July 2018 (Chapter 9, http://www.ebrsr.com/).

1. Cyclic NMES in which a muscle is repetitively stimulated at near maximum contraction on a pre-set schedule and patient participation is passive (Nascimento et al. 2014);
2. Electromyography (EMG) triggered NMES, in which a target muscle is directly controlled or triggered by volitional EMG activity from the target or a different muscle to elicit a desired stimulation {Monte-Silva, 2019 #157}.

Highlighted Study

Suh JH, Han SJ, Jeon SY et al. Effect of rhythmic auditory stimulation on gait and balance in hemiplegic stroke patients. NeuroRehabilitation 2014; 34(1):193-199.

RCT (PEDro=8) N_{start}=42 N_{end}=42 TPS=Subacute	E: Interferential current NMES C: Sham NMES Duration: one 60min session	• 10-Meter Walk Test (+exp) • Timed Up-and-Go Test (+exp) • Functional Reach Test (+exp) • Berg Balance Scale (+exp) • Modified Ashworth Scale (+exp)

Level of Evidence for Neuromuscular Electrical Stimulation

Intervention	Motor Function	ADLs	Spasticity	ROM	Stroke Severity	Muscle Strength	Fnal Ambulat.	Balance	Functal Mobility	Gait
NMES	1b 1 RCT	1b 2 RCTs	1a 6 RCTs	1a 2 RCTs	1a 2 RCTs	1b 1 RCT	1a 5 RCTs	1a 18 RCTs	2 1 RCT	1b 1 RCT

Conclusions

NMES may be beneficial for functional mobility and muscle strength.

The literature is mixed for NMES regarding its improvement to functional ambulation, balance, spasticity, range of motion, stroke severity and activities of daily living.

NMES may not be beneficial for improving motor function or gait.

There was considerable heterogeneity in the delivery and type of NMES used.

3.3.14 Biofeedback

Feedback-based training has been used to help improve balance and mobility. Feedback can come in the form of auditory, visual and touch sensation sensory inputs and these additional sensory cues can improve motor performance. The type of feedback can be quite variable but tends to fall under one of these categories: auditory stimulation, action observation and biofeedback methods. Feedback to patients as to how they perform motor tasks during gait rehabilitation has been shown to improve performance and learning (Johnson, Burridge, & Demain, 2013).

Classification of biofeedback used for stroke rehabilitation (Giggins, Persson, & Caulfield, 2013)

Biofeedback category	Subcategories	Examples
Biomechanical	Movement Postural Control Force	Inertial sensors Force plates Electrogoimeters Pressure biofeedback units Camera based systems
Physiological	Neuromuscular system	EMG biofeedback Real time ultrasound imaging biofeedback
	Cardiovascular system	Heart rate biofeedback Heart rate variability biofeedback
	Respiratory system	Breathing electrodes and sensors that convert breathing to auditory and visual signals

In a systematic review of 22 RCTs, Stanton et al. (2011b) examined a variety of feedback interventions as part of the rehabilitation practice. Collectively, feedback was associated with a moderate treatment effect for both short-term and long-term improvement in lower limb motor function. However, there was considerable heterogeneity between the studies in terms of feedback modality, stroke onset, and outcome measures. As well, many of the studies had small sample sizes and poor methodological quality. Therefore, the review may have overestimated the effect of biofeedback and its findings should be taken with caution. A total of 37 RCTs were found evaluating feedback for lower extremity motor rehabilitation (Chapter 9, http://www.ebrsr.com/).

3.3.15 Gait Training with Movement or Postural Control Visual Biofeedback

Nine RCTs compared gait training with movement or postural control visual biofeedback to gait training with little or no biofeedback (Chapter 9, http://www.ebrsr.com/).

Highlighted Study

Drużbicki M, Guzik A, Przysada G, Kwolek A, Brzozowska-Magoń A. Efficacy of gait training using a treadmill with and without visual biofeedback in patients after stroke: a randomized study. J Rehabil Med 2015; 47(5)P:419-425.		
RCT (PEDro=7) N_{start}=50 N_{end}=44 TPS=Chronic	E: Treadmill training + camera-based movement visual feedback C: Treadmill training Duration: 1.5hr/d, 5d/wk for 2wk	• 10-Metre Walk Test (-) • 2-Minute Walk Test (-) • Timed Up & Go Test (-) • Cadence (-) • Swing phase (-) • Stance phase (-)

Highlighted Study

Dobkin et al. International randomized clinical trial, stroke inpatient rehabilitation with reinforcement of walking speed (SIRROWS) improves outcomes. Neurorehabili Neural Repair 2010; 24(3):235-242.		
RCT (PEDro=7) N_{start}=179 N_{end}=169 TPS=Subacute	E: Gait training + Daily reinforcement C: Gait training Duration: 45min/d, 3d/wk for 4wk	• Gait speed (+exp) • Walking distance (-) • Functional Ambulation Classification (-)
This RCT found that patients who had feedback about self-selected fast walking speed walked faster than those with no reinforcement; this did not translate into more independent walkers or walking longer distances.		

Highlighted Study

Dorsch et al. SIRRACT: An international randomized clinical trial of activity feedback during inpatient stroke rehabilitation enabled by wireless sensing. Neurorehabil Neural Repair 2015; 29(5):407-415.		
RCT (PEDro=6) N_{start}=135 N_{end}=125 TPS=Acute	E1: Gait training + Daily accelerometer biofeedback (speed and activity) E2: Gait training + Daily accelerometer feedback (speed only) Duration: 30min/d, 5d/wk for 4wk	• Gait speed (-) • Walking distance (-) • Daily walking time (-) • Functional Ambulation Category (-) • Stroke Impact Scale (-)
This RCT provided speed-only feedback or augmented feedback by a computer; there was no significant difference between the two in daily walking time or walking speed.		

Intervention	Motor Function	Functional Ambulation	Balance	Functional Mobility	Gait

Gait Training with Movement or Postural Control Visual Biofeedback	**1b** **1 RCT**	**1a** **3 RCTs**	**1a** **3 RCTs**	**2** **1 RCT**	**1a** **8 RCTs**

Levels of Evidence

Conclusions

Gait training with movement or postural visual feedback is likely not beneficial for lower limb rehab post stroke.

3.3.16 EMG Biofeedback

Electromyography (EMG) biofeedback therapy has been used as a means to improve gross motor function, which can lead to improvements in standing balance and gait, using either auditory or visual feedback. Moreland et al. (1994; 1998) concluded that EMG-biofeedback was an effective adjunct to lower limb physiotherapy. Cochrane review evaluating EMG-biofeedback vs. either sham or no treatment found no benefit to treatment on pooled results (Woodford & Price, 2007). Most of the studies are small RCTs. Biofeedback training improved gait and standing post-stroke in a majority of "fair" to "good" quality RCTs. However, there is enough negative trials that evidence regarding the effect of EMG Biofeedback on lower limb function post stroke was regarded as conflicting and "not ready". Seven RCTs compared EMG biofeedback with therapy to conventional therapy or motor relearning for lower extremity motor rehabilitation (Chapter 9, http://www.ebrsr.com/)

Highlighted Study

Xu H, Jie J, Hailiang Z, Ma C. Effect of EMG-triggered stimulation combined with comprehensive rehabilitation training on muscle tension in poststroke hemiparetic patients. J Sport Med Phys Fit 2015; 55(11):1343-1347.		
RCT (PEDro=5) N_{start}=40 N_{end}=40 TPS=Subacute	E: Comprehensive rehabilitation + EMG biofeedback C: Conventional rehabilitation Duration: 45min/d, 5d/wk for 4wk	• Fugl-Meyer Assessment (+exp) • Functional Ambulation Category (+exp)

Levels of Evidence for EMG Biofeedback

Intervention	Motor Function	ADLs	ROM	Muscle Strength	Functional Ambulation	Functional Mobility	Gait
EMG Biofeedback	**2** **1 RCT**	**1b** **1 RCT**	**1b** **2 RCTs**	**1b** **1 RCT**	**2** **1 RCT**	**2** **1 RCT**	**1a** **4 RCTs**

Conclusion

EMG biofeedback may produce improvements in motor function, muscle strength and functional ambulation, but not ADLs, ROM or functional mobility.

The evidence is mixed regarding gait.

3.3.17 Rhythmic Auditory Stimulation

Rhythmic auditory stimulation (RAS) is a form of gait training that involves the sensory cuing of motor systems. The rhythmic auditory stimulus provides a time reference for motor gait response, such that the gait response and auditory stimulus develop into a stable temporal relationship (M. H. Thaut, McIntosh, & Rice, 1997). In a meta-analysis of seven RCTs, Nascimento et al. (2015) found that gait training with RAS significantly improved gait speed, stride length, cadence, and symmetry when compared to gait training alone. A subsequent meta-analysis by Yoo and Kim (2016) found equivalent results, with additional subgroup analysis revealing that stroke onset did not have an impact on treatment effect. Sixteen RCTs were found evaluating rhythmic auditory stimulation for lower extremity motor rehabilitation.

Highlighted Study

Thaut MH, Leins AK, Rice RR et al. Rhythmic auditory stimulation improves gait more than NDT/Bobath training in near-ambulatory patients early poststroke: A single-blind, randomized trial. Neurorehabil and Neural Repair 2007; 21(5):455-459.		
RCT (PEDro=7) N_{start}=78 N_{end}=56 TPS=Acute	E: Overground gait training + Rhythmic auditory stimulation C: Gait training Duration: 30min/d, 5d/wk for 3wk	• Gait speed (+exp) • Stride length (+exp) • Cadence (+exp) • Symmetry Index (+exp)

Levels of Evidence for Rhythmic Auditory Stimulation

Intervention	ROM	Muscle Strength	Functional Ambulation	Balance	Gait
Rhythmic Auditory Stimulation	2 1 RCT	1b 2 RCTs	1a 8 RCTs	1a 4 RCTs	1a 10 RCTs

<u>Conclusion</u>
Rhythmic auditory stimulation with physical exercise, including over ground gait training or treadmill training, is likely beneficial for lower limb rehabilitation following stroke.
Rhythmic auditory stimulation training may improve gait, functional ambulation and balance post stroke.

3.3.18 Dual Task Training

Dual task training, or cognitive motor interference, involves the simultaneous performance of a motor task and a cognitive task. Many activities of daily living involve dual tasks, although neurological deficits can increase the difficulty of performance and rate of failure, and so rehabilitation has begun to incorporate combined cognitive-motor training. In a systematic review of 15 RCTs, Wang et al. (2015) found that dual task training was superior to conventional training in improvements to gait speed, stride length, cadence, postural sway, and balance. Eight RCTs were found evaluating dual-task training interventions for lower extremity motor rehabilitation.

Levels of Evidence of Dual-Task Training

Intervention	Motor Function	ADLs	Fnal Ambulat.	Balance	Gait
Dual -Task Training	2 1 RCT	2 1 RCT	1b 2 RCTs	1b 2 RCTs	1a 4 RCTs

Conclusions

The literature is mixed concerning dual-task training's ability to improve functional ambulation, balance and gait.

Dual-task training may not be beneficial for improving motor function and activities of daily living.

3.3.19 Transcutaneous Electrical Nerve Stimulation

Transcutaneous electrical nerve stimulation (TENS) involves the application of electrical current through surface electrodes on the skin to facilitate activation of nerves (Teoli et al. 2019). TENS units are often small, portable, battery-operated devices, and have been used over antagonist muscles to reduce the spasticity of corresponding agonist muscles in stroke rehabilitation practice (Teoli et al. 2019; Koyama et al. 2016).

Level of Evidence of TENS

Intervention	Motor Function	ADLs	Spasticity	ROM	Muscle Strength	Functional Ambulat.	Balance	Functal Mobility	Gait
TENS	1a 2 RCTs	1a 3 RCTs	1a 7 RCTs	1a 2 RCTs	1a 4 RCTs	1a 6 RCTs	1a 4 RCTs	1a 3 RCTs	1a 2 RCTs

Conclusions

TENS may be beneficial for improving functional mobility, functional ambulation, range of motion and spasticity.

The literature is mixed regarding TENS for improving motor function, activities of daily living, gait, balance, and muscle strength.

3.3.20 Aquatic Therapy

Aquatic therapy has demonstrated benefit in improving motor function during rehabilitation. The natural properties of water – including buoyancy, hydrostatic pressure, hydrodynamic forces, thermodynamics, and viscosity – can assist with rehabilitative exercises (Becker, 2009a). In particular, underwater rehabilitation can offset gravity, support weight, provide balance, assist gait, and thus encourage confidence in both balance and gait (Becker, 2009b). 14 RCTs were found evaluating aquatic therapy for lower extremity motor rehabilitation.

Levels of Evidence for Aquatic Therapy

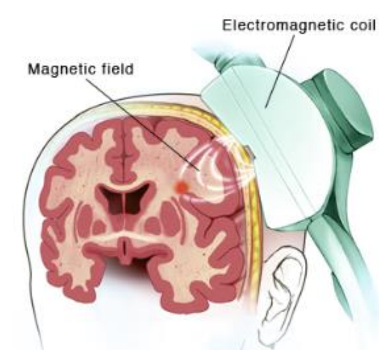
Intervention	ADLs	Propriocep-tion	Stroke Severity	Muscle Strength	Functional Ambulation	Balance	Functional Mobility	Gait
Aquatic Therapy	1a 3 RCTs	2 1 RCT	1b 1 RCT	1a 3 RCTs	1a 8 RCTs	1a 9 RCTs	1b 1 RCT	1b 2 RCTs

Conclusions

Aquatic therapy may be beneficial for improving functional ambulation, activities of daily living, muscle strength, and proprioception.
The literature is mixed regarding aquatic therapy for improving gait and balance.
Aquatic therapy may not be beneficial for improving mobility or spasticity although the data is limited.

3.3.21 Brain Stimulation

3.3.21.1 Repetitive Transcranial Magnetic Stimulation



Prior to a stroke, both hemispheres remain balanced, with motor cortex interactions mostly inhibited. However, following a stroke, the contralesional hemisphere becomes disinhibited, with the ipsilesional hemisphere increasingly inhibited (Elkholy, Atteya, Hassan, Sharaf, & Gohary, 2014). Previous literature into regaining hemispheric balance has advocated the use of applying high-frequency repetitive transcranial magnetic stimulation (rTMS) to the ipsilesional hemisphere in order to enhance excitability and low-frequency rTMS to the contralesional hemisphere to reduce excitability (Fregni et al., 2006). This series of non-invasive magnetic pulses can alter neural activity, and modulate excitability of the motor cortex transiently but beyond the duration of stimulation (Cha & Kim, 2015). It has been suggested that use of rTMS may result in quicker recovery times due to enhanced re-innervation of paretic limbs and changes in neuroplasticity, potentially affecting behaviour and motor ability (Mally & Dinya, 2008). A Cochrane review by Hao et al. (2013) found that rTMS treatment had few mild adverse events, but did not significantly improve independence or motor function. 16 RCTs were found evaluating rTMS for lower extremity motor rehabilitation up to July 2018. A majority of the studies identified compared real rTMS with a sham rTMS protocol with largely positive results.

Highlighted Study

Du J, Tian L, Liu W, Hu J, Xu G, Ma M, Fan X, Ye R, Jiang Y, Yin Q, Zhu W, Xiong Y, Yang F, Liu X. Effects of repetitive transcranial magnetic stimulation on motor recovery and motor cortex excitability in patients with stroke: a randomized controlled trial. Eur J Neurol 2016; 23(11):1666-1672.		
RCT (PEDro=7) N_{Start}=69 N_{End}=55 TPS=Acute	E1: Ipsilesional rTMS (3Hz) E2: Contralesional rTMS (1Hz) C: Sham rTMS	<u>E1/E2 vs C</u> • Fugl-Meyer Assessment (+exp, +exp2) • Medical Record Council (+exp, +exp2) • Barthel Index (+exp, +exp2) • Modified Rankin Scale (+exp, +exp2)

	Duration: 5d Data analysis: Two-way ANOVA; Bonferroni post hoc tests	• NIH Stroke Scale (+exp, +exp2)

Levels of Evidence for Repetitive Transcranial Brain Stimulation

Intervention	Motor Function	ADLs	Spasticity	ROM	Stroke Severity	Muscle Strength	Fnal Ambulat.	Balance	Gait
Low Frequency rTMS	1a 6 RCTs	1a 4 RCTs	2 1 RCT	1b 1 RCT	1a 2 RCT	1b 1 RCT	1a 3 RCTs	1a 3 RCTs	1a 2 RCTs
High Frequency rTMS	1a 3 RCTs	1a 4 RCTs			1a 4 RCTs	1b 1 RCT	1a 3 RCTs	1b 1 RCT	

Conclusions

Repetitive transcranial magnetic stimulation may be an effective intervention improving gait, balance, spasticity, range of motion, activities of daily living, muscle strength and stroke severity.
The literature is mixed regarding the effect of rTMS on motor function and functional ambulation.
The levels of evidence for low and high frequency rTMS are shown in the colour coded table above.

3.3.21.2 Transcranial Direct Current Stimulation (tDCS)

Similar to rTMS, tDCS is a form of non-invasive electrical stimulation that involves the application of mild electrical currents conducted through surface electrodes applied to the scalp, over the area of interest. There are two forms of stimulation: (1) anodal, which increases cortical excitability, and (2) cathodal, which decreases excitability (Alonso-Alonso, Fregni, & Pascual-Leone, 2007a). In contrast to TMS, tDCS does not induce action potentials but instead manipulates the ion balance inside and outside the resting neural membrane, through polarising and depolarising the brain tissue (Alonso-Alonso, Fregni, & Pascual-Leone, 2007b; Schlaug, Renga, & Nair, 2008). Anodal tDCS over the sensorimotor cortex has been found to increase the size evoked potentials of ipsilateral cortical components and enhances synaptic strength, while anodal tDCS of the primary motor cortex increase spinal network excitability (Dutta, Paulus, & Nitsche, 2014).

Highlighted Study

Andrade SM, Batista LM, Nogueira LL, et al. Constraint-induced movement therapy combined with transcranial direct current stimulation over premotor cortex improves motor function in severe stroke: a pilot randomized controlled trial. Rehabilitation Research and Practice 2017.		
RCT (PEDro=10) N$_{Start}$=60 N$_{End}$=60 TPS=Subacute	E1: Anodal tDCS E2: Dual tDCS E3: Cathodal tDCS C: Sham tDCS Duration: 5d/wk for 2wk Data analysis: split-plot ANOVA with Bonferroni correction	<u>E1/E2/E3 vs. C</u> • Rate of falls (+exp, +exp$_2$, +exp$_3$) • Four Square Step Test (+exp, +exp$_2$, +exp$_3$) • Overall Stability Index (+exp, +exp$_2$, +exp$_3$) • Falls Efficacy Scale (+exp, +exp$_2$, +exp$_3$) • Berg Balance Scale (+exp, +exp$_2$, +exp$_3$) • 6-Minute Walk Test (+exp, +exp$_2$, +exp$_3$) • Sit-to-Stand Test (+exp, +exp$_2$, +exp$_3$) <u>E2 vs E1/E3</u> • Rate of falls (-)

		• Four Square Step Test (-) • Overall Stability Index (-) • Falls Efficacy Scale (+exp$_2$) • Berg Balance Scale (+exp$_2$) • 6-Minute Walk Test (+exp$_2$) • Sit-to-Stand Test (+exp$_2$)

Highlighted Study

Saeys W, Vereeck L, Lafosse C, Truijen S, Wuyts FL, Van De Heyning P. Transcranial direct current stimulation in the recovery of postural control after stroke: a pilot study. Disabil Rehabil 2015; 37(20):1857-1863.		
RCT (PEDro=8) N_{Start}=31 N_{End}=31 TPS=Subacute	E: Dual tDCS + Rehabilitation C: Sham tDCS + Rehabilitation Duration: 20min/d, 4d/wk for 4wk Data analysis: Independent *t*-test	• Tinetti Balance Scale (-) • Tinetti Gait Scale (-) • Rivermead Motor Assessment (-) • Trunk Impairment Scale (-)

A total of twelve RCTs were found evaluating tDCS interventions for lower extremity motor rehabilitation. One systematic review examining anodal tDCS found small but significant increases in corticomotor excitability and nonsignificant improvements in motor function (Bastani & Jaberzadeh, 2012).

Levels of Evidence for tDCS

Intervention	Motor Function	Muscle Strength	Functional Ambulation	Balance	Functional Mobility	Gait
Anodal tDCS	**1b** **1 RCT**	**1a** **2 RCTs**	**1a** **2 RCTs**	**1a** **2 RCTs**		**1b** **1 RCT**
Dual tDCS		**1b** **1 RCT**		**1a** **3 RCTs**	**1b** **1 RCT**	**1b** **1 RCT**

<u>Conclusions</u>
The literature is mixed concerning the benefit of tDCS on lower extremity motor outcomes.
Anodal tDCS improves muscle strength and may improve motor function, functional ambulation and balance.
Dual tDCS may improve balance.

3.3.22 Virtual Reality and Gait/Balance

Virtual reality (VR) is a technology that allows individuals to experience and interact with virtual environments. VR tools are classified as either immersive (i.e. three-dimensional environment via head-mounted display) or non-immersive (i.e. two-dimensional environment via conventional computer monitor or projector screen). Customized VR programs have been created and tested in rehabilitation research, although commercial gaming consoles (e.g. Nintendo Wii, Playstation EyeToy,) have also been used to deliver VR training.

There are no key studies to highlight even though there are a lot of RCTs because they are all relatively small. Several systematic reviews and meta-analyses have examined the impact of VR training on motor function in stroke rehabilitation. A Cochrane review reported that VR-enhanced training demonstrated no treatment effect on gait or balance when compared to conventional rehabilitation (Laver et al., 2017). However, in a review of 22 trials specific to lower limb recovery, Gibbons et al. (2016) reported that VR-enhanced rehabilitation significantly improved gait speed, cadence, stride length, and balance relative to standard rehabilitation, particularly in patients with chronic stroke. Corbetta et al. (2015) in a systematic review, analyzing the results form 15 trials found that when VR therapy replaced standard rehab, walking speed, balance and mobility were significantly improved (Corbetta et al. 2015). Conversely, when VR therapy was delivered in addition to standard therapy, only mobility was found to be improved.

Levels of Evidence for Virtual Reality

Intervention	Motor Function	ADLs	Spasticity	ROM	Propriocep-tion	Stroke Severity	Muscle Strength	Functional Ambulat.	Balance	Functional Mobility	Gait
Virtual Reality	**1a 5 RCTs**	**1a 10 RCTs**	**2 1 RCT**		**2 1 RCT**	**1a 2 RCTs**	**2 1 RCT**	**1a 9 RCTs**	**1a 17 RCTs**	**1b 2 RCTs**	**1a 6 RCTs**
VR with Treadmill	**2 1 RCT**			**2 1 RCT**				**1a 3 RCTs**	**1a 9 RCTs**	**2 1 RCT**	**1a 7 RCTs**

<u>Conclusions</u>
Virtual reality training has been shown to improve gait and may improve motor function, ADLs, functional ambulation, balance and functional mobility.
Virtual reality with treadmill training has been shown to improve gait, balance and functional ambulation.

3.3.23 Action Observation

Action observation is a form of therapy whereby an individual observes another individual performing a motor task, either on a video or a real demonstration, and then may attempt to perform the same task themselves. For example, the patient may be instructed to watch a video showing an adult stretching out his hand to pick up a cup, bringing the cup to his mouth, and then returning the cup to its initial position - the act of drinking. After observing the video sequence for a time, the participants may or may not be asked to perform the same action (Borges et al. 2018).

Levels of Evidence for Action Observation

Intervention	Functional Ambulation	Balance	Gait
Action Observation	**2 2 RCTs**	**1b 2 RCTs**	**1b 3 RCTs**

Conclusions

Action Observation has been shown to improve gait and balance and may improve functional ambulation.

3.3.24 Motor Imagery/Mental Practice

The use of motor imagery to improve gait/lower extremity performance has been adapted from the field of sports psychology. Motor imagery involves rehearsing a specific task or series of tasks mentally. Mental practice can be used to supplement conventional therapy and can be used at any stage of recovery. Systematic reviews have found some evidence for mental practice in improving overall functional recovery (i.e. both upper and lower limbs) in chronic stroke (El-Shennawy & El-Wishy, 2012), but there was a lack of evidence for it improving outcomes related to mobility (Braun et al., 2013). The authors of both reviews noted that evidence was limited, and that it was unclear whether improvements were retained over time. There is strong evidence that mental practice/mental imagery may improve gait and balance problems when used as an adjunct to other treatments. Six RCTs were found evaluating mental practice for lower extremity motor rehabilitation.

Highlighted Study

Kumar VK, Chakrapani M, Kedambadi R. Motor imagery training on muscle strength and gait performance in ambulant stroke subjects-a randomized clinical trial. JCDR 2016; 10(3):YC01.		
RCT (PEDro=7) N_{start}=40 N_{end}=40 TPS=Chronic	E: Task-specific training + Mental practice C: Task-specific training Duration: 50min/d, 4d/wk for 3wk Data analysis: Independent *t*-test	• 10-Metre Walk Test (+exp) • Hip flexor and extensor strength (+exp) • Knee extenso • Ankle dorsiflexor strength r strength (+exp) • Knee flexor strength (-) (+exp) • Ankle plantarflexor strength (-)

Levels of Evidence for Mental Practice/Motor Imagery

Intervention	Motor Function	ADLs	Muscle Strength	Functional Ambulation	Balance	Functional Mobility	Gait
Mental Practice	**1b** **2 RCTs**	**1b** **2 RCTs**	**1b** **1 RCT**	**1a** **3 RCTs**	**1b** **4 RCTs**	**1b** **1 RCT**	**1b** **1 RCT**

Conclusions

Mental practice/motor imagery in combination with gait/balance training, may improve gait, balance, functional ambulation and motor function.

Mental practice may not be beneficial for improving functional mobility and activities of daily living.

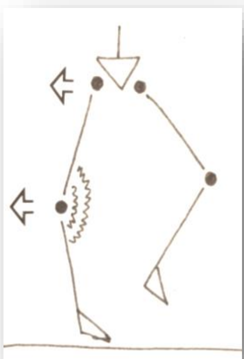
3.3.25 Assistive Walking Devices: Canes

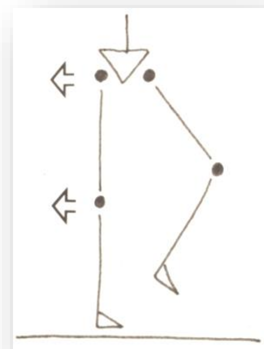
Walking aids, such as canes and walkers, are frequently employed in the rehabilitation of stroke patients. These devices are used to assist hemiplegic patients with impaired balance in achieving independent ambulation by increasing the base of support (Kuan, Tsou, & Su, 1999a). The major functions of walking aids are to: (1) increase stability; (2) improve muscle action; and (3) reduce weight-bearing loads through targeted anatomical structures (Kuan, Tsou, & Su, 1999b).

In comparing cane type, single-point canes were found to be more effective than quad canes and walkers in improving gait speed and endurance (Jeong, Jeong, Myong, & Koo, 2015), while quad canes improved aspects of balance compared to single-point canes (Laufer, 2002).

<u>Conclusion</u>
Single-point canes improve gait speed and endurance, while quad canes improve balance.

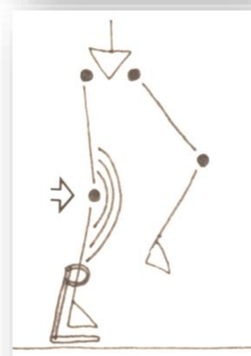
3.3.26 Ankle Foot Orthoses





Upper motor neuron injury in gait deviation, including hip and knee extension and ankle plantar flexion during the stance phase. To facilitate swing phase of gait an AFO may be used to compensate for excessive ankle plantar flexion and lack of knee flexion.

One of the advantages of hemiplegic hypertonicity is it maintains the hip and knee in extension during stance phase (see diagram to right).



Patients who are unsure of their stance phase will sometimes overextend their knee to push up against the posterior ligaments; however, this places an enormous amount of stress on the knee ligaments during weight bearing and should be discouraged (see diagram to left).

An AFO set in 5 degrees of dorsiflexion will not only help to clear the foot but will make it more difficult for patient to hyperextend the knee (see diagram on right).

There is limited evidence that an AFO when combined with posterior tibial nerve denervation, improves gait outcomes in hemiplegic patients. There is limited evidence AFOs improves various parameters of gait.

Highlighted Study

Wang R, Lin P, Lee C, Yang Y. Gait and balance performance improvements attributable to ankle-foot orthosis in subjects with hemiparesis. American J Phys Med Rehab 2007; 86(7):556-562.		
Cross-over RCT (PEDro=6) N_{start}=58 N_{end}=58 TPS=Subacute	E: AFO C: No device Duration: Single Session	• Gait speed (+exp) • Step length (+exp) • Stride length (+exp) • Weight bearing (+exp) • Sway velocity (+exp) Sway distance (+exp)

AFOs are commonly used for improving gait in patients with hemiplegic stroke, and research suggests that they are effective at improving gait.

Highlighted Study

Pomeroy VM, Rowe P, Clark A et al. A Randomized controlled evaluation of the efficacy of an Ankle-Foot Cast on walking recovery early after Stroke: SWIFT Cast Trial. Neurorehabil Neural Repair 2016; 30(1):40-48.		
RCT (PEDro=8) N_{start}=105 N_{end}=78 TPS=Acute	E: Individualized AFO C: Standard AFO Duration: 6wks	• Gait speed (-) • Functional Ambulation Category (-) Modified Rivermead Mobility Index (-)

Three trials compared an individualized AFO to a standard AFO, and all reported the two devices to be similar in terms of improving gait.

Levels of Evidence for AFOs

Intervention	Fnal Ambulat.	Balance	Gait
AFO	**1a** **4 RCTs**	**2** **4 RCTs**	**1b** **3 RCTs**

Conclusions

Ankle foot orthoses may be effective for improving gait and functional ambulation, but the evidence is mixed for balance.

3.3.27 Pharmaceuticals

3.3.27.1 Amphetamines

Amphetamines increase the release of noradrenaline and dopamine in the brain and act as potent stimulants. They have been shown to accelerate motor recovery following motor cortex lesions in the rat model (Feeney, Gonzalez, & Law, 1982), especially when combined with task-specific training. Sprigg and Bath (2009a) reported that there was no evidence of significantly reduced death/dependency or enhanced motor recovery following treatment with amphetamine in a subsequent review of 11 trials. The authors also raised questions about the safety of the medication, given significant increases in heart rate and systolic blood pressure, as well as a non-significant increase in risk of death (Sprigg & Bath, 2009b).

Highlighted Study

Gladstone DJ, Danells CJ, Armesto Y et al. Physiotherapy coupled with Dextroamphetamine for rehabilitation after hemiparetic stroke: A randomized, double-blind, placebo-controlled trial. Stroke 2006; 37(1):179-185.		
RCT (PEDro=7) Nstart=71	E: Amphetamine (10mg/d) C: Placebo	• Fugl-Meyer Assessment (-) • Clinical Outcome Variable Scale (-)

Nend=67 TPS=Acute	Duration: 2d/wk for 5wk	• Functional Independence Measure (-) • Modified Rankin Scale (-) • Chedoke-McMaster Disability Inventory (-)

Levels of Evidence for Amphetamines and Lower Limb Recovery

Intervention	Motor Function	ADLs	Stroke Severity	Functional Ambulation	Functional Mobility
Amphetamines	**1a** **8 RCTs**	**1a** **6 RCTs**	**1a** **3 RCTs**	**1b** **1 RCT**	**1b** **1 RCT**

Conclusion

Amphetamines do not improve lower limb motor function or ADLs post stroke.

3.3.27.2 Methylphenidate

Methylphenidate increases endogenous noradrenaline and dopamine by blocking catecholamine reuptake, thereby affecting noradrenergic and dopaminergic modulation (Lokk, Roghani, & Delbari, 2011).

Highlighted Study

Lokk J, Roghani RS, Delbari A et al. Effect of methylphenidate and/or levodopa coupled with physiotherapy on functional and motor recovery after stroke: A randomized, double-blind, placebo-controlled trial. Acta Neurologica Scandinavica 2011; 123(4):266-273.		
RCT (PEDro=8) N_{start}=100 N_{end}=78 TPS=Subacute	E1: Methylphenidate (20mg/d) E2: Levadopa (125mg/d) E3: Methylphenidate + Levadopa C: Placebo Duration: 5d/wk for 3wk	Fugl-Meyer Assessment (-) <u>E1 vs C:</u> Barthel Index (+exp) NIH Stroke Scale (+exp) <u>E2 vs C:</u> Barthel Index (+exp_2) NIH Stroke Scale (+exp_2) <u>E3 vs C:</u> Barthel Index (+exp_3) NIH Stroke Scale (+exp_3)

Levels of Evidence of Methylphenidate for Lower Extremity Recovery

Intervention	Motor Function	ADLs	Stroke Severity
Methylphenidate	**1a** **2 RCTs**	**1a** **2 RCTs**	**1b** **1 RCT**

Conclusion

Methylphenidate can improve functional independence but not lower limb motor function post stroke.

3.3.27.3 Levodopa

Previous literature has suggested that the dopamine system is an important aspect of motor learning, so related pharmacological interventions may be useful adjuvants in motor rehabilitation (Rösser et al., 2008). Levodopa is a dopamine precursor which is metabolised to dopamine and converted to norepinephrine upon crossing the blood-brain barrier (Scheidtmann, Fries, Müller, & Koenig, 2001). Given that dopamine cannot cross the blood-brain barrier, levodopa is used to increase dopamine levels.

Levels of Evidence for Levodopa for Lower Extremity Recovery

Intervention	Motor Function	ADLs	Stroke Severity
Levadopa	**1a** **2 RCTs**	**1a** **3 RCTs**	**1b** **1 RCT**

Conclusion

Levodopa has been shown to improve lower limb motor function and may improve ADLs.

3.3.27.4 Serotonergic Agents

Selective serotonin-reuptake inhibitors (SSRIs) selectively block serotonin reuptake rather than blocking both serotonin and norepinephrine reuptake. Although they are most commonly used to treat depression, animal studies have demonstrated that modification of serotonergic neurotransmission also enhanced motor function. It remains unclear whether the potential benefit of SRRIs is brought about through modulation of motor cortex excitability or their anti-depressive effects.

A meta-analysis of 56 randomized and non-randomized trials by Mead et al. (2013) concluded that SSRIs may reduce dependence, disability, and neurological impairment, as well as improve depression and anxiety post stroke. Notable risks identified in the trials were seizures, bleeding, and hyponatremia. The authors stated that large, high-quality trials are necessary to elucidate the true benefits of SSRIs in post-stroke motor recovery.

Fluoxetine

Fluoxetine is a commonly-used SSRI. Five RCTs have examined the use of this agent in motor recovery following stroke. The largest RCT (Chollet et al., 2011b) recruited patients within 10 days of stroke who were not depressed, while the remaining studies included patients at a later stage of recovery and at least a portion were depressed at study entry.

Highlighted Study

Chollet F, Tardy J, Albucher JF, Thalamas C, Berard E, Lamy C, Bejot Y, Deltour S, Jaillard A, & Niclot P. Fluoxetine for motor recovery after acute ischaemic stroke (FLAME): a randomised placebo-controlled trial. The Lancet Neurology 2011; 10(2):123-130.		
RCT (9) N_{start}=118 N_{end}=113 TPS=Acute	E: Fluoxetine (20mg/d) C: Placebo Duration: 90d Data analysis: Mann-Whitney *U* test	Fugl-Meyer Assessment (+exp) Modified Rankin Scale (+exp) NIH Stroke Scale (-)

The use of fluoxetine in the recovery of lower limb motor function has revealed mixed results. In the largest and highest quality trial to date, Chollet et al. (2011a) reported significantly greater improvement on the Fugl-Meyer Assessment (FMA) and Modified Rankin Scale (mRS) among patients receiving fluoxetine than placebo. These findings were replicated in a RCT by Shah et al. (2016), who reported significant improvements on the FMA for fluoxetine compared to placebo. Both studies noted that adverse events including nausea, diarrhea, insomnia, and abdominal pain were higher in the fluoxetine group. In contrast, Fruehwald et al. (2003) did not report any significant differences between fluoxetine and placebo in functional independence or neurological recovery. However, the study did not specifically assess lower limb motor function, and depression was the primary outcome of the study.

Levels of Evidence for Fluoxetine in Improving Lower Extremity Recovery

Intervention	Motor Function	ADLs	Stroke Severity
Fluoxetine	**1a** **2 RCTs**	**1a** **4 RCTs**	**1a** **3 RCTs**

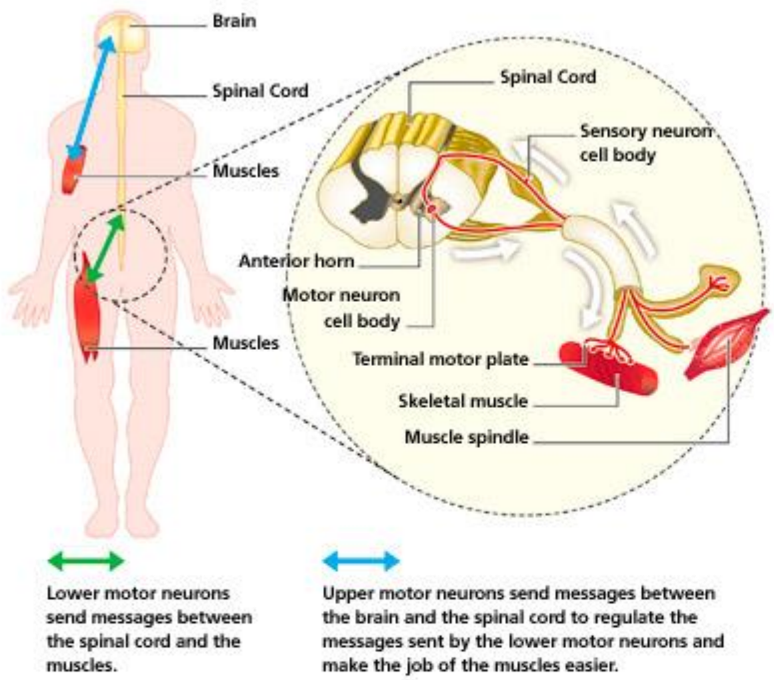
Conclusion

Fluoxetine has been shown to improve lower limb motor function post stroke, it may improve functional independence but does not change stroke severity outcomes measures.

3.4 Spasticity Post Stroke

3.4.1 Defining Spasticity Post Stroke

Spasticity is usually seen days to weeks post-ischemic stroke. Spasticity is velocity-dependent resistance to passive movement of affected muscles at rest. Spastic equinovarus is the most common presentation. It is most frequently encountered during the terminal swing and stance phase.



3.4.2 Clinical Features of Spastic Equinovarus and Associated Problems.

Pain on loading	Decreased weight bearing in the heel	Functional leg-length discrepancy
• Pain on weight bearing on the hemiplegic limb, thus affecting transfers • Increased loading phase, shortened stance phase	• Ankle instability • Abnormal base of support • Genu varum and recurvatum • Unstable gait , impaired balance • Increased energy consumption	• Interference with transfers • Interference smooth forward progression of the center of gravity • Shortened contralateral step length

3.4.3 Potential Treatments for Spasticity in Lower Extremity Post-Stroke

Non-pharmacological management	Pharmacological management		Surgical Procedure
	Focal	Generalized	
Stretching Cold/hot therapy Hydrotherapy Orthotics	Botulinum Toxin A Phenol	***Oral Medications:*** baclofen, dantrolene sodium, tizanidine ***Intrathecal :*** Baclofen	Tendon, muscle: Release Lengthening Transfer

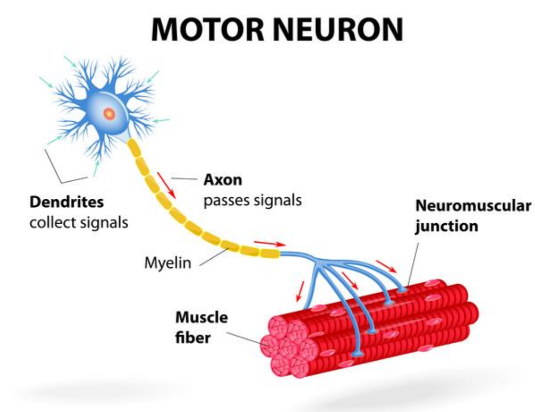
Serial Casting			

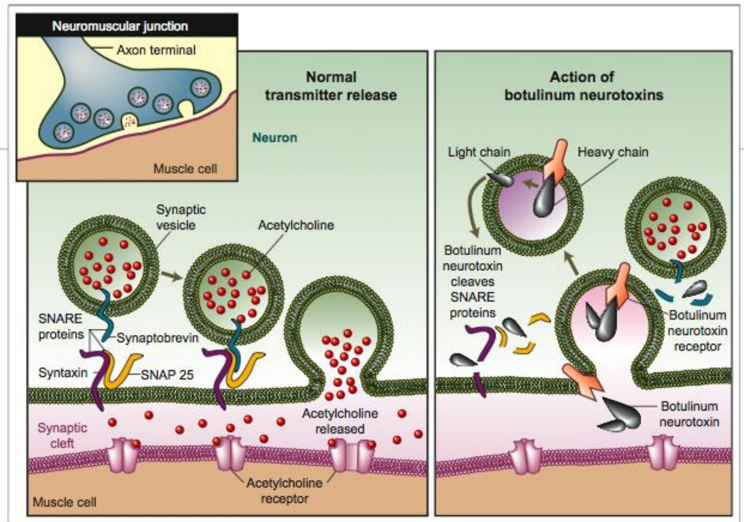
Indications for Treatment of Spasticity of Lower Extremity
Lower limb spasticity may aid hemiplegic patient to weight-bear on affected leg during stance phase. Primary goals of treatment are improvement in gait velocity and quality, reduced pain and improved posture. Spasticity in the hemiplegic lower extremity is generally not treated, unless it impacts function and results in significant pain. Main indication for treatment of lower extremity spasticity is equinovarus, caused by spasticity of the gastrocnemius and tibialis posterior muscles.

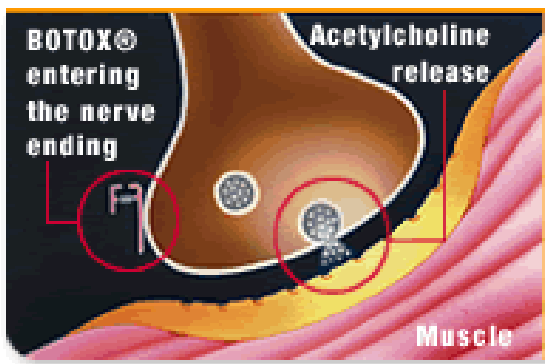
Common indications for use of botulinum toxin in the spastic lower extremity, muscles commonly involved and functional impact of these spastic muscles
- Hip adductors (adductor longus/brevis/magnus) to reduce scissoring thighs and improve hygiene.
- Flexed knee (hamstrings/gastrocnemius) to improve swing step length.
- Extended knee (gluteus medius/quadriceps) to improve knee flexion in the early swing phase of gait.
- Equinovarus foot (gastrocsoleus/tibialis posterior) to improve dorsiflexion and eversion.
- Extended big toe (extensor hallucis longus) to reduce hyperextension and improve ability to wear shoes.

3.4.4 Botulinum Toxin

Botulinum toxin works by weakening spastic muscles by blocking the neuromuscular junction and preventing release of acetylcholine. There are 2 main serotypes: A, B. Mode of action of BTX-A : Botulinum toxin-A is taken up at the presynaptic cholinergic nerve terminals via endocytosis --> cleaves the SNAP-25 (synaptosome associated protein 25) --> prevent assembly of fusion complex --> prevent release of ACH --> relaxation of the muscle. Effect is reversible due to axonal sprouting proximal to the nerve terminals and formation of new neuromuscular junctions. Clinical therapeutic effects may last for up to 6 months.







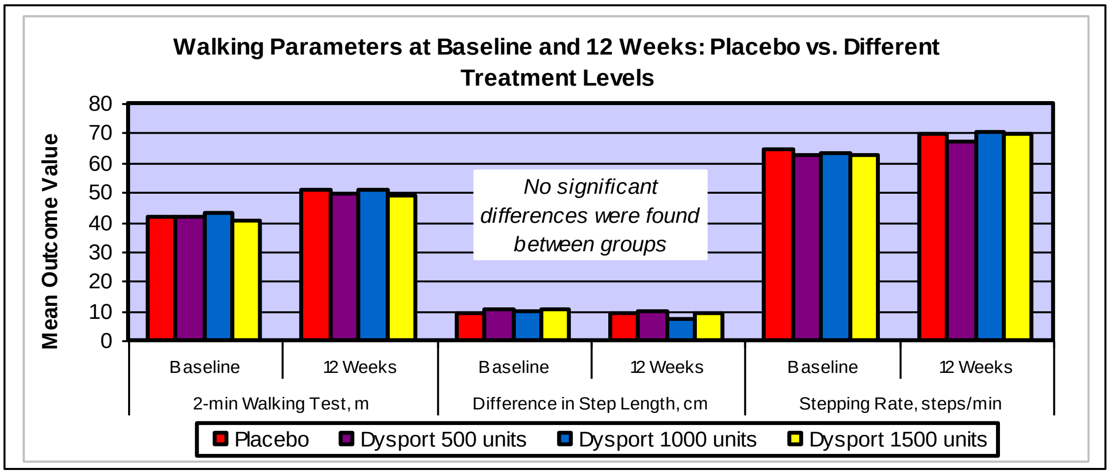
The benefits of BTx injections are generally realized within 3 to 7 days following injection and are dose-dependent. The effects have been studied extensively in the upper extremity and last approximately 2 to 4 months. Two main types of BTx are available: Type A (Botox® and Xeomin®) and Type B (Dysport®); incobotulinum toxin (Xeomin®) is a less common form. BTx guidelines suggest a dose no larger than 600U to prevent adverse effects and antibody development. The advantages of BTx include the ability to selectively target certain muscle groups and the lack of an ostensible effect on the sensory system.

Several systematic reviews and meta-analyses have examined the effectiveness of BTx in treating post-stroke spasticity. In a systematic review of various anti-spastic pharmacological agents for the lower limbs, McIntyre et al. (2012) found that both BTxA and BTxB were effective in decreasing ankle spasticity relative to placebo, but BTxA was more effective in the short term. More recently, a meta-analysis of seven studies reported that BTx significantly reduced lower limb spasticity at 4 and 12 weeks post injection, but not after 24 weeks (Wu, Li, Song, & Dong, 2016a).

While BTx has been shown to reduce spasticity and pain following stroke, it remains unclear whether this yields functional improvements. A meta-analysis of 8 studies found that BTx treatment was associated with a small improvement in gait velocity, representing a mean increase of 0.044 metres/second (N Foley et al., 2010); these findings were not replicated in a subsequent meta-analysis (Wu, Li, Song, & Dong, 2016b). In a systematic review of 4 studies, it was reported that BTx was associated with significant improvements in standing balance (Phadke, Ismail, Boulias, Gage, & Mochizuki, 2014). As well, BTx was associated with significant improvements in Fugl-Meyer Assessment score when compared to controls (Wu et al., 2016b).

Highlighted Study

Pittock SJ, Moore AP, Hardiman O et al. A double-blind randomised placebo-controlled evaluation of three doses of botulinum toxin type A (Dysport®) in the treatment of spastic equinovarus deformity after stroke. Cerebrovasc Dis 2003; 15:289-30.		
RCT (PEDro=8) N_{start}=234 N_{end}=221 TPS=Chronic	E: Botulinum toxin A (500U, 1000U, 1500 U) C: Placebo	• Modified Ashworth Scale (+exp) • 2-Minute Walk Test (-) • Stepping rate (-) • Step length (-)



Highlighted Study

Foley N, Murie-Fernandez M, Speechley M, Salter K, Sequeira K, Teasell R. Does the treatment of spastic equinovarus deformity following stroke with botulinum toxin increase gait velocity? A systematic review and meta-analysis. Eur J Neurol (2010); 17(12):1419-1427.

Methods

8 trials, 5 RCTs, 3 uncontrolled (before/after) trials identified. BTX-A doses ranged from 190 to 400 U of Botox ® and 500 to 2,000 U of Dysport ®.

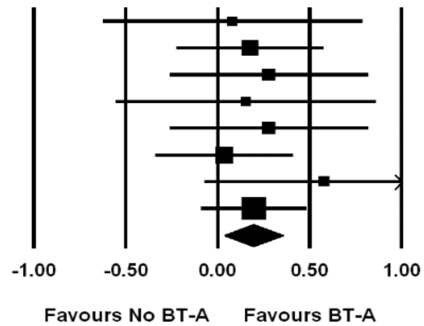
Results

BTX-A was associated with a small, but significant treatment effect on gait velocity, (Hedges g = 0.193 ± 0.081; 95% CI: 0.033 to 0.353, p<0.018) representing an increase of 0.044 m/sec.

Study name	Hedges's g	Standard error	Variance	Lower limit	Upper limit	p-Value
Bayram 2006	0.080	0.359	0.129	-0.623	0.783	0.823
Burbaud 1996	0.175	0.203	0.041	-0.223	0.573	0.388
Hesse 1994	0.278	0.274	0.075	-0.260	0.816	0.310
Hesse 1995	0.152	0.361	0.130	-0.556	0.859	0.674
Hesse 1996	0.278	0.274	0.075	-0.260	0.816	0.311
Pittock 2003	0.036	0.190	0.036	-0.337	0.409	0.851
Reiter 1998	0.579	0.331	0.109	-0.069	1.226	0.080
Rousseaux 2005	0.196	0.145	0.021	-0.088	0.480	0.175
	0.193	0.081	0.007	0.033	0.353	0.018

Statistics for each study

Hedges's g and 95% CI



Botulinum toxin in the lower extremity has been shown to reduce spasticity but not necessarily function, with exception of gait velocity.

Part of the challenge in demonstrating improvements in ADLs or function with botulinum toxin injections are:

- Weakness, part of UMN syndrome, more than spasticity, contributes to disability
- Studies have been inadequately powered to detect functional gain
- The outcome measures on function have been insufficiently sensitive
- May need to be used in combination with other treatments to maximize the impact of both

Highlighted Evidence

Picelli A, Dambruoso F, Bronzato M, Barausse M, Gandolfi M, Smania N. Efficacy of therapeutic ultrasound and transcutaneous electrical nerve stimulation compared with botulinum toxin type A in the treatment of spastic equinus in adults with chronic stroke: a pilot randomized controlled trial. Top Stroke Rehabilitation 2014; 21(S1):8-16.		
RCT (PEDro=8) N_{start}=30 N_{end}=30 TPS=Chronic	E1: Botulinum toxin A (200U) E2: TENS E3: Therapeutic Ultrasound	<u>E1 vs E2/E3:</u> • Modified Ashworth Scale (+exp) • Passive Range of Motion (+exp) <u>E2 vs E3:</u> • Modified Ashworth Scale (-) • Passive Range of Motion (-)

Levels of Evidence for Botulinum Toxin in Treating Focal Spasticity of Lower Extremity

Intervention	Motor Function	ADLs	Spasticity	Functional Ambulation	Gait
Botulinum Toxin A	**1a** **2 RCTs**	**1b** **1 RCT**	**1a** **5 RCTs**	**1a** **4 RCTs**	**1a** **2 RCTs**

<u>Conclusions</u>

Botulinum Toxin A injections used to treat focal spasticity has been shown to improve spasticity when compared to conventional care.
There is less evidence to show it improves motor function in the lower extremity.
Botulinum Toxin A may improve functional ambulation and gait.

Additional Conclusions
Botulinum toxin injection reduces lower limb spasticity post stroke compared to placebo or nerve block.
Botulinum toxin injection is more effective in combination with an ankle foot orthosis, but not with electrical stimulation, taping, or stretching.
Botulinum toxin injection may be more effective in higher dosages, but is not impacted by location of injection.
Botulinum toxin injection guided by ultrasonography may be more effective than by electrical stimulation or palpation.

3.4.5 Oral Medications

Traditional pharmacotherapies for spasticity treatment have been studied, including centrally-acting depressants (e.g baclofen, tizanidine, clonidine, benzodiazepines) and muscle relaxants (dantrolene). There is evidence from older trials that these treatments are only partially effective in treating spasticity and have negative side effects (e.g. weakness and sedation). With the introduction of more focal spasticity treatments, the use of these systemic agents has decreased.

Highlighted Study

Stamenova P, Koytchev R, Kuhn K et al. A randomized, double-blind, placebo-controlled study of the efficacy and safety of tolperisone in spasticity following cerebral stroke. European Journal of Neurology (2005); 12(6):453-61.		
RCT (PEDro=8) N_{start}=120 N_{end}=106 TPS=Chronic	E: Tolperisone (300-900mg) C: Placebo Duration: 300-900mg of Tolperisone, 1x/d for 20d	• Ashworth Scale (+exp) • Modified Barthel Index (+exp)

Levels of Evidence for Oral Anti-Spastic Medications in the Lower Extremity

Intervention	Motor Function	ADLs	Spasticity
Oral Anti-Spastic Medications	1b 1 RCT	1a 3 RCTs	1a 4 RCTs

Conclusions
Oral medications are effective interventions for reducing lower limb spasticity post stroke, although some may be associated with side effects.
Oral anti-spastic medications may improve ADLs.

3.4.6 TENS/NMES and Spasticity

TENS has been suggested to reduce muscle tonicity through an enhancement in presynaptic inhibition of the spastic plantarflexors, or a disinhibition of descending voluntary commands to the paretic dorsiflexors (Bakhtiary & Fatemy, 2008). TENS can also reduce spasticity without the adverse effect of muscle weakness and paralysis, which have been associated with other anti-spastic treatments such as botulinum toxin. While transcutaneous electrical stimulation treatments have been examined in previous sections, several studies were identified in which evaluation of spasticity was a primary objective of the investigation.

Highlighted Study

Tekeolu YB, Adak B, Göksoy T. Effect of transcutaneous electrical nerve stimulation (TENS) on Barthel Activities of Daily Living (ADL) index score following stroke. Clinical Rehabilitation. 1998;12(4):277-80.		
RCT (9) N_{start} =60 N_{end}=58 TPS= Subacute	E: TENS C: No TENS Duration: 40 sessions over 8wk	• Barthel Index (+exp) • Ashworth Scale (+exp)

Highlighted Study

Bakhtiary AH, Fatemy E. Does electrical stimulation reduce spasticity after stroke? A randomized controlled study. Clinical Rehabilitation 2008; 22(5):418-25.		
RCT (PEDro=8) N_{start}=40 N_{end}=35 TPS=Not reported	E: Cyclic NMES C: Bobath approach	• Modified Ashworth Score (+exp) • Ankle joint dorsiflexion range of motion (+exp) • Dorsiflexor strength (+exp)

The effectiveness of TENS in reducing lower limb spasticity post stroke was examined in eight RCTs. All studies found that TENS was more effective than sham stimulation (Cho, In, Cho, & Song, 2013; Levin & Hui-Chan, 1992; Ng & Hui-Chan, 2007a; J. Park, Seo, Choi, & Lee, 2014; Tekeoglu et al., 1998; Yan & Hui-Chan, 2009a) or no treatment (Laddha, Ganesh, Pattnaik, Mohanty, & Mishra, 2016b; Ng & Hui-Chan, 2007b; Yan & Hui-Chan, 2009b) in reducing spasticity. One study reported that TENS in combination with task-specific training was more effective in reducing spasticity than TENS or training alone (Ng & Hui-Chan, 2007b). However, the duration of TENS may not have an impact on its effectiveness (Laddha, Ganesh, Pattnaik, Mohanty, & Mishra, 2016a).

Conclusions

Transcutaneous electrical stimulation is an effective intervention for reducing lower limb spasticity post stroke, while neuromuscular/functional electrical stimulation may not be effective.

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