Evidence-based interventions for improving walking speed and function

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Overview

Walking speed is an important indicator of safe ambulation as well as ability to access the home and community environments and is therefore frequently a goal of physical therapy following an acquired brain injury (ABI). A review of research will be provided with case study examples showing how to implement some of the most effective interventions.
Objectives

● Gain understanding of what gait speed indicates about a person’s safety and function
● Review means of measuring and establishing goals for gait speed
● Identify several evidence-based interventions that can be used for increasing gait speed in clients post ABI
● Gain understanding of how to implement these interventions with a variety of clients post ABI
Implications for gait training post ABI

- Stroke is the leading cause of disability in the US
  - The majority of stroke survivors who achieve independent ambulation will demonstrate limitations in walking ability
- Traumatic Brain Injury (TBI) survivors may demonstrate various gait impairments depending on location and severity of TBI
- Walking limitations post ABI include abnormal muscle activation patterns, grading of muscle activity, altered muscle tone, and abnormal timing.
- Maximizing ability to ambulate may be accomplished by creation of compensatory strategies, recovery of impaired movements, or both
Neuroplasticity in gait training
Kleim et al 2008

- Research on neuroplasticity relevant and applicable to gait training
- New neural connections promote recovery in the undamaged and damaged brain

<table>
<thead>
<tr>
<th>Principle</th>
<th>Description</th>
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<tbody>
<tr>
<td>1. Use It or Lose It</td>
<td>Failure to drive specific brain functions can lead to functional degradation.</td>
</tr>
<tr>
<td>2. Use It and Improve It</td>
<td>Training that drives a specific brain function can lead to an enhancement of that function.</td>
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<tr>
<td>3. Specificity</td>
<td>The nature of the training experience dictates the nature of the plasticity.</td>
</tr>
<tr>
<td>5. Intensity Matters</td>
<td>Induction of plasticity requires sufficient training intensity.</td>
</tr>
<tr>
<td>6. Time Matters</td>
<td>Different forms of plasticity occur at different times during training.</td>
</tr>
<tr>
<td>7. Salience Matters</td>
<td>The training experience must be sufficiently salient to induce plasticity.</td>
</tr>
<tr>
<td>8. Age Matters</td>
<td>Training-induced plasticity occurs more readily in younger brains.</td>
</tr>
<tr>
<td>9. Transference</td>
<td>Plasticity in response to one training experience can enhance the acquisition of similar behaviors.</td>
</tr>
<tr>
<td>10. Interference</td>
<td>Plasticity in response to one experience can interfere with the acquisition of other behaviors.</td>
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The most commonly used outcome measure of walking ability in locomotor rehab because it is simple, valid, reliable, cost effective, sensitive, and specific (Wonsetler et al 2017)

Assessment can be performed in various settings with minimal equipment

The “6th vital sign” that serves as a predictor of level of independence, functional capabilities, hospital length of stay, mortality, health status, quality of life, etc.
10m Timed Walk (10m TW)

- Assesses walking speed in meters/second over a 6-10 meter walking course
- Average of 3 trials calculated
- Assistive device allowed
- Can be performed at “preferred” and “fast” speeds
- MCID (CVA): 0.14 m/s (Perera et al 2006)
6 Minute Walk Test (6 MWT)

- A submaximal walking test used to measure aerobic capacity/endurance
- Distance is tracked with a trundle wheel or by using a pre-measured course that a patient walks along for 6 minutes
- Assistive devices are permitted as well as standing rest breaks
- Standardized verbal cues allowed throughout
  - "You are doing well. You have 2 minutes to go."
- MCD: 13% (Flansbjer et al, 2005)
Borg Rating of Perceived Exertion Scale (RPE)

- A subjective outcome measure used to measure exercise intensity
- Assists in selecting exercise intensity based on individual cardiovascular fitness, can be helpful with cardiac medications that blunt heart-rate increase with exercise (ie. beta-blockers)
Treadmill training

Unique advantages:

- Utilizes principles of neuroplasticity with task-specific training and massed practice
- Effective tool to promote cardiac and muscular endurance in order to improve efficiency of gait
- Provides motivational feedback regarding distance and speed completed
Influence of treadmill walking on gait kinematics

Tyrell et al 2011

Walking at speeds faster than self-selected walking speed result in:

- Larger step lengths bilaterally
- Improved symmetry of step length for those who initially had shorter step length on the non-paretic limb
- Decreased double limb support time/increased single limb support time bilaterally
- Increased hip extension and trailing limb angle on paretic limb
- Slight increase in knee flexion during swing on paretic limb

... with no increase in compensatory hip hiking or circumduction
Influence of treadmill training on gait parameters
Mulroy et al 2010

Responders to treadmill training showed the following improvements:

- Increased activation of soleus and semimembranosus muscles on affected side
- Increased hip extension and plantar flexion at pre-swing
- Greater hip flexion and plantar-flexion power generation
Effects of treadmill training on ankle activation
Mohammadi et al 2016

- Increasing speed resulted in concurrent increases in gastrocnemius activation on the paretic side
- Increasing incline had no impact on paretic gastrocnemius but increased activation on contralateral side; incline may exacerbate an existing asymmetry
- Spasticity severity had no impact on muscle activation
Subjects > 6 months poststroke who participated in treadmill training 3x/week for 3 months working up to 30-50 minutes at 60-80% HR reserve showed significant improvement in max speed on the 10m TW, 6 MWT distance, and VO2 peak compared with control group who had conventional PT group which excluded aerobic training.
A review of literature on treadmill training in those with chronic stroke with or without body weight support showed that treadmill training improved walking speed by 0.14 m/s and walking distance by 40m vs no intervention or non-walking intervention.
Benefits of treadmill training
Moore et al 2010

Subjects with chronic stroke discharged from PT received 4 weeks of treadmill training at 2-5x/week frequency. They performed significantly more stepping practice during the locomotor training and significantly improved their daily step count compared with their time in conventional PT.
Treadmill training prescription - frequency & duration
Cochrane Review 2017

Gait speed:
- Treadmill training 3-5x/week showed significant improvement in gait speed

Endurance:
- Treadmill training 5x/week showed significant improvement in endurance
- Duration of treatment needed to be > 4 weeks to show significant improvement in endurance
4 months of treadmill training in subjects with chronic stroke at 3x/week for 30 minute sessions resulted in longer distance walked on 6 Minute Walk Test compared with 2 months of training vs control with no training.
Recent research using high-intensity interval training (HIT) shows promising results with greater effectiveness for improving gait speed compared with moderate-intensity continuous aerobic exercise.

<table>
<thead>
<tr>
<th>Protocol examples: High-intensity Interval Training (HIT) and traditional aerobic training</th>
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<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
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<tbody>
<tr>
<td><strong>Short-interval HIT</strong></td>
<td><strong>Low-volume HIT</strong></td>
<td><strong>Long-interval HIT</strong></td>
<td><strong>Traditional aerobic exercise</strong></td>
</tr>
<tr>
<td>Peak power output (% max capacity)</td>
<td>50-80%</td>
<td>90-100%</td>
<td>30-40%</td>
</tr>
<tr>
<td>(% workload associated with VO2peak)</td>
<td>100-120%</td>
<td>175-250%</td>
<td>80-90%</td>
</tr>
<tr>
<td>High-intensity burst duration</td>
<td>15-60 seconds</td>
<td>10-30 seconds</td>
<td>3-4 minutes</td>
</tr>
<tr>
<td>Recovery period duration</td>
<td>15-60 seconds</td>
<td>2-4.5 minutes</td>
<td>3-4 minutes</td>
</tr>
<tr>
<td>Burst:recovery ratio</td>
<td>1:1</td>
<td>1:4 - 1:12</td>
<td>1:1 or 4:3</td>
</tr>
<tr>
<td>Recovery type</td>
<td>Passive</td>
<td>Light active (&lt;30% VO2peak)</td>
<td>Active (30-50% VO2peak)</td>
</tr>
<tr>
<td>Number of bursts in 20 minutes</td>
<td>10-40</td>
<td>4-10</td>
<td>3</td>
</tr>
<tr>
<td>Total burst time in 20 minutes</td>
<td>10 minutes</td>
<td>1-4 minutes</td>
<td>12 minutes</td>
</tr>
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</table>
Protocols for HIT in stroke research
Boyne et al 2013

- 1-2 minute ramp up followed by 10 seconds at maximum speed alternating with recovery period adequate to allow HR to return to baseline; 30 minute sessions 3x/week for 4 weeks
- 30 second maximum speed bursts alternating with 2 minute recovery; 30 minutes 5x/week for 2 weeks
- 4 minute bursts at 85-95% of HRmax alternating with 3 minute recovery period at 50% HRmax; 5x/week for 4 weeks
Case Example JA

Client is a 59 year-old male s/p R MCA CVA on 4/1/17. After 2 weeks in acute care he was transferred to in-patient rehabilitation for a month followed by 3 months in a SNF. He was discharged home with services for several weeks prior to his evaluations at our clinic on 8/16/17.

Initial evaluation findings:

- 10m TW: self-selected gait speed 0.19 m/s
- 6 MWT: 289 ft
Case Example JA

10/11/17 re-assessment results:

- 10m TW: self-selected gait speed 0.35 m/s with straight cane
- 6 MWT: 372 ft with straight cane

Client participated in PT 4x/week with a focus on gait training progressing on the treadmill from 4 x 4 minutes (1.6mph max) to 4 x 5 minutes (2.0mph max) as well as gait training overground, in the community, and development of a home walking program

11/9/17 re-assessment results:

- 10m TW: self-selected gait speed 0.58 m/s with straight cane
- 6 MWT: 676 ft with straight cane
Case Example
JA
Candidates for Treadmill Training

Clients with ability to walk at least short distances with no more than assist of 1 with or without an assistive device or orthotic support

Safety considerations include:

- Cardiovascular stability - monitor BP response, cardiac symptoms
- Balance - use of harness, gait belt, rails
- Cognition - ability to follow instructions
- Communication deficits
- Orthopedic issues - weight bearing restrictions or pain
Improving Symmetry of Gait

Typical hemiplegic gait is marked by a shortened step length on the nonparetic limb. A shorter nonparetic step results in decreased propulsive force on the paretic leg.

Interventions to improve step length on nonparetic side can result in improved efficiency of gait and increased speed.
Split-belt treadmill training

Research with use of split-belt treadmills has shown that error augmentation can exploit motor adaptation to improve symmetry at least temporarily. Initially faster, shorter steps are taken with the nonparetic limb on a faster belt but within several minutes adaptation results in longer steps and this result will carryover to overground walking for several minutes.

https://www.youtube.com/watch?v=N23QHGSijGo
Split-belt treadmill training

Reisman 2013

“Responders” showed greatest reduction in RPE over the course of training indicating that improved efficiency of gait could lead to increased likelihood of adopting a new pattern long term.

**Figure 1.** Step length during overground walking measured at each baseline session (Baseline 1, Baseline 2) at posttraining (Post) and at 1 and 3 months (mo) after training: A. Step length asymmetry for the entire group (n = 12). B. Step length in meters for the nonparetic (gray bars) and paretic (black bars) leg for the entire group (n = 12). C. Step length asymmetry in the group identified as responders based on their pretraining to posttraining change in asymmetry (n = 7). D. Step length asymmetry in the group identified as nonresponders based on their pretraining to posttraining change in asymmetry (n = 5). *Asterisk indicates P < .05.
Unilateral step training (UST)

Kahn et al 2009

- 10 sessions, each consisting of 20 minutes of UST completed over a 2-3 week period
- Starting speed determined by overground self-selected gait speed with speed increased by 25% every 5 minutes
- Starting at 3rd session initial speed increased by 25% every 2 sessions with additional increments of 25% every 5 minutes
- Unimpaired limb on the belt, impaired limb stationary at same level
- Rests provided as needed, UE support permitted but limited use encouraged
UST

Kahn et al 2009

Improvement in step length symmetry and step length of unimpaired limb maintained at 2 week follow-up.

Figure 3. Phase 2 changes in step length symmetry (SLA) and step length during self-selected walking speed (A–B) and during fast walking speed (C–D). (A–B) Asterisks indicate significant decrease in SLA maintained at 2 weeks posttraining. (P<.01). (C–D) Asterisks indicate significant decreases in SLA at 1 and 2 weeks posttraining and increases in step length following 6 sessions of unilateral step training maintained at 1 and 2 weeks posttraining at fast walking speed (P<.01). Blue bars indicate impaired limb, white bars indicate unimpaired limb. Error bars indicate 95% confidence intervals.
Case example WG

Client is a 53 year-old male s/p L CVA 9/12/15. He had a 1 month acute care stay followed by 5 months at in-patient rehabilitation/SNF. He was discharged home and after 1 month of home care was evaluated at our clinic on 4/27/16.

Initial evaluation findings:

- 10m TW: self-selected gait speed 0.18 m/s with SBQC
- 6 MWT: 213 ft
Case example

WG

Initial gait
Case example WG

1/5/16 re-assessment results:

- 10m TW: self-selected gait speed 0.66 m/s (no device), fast walking speed 0.85 m/s (no device)
- 6 MWT: 800 ft

Client completed 10 sessions of UST over a month time period.

2/2/16 re-assessment results:

- 10m TW: self-selected gait speed 0.71 m/s, fast walking speed 0.94 m/s
- 6 MWT: 863 ft
Case example
WG

Final gait
Candidates for UST

Clients with hemiplegia and asymmetrical step length

Safety considerations - see treadmill training
Rhythmic auditory stimulation (RAS)

- Dense connections between auditory and motor pathways at various levels in brain including basal ganglia, cerebellum, and neocortex
- Rhythmic activity guided by metronome can promote growth of new neural circuits in the brain
- Auditory cueing may provide an anticipatory and continuous time reference that assists with timing, speed, and consistency of movement
- Audible cues may enhance motivation and arousal level
Methods to incorporate RAS

- Metronome device or smartphone app that produces an audible beat to use for cueing with ability to increase or decrease frequency

- Musical beats can be utilized for cueing at a certain speed dependent on the song/genre
RAS use in neurological disorders

Wittwer at al 2012

Review of research showed that RAS (metronome or music) may result in significant improvements in:

- Walking speed, stride length, cadence, temporal symmetry (post CVA)

**Overall findings:** Short-term improvements in gait measures post CVA, insufficient evidence found for TBI due to low study numbers and lower quality studies reviewed

- Further high quality studies required to develop formal practice recommendations and exploration of long term effects
RAS in gait speed changes post CVA
Wonsetler et al 2017

- Systematic review of various rehab interventions used to increase gait speed post CVA, with a focus on spatiotemporal parameters and asymmetry ratios
  - Do increases in walking speed lead to increases in step/stride length, or do increases in step/stride length lead to increased walking speed?

- RAS (in conjunction with alternative sensory stimulation interventions) found to have an effect size range of 0.06-2.8 (small - large effect)
RAS vs. Conventional therapy
-Sangita et al 2016

- Experimental study design in which Group A (15 patients) received conventional therapy alone and Group B (15 patients) received RAS using metronome training in addition to conventional therapy
- Pre-testing and post-testing of gait velocity through the ten meter walk test (10 MWT) and cadence
- Significant improvements observed in response to RAS intervention as well as statistically significant between group difference in favor of RAS
Rhythmic Auditory Stimulation (RAS) cont.

-Sangita et al 2016

- Study duration: 3 weeks
- Intensity: gait training x 30 minutes x 5 days/week
  - 1-2 minute warm-up walk to gauge baseline cadence
  - 1st quarter: baseline cadence used for 1st quarter of session
  - 2nd and 3rd quarters: frequency increased by 5-10% (pending patient ability)
  - 4th quarter: RAS faded to train for independent carryover

Conventional therapy included: range of motion exercises, strengthening exercises, spasticity management, balance training, and gait training
Rhythmic Auditory Stimulation (RAS) cont.

-Sangita et al 2016

Table 3: Analysis of pre test and post test value difference of TMW & CADENCE in group A and B.

<table>
<thead>
<tr>
<th>GROUP</th>
<th>MEAN</th>
<th>STD. DEVIATION</th>
<th>STD. ERROR MEAN</th>
<th>95% CONFIDENCE INTERVAL OF THE DIFF.</th>
<th>MEAN DIFF.</th>
<th>SIG. (P VALUE)</th>
<th>t</th>
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</thead>
<tbody>
<tr>
<td>CONTROL GROUP</td>
<td>.101</td>
<td>.0247</td>
<td>.0063</td>
<td>.3544 -.2634</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>EXPERIMENTAL GROUP</td>
<td>.410</td>
<td>.0823</td>
<td>.0212</td>
<td>.3558 -.2619</td>
<td>.308</td>
<td>.000</td>
<td>13.91</td>
</tr>
<tr>
<td>TMW</td>
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<td>.0247</td>
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<td>.3544 -.2634</td>
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<td>.3558 -.2619</td>
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<td>.000</td>
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<tr>
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<td>1.2649</td>
<td>.3266</td>
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<tr>
<td>EXPERIMENTAL GROUP</td>
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<td>2.9712</td>
<td>.7671</td>
<td>10.5457 -7.0542</td>
<td>8.800</td>
<td>.000</td>
<td>10.55</td>
</tr>
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RAS with Treadmill Training
-Fouad et al 2016

- Randomized control trial with 30 male participants who were chronic ischemic stroke survivors
- Group 1 received metronome training paired with treadmill training in addition to conventional PT. Group 2 received treadmill training and conventional PT but no RAS
- Intervention lasted 6 weeks, with post-testing results showing significantly increased step length in both experimental groups
- Improvement in RAS group was significantly more than control group
RAS Impact on Gait Parameters and Standing Balance
-Suh et al 2014

- 2 groups of patients with hemiplegic gait split into 2 groups of 8
- 1 group received gait training with RAS and 1 received gait training without
- Balance measured through dynamic posturography system - Biodex Balance System
- Gait training was 15 minutes x 5 days / week x 3 weeks total
RAS Impact on Gait and Balance: Findings

- Medial-lateral and anterior-posterior sway decreased in experimental group
- Gait velocity, stride length, and cadence increased in experimental group per 10 MWT time and number of steps taken during testing
- RAS may be effective therapeutic method to improve gait and standing balance post CVA
RAS in patients with TBI
-Goldshtrom et al 2009

- Case report on a 24 year old female patient 9 years post hemispherectomy following TBI that resulted in R hemiparesis

- Patient taught rhythmic exercises with auditory cues to perform at home
  - Alternating hand/foot coordination and cross-midline movements with use of a metronome
  - 20-30 min/day x 4-5 days/week for 1 year

Figure 4  Jill shifting her weight to the left rotating her upper body to the right and crossing midline with her left arm – dancing.
RAS in patients with TBI
-Goldshtrom et al 2009

- Clinical improvements observed in patient’s gait pattern
  - Reduced hip hiking and improved isolated hip function
  - Increased cadence: 4 steps per 10 sec → 14 steps per 10 sec
  - Increased gait speed from 0.4 m/s → 1.2 m/s (post)
  - Decreased spasticity in R arm and leg
  - Some return of light touch sensation from R knee to ankle
Rhythmic Auditory Stimulation (RAS)

Candidates for RAS training may include:

- Patients with
  - impaired coordination
  - impaired motor control
  - step asymmetries
  - hemiplegic gait
  - ataxic gait
  - decreased gait speed

Example diagnoses: cerebral and cerebellar CVAs, TBI (less research supporting)
Safety Considerations

- *Activity tolerance* - monitor rate of perceived exertion (RPE) to assist frequency setting
- *Physical assistance* - use of external supports (ie. gait belts, assistive devices)
- *Cognition* - ability to follow instructions
Case example XM

Client is a 17 year-old male s/p R cerebellar bleed on 5/5/17. Client spent 2-3 weeks in acute care before transitioning to acute inpatient rehabilitation in early June until August. From acute rehab, he was discharged home before beginning outpatient services on 8/21/2017.

Initial evaluation findings:

- 10m TW: 0.24 m/s without device
- 6 MWT: 203 ft with rolling walker
Case example XM

Client began overground gait training with use of a metronome on 10/2/2017 at 70 beats per minute.

Reassessment findings 10/17/2017:
- 10m TW: 0.45 m/s without device
- 6 MWT: 343 without device

Client continued overground gait training with metronome with incremental increases (2 BPM) as appropriate up to 80 BPM.

Reassessment findings 11/17/2017
- 10m TW: 0.56 m/s
- 6 MWT: 610 ft
Case example XM

Reassessment findings 12/15/2017 following additional metronome training (up to 100 BPM):

- 10m TW: 0.88 m/s
- 6 MWT: 779 ft

Additional progressions in training over span of 2 months included: “comfortable” and “fast” metronome settings for interval training, forwards and backwards ambulation with metronome, lateral ambulation with metronome, cognitive dual task incorporation throughout
Case example
XM
Initial gait
Case example
XM
Gait with metronome
Case example
XM

Current gait
Considerations/Limitations

Re-assessment findings:

- Frequency/duration of treatment sessions
- Order of re-assessment testing
- Treatment not strictly isolated to interventions discussed
- Progression of recovery over time vs. intervention provided
Conclusions

- No strong conclusion that one method is better than another
- **Choice of intervention depends on:**
  - Equipment available
  - Client status and challenges
  - Client motivation
- **More is better**
Comments/Questions?
References

References cont’d


