4. Motor Rehabilitation

4A. Lower Extremity and Mobility

Robert Teasell MD, Norhayati Hussein MD

4.1 Motor Recovery of the Lower Extremity Post Stroke

Factors that Predict Motor Recovery

Motor deficits post-stroke are the most obvious impairment (Langhorne et al. 2012) 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. 2012; Wade 1992). Given its importance, a large proportion of stroke rehabilitation efforts are directed towards the recovery of movement disorders. Langhorne et al. (2012) 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 et al. 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 (Wooley 2001; Robbins et al. 2006; Pizzi et al. 2007, Pereira et al. 2012). 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 that normal individuals when walking at the same velocity (Wooley et al. 2001).

For mobility outcome, trunk balance is an additional predictor of recovery (Veerbeek et al. 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.

4.2 Assessments of Mobility

Some commonly used assessments of motor function post stroke include:

- The Berg Balance Score
Berg Balance Score

<table>
<thead>
<tr>
<th>Questions</th>
<th>Answer</th>
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<tbody>
<tr>
<td>What is the scale?</td>
<td>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.</td>
</tr>
<tr>
<td>What are the key scores?</td>
<td>Maximum score = 56. A score of less than 45 is indicative of balance impairment or risk of falling.</td>
</tr>
<tr>
<td>What are its strengths?</td>
<td>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.</td>
</tr>
<tr>
<td>What are its limitations?</td>
<td>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.</td>
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Chedoke-McMaster Stroke Assessment Scale

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<thead>
<tr>
<th>Questions</th>
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<tbody>
<tr>
<td>What does it measure?</td>
<td>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.</td>
</tr>
<tr>
<td>What is the scale?</td>
<td>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.</td>
</tr>
<tr>
<td>What are the key scores?</td>
<td>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).</td>
</tr>
<tr>
<td>What are its strengths?</td>
<td>The use of Brunnstrom staging and FIM scoring increases the interpretability of the CMSA and may facilitate comparisons across groups of stroke patients. The CMSA is relatively comprehensive and has been well studied for reliability and validity.</td>
</tr>
<tr>
<td>What are its limitations?</td>
<td>Taking approximately 1 hour to complete, the length and complexity of the CMSA may make the scale less useful in clinical practice.</td>
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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.

7 Brunnstrom Stages of Motor Recovery

1. Flaccid paralysis. No reflexes.
3. Spasticity is marked. Synergistic movements may be elicited voluntarily.
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. 1993)

<table>
<thead>
<tr>
<th>Stages</th>
<th>Characteristics</th>
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<tbody>
<tr>
<td>1</td>
<td><strong>Flaccid paralysis is present.</strong> Phasic stretch reflexes are absent or hypoactive. Active movement cannot be elicited reflexively with a facilitatory stimulus or volitionally.</td>
</tr>
<tr>
<td>2</td>
<td><strong>Spasticity is present</strong> and is felt as a resistance to passive movement. <strong>No voluntary movement</strong> is present but a <strong>facilitatory stimulus will elicit the limb synergies reflexively</strong>. These limb synergies consist of stereotypical flexor and extensor movements.</td>
</tr>
<tr>
<td>3</td>
<td><strong>Spasticity is marked.</strong> The <strong>synergistic movements can be elicited voluntarily</strong> but are not obligatory.</td>
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<tr>
<td>4</td>
<td><strong>Spasticity decreases.</strong> 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.</td>
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<tr>
<td>5</td>
<td><strong>Spasticity wanes</strong>, 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.</td>
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<tr>
<td>6</td>
<td><strong>Coordination and patterns of movement can be near normal.</strong> <strong>Spasticity</strong> as demonstrated by resistance to passive movement is <strong>no longer present</strong>. Abnormal patterns of movement with faulty timing emerge when rapid or complex actions are requested.</td>
</tr>
<tr>
<td>7</td>
<td><strong>Normal.</strong> 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.</td>
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Timed Up and Go (TUG)

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<th>Questions</th>
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<tr>
<td><strong>What does it measure?</strong></td>
<td>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.</td>
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<tr>
<td><strong>What is the scale?</strong></td>
<td>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.</td>
</tr>
<tr>
<td><strong>What are the key scores?</strong></td>
<td>The TUG score consists of the time taken to complete the test activity, in seconds.</td>
</tr>
<tr>
<td><strong>What are its strengths?</strong></td>
<td>The TUG is quick and easy to administer, requiring no specialized equipment or training.</td>
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Timed scores are objective, straightforward, and more sensitive to change over time than ordinal measures (Whitney et al. 1998).

| 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 et al. 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 et al. 1998). |

### 6 Minute Walking Test (6MWT)

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<tr>
<td><strong>What does it measure?</strong></td>
<td>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.</td>
</tr>
<tr>
<td><strong>What is the scale?</strong></td>
<td>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.</td>
</tr>
<tr>
<td><strong>What are the key scores?</strong></td>
<td>The 6MWT consists of the distance taken to walk within 6 minutes, in meters. Number of rest should also be recorded.</td>
</tr>
<tr>
<td><strong>What are its strengths?</strong></td>
<td>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.</td>
</tr>
<tr>
<td><strong>What are its limitations?</strong></td>
<td>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.</td>
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4.3 Intervention 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)”.

4.3.1 Therapy Intensity

Kwakkel et al. (2004) conducted a further 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 et al., 2004), with a treatment time of 3 hours or longer being associated with greatest functional improvements (Wang et al. 2013).

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.

4.3.2 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.

**HIGHLIGHTED STUDY**


**Methods:** Examined 6 RCTs which included repetitive practice of functional tasks arranged in a circuit with the aim of improving mobility. Trials were performed on 292 participant whom were long-term stroke survivors living in the community or receiving inpatient rehabilitation. Most could walk 10 metres without assistance.

**Results:** Four studies measured walking capacity and three measured gait speed, demonstrating that CCT was superior to the comparison intervention: 1) Six Minute Walk Test: mean difference (MD), fixed 76.57 metres, 95% confidence interval (CI) 38.44 to 114.70, P < 0.0001; 2) Gait speed: MD, fixed 0.12 m/s, 95% CI 0.00 to 0.24, P=0.004; Two studies measured balance, showing a superior effect in favour of CCT; 3) Step Test: MD, fixed 3.00 steps, 95% CI 0.08 to 5.91, P = 0.04; 4) Activities-specific balance and confidence: MD, fixed 7.76, 95% CI 0.66 to 14.87, P = 0.03.

**HIGHLIGHTED STUDY**


**Methods:** Included 250 patients who completed inpatient stroke rehabilitation, able to walk 10 m without physical assistance. Randomized to receive graded task-specific circuit program vs usual outpatient physiotherapy.

**Results:** At the end of follow-up (24 weeks), patients in the task-specific therapy group had significantly higher scores on the mobility sub scale of the Stroke Impact Scale and increased distance walked on the 6MWT, compared with patients in the control group.
HIGHLIGHTED STUDY

**Methods:** 91 community-dwelling stroke survivors with residual walking deficit within 1 year of stroke randomized to intervention of 10 functional tasks designed to strengthen L/E and enhance walking balance, speed and distance vs. control intervention focusing on U/E activities, 3x/week x 6 weeks.

**Results:** Intervention group improved more in 6minWT (40meters vs. 5meters); comfortable walking speed (0.14 vs. 0.03 meters/second); maximum walking speed (0.20 vs. -0.01 meters/second); TUG (-1.2 vs. 1.7 second).

There is strong evidence that task-specific gait training improves gait post-stroke. Canadian Best Practice Guidelines: Update 2015 (Hebert et al. 2016) noted that, “task and goal-oriented training that is repetitive and progressively adapted should be used to improve performance of selected lower extremity tasks such as walking distance and speed and sit to stand (Evidence Level A)”.

**4.3.3 Treadmill Training in the Absence of Partial Body Weight Support**

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.

HIGHLIGHTED STUDY

**Methods:** 60 ambulatory patients suffering from hemiparesis, were randomized into 1 of 3 groups: structured speed-dependent treadmill training (STT), limited progressive treadmill training (LTT), and conventional gait therapy (CGT).
**Results:** After 4 weeks training period, the STT group scored significantly higher than the LTT and CGT for all outcome measures.

**HIGHLIGHTED STUDY**

**Methods:** 61 chronic stroke patients with hemiparetic gait patients were randomized to receive 6 months of progressive treadmill aerobic exercise program or stretching plus low intensity walking.

**Results:** Significant greater improvement in ambulatory performance and mobility function in the treadmill training group compared with patients who received a program of stretching plus low-intensity walking.

**HIGHLIGHTED STUDY**

**Methods:** Intervention consisting of 2.5 weeks/5 days week for 30 minutes of treadmill training versus a control intervention consisting of outdoor walking.

**Results:** Patients in the treadmill group had better walking speed, endurance, and walking distance compared to controls who were involved in outdoor walking.

There is strong evidence that treadmill training either in combination with conventional therapy or delivered alone, may improve gait velocity, stride length and lower limb functional mobility; however, it may not improve balance.

**4.3.4 Partial Body Weight Support and Treadmill Training (PBWSTT)**

“Those who want to walk learn by walking” (Hesse et al. 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. It does require some equipment and can be therapist intensive.

**HIGHLIGHTED STUDY**

**Methods:** 100 stroke patients (onset > 6 months) randomized to walk training on treadmill with 40% of BW supported by overhead harness or treadmill with no BWS.

**Results:** Significant effect in favour of BWS at end of treatment and 3 months follow-up for motor recovery and overground walking speed.

**HIGHLIGHTED STUDY**

**Methods:** 126 acute (<28 days post stroke), non-ambulatory stroke patients randomly allocated to 30 minutes/day treadmill training with BWS via overhead harness or control group with 30 minutes/day overground walking. Primary outcomes was proportion of participants achieving independent walking within 6 months

**Results:** 37% of PWBTT and 26% of control patients achieved independent walking at 1 month; 66% vs. 55% at 2 months, 71% vs. 60% at 6 months (p=0.13). The PWBTT groups walked 2 weeks earlier, with median time to independent walking 5 weeks compared to 7 weeks for control group. Secondary outcomes reported: walking quality and capacity, walking perception, community participation and falls.

Among independent walkers at 6 months, there was no difference between the groups in speed (0.10 meters/second) or stride (6 cm). Independent walkers in PWBTT group walked 57m further in 6 min walk test vs.
control group. PBWTT group (walkers and non-walkers) rated their walking 1 point out of 10 higher than the control group. No differences noted between groups in community participation or number of falls.

**HIGHLIGHTED STUDY**

**LEAPS (Locomotor Experience Applied Post-Stroke) trial - Duncan PW et al. Body-weight-supported treadmill rehabilitation after stroke. NEJM. 2011; 364:2026-36.**

This is a Phase 3, single blinded, multicentred RCT.

**Objective:** To compare the efficacy of three protocols for improving walking ability post stroke

1. Body weight supported treadmill training (BWSTT) initiated 2 months post stroke (AKA early locomotor training (LT)).
2. BWSTT initiated 6 months post stroke (AKA late LT).
3. Home exercise program initiated 2 months post stroke (AKA HE group).

**Methods:**

1. Early or late LT group: 90 minute sessions 3x/week, duration of 12-16 weeks (minimum 30-36 sessions), BWSTT with manual assistance as needed for 20-30 minutes followed by walking over ground for 15 minutes.
2. Home exercise group: Physical therapist guided program in the home, focused on flexibility, ROM, strength of arms and legs, static and dynamic balance, coordination. Designed as active control (not task-specific walking). All patients also received “usual care”.

**Results:** 408 subjects stratified by severity and study site then randomized to one of three groups. Outcomes measured at baseline, 6 months and 12 months. There was no significant difference in primary outcome (higher functional walking level). Overall 52% of participants transitioned to higher functional walking level. Early LT compared to HE: OR 0.83 (CI 0.5-1.39); Late LT compared to HE: OR 1.19 (CI 0.72-1.99). Secondary outcomes showed at one year, no difference between groups for walking speed, number of steps in a day, ADLs, motor recovery, social participation, balance. Late LT group was significantly slower at 6 months, less steps in a day at 6 months.

**Conclusions:** BWSTT was not found to be superior to a home-based physiotherapist provided multi-modal exercise program for improving functional walking. At 1 year, all groups showed significant improvements. At 6 months, late LT results lagged behind (had only had “usual care” up until then). Study showed BWSTT may be associated with higher of multiple non-injurious falls. Home based therapy program was more pragmatic based on cost and outcomes.

**PBWS and Treadmill Training – Summary of Studies**

<table>
<thead>
<tr>
<th>Author</th>
<th>PEDro Score</th>
<th>N</th>
<th>Outcome</th>
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<tbody>
<tr>
<td>Eich et al. 2004</td>
<td>8</td>
<td>50</td>
<td>+</td>
</tr>
<tr>
<td>Nilsson et al. 2001</td>
<td>7</td>
<td>73</td>
<td>-</td>
</tr>
<tr>
<td>Werner et al. 2002</td>
<td>7</td>
<td>30</td>
<td>+</td>
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<tr>
<td>Visintin et al. 1998</td>
<td>6</td>
<td>100</td>
<td>+</td>
</tr>
<tr>
<td>Suputtiiada et al. 2004</td>
<td>6</td>
<td>48</td>
<td>-</td>
</tr>
<tr>
<td>Yagura et al. 2006</td>
<td>6</td>
<td>49</td>
<td>-</td>
</tr>
<tr>
<td>Duncan et al. 2011</td>
<td>8</td>
<td>480</td>
<td>-</td>
</tr>
</tbody>
</table>
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). 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.

### 4.3.5 Cardiovascular/Aerobic Training

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.

#### HIGHLIGHTED STUDY


- **Methods:** 100 stroke patients randomly assigned to structured, progressive exercise program (36x90 minute sessions over 12 weeks) or usual care in single-blinded study.
- **Results:** Improvements seen in balance, endurance, peak aerobic capacity and mobility.

#### HIGHLIGHTED STUDY


- **Methods:** Conducted systematic review of aerobic exercise post-stroke which included 7 RCTs.
- **Results:** Exercise intensity ranged from 50-80% heart rate reserve, while duration varied from 20-40 minutes x 3-5 days/week. Regardless of stage of stroke recovery, there was a significant benefit of therapy in parameters of VO2 peak workload, walking speed and endurance.
HIGHLIGHTED STUDY

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.

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.

4.3.6 Strength Training to Improve Mobility

HIGHLIGHTED STUDY

Methods: A case controlled study of 133 stroke patients were randomized to the experimental group, receiving 9 lower-extremity progressive resistance exercises or to the control group who performed the same exercises without resistance.

Results: No significant difference on the rate of change on the Disability Inventory or the 2-minute walking test was found between the groups.

HIGHLIGHTED STUDY

Methods: 66 ambulatory stroke patients who completed inpatient rehab randomized to receive a 12 week outpatient program of strength and resistant treatment or relaxation with treatments provided 1.5 hours, 3 x per week.

Results: At 3 months, the role-physical component of the SF-36, timed up and go, and walking economy were significantly better among patients in the exercise group compared to the relaxation group. By 7 months, the only difference that remained between groups was the role physical component of the SF-36.

There is mixed evidence that strength training improves outcomes post stroke. Some of the studies were positive while others were not. For instance, there is strong evidence that functional strength training may improve gait speed but may not improve knee extension and flexion strength. There is also strong evidence that progressive resistance training may improve strength and knee extension but not gait.

Canadian Best Practice Guidelines: Update 2015 (Hebert et al. 2016) has noted that, “Strength training should be considered for persons with mild to moderately lower extremity function in both subacute (Level Evidence C) and chronic phases (Evidence Level B) of recovery. Strength training does not affect tone or pain (Evidence Level A)”.

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4.3.6 Balance Training and Falls Prevention Post Stroke

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.

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**


**Methods:** 156 participants with stroke at risk of recurrent falls being discharged home from rehab were randomized to a tailored multifactorial falls prevention program and usual care (n=71) or to control usual care (N=85).

**Results:** There was no significant difference in the fall rate or the proportion of fallers between the two groups. There was also no significant difference in injury fall rate.

There is strong evidence that exercise-based falls prevention programs may not reduce the rate of falls post stroke.

4.3.7 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.
### HIGHLIGHTED STUDY


**Methods:** 155 stroke patients admitted to rehab unit randomized to receive either 20 minutes of repetitive practice on a gait trainer, followed by 25 minutes of individual PT every day for 25 minutes x 4 weeks (group A) or 45 minutes of individual PT (group B). Total treatment time was identical between groups.  
**Results:** At end of treatment a significantly greater proportion of patients in group A were able to walk independently (53% vs. 22%, p<0.0001). Significantly more patients in group A attained a BI score of >75 (57% vs. 27%, p<0.0001). By 6 months, significantly more patients could walk independently (70% vs. 36%, p<0.0001) although there were no longer differences in the proportion of patients with BI > 75 (58% vs. 46%, p=0.025). There were no differences in proportion of patient living at home (68% vs. 68%).

### HIGHLIGHTED STUDY


**Methods:** 67 patients admitted to rehab < 3 months post stroke randomized to 2 groups. Both groups received PT for 30 minutes/day x 5 days/week x 6 weeks. Experimental group received additional therapy (20 minutes x 3x/week x 6 weeks) using the Lokomat training device.  
**Results:** Control group received an equal amount of PTA after 6 weeks, a greater proportion of subjects in experimental group could walk independently (20/37 vs. 8/28, p<0.03). Subjects in experimental group had better NIHSS scores at the end of treatment (6.6 vs. 8.0, p<0.01).

### HIGHLIGHTED STUDY


**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.

### HIGHLIGHTED STUDY

Methods: 48 nonambulatory participants after subacute stroke were stratified by Motricity Index into high (<29) and low (≥29) motor impairment groups. Each arm was randomized to a robotic (robotic-assisted and conventional gait training or control group (conventional gait training only) at a mean of 20 days after stroke. The primary outcome was Functional Ambulation Category, and secondary measures were the Rivermead Mobility Index and Barthel Index scores. The scales were administered before and after the inpatient stay and 2 years after discharge.

Results: Low motor-impairment group: Participants in the low impairment robot group had improved significantly more than subjects in the control group – Functional ambulation category (4.7±0.5 versus 3.1±1.5, P=0.002), Barthel Index (76.9±11.5 versus 64.7±14.0, P=0.024), and Rivermead Mobility Index (11.8±3.5 versus 7.0±3.6, P=0.010). High motor-impairment group: Highly impaired participants improved over time, but there were no significant between-group differences on any of the outcomes. Conventional and robotic therapies were equally effective in the high impairment groups.

There is strong evidence that Lokomat may not improve gait and balance in the acute phase of stroke recovery. Evidence is less clear regarding its use in the subacute and chronic phase of stroke. 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)”.

4.3.9 Functional Electrical Stimulation FES-Based Neural Orthosis for Gait Cycle

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. Although not widely used or available, 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. 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**


**Methods:** 53 patients with stroke onset > 6 months received 12 week treatment program (1.5 hours, 4X per week) consisting of strengthening exercises, overground gait training and BWSTT. Patients randomized to intramuscular FES (implanted into 8 muscles). Primary outcome measure was Gait Assessment and Intervention Tool (GAIT) assessed at baseline, post-treatment and at 6 months.

**Results:** Patients in both groups improved over treatment period. Patients in IM FES group achieved significantly greater improvements in GAIT (p=0.045) following treatment that were maintained at 6 months. 50% of IM FES group improved by at least 10 points on GAIT compared to 21% of control group.

**4.3.10 Feedback**

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 et al. 2013). Stanton et al. (2011) in a systematic review reported that taking into
consideration all types of sensory feedback, in aggregate it was associated with significant short and long-term outcomes.

**HIGHLIGHTED STUDY**


**Methods:** 151 participants were randomized to receive either speed-only feedback or augmented feedback by a computer.

**Results:** No significant differences were found between the two feedback groups in daily walking time or 15-meter walking speed. 30% of participants decreased their total daily walking time over their rehabilitation stay.

**HIGHLIGHTED STUDY**

**Dobkin et al. International randomized clinical trial, stroke inpatient rehabilitation with reinforcement of walking speed (SIRROWS) improves outcomes. Neurorehab Neural Repair 2010; 24(3):235-242.**

**Methods:** 179 inpatients were randomized to either feedback about self-selected fast walking speed (daily reinforcement of speed) immediately after a single day, daily 10-metre walk, or to no reinforcement of speed.

**Results:** Participants receiving reinforcement of speed performed better on the walking speed; however, no difference between groups was found on the length of stay, as both groups showed a decrease. The reinforcement group did not have a higher proportion of the functional ambulation category of independent walkers and did not walk longer distances.

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 and 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”. There is strong and moderate evidence that auditory feedback may improve gait activity. There is limited and conflicting evidence regarding visual feedback on gait.

### 4.3.11 Repetitive Transcranial Magnetic Stimulation

Repetitive Transcranial Magnetic Stimulation (rTMS) has not been widely researched as a rehab treatment of lower extremity motor recovery. In a single study (Beaulieu et al. 2015) has demonstrated moderate evidence that rTMS may improve muscle strength and ankle ROM.

### 4.3.12 Virtual Reality

This technology allows individuals to experience and interact with 3-dimensional environments. Virtual reality is classified as immersive (person is within a virtual environment through a worn piece of equipment, such as a head-mounted display) or non-immersive (2-dimensional environments using computer monitors or projection screens). Corbetta et al. (2015) in a systematic review, analyzing the
results from 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.

In summary, VR may improve gait and balance when combined with treadmill training. When delivered alone, it may only improve balance.

4.3.13 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. There is strong evidence that mental practice/mental imagery may improve gait and balance problems when used as an adjunct to other treatments.

4.3.14 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.

4.4 Spasticity Post Stroke

4.4.1 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.

4.4.2 Clinical Features of Spastic Equinovarus and Associated Problems.

- **Pain on loading**
  - Pain on weight bearing on the hemiplegic limb, thus affecting transfers
  - Increased loading phase, shortened stance phase

- **Decreased weight bearing in the heel**
  - Ankle instability
  - Abnormal base of support
  - Genu varum and recurvatum
  - Unstable gait, impaired balance
  - Increased energy consumption

- **Functional leg-length discrepancy**
  - Interference with transfers
  - Interference smooth forward progression of the center of gravity
  - Shortened contralateral step length

4.4.3 Potential Treatments for Spasticity in Lower Extremity Post-Stroke

<table>
<thead>
<tr>
<th>Non-pharmacological management</th>
<th>Pharmacological management</th>
<th>Surgical Procedure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Focal</td>
<td>Generalized</td>
<td></td>
</tr>
</tbody>
</table>
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.

4.4.4 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.
HIGHLIGHTED STUDY

Methods: A case controlled study of 234 patients with hemiparesis with spastic equinovarus deformity of the ankle after stroke. One of 4 treatment groups: 500 units of Dysport; 1000 units of Dysport; 1500 units of Dysport and placebo.

Results: Distance covered during 2-minute walking test significantly increased in each group, but there were no differences between groups.
**HIGHLIGHTED STUDY**

**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.

**Figure 2.** 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. (Pittock et al. 2003)

234 stroke patients with hemiparesis and spastic equinovarus deformity of the ankle were randomized to one of 4 treatment groups: 500 units of Dysport; 1000 units of Dysport; 1500 units of Dysport and placebo. Patients were assessed every 4 weeks over a 12-week period.

Distance covered during the 2-minute walking test significantly increased in each group, but there were no between-groups differences. Significant improvement in calf spasticity and limb pain reduction in use of walking was noted in the Dysport groups relative to the control group.

**Walking Parameters at Baseline and 12 Weeks: Placebo vs. Different Treatment Levels**

<table>
<thead>
<tr>
<th>Mean Outcome Value</th>
<th>Placebo</th>
<th>Dysport 500 units</th>
<th>Dysport 1000 units</th>
<th>Dysport 1500 units</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-min Walking Test, m</td>
<td>▢</td>
<td>▢</td>
<td>▢</td>
<td>▢</td>
</tr>
<tr>
<td>Difference in Step Length, cm</td>
<td>▢</td>
<td>▢</td>
<td>▢</td>
<td>▢</td>
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<tr>
<td>Stepping Rate, steps/min</td>
<td>▢</td>
<td>▢</td>
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</tr>
</tbody>
</table>

No significant differences were found between groups.

<table>
<thead>
<tr>
<th>Study name</th>
<th>Hedge's g</th>
<th>Standard error</th>
<th>Variance</th>
<th>Lower limit</th>
<th>Upper limit</th>
<th>p-Value</th>
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<tbody>
<tr>
<td>Bayram 2006</td>
<td>0.080</td>
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<td>0.859</td>
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<tr>
<td>Hesse 1996</td>
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<td>0.075</td>
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<tr>
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<td>0.021</td>
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</tr>
<tr>
<td>0.193</td>
<td>0.081</td>
<td>0.007</td>
<td>0.033</td>
<td>0.353</td>
<td>0.018</td>
<td></td>
</tr>
</tbody>
</table>

**HIGHLIGHTED STUDY**

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Methods: 30 participants were randomized to receive either therapeutic ultrasound to the affected leg calf muscles, TENS, or 200 units of botulinum toxin in the treatment of focal spasticity in chronic stroke patients. Results: Botulinum toxin improved the Ashworth Scale when compared to the therapeutic ultrasound and improved ankle passive ROM when compared to TENS.

Botulinum toxin in the lower extremity has been shown to reduce spasticity but not necessarily function, with the 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
References


