Current affairs

- There are more than 795,000 new strokes each year in the U.S.\(^1\)
- On average, every 40 seconds someone has a stroke in the U.S.\(^1\)
- More than 80% of these persons will experience gait dysfunction as a result of the stroke.\(^2\)

Self-fulfilling prophecy?

- Have we grown accustomed to the notion that gait after stroke is **destined** to be slow and asymmetrical?
- Do we even consider it **possible** to recover typical gait after stroke?

Reality check

- **Fact:** Gait is slow after stroke, as well as asymmetrical and inefficient.\(^3,4\)
- **Fact:** Less than 50% of persons walk at a velocity adequate for community re-integration (> 0.8 m/s).\(^5,6\)
- **Fact:** 93% of people with stroke consider independent community ambulation to be important or essential.\(^7\)
- **Fact:** Many patients are dissatisfied with their outcomes after stroke.\(^8\)
Traditional approaches to gait training after stroke

- Historically we have used a variety of techniques, including strength training, Neuro Developmental Treatment (Bobath), PNF, biofeedback, use of assistive devices, AFOs, etc. to retrain gait after stroke.

Are we missing the target?

- Unfortunately, there remains a significant gap between what the evidence shows to be effective and what is actually done in clinical practice.

What does the evidence say?

1. Experience-dependent neural plasticity

- The concept of neural plasticity is the idea that the brain has the ability to alter its structure and function in response to a variety of internal and external pressures, including behavioral training.
- This is considered to be the mechanism by which the damaged brain relearns lost skills during rehabilitation.

The Ten Commandments of neural plasticity

1. Use it or lose it: Failure to drive specific brain functions can lead to functional degradation.
2. Use it and improve it: Training that drives a specific brain function can lead to an enhancement of that function.
3. Specificity: The nature of the training experience dictates the nature of the plasticity.
5. Intensity matters: Induction of plasticity requires sufficient training intensity.

More principles....

6. Time matters: Different forms of plasticity occur at different times during training.
7. Salience matters: The training experience must be sufficiently salient to induce plasticity.
8. Age matters: Training-induced plasticity occurs more readily in younger brains.
9. Transference: Plasticity in response to one training experience can enhance the acquisition of similar behaviors.
10. Interference: Plasticity in response to one experience can interfere with the acquisition of other behaviors.
Timing of gait acquisition after stroke

- A multitude of studies have examined the time course of gait recovery after stroke.\textsuperscript{11-14}
- The resounding message of these studies is that gait recovery (and lower limb recovery) occurs SOON after stroke, with one study reporting that 80\% of persons reached a plateau in gait recovery at 5 weeks post stroke!\textsuperscript{11}

3. Earlier is generally better

- When should gait training be done after stroke?
  - No definitive answers have been found to this question but a growing body of evidence supports EARLY interventions for the promotion of neural plasticity\textsuperscript{15,16}
  - Initial studies on early and aggressive therapy after stroke have found it to be safe.\textsuperscript{17}

4. Automaticity of gait after stroke

- Healthy adults are able to multi-task while walking, making walking an “automatic” activity.
- Is this a realistic goal for persons after stroke?
- Canning and colleagues found that walking \textbf{DOES} in fact reach the level of automatic behavior once well-learned after stroke.\textsuperscript{18}

5. Resistance to change in established gait

- Since gait does return to the automatic level, what are the implications if changes in gait are the target of therapy?
- Buzzelli and colleagues\textsuperscript{8} studied 42 persons who were 1 year post stroke and were very motivated to improve their walking.
- After 3 months of therapy (5 days/week!) there were NO detectable changes in their gait quality!
- They suggested that it might be a \textbf{waste of time and resources} to attempt gait changes at this point!
3. SPECIFICITY

- ESTT is focused on one thing...GAIT!
  - Training begins on a treadmill, which has been demonstrated to be task-specific for walking over ground.19,20
  - Transition to over ground walking is contingent on achievement of established criteria—speed, weight support, duration, and amount of assistance for limb advancement.

4. REPETITION
5. INTENSITY

- ESTT affords repetitive practice of optimum kinematics in bouts of at least 3 minutes, longer if possible.
  - This provides the opportunity for MULTIPLE correct steps, more than could be performed during over ground gait.
  - ESTT training is provided 5 days a week throughout the course of the inpatient rehabilitation stay.

6. TIME

- Earlier is better!
  - ESTT begins as soon as the patient is in the rehabilitation center.
  - For many of the participants who receive the training, this occurs within 1-2 weeks of stroke onset.
  - ESTT training is done on the treadmill BEFORE any significant over ground gait training has commenced.

7. SALIENCE

- Almost all patients after stroke identify walking as a primary goal of rehabilitation.7
  - ESTT participants consistently rate their overall degree of recovery as high (greater than 70 on a 0-100 scale) on the Stroke Impact Scale.
  - Independent mobility also improves the chance of discharge to home following rehabilitation.11,21

10. INTERFERENCE

- ESTT is designed to teach the patient optimum gait from the beginning.
  - As a result, there is no maladaptive learning, no development of stereotypical gait, so there is no need to attempt to change it later when it may not be possible to change.8,22

Integrating evidence into clinical practice: the HISTORY of Early Standardized Treadmill Training (ESTT)

RAISING THE BAR – HIGHER
In 1997 we first attempted this general approach, i.e. treadmill training BEFORE overground gait training.

The subject was a 60-year-old man with a right basal ganglia stroke, significant sensory loss and inattention, as well as hypertonicity.

**Outcome**: gait with AFO and single point cane, 1000+ feet with standby assist after 4 weeks of rehabilitation.

In late 2005, we began enrolling participants in a clinical trial of ESTT. Data on the first 7 participants was compared to data on 7 individuals who received traditional gait training.

The results were reported in the *Archives of Physical Medicine and Rehabilitation* in 2008.

Participants who received ESTT walked more symmetrically, faster, and with more typical gait kinematics than persons that received traditional training.
ANKELE SYMMETRY

Comparison Group Ankle Sagittal Angles

Treadmill Group Ankle Sagittal Angles

PROTOCOL

Inclusion criteria
1. Males or females 18-85 years of age
2. < 6 weeks post first-time ischemic or hemorrhagic stroke
3. Able to sit independently at least 3 minutes
4. Able to stand with or without assistance
5. Able to give consent or have available authorized surrogate for consent
6. No significant therapeutic gait practice prior to start of study

Exclusion criteria
1. Cerebellar or bilateral stroke
2. Non-ambulatory prior to stroke
3. Significant cognitive impairment
4. Severe cardiac problems and/or recent MI (4 weeks)
5. Presence of co-morbidities or health conditions that would impact gait training
6. Able to complete 5 or more full heel raises with affected ankle in standing with knee extended with no more than 1-2 fingers on support surface at time of enrollment in treadmill group

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Amount of BWS
- Initial amount of body weight support (BWS) is 30% for all participants.
- The goal is to reduce the amount of BWS in 5% increments.
- BWS is adjusted daily in combination with adjustments in speed.

Treadmill speed
- Initial speed of the treadmill is set at 0.7 mph.
- The goal is to attempt to increase the speed by 0.1 mph increments.
- Speed is increased when the participants can tolerate 2 consecutive bouts of 3 minutes at the same speed.

Amount of assistance
- The participants is assisted by two people, one who assists the hemiparetic LE and one who assists with weight shift at the hips.
- Occasionally a third person is required for initial training sessions to achieve good mechanics on the less affected LE.

Duration of treadmill training
- Treadmill training continues throughout the rehabilitation stay until the participant can tolerate 10 consecutive minutes at 1.5 mph with no BWS and no assistance for LE or weight shift. The vest is still on for safety.
- Each training session is 30 minutes TOTAL.

The Orthosis & UE
- All participants wear an ankle foot orthosis with a double-adjustable ankle joint for all gait training (treadmill and over ground).
- Participants are NOT allowed to hold the treadmill bar at any time during training.

Transition to Over ground (OG)
- Gait training OG is initiated when the participant is able to tolerate 2 consecutive bouts of at least 3 minutes at ≤10% BWS at 0.8 mph or greater with minimum assistance or less for LE advancement. OG training is done with the AFO and a single point cane.
- Once OG gait begins, 20 minutes is spent on TM gait and 10 minutes on OG gait.

Primary outcome measures
- The primary outcome measures are the Stroke Rehabilitation Assessment of Movement (STREAM test), the 6-Minute Walk Test (6MWT), and full kinematic gait analysis.

Assessment schedule
- Participants are assessed at the time of admission to rehabilitation (STREAM) as well as at the time of d/c from rehab (STREAM, 6MWT).
- Participants return at 6 months post enrollment for final testing: STREAM, 6MWT, kinematic gait analysis.
In 2010, we further examined outcomes from 18 persons who had participated in ESTT. Participants had a variety of lesion sizes and locations, as well as co-morbidities. Outcomes of interest included gait symmetry, gait velocity and endurance, incidence of falls, and assistive device use (orthoses, walking aids).

CASE SERIES RESULTS

Symmetry data
- Step length ratio, swing symmetry, and stance symmetry were calculated from kinematic data, comparing paretic to non-paretic limbs.
- Symmetry values were superior in the ESTT group compared to published values of symmetry in similar patients.
- Step length symmetry for the group was 1.06 (SD ±0.13) compared to 1.37 (+/- 0.79) [26].
- Swing symmetry was 1.25 (SD ±0.25) vs. 1.56 (+/- 0.52).
- Stance symmetry was 0.91 (SD ±0.08) vs. 0.87 (+/- 0.07).

CASE SERIES RESULTS

Speed data
- The 6-Minute Walk Test was used to measure both self-selected walking velocity and gait endurance.
- Based on Perry's [27] classification of gait after stroke, all but 1 of the 18 participants had speeds adequate for community ambulation (0.8 m/s).
- Mean baseline velocity at d/c from rehab for all participants was 0.44 m/s (+/- .30).
- Final mean velocity at 6 months post d/c for all was 0.90 m/s (+/- .32).

CASE SERIES RESULTS

Endurance data
- The 6-MWT mean distance at the 6-month reassessment for all participants was 322.42 m (+/- 114.33).
- Patterson et al. [26] reported distances of 227 m (+/- 105) for persons who were at least 6 months post stroke.

CASE SERIES RESULTS

Assistive device inventory
- Use of assistive devices was tracked for each participant.
- At the time of the 6-month reassessment, 10 of the 18 participants walked at home and in the community without any AD or AFO. Three persons used only an AFO, 4 used an AFO and STC, and 1 used only a STC.

Falls data
- Falls for each participant were tracked.
- Of the 18 subjects, only 28% reported falls (1 participant had 2 falls), whereas incidence of falls has been reported between 40-73% for community-dwelling persons 6 months post stroke.

CASE SERIES DETAILS

- Average days after CVA participants began training: 17.27 +/- 12.43
- Total weekdays in rehab: 20.22 +/- 3.97
- Total days on the treadmill: 16.06 +/- 4.21
- Total minutes on the treadmill: 124.17 +/- 41.15
- Maximum treadmill speed: 1.36 mph +/- 0.25
- Progression to OG gait: day 9.8 +/- 2.64
In 2010, we initiated a pilot study to examine the contribution of the double adjustable AFO design used in ESTT training. Data was collected on 3 participants who were no longer wearing the AFO at 6 months post stroke. Outcomes included lower extremity strength, range of motion, STREAM test, 6MWT, GAITRite computerized gait analysis at self-selected and fast walking speeds, and EMG activity of target muscles including gastrocnemius, tibialis anterior and quadriceps.

Muscle activity: Timing of muscle activity across the gait cycle was consistent with expected patterns, i.e. activation of the AT at initial contact, VL activation early in the gait cycle, and peak activation of GAS late in stance. In addition, amplitude increases are seen appropriately in relationship to increases in velocity. Likewise, similar peak muscle activation is seen in the non-paretic limb across muscle groups.

Symmetry: Step length symmetry ratios obtained at the time of final testing ranged from 1.0 to 1.08 across conditions. Swing symmetry ranged from 1.0 to 1.05 and stance symmetry from 1.0 to 1.03. These values are surprisingly close to the values of healthy persons as reported by Patterson et al. 28

Integrating evidence into clinical practice: the FUTURE of Early Standardized Treadmill Training (ESTT)

RAISING THE BAR – HOW HIGH CAN WE GO?

FUTURE PLANS

We are seeking extramural funding for a multisite trial of ESTT.
Further investigation of the role of the AFO will include early EMG testing of participants (during treadmill training) as well as contrasting the findings in persons who were braced with other orthoses.
We currently have funding to examine the cardiovascular benefits of ESTT.

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