Locomotor Recovery After Stroke

Darcy Reisman, PhD, PT
Professor
Associate Chairperson
Physical Therapy
Biomechanics & Movement Science
University of Delaware

University of Delaware

University of Delaware

Objectives:

1) Participants will be able to identify key factors across the WHO ICF domains that should be considered when designing rehabilitation interventions for improving walking after stroke.
2) Participants will be able to discuss the importance of examining how key factors inter-relate to impact the effect of rehabilitation interventions for improving walking after stroke.
3) Participants will be able to discuss the role of exercise intensity for walking recovery after stroke.
4) Participants will be able to discuss motor learning strategies for walking recovery after stroke.

University of Delaware

Develop scientifically-based therapies to advance physical rehabilitation and recovery after stroke

---

University of Delaware

World Health Organization ICF model

Health Condition
(Stroke)

Body function/structure ⟷ Activity ⟷ Participation

Environmental Factors
Personal Factors

University of Delaware — BACKGROUND

One major goal of PT is to return patients to their previous level of function and community participation



University of Delaware — BACKGROUND

Recovery of Function

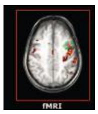
Restoration   Compensation

BACKGROUND

Definitions

(inspired by Behrman et al. 2006; Kleim and Jones 2008; Levin et al. 2009)

Recovery: restitution of damaged structures? **OR** clinical improvement?
(Levin et al, 2009)



BACKGROUND

Definitions

- **Recovery:** return to, or emergence of, a desired level of function
  - as viewed from the perspective of the patient and family
  - "I want to be able do what I want/need to do each day"

BACKGROUND

- **Restoration**: remediation of an impairment
  - Example: return of optimal or baseline quadriceps muscle performance after surgery

BACKGROUND

- **Compensation**: atypical motor patterns are used to substitute for impairments.
  - This can occur through the reorganization of movement by the subject or through the application of assistive devices or techniques

BACKGROUND

- These terms are most effectively used when followed by explanatory terms
  - Recovery of ***what function***?
  - Restoration of ***what impairment***?
  - Compensation for ***which impairment***?

BACKGROUND

Questions to consider

- When we are thinking about functional recovery is it **either** restoration **or** compensation or is it continuum?
- What is the empirical or theoretical evidence that compensatory movement patterns are detrimental to long-term recovery?

BACKGROUND

Questions to consider

- Is all PT, at the level of individual intervention, part compensation and part restoration?

BACKGROUND

Goal Setting

- **Goals should be written at the level of Activity/Participation of the WHO ICF model**
  - What does the patient want to be able to do that they are not currently able to do?
  - Details matter, may need to "drill down"

Principles of Neuroplasticity

NEUROPLASTICITY

Principles of Neuroplasticity

Based on the article by Kleim and Jones, 2008

- **The nervous system can adapt its processes, structure and function in response to a variety of input**
- **"…neural plasticity is the mechanism by which the brain encodes experience and learns new behavior."**
- **"…currently learning is our best hope for remodeling the damaged brain…"**

NEUROPLASTICITY

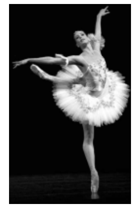
- **The brain continuously remodels in response to new experiences and behaviors**
- **The brain reorganizes in adaptive and maladaptive ways**

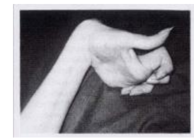
Kleim & Jones, 2008

NEUROPLASTICITY

- **"…this process of functionally appropriate reorganization in the healthy brain is also the key to promoting reorganization… in the damaged brain."**
- **Using learning, alone and in combination with other therapies to promote adaptive neural plasticity is an important focus of animal and human research into brain damage.**

- **After nervous system damage, compensatory behaviors will lead to reorganization** ***(e.g.-Jones & Shallert, 1994; Jones, Kleim and Greenough, 1996)***





- **Damage to the brain can affect how it responds to learning**
  - Need for learning studies in persons with damage to the brain
  - How much of what we know about the principles of motor learning has been shown to hold true in persons with brain damage?

Kleim & Jones, 2008

- **Principle 1: Use It or Lose It**
  - **Neural circuits can degrade without activity**
  - **Brain area can shift responsibility**

Kleim & Jones, 2008

Principle 1: Use It or Lose It

Wolf et al. Forced use of hemiplegic upper extremities to reverse the effect of learned nonuse among chronic stroke and head-injured patients. Exp Neurol. 1989 May;104(2):125-32.

- Studied 25 patients with chronic stroke and TBI
- 2 weeks of forced use through wearing a sling during all waking hours(allowed to remove for 30min/day)
- Significant changes from baseline in a variety of functional tasks.
- First study to identify learned non-use in humans

TABLE 3

Median Change from Baseline[a]

Task	Target joints	Forced use		Follow-up			
		Week 1	Week 2	1 week	2 months	4 months	1 year
Timed activities (s)							
1. Forearm-table	Shoulder	−0.03	−0.08*	−0.12*	−0.18*	−0.21*	−0.23*
2. Forearm-box	Shoulder	−0.09*	−0.11*	−0.19*	−0.25*	−0.22*	−0.22*
3. Hand to table	Shoulder	+0.01	−0.07*	−0.07*	−0.11*	−0.17*	−0.18*
4. Hand to box	Shoulder	−0.18	−0.17*	−0.20*	−0.29*	−0.27*	−0.34*
5. Trace circle with elbow	Shoulder	−0.89	−1.17*	−1.26*	−1.50*	−1.71*	−1.67*
6. Extend elbow	Elbow	−0.03	−0.12	−0.13	−0.15*	−0.18*	−0.24*
9. Extend elbow with weight	Elbow	−0.05	−0.08	−0.13*	−0.17*	−0.17*	−0.23*
10. Reach–retrieve object	Elbow	−0.21	−0.29	−0.35*	−0.40*	−0.41*	−0.49*
11. Lift can to mouth	All joints	−0.14	−0.09	−0.25*	−0.51*	−0.37*	−0.47*
12. Lift pencil	All joints	−0.32	−0.60*	−0.69	−0.70*	−0.88*	−0.85*
13. Lift paperclip	All joints	−0.15	−0.19	−0.11	−0.59	−0.50*	−0.63*
14. Stack checkers	All joints	−1.05	−1.60*	−1.72*	−2.01*	−1.23*	−2.05*
15. Flip note cards	All joints	−1.93	−1.90	−2.17*	−2.30*	−2.53*	−2.74*
17. Release time of grip	All joints	−0.03	−0.05	+0.02	−0.06	−0.04	−0.20
18. Turn key	All joints	−0.04	−0.45	−0.68	−0.68*	−0.56*	−1.09*
19. Fold towel	All joints	−1.83	−2.76*	−4.04*	−0.91	−4.13*	−3.69*
20. Lift basket	All joints	+0.15	−0.20	−0.27	−0.61	−0.89*	−0.97*
21. Write name	All joints	−2.76	−0.28	−2.14	−0.40	−5.59*	−7.64*
Force measures							
7. Weight to box (lb)	Shoulder	0.0	+2.0	+2.0	+4.0	+4.0*	+4.0*
8. Stabilize cardboard (lb)	Shoulder	0.0	+1.0	+2.0	0.0	+2.0	+2.0
16. Grip strength (lb)	All joints	−1.0	−1.0	−0.5	+2.0	+2.0*	+4.0*

NEUROPLASTICITY

Principle 2: Use It and Improve It

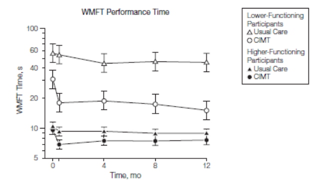
- **Practice of specific tasks can increase areas of the brain that respond during the task**

Kleim & Jones, 2008

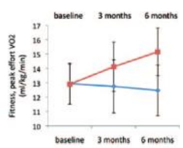
NEUROPLASTICITY

Principle 2: Use It and Improve It

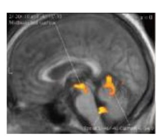
- **EXCITE trial (*Wolf et al, 2006)***
- 222 subjects (3 to 9 months post-stroke)
- 106 subjects received 2 weeks intensive constraint induced movement 116 received usual care



- **Treadmill training improves gait speed and endurance and leads to increased brain activation after stroke (fMRI) *(Luft et al, 2008)***
- 71 chronic stroke survivors
- 37 in aerobic exercise group (T-EX) and 34 in stretching group (CON) for 6 months
- T-EX = 3 40 minute treadmill walking sessions/week at 60% HRR; CON=13 different stretches 3x/week

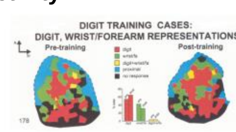


- Improvements in peak VO2, walking speed during 6 minute walk test increased more in T-TEX.
- Changes in subcortical activation were associated with improvements in T-EX group.



NEUROPLASTICITY

- **Principle 3: Specificity Matters**
  - **Changes in specific brain areas occur relative to the task that is practiced**
  - **Skilled practice results in changes in neural connectivity**



Nudo et al, 1996

NEUROPLASTICITY

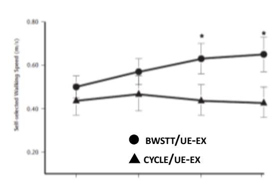
Principle 3: Specificity Matters

- 42 post-acute stroke survivors
- 2 groups - One group received standing balance training with a specially designed feedback device that provided dynamic visual information about relative weight distribution over the paretic and nonparetic limb and the other group did not receive augmented feedback.
- Trained for 3-4 weeks

- **Static standing asymmetry improved, but asymmetry in walking did not improve** ***(Winstein et al, 1989)***

NEUROPLASTICITY

- **80 chronic stroke survivors**
- **4 groups - focus on BWSTT/UE-EX and CYCLE/UE-EX**
- **1-hour sessions, 4 days per week, for 6 weeks**



Sullivan et al. *Phys Ther.* 2007; 87:1580-11602

NEUROPLASTICITY

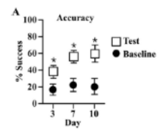
Principle 4: Repetition Matters

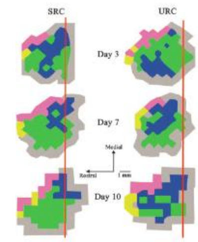
- **Repetition of new task required to see neural changes**
- **Changes at the neuronal level not observed until significant repetition of new task, even when behavioral improvements observed**

Kleim & Jones, 2008

NEUROPLASTICITY

Principle 4: Repetition Matters





Kleim et al, 2004

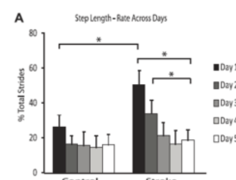
NEUROPLASTICITY

Principle 4: Repetition Matters

- Animal literature suggests 100's to thousands of reps to get neuroplastic changes. Amount of practice needed in humans not known.
- 300 reps of UE activity after stroke "doable" and results in significant improvement in ARAT *(Birkenmeier et al, 2010)*

NEUROPLASTICITY

- More repetition required for learning after stroke

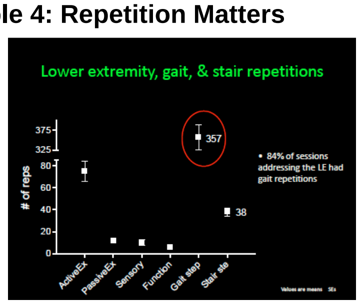


•(~1200 more strides)

Tyrell, Helm & Reisman, 2013

NEUROPLASTICITY

Principle 4: Repetition Matters



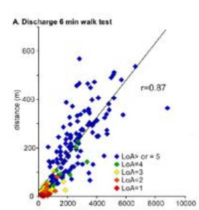
Lang CE, Macdonald JR, Reisman DS, Boyd L, Jacobson Kimberley T, Schindler-Ivens SM, Hornby TG, Ross SA, Scheets PL. Observation of amounts of movement practice provided during stroke rehabilitation. Archives of physical medicine and rehabilitation. 2009; 90(10):1692-8.

NEUROPLASTICITY

Principle 4: Repetition Matters

Hornby et al, 2015

- 201 sub-acute stroke survivors in inpatient rehab
- Participated in treatments focused on increasing the amount and intensity of walking practice

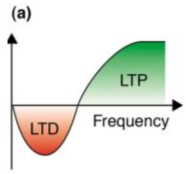


UNIVERSITY OF DELAWARE

NEUROPLASTICITY

Principle 5: Intensity Matters

- Hebbian learning:
  - Cells that fire together, wire together
  - Depends on firing patterns
- Brief, intermittent, high frequency stimuli – **long-term potentiation**
- Frequency of activity (impulses per unit time) determines extent of short-term alterations in synaptic plasticity



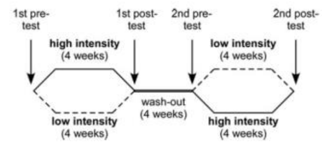
UNIVERSITY OF DELAWARE

NEUROPLASTICITY

Principle 5: Intensity Matters

Holleran et al, 2015

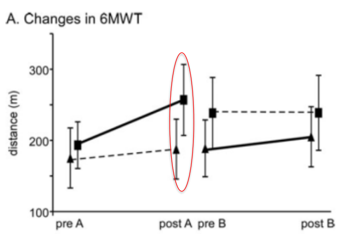
- Trained 12 persons with chronic stroke
- 12 sessions over 4-5 weeks
- 30 minutes of treadmill stepping and 10 minutes of overground walking at different training intensities, but with equivalent amounts of stepping practice.



UNIVERSITY OF DELAWARE

NEUROPLASTICITY

Principle 5: Intensity Matters



Holleran et al, 2015

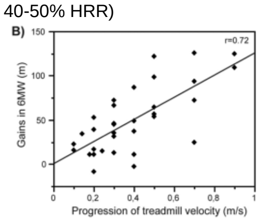
UNIVERSITY OF DELAWARE

NEUROPLASTICITY

Principle 5: Intensity Matters

Globas et al, 2011

- Trained 38 persons with chronic stroke
- Randomized to 3x/week for 12 weeks of high intensity treadmill training or conventional PT
- 30-50 minutes (start at 10-20 min) at 60-80% HRR (started at 40-50% HRR)



UNIVERSITY OF DELAWARE

NEUROPLASTICITY

Conclusions

- Animal and human neurophysiologic studies provide substantial information regarding factors that impact neuroplasticity
- Optimal design of neurorehabilitation interventions incorporates these principles

UNIVERSITY OF DELAWARE

Walking after Stroke

•Many patients perceive improvement in their walking ability as the ultimate goal of rehabilitation *(Bohannon et al. 1991)*

•Walking soon after stroke can predict if a patient will be discharged from the hospital to home *(Mayo et al. 1999)*

•Walking soon after a stroke is a strong predictor of who will return to work after stroke *(Vestling et al. 2003).*

Why do we walk?

•To transport ourselves
•To transport objects
•For exercise

These are important concepts that we must consider when designing gait re-training programs….*more on this later*….

Basic facts about walking

•Average walking speed in healthy adults is ≈1.2 m/s (approx. 2.7 mph)

•Average speed when persons transition from walking to running is ≈ 2.0 m/s (approx. 4.47 mph)

Basic facts about walking

•To function independently in the community you must be able to walk a minimum of 500-1000 feet *(Hill et al., 1997; Shumway-Cook et al, 2002)*

•To function independently in the community, you should be able to carry packages averaging 6.7 pounds *(Shumway-Cook et al, 2002)*

Perry J, Garrett M, Gronley JK, Mulroy SJ. Classification of walking handicap in the stroke population. Stroke. 1995 Jun;26(6):982-9.

Seminal study on importance of walking speed post-stroke

•Three classifications:

Household ambulator <0.4 m/s
Limited community ambulator 0.4 - 8.0 m/s
Unlimited community ambulator > 0.8 m/s

These findings corroborated by later studies:

•Improvements in speed are associated with improvements in self-assessment of disability as measured by SIS *(Schmid et al., 2007)*

•Patients in different categories were found to have significantly different amounts of daily step activity. Slower walking = less daily activity *(Bowden et al, 2008)*

Energy Cost

- Recent meta-analysis found that the median VO_{2peak} in stroke survivors is 14 mL/kg/min *(Marsden et al, 2013).*

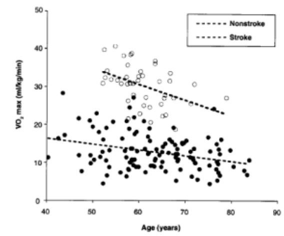


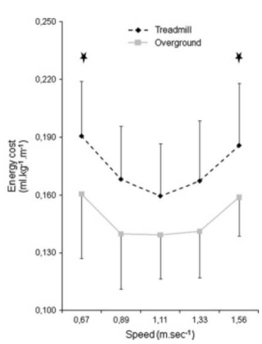
Figure 2. Aerobic fitness deficits in stroke survivors as a function of age compared with healthy individuals.
VO_2 max: Volume of oxygen that can be utilized in 1 min.

(Globas et al. 2009)

- Given that basic activities of daily living, such as cooking and food shopping, require around 8.25 ml/kg/min, persons with stroke are working at a high percentage of their VO_{2peak} just to complete basic, daily activities.
- In adults aged 55-97 years, VO_{2peak} values below 18-20 mL/kg/min are associated with a loss of independence because activities of daily living become too tiring *(Paterson et al, 1999; Cress et al, 2003)*

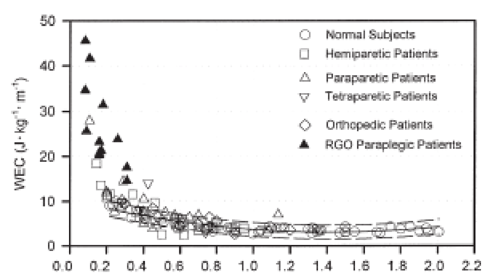
•In healthy individuals the aerobic demand – speed relationship is U-shaped with higher aerobic demand occurring at speeds faster or slower than the self-selected walking speed *(Martin et al. 1992; Bernardi et al. 1999; Malatesta et al. 2003)*.

•Older adults show the same U-shaped speed-aerobic demand response curve as young subjects, but the curve is shifted up such that for a given speed, older adults expend more energy per unit distance *(Malatesta et al. 2003).*



(Berryman et al. 2011)

Energy costs of walking in persons with neurologic damage/disease



Bernardi et al., 1999

UNIVERSITY OF DELAWARE

ENERGY COST

Table 3
Energy expenditure of flexed knee gait *

Degrees	Velocity (m/min)	O_2 rate (ml/kg per min)	O_2 cost (ml/kg per m)
0	80	11.8	0.16
15	77	12.8	0.17
30	75	14.3	0.19
45	67	14.5	0.22

* Waters [65].

Waters and Mulroy, 1999

UNIVERSITY OF DELAWARE

ENERGY COST

Table 7
Energy expenditure adults with spinal injury by orthotic requirement*

	2 KAFO'S ($n = 6$)	1 KAFO ($n = 7$)	No KAFO ($n = 23$)
Velocity (m/min)	18.9	37.1	48.1
O_2 rate (ml/kg per min)	14.9	14.7	15.1
O_2 rate increase (% normal)	226	107	81
O_2 cost (ml/kg per m)	1.15	0.46	0.37
Heart rate (beats/min)	122	125	115
RER	0.82	0.88	0.86
Peak axial load (% body weight)	79.0	20.4	13.9

* Waters [111]. KAFO, knee–ankle–foot orthosis; RER, respiratory exchange ratio.

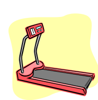
Waters and Mulroy, 1999

UNIVERSITY OF DELAWARE

ENERGY COST

- What is the energy cost of walking faster than self-selected speed for a person with a neurologic condition or injury?

- This is important when we consider the slow walking speeds often observed post-stroke and therefore, the goal to increase speed



UNIVERSITY OF DELAWARE

ENERGY COST

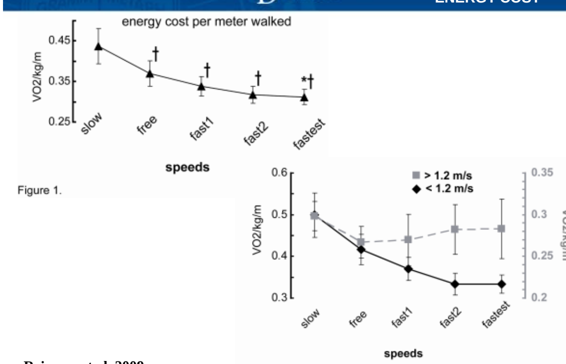


Figure 1.

Figure 4.

Reisman et al, 2009

UNIVERSITY OF DELAWARE

ENERGY COST

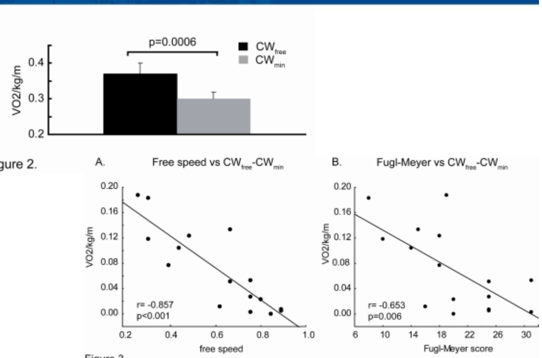


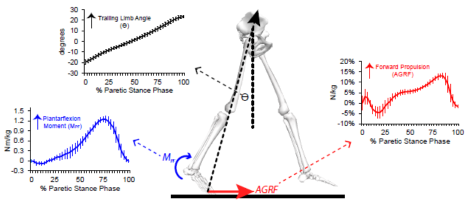
Figure 2.

Figure 3.

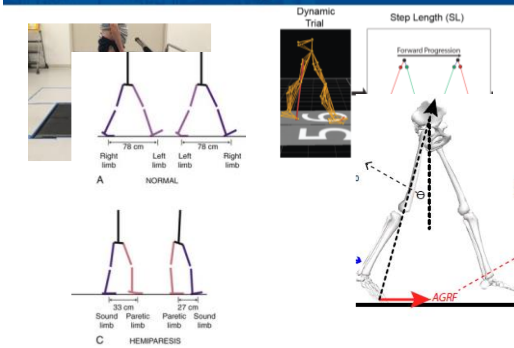
Reisman et al, 2009

UNIVERSITY OF DELAWARE

Biomechanics



•**Paretic propulsion strongly related to walking speed after stroke** *(Awad et al. 2016; Awad et al. 2015; Bowden et al, 2006; Hall et al, 2010)*



Walking Activity

Determining daily walking activity after stroke

•Stroke survivors over-estimate amount of daily activity when compare self-report to objective measurement *(Resnick et al, 2008)*

WHY??

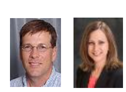
•One way to objectively evaluate walking activity is through monitoring step activity using an accelerometer based device

Research grade accelerometer based devices (SAM, Actical)

•**Advantages:** good accuracy and test-retest reliability in stroke and other neuro conditions *(Macko et al, 2002; Rand et al, 2009)*

•**Disadvantages:** expensive, not easy to use

Commercially available pedometers notoriously inaccurate in those with slow walking speed and/or asymmetric gait *(Macko et al, 2002)*



Collaboration with George Fulk, PT, PhD at Clarkson University, Stephanie Combs, PhD, PT, University of Indianapolis, Coby Nirider, PT, Touchstone Neurorecovery

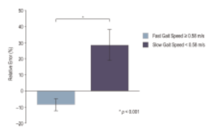
- Accuracy of Fitbit One in community dwelling persons with stroke and TBI is acceptable ($ICC_{2,1}$= 0.73)
- Accuracy decreased with walking speeds <0.58 m/s

Fulk GD, Combs SA, Danks KA, Nirider CD, Raja B, Reisman DS. Accuracy of 2 activity monitors in detecting steps in people with stroke and traumatic brain injury. Physical therapy. 2014; 94(2):222-9.

University of Delaware — WALKING ACTIVITY

- Improved accuracy in persons post-stroke when Fitbit worn on non-paretic ankle in community dwelling stroke survivors. 4-7% mean error (versus hand counting) for speeds ≥0.4 m/s, 15.8% error at 0.3 m/s *(Klassen et al, 2016)*

- 3.8% error Fitbit One compared to Actical in community dwelling stroke survivors, but error significantly increased at <0.58 m/s *(Tang et al, 2018)*



University of Delaware — WALKING ACTIVITY

Inpatient rehab post-stroke *(Klassen et al, 2017)*

Fitbit error compared to SAM:
- 10.9% at walking velocities <0.4 m/s
- 6.8% at walking velocities between 0.4 and 0.8 m/s
- 4.4% at walking velocities >0.8 m/s.

Table 2. Accuracy of the Fitbit One Using Perry Gait Categories[10]

Baseline Walking Speed, m/s	Participants (n)	Total PT Sessions Monitored (n)	6-min Walk Velocity (m/s) Mean (SD)	Fitbit Mean Step Count (SD)	95% CI	SAM Mean Step Count (SD)	95% CI	Fitbit Error (%) Mean (SD)	95% CI
<0.4 m/s	12	259	0.2 (0.1)	2112 (1091)	1855, 2369	2247 (1013)	1974, 2521	10.9 (5.3)	7.9, 13.9
0.4–0.8 m/s	7	181	0.6 (0.1)	2992 (933)	2557, 3428	3191 (986)	2726, 3655	6.8 (3.0)	4.6, 9.0
>0.8 m/s	2	31	1.0 (0.2)	2556 (512)	1656, 3455	2639 (512)	1710, 3567	4.4 (2.8)	0.6, 8.2

CI indicates confidence interval; PT, physical therapy; and SAM, StepWatch Activity Monitor.

University of Delaware

Take home message

Fitbit has best accuracy of commercially available devices, but is more inaccurate at speeds <0.3 m/s

University of Delaware — WALKING ACTIVITY

•Recommended steps/day for healthy persons is ≈10,000

•Recommended steps/day for those with disability ≈8,000

•Average steps/day older adults = 6559±2956

•Average steps/day for sedentary older adults = 5000-6000
(Tudor-Locke et al, 2002)

University of Delaware — WALKING ACTIVITY

How Physically Active Are People Following Stroke? Systematic Review and Quantitative Synthesis
Fini et al, 2017 PTJ

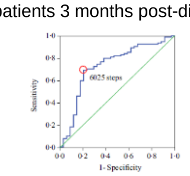
- 5535 steps per day in sub-acute phase
- 4078 steps per day in chronic phase
- >78% sedentary time regardless of phase….However 2 studies measured sedentary time in acute phase and found a mean of 93.9% and a median of 87.0%!

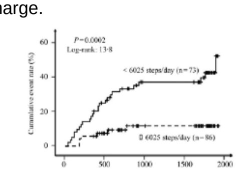
7 studies measured activity change from subacute to chronic phase:
- 2 showed improvement within subacute phase, but plateaued from the late subacute to chronic phase
- 3 showed improvement from subacute to chronic phase
- 2 showed no change between subacute and chronic phases

University of Delaware — WALKING ACTIVITY

Predictive impact of daily physical activity on new vascular events in patients with mild ischemic stroke
Kono et al, 2015 Int J Stroke

- Steps/day is significant predictor of death and hospitalization due to vascular events including stroke recurrence, myocardial infarction, angina pectoris and peripheral artery disease in stroke patients 3 months post-discharge.



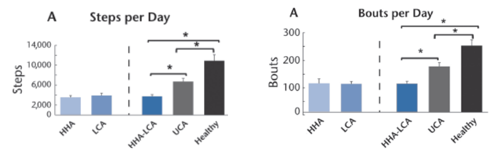


WALKING ACTIVITY

Validation of a Speed-Based Classification System Using Quantitative Measures of Walking Performance Poststroke
Bowden et al, 2008 NNR

Steps/day:
- Household = 1411 ± 803
- Limited community = 2668 ± 1193.3
- Unlimited community = 3659 ± 1447.4

WALKING ACTIVITY



Roos MA, Rudolph KS, Reisman DS. The structure of walking activity in people after stroke compared with older adults without disability: a cross-sectional study. Physical therapy. 2012; 92(9):1141-7.

WALKING ACTIVITY

Predicting Home and Community Walking Activity Poststroke
Fulk et al, 2017 stroke

a priori categorized based on previous research
- Household = 100-2499 steps/day
- Most Limited community = 2500-4999
- Least Limited community = 5000-7499
- Unlimited community = ≥7500

<u>441 participants</u>:
43.08% = household ambulators
30.39% = most limited community ambulators
14.29% = least limited community ambulators
12.24% = unlimited community ambulators

WALKING ACTIVITY

- What factors are significant predictors of real world walking activity after stroke?
- If we know this, then we know what to target in rehab

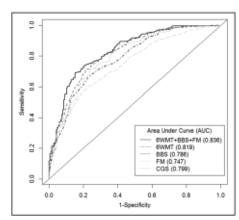


Figure 1. Receiver-operating characteristic curves for predicting community ambulation vs home ambulation. BBS indicates Berg Balance Scale; CGS, comfortable gait speed; FM, Fugl Meyer; and 6MWT, 6-minute walk test.

Fulk et al, 2017

- 6MWT distance ≥205m discriminated between home & community ambulators
- 6MWT distance ≥288m discriminated between limited & unlimited community ambulators.
- Distances <288m on 6 MWT may mean stroke survivors don't have endurance for community mobility

WALKING ACTIVITY

- Many studies have shown that while walking capacity as measured by 6MWT distance or walking speed is important for steps/day, these capacity measures usually only explain 30-55% of variance *(Mudge & Stott, 2009; Fulk et al, 2010)*
- Moreover, significant improvements in walking speed and distance don't result in significant improvements in steps/day *(Mudge et al, 2009; Michael et al, 2009; Pang et al, 2005)*
- What are the other factors, besides physical capacity, that are influencing real world walking after stroke?

WALKING ACTIVITY

- Studies suggest that balance and balance self-efficacy may be important, however these studies measured activity subjectively *(Robinson et al, 2011; Schmid et al, 2011)*
- Depression and co-morbidities may also influence post-stroke activity and participation *(Carod-Artal et al, 2009; Berlowitz et al, 2008)*
- Need for a comprehensive model to look at the role of all of these factors in objectively measured post-stroke real world walking activity.

WALKING ACTIVITY

Walking Capacity
- Walking Economy (WE)
- Functional Gait Assessment (FGA)

*R^2=0.359

→

Biopsychosocial Factors
- Geriatric Depression Scale (GDS)
- Fatigues Severity Scale (FSS)
- Modified Cumulative Illness Rating Scale (MCIR)

R^2=0.414

→

Self Efficacy Measures
- Walk 12
- Activities Balance Confidence Scale (ABC)

*R^2=0.566

→

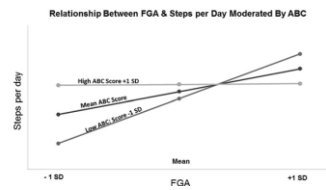
Interactions
- ABC & FGA

*R^2=0.612

*$p<0.001$

Danks KA, Pohlig RT, Roos M, Wright TR, Reisman DS. Relationship Between Walking Capacity, Biopsychosocial Factors, Self-efficacy, and Walking Activity in Persons Poststroke. Journal of neurologic physical therapy : JNPT. 2016; 40(4):232-8.

WALKING ACTIVITY



Danks KA, Pohlig RT, Roos M, Wright TR, Reisman DS. Relationship Between Walking Capacity, Biopsychosocial Factors, Self-efficacy, and Walking Activity in Persons Poststroke. Journal of neurologic physical therapy : JNPT. 2016; 40(4):232-8.

Motor Learning

MOTOR LEARNING

•Motor learning is the foundation of neurorehabilitation

•We have limited information regarding how stroke effects learning

•Much of what we know about motor learning is from neurologically intact subjects doing tasks that are quite simple

•Unclear how this applies to complex tasks taught in rehab to persons who have neurologic damage/disease

MOTOR LEARNING

Types of Learning

implicit vs. explicit

procedural vs. declarative

Implicit, procedural learning — **Explicit, declarative learning**

Split Belt Treadmill — Reaching to a target with feedback

MOTOR LEARNING

Procedural Learning

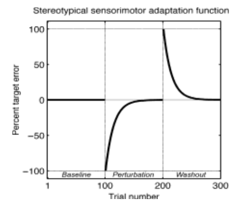
- Develops slowly
- Requires repetition
- Traditionally thought to <u>not</u> require awareness, attention or other higher cognitive processes, however, because learning exists on a continuum, it is difficult to find tasks where this is completely true

Declarative Learning

- Results in knowledge that can be consciously recalled
- Significant repetition can move declarative learning into procedural knowledge (e.g.- initially patient has to tell themselves each step of a transfer, but eventually, with enough practice, they can just complete the transfer without consciously going through the steps)
- Traditionally thought to require awareness, attention or other higher cognitive processes, however, because learning exists on a continuum, the level of awareness varies

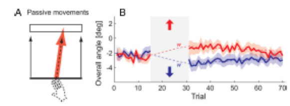
Forms of Motor Learning

- **Adaptation learning**
  - **Error-based**
  - **Cerebellum-dependent**



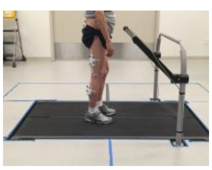
(Taylor & Ivry 2014)

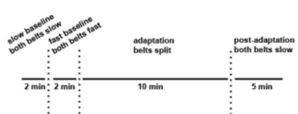
- **Reward-based learning**
  - **Binary responses; strategies**
  - **Dopamine systems?**
  - **Basal ganglia involved? Cortex involved?**
- **Use-dependent learning**
  - **Repetition-based; reward-irrelevant**
  - **Hebbian learning?**
  - **Cortex involved?**



Split-belt treadmill

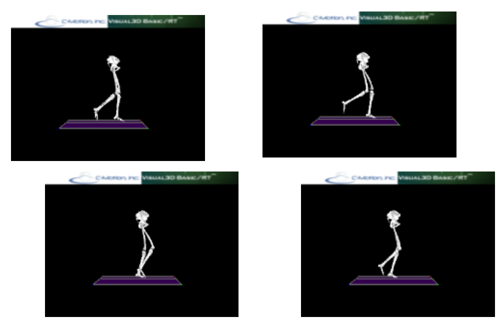
- **Two treadmill belts controlled by two independent motors**
- **Legs can be made to move at two different speeds**



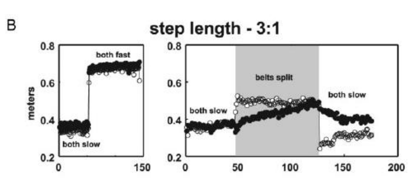


This type of learning is thought to be quite implicit

Split-belt treadmill

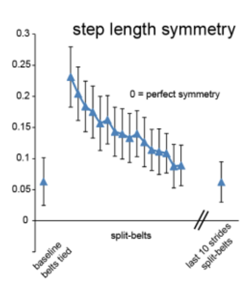


Split-belt treadmill



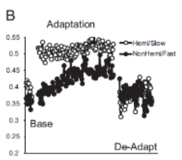
Neurologically intact subjects can adapt to walking on the split-belt treadmill and show after-effects *(Reisman et al, 2005)*

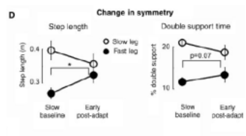
Persons post-stroke (not involving cerebellum) can adapt step length during split-belt treadmill walking *(Reisman et al, 2007, 2009; Tyrell et al, 2014, 2015; Helm et al, 2016).*



MOTOR LEARNING

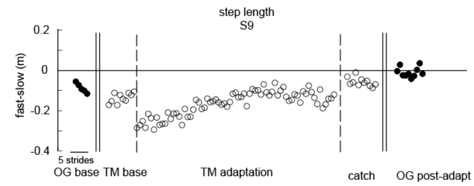
This adaptation can lead to improved symmetry ***(Reisman et al, 2007, 2009; Tyrell et al, 2015)………***





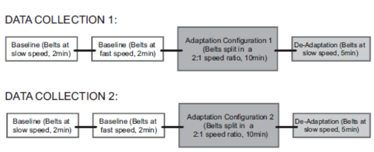
MOTOR LEARNING

……and can transfer to overground walking ***(Reisman et al, 2009).***



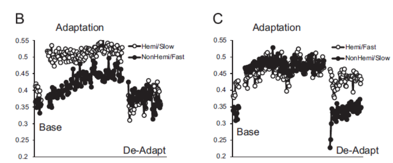
MOTOR LEARNING

Adaptation is impacted by how subject is set-up on split-belt treadmill ***(Tyrell et al, 2015).***



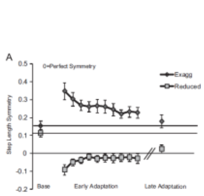
Depending on direction of baseline asymmetry, paretic leg on the slow belt could either exaggerate or reduce the subject's asymmetry when the belt's are initially split ***(Tyrell et al, 2015).***

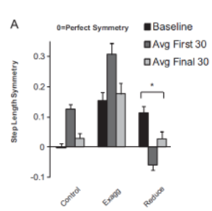
MOTOR LEARNING



For this subject, because the paretic leg took a longer step than the nonparetic at baseline, putting the paretic leg on the slow belt initially exaggerated their asymmetry. The opposite was true when the nonparetic leg was on the slow belt ***(Tyrell et al, 2015).***

MOTOR LEARNING



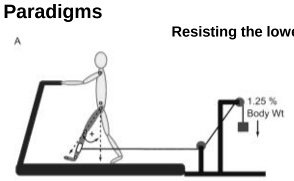


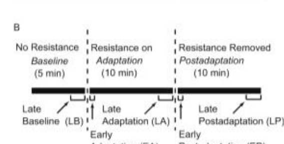
When asymmetry is exaggerated subjects adapt back to baseline. When asymmetry is reduced, subject adapt less and appear to stay closer to symmetry ***(Tyrell et al, 2015).***

MOTOR LEARNING

Resistance Paradigms

Resisting the lower leg during swing

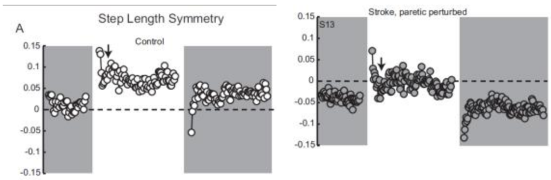




Savin,D.N.,Tseng,S.C.,Whitall,J.,Morton,S.M. Post stroke hemiparesis impairs the rate but not magnitude of adaptation of spatial and temporal locomotor features. Neurorehabil.NeuralRepair, 2012; 27:24–34.

MOTOR LEARNING

Resistance paradigm

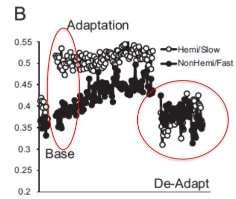


Both neurologically intact and subjects post-stroke adapt and show after-effects ***(Savin et al, 2012)***

MOTOR LEARNING

Error Augmentation

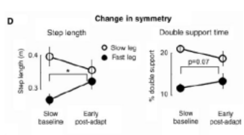
Earlier we showed that if we set up a stroke survivor "correctly" on the split-belt treadmill, we will augment their error. They will correct this error, such that when the belts are again tied, they will walk with symmetric step length.

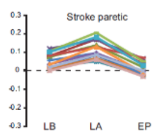


MOTOR LEARNING

Error Augmentation

If the stroke survivor has the capacity to use trial & error practice to correct gait deviations, why don't they?

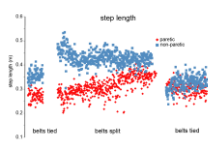




MOTOR LEARNING

Error Augmentation

What is an error to the damaged nervous system?



May need to augment or "draw attention" to the error to get system to correct

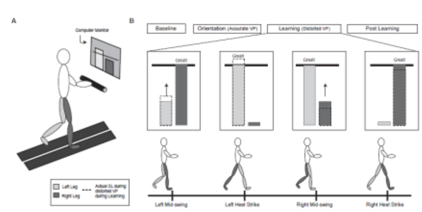
MOTOR LEARNING

- **We don't often use error augmentation in rehab.** ***More on this later….***

- **In rehab we often use reward based or strategic forms of learning**
  - *Thought to require more cognitive processing*
  - *Often called skill-based learning*
  - *Instead of responding to a perturbation, person responds to verbal or visual feedback/information to develop strategies to accomplish the task*

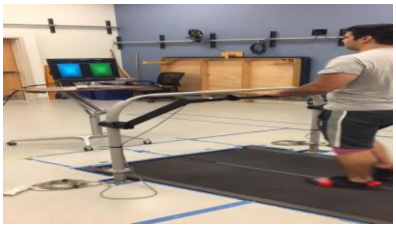
MOTOR LEARNING

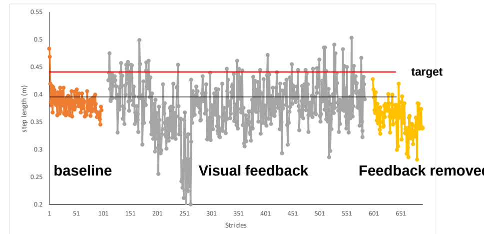
Visual feedback paradigm



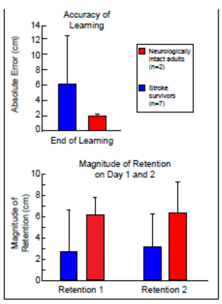
MOTOR LEARNING

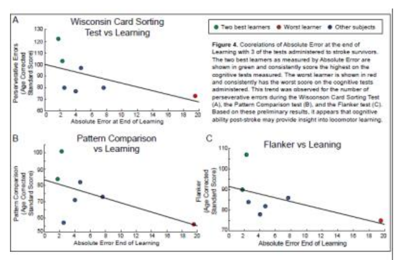
Visual feedback paradigm





MOTOR LEARNING





MOTOR LEARNING

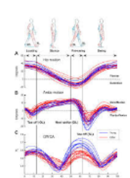
- Years of motor learning research in neurologically intact subjects suggests that learning of different tasks via variable practice enhances learning (contextual interference effect; *e.g.-Shea &Morgan, 1979; Schmidt and Bjork, 1992; Brady, 1998)*
- Although recent work suggests that the advantage of variable practice may depend on the skill of learner and on the complexity of the task to be learned *(Brady, 2008; Jones & French, 2007)*
- Contextual interference refers to variability of practice of tasks or skills. In rehabilitation it is important to consider not only variability of practice at this level, but also the variability of movement during practice of a given task or skill.

MOTOR LEARNING

Variability

At the task level

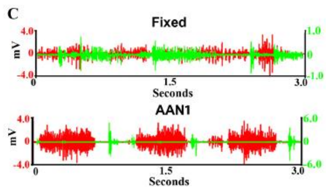
At the movement level



UNIVERSITY OF DELAWARE — MOTOR LEARNING

- Natural properties of neural networks may be disrupted when variability is not allowed *(Cai et al, 2006; Ziegler et al, 2010)*

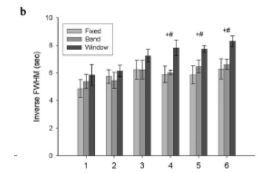
Red=soleus
Green=TA



Ziegler et al, 2010

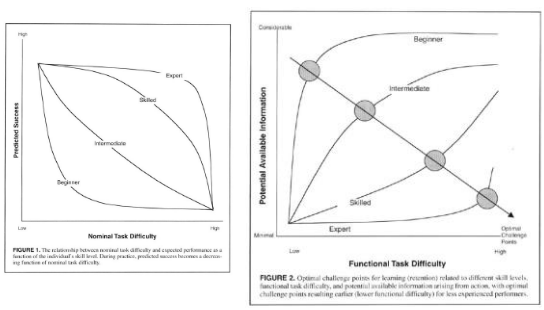
UNIVERSITY OF DELAWARE — MOTOR LEARNING

- Greater stepping variability during training lead to greater step rhythmicity following 6 weeks of robotic training in mice with spinal cord transection *(Cai et al, 2006)*



UNIVERSITY OF DELAWARE — MOTOR LEARNING

Challenge point hypothesis (Guadagnoli and Lee, 2004)



UNIVERSITY OF DELAWARE

Evidence Based Treatment for Locomotor Recovery after Stroke

UNIVERSITY OF DELAWARE — TREATMENT

Treatment follows directly from all the basic principles we have been discussing in previous sections

Get creative!

UNIVERSITY OF DELAWARE — TREATMENT

Practical Considerations

- **Monitor, Measure and Document**
  - **Include in EMR**
  - **Chart review related to documentation of intensity and repetition**
- Calculate target HR for everyone
- Obtain necessary medical history and clearances for safety (e.g.-contact cardiologist for patients with significant cardiac history)
- Use signs or symptoms to determine when rest break is needed (e.g.-HR, RPE, shortness of breath)

TREATMENT

What treatments can be applied related to intensity?

Key is to get heart rate up to 70-80% heart rate reserve (HRR).
Can calculate with Karvonen formula:

target training HR = resting HR + (% target [maximum HR -resting HR])

What to use for max HR…220-age?? Other options

TREATMENT

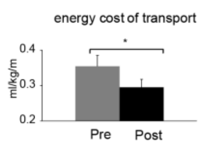
- Use heart rate monitor to measure intensity during PT
- Educate clients re: target heart rate zone for intensity and encourage them to measure HR during exercise

TREATMENT

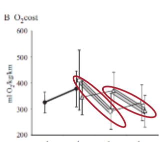
How do I train at a high intensity?

Easiest manipulation is speed….have patients train at as fast a possible walking speeds.

- **Cost of transport ↓ with training at fastest possible speed**



(Reisman et al,2011)

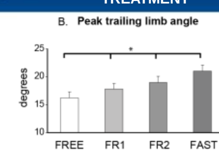


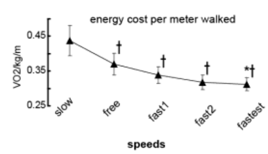
(Moore et al,2010)

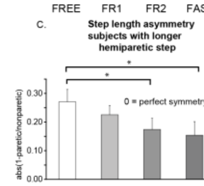
TREATMENT

Tested chronic stroke survivors at 4 speeds:
FREE
FAST1
FAST2
FASTEST

- **Trailing limb angle**
- **Step length asymmetry**





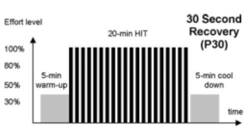


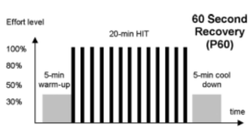
Tyrell CM, Roos MA, Rudolph KS, Reisman DS. Influence of systematic increases in treadmill walking speed on gait kinematics after stroke. Physical therapy. 2011; 91(3):392-403.

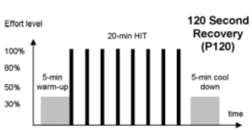
Reisman DS, Rudolph KS, Farquhar WB. Influence of speed on walking economy poststroke. Neurorehabilitation and neural repair. 2009; 23(6):529-34.

TREATMENT

- **High intensity interval training may be important**



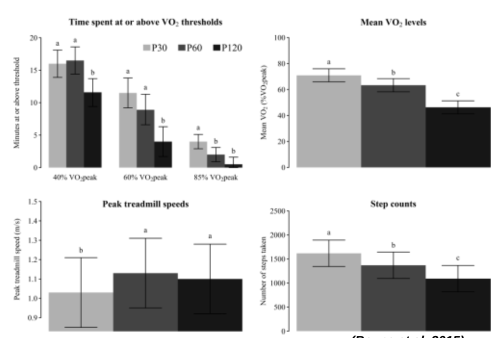




	P30	P60	P120
Burst duration	30 sec	30 sec	30 sec
Burst treadmill speed	Max tolerated	Max tolerated	Max tolerated
Recovery duration	30 sec	1 min	2 min
Burst:recovery ratio	1:1	1:2	1:4
No. bursts in 20 min	20	13	8
Total burst time	10 min	6.5 min	4 min

(Boyne et al, 2015)

TREATMENT



(Boyne et al, 2015)

TREATMENT

No serious adverse events with HIT training and preliminary studies show greater improvements with HIT than MAT

Table 1. 4-Week Outcomes in Pilot RCT of Treadmill HIT and MAT		*data presented as mean [95% CI]*	
Clinical Measure	HIT Group Change (n=11)	MAT Group Change (n=5)	HIT – MAT Change (n=16)
Aerobic capacity (ventilatory threshold), $mLO_2/kg/min$	+4.4 [3.1, 5.7] (+43%)	+0.6 [-1.3, 2.5] (+4%)	+3.8 [1.5, 6.1]
Fastest treadmill walking speed, m/s	+0.36 [0.25, 0.47] (+41%)	+0.07 [-0.10, 0.24] (+7%)	+0.29 [0.09, 0.49]
Fastest (floor) walking speed (10m walk test), m/s	+0.10 [0.06, 0.13] (+13%)	+0.01 [-0.04, 0.06] (+1%)	+0.08 [0.02, 0.14]
Comfortable walking speed (10m walk test), m/s	+0.10 [0.06, 0.14] (+16%)	+0.02 [-0.03, 0.08] (+3%)	+0.08 [0.01, 0.14]
Metabolic cost of walking, $mLO_2/kg/m$ (*lower is better*)	-0.10 [-0.17, -0.03] (-25%)	-0.01 [-0.10, 0.09] (-4%)	-0.09 [-0.21, 0.03]
Method: Subjects with chronic stroke were randomized 2:1 to treadmill HIT or MAT (25 min, 3x/wk, 4 weeks). A blinded rater assessed outcomes.			

TREATMENT

New study:

Moderate-Intensity Exercise Versus High-Intensity Interval Training to Recover Walking Post-Stroke: ***HIT-Stroke Trial***

Lead site: University of Cincinnati, Pierce Boyne, PT, PhD
Other sites: University of Delaware, Darcy Reisman, PT, PhD; University of Kansas, Sandy Billinger, PT, PhD

TREATMENT

How else can I increase intensity?

- Treadmill incline
- Weighted vest
- Resistance while walking (e.g.-Tband around waist/chest and pull back)
- Walking and carrying (e.g.- laundry basket with weights, medicine ball etc)

TREATMENT

TREATMENT

12 lb weighted vest and 15 lb weighted basket

12 lb weighted vest and 6 lb weighted ball

12 lb weighted vest, 5 lb ankle weights and 6 lb weighted ball

TREATMENT

TREATMENT

What can we do to get enough repetition during treatment?

- Is it feasible to do more, particularly during inpatient rehabilitation?

Training characteristics	
Length of stay (days)	28 (21-35; 201)
PT sessions per day	1.1 (0.94-1.3; 201)
PT min/session (min)	54 (52-56; 201)
Peak HR/session (percentage maximum)	70 (62-76; 161)
Peak RPE/session	16 (15-17; 160)
Mean percentage session RPE >13	38 (31-44; 157)
Daily stepping (steps/d)	1516 (594-2645; 201)

Hornby et al, Feasibility of Focused Stepping Practice During Inpatient Rehabilitation Poststroke and Potential Contributions to Mobility Outcomes, Neurorehab Neural Repair 2015, Vol. 29(10) 923–932 2015

TREATMENT

Repetition during treatment

- Use Fitbit to monitor steps taken in PT to determine repetition
- Provide Fitbits to clients to monitor repetition in real-world

TREATMENT

- **Preparation is key**
- Identify <u>all</u> aspects of the desired activity

TREATMENT

•Need variety of objects, readily available or set-up by an aide so transitions can happen quickly

TREATMENT

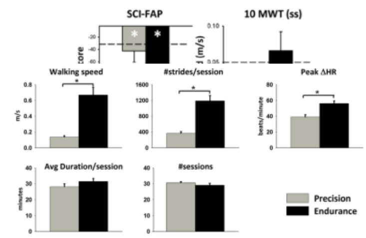
Interaction of intensity, specificity and repetition?

Yang et al, 2014

- Trained 20 persons with chronic spinal cord injury on obstacle walking (Precision group) vs. BWSTT for speed and endurance (Endurance group)
- Trained 1 hour/day 5 days/week for 8 weeks on one intervention, then no intervention for 2 months, then participated in the other intervention
- Primary outcome: SCI-FAP - (*7 tasks: (1) Carpet, (2) Up & Go, (3) Obstacles, (4) Stairs, (5) Carry, (6)Step, and (7) Door).*

Hypothesis was that task-specific over ground obstacle course training would result in greater improvements.

TREATMENT



High specificity, but low intensity and limited repetition = less improvement

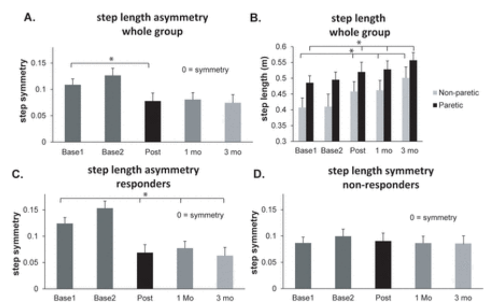
Yang, Musselman et al, Repetitive Mass Practice or Focused Precise Practice for Retraining Walking After Incomplete Spinal Cord Injury? A Pilot Randomized Clinical Trial, NNR; 2014 May;28(4):314-24.

TREATMENT - Learning

Error Augmentation

TREATMENT - Learning

Error Augmentation



(Reisman et al. 2013)

TREATMENT - Learning

Considerations for practice with variability/error :

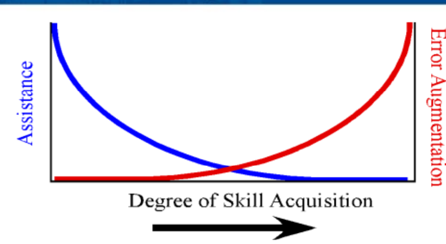
1) **Safety**
2) **Task accomplishment**

   What is task completion for <u>walking</u>? Continuous reciprocal stepping, positive step lengths, plantar surface contact, limb support during loading

   For <u>reaching</u>? Make contact with object on at least 2/3 of trials? complete at least ½ of trials for the complete task?

3) **Error size and number of errors**
   - **errors that are too large may limit learning (Sanger, 2004; Guadagnoli and Lee, 2004)**
   - **too many errors may limit learning (Domingo & Ferris, 2010; Guadagnoli and Lee, 2004)**
4) **Sufficient repetition**

TREATMENT - Learning



Guidance → Assist-as-needed → Unassisted → Error augmentation

Trial and Error Practice

Based on ideas from
Guadagnoli and Lee, 2004; Winstein et al, 1994

TREATMENT - Learning

Variable Intensive Early Walking Poststroke (VIEWS): A Randomized Controlled Trial

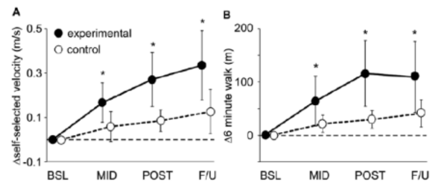
(Hornby et al, 2016)

- Sub-acute stroke (1-6 months post)
- Control group=conventional PT (n=17)
- Experimental group=variable, intense stepping practice (n=15)
  - High intensity forward treadmill walking (10min)
  - **Skill-dependent walking (10min)-** walking in multiple directions, over inclines and obstacles, and/or with weighted vests and leg weights with limited handrail use as tolerated. Perturbations were applied such that 2 to 5 different tasks were randomly alternated and repeated within 10-minutes
  - Overground walking (10 min)-focused on high speeds or variable tasks as above
  - Stair climbing (10 min)

TREATMENT - Learning

VIEWS *(Hornby et al, 2016)*

- Goal was 40 training sessions of 1 hour each over 10 weeks (4-5 sessions/wk).
- Greater improvements in walking speed and 6MWT distance in experimental group



TREATMENT - Learning

Varied Overground Walking Training Versus Body-Weight Supported Treadmill Training in Adults Within 1 Year of Stroke: A Randomized Controlled Trial *(DePaul et al, 2015)*

- Stroke <1 year
- Control group=BWSTT (n=34)
- Experimental group=variable, overground walking training (n=30)
  - 7 core walking activities at every session: (1) short walks; (2) longer distance (≥50 m); (3) steps, curbs, and slopes; (4) obstacle avoidance; (5) transitions (eg, sit to stand and walk); (6) changes in centre of gravity (eg, pick up an object off floor); and (7) changes in direction.
  - Each activity practiced for equal amount of time per session, challenge level adjusted when subject could perform task without assistance

TREATMENT - Learning

DePaul et al, 2015

- 15- 1 hour sessions over 5 weeks.
- Primary outcome was self-selected gait speed, also tested 6MWT, ABC, Functional Balance Test and Stroke Impact Scale
- NO differences between groups on any outcome measure

Differences compared to VIEWS:

- Less than ½ number of treatment sessions – variable practice effects may require more training
- No control over intensity in variable, over ground group, BWSTT group trained at above 0.89 m/s as soon as possible

TREATMENT – Activity

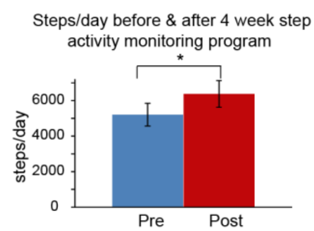
As we discussed….

- Stroke survivors have low levels of real world walking activity
- Some of this can explained by physical factors (capacity), but biopsychosocial factors also play major role
- So how do we treat to address both capacity and other factors?

TREATMENT – Activity

Step Activity Monitoring Program

- Measuring activity and providing feedback
- Setting goals
- Identifying barriers and facilitators (motivational interviewing techniques)



Danks KA, Roos MA, McCoy D, Reisman DS. A step activity monitoring program improves real world walking activity post stroke. Disability and rehabilitation. 2014; 36(26):2233-6.

TREATMENT – Activity

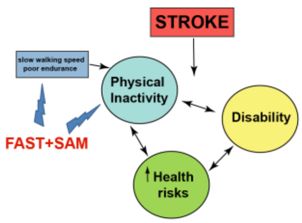
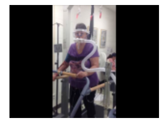


Figure 1. Model illustrating the proposed relationships between physical inactivity, disability, and health after stroke. The FAST+SAM intervention is designed to improve physical inactivity both directly ***and*** through improvements in slow walking speed and poor endurance.

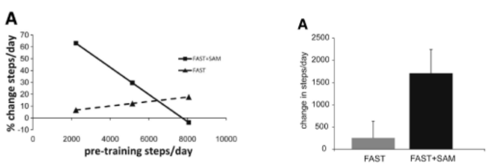
TREATMENT – Activity

Combining Fast walking training with step activity monitoring program

- 2 groups – FAST and FAST+SAM
- 3x/week for 12 weeks
- Hypothesized that those with low levels of activity at baseline would benefit the most



TREATMENT – Activity



Danks KA, Pohlig R, Reisman DS. Combining Fast-Walking Training and a Step Activity Monitoring Program to Improve Daily Walking Activity After Stroke: A Preliminary Study. Archives of physical medicine and rehabilitation. 2016; 97(9 Suppl):S185-93.

TREATMENT – Activity

PROWALKS

- Promoting Recovery Optimization with WALKing Exercise after Stroke **(PROWALKS)**
- 1 R01 HD086362-01A1
- Began September, 2016

ClinicalTrials.gov #NCT02835313

FAST=Fast walking training
SAM=Step activity monitoring program

<u>3 groups:</u>
FAST+SAM
FAST
SAM

<u>Outcomes:</u>
Primary= steps/day
Secondary= 6MWT, walking speed, energy cost
Exploratory= MACCE (secondary prevention)

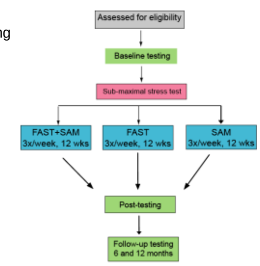


Figure 2. General training study design.

TREATMENT – Activity

<u>Key characteristics of SAM</u>:

- Goal setting should occur by asking the participant how many additional steps they feel they can achieve each day; beyond what they are currently doing. SUBJECTS SHOULD ARRIVE AT THEIR OWN GOAL
- Evaluation of daily activity will occur at each training session and goal setting will occur at every 6-8th visit
- In order to advance the goal, subjects need to attain 3 days of goal achievement over ~10-14 days.

TREATMENT – Activity

<u>At each session:</u>

- Patients should be told the number of steps they have taken and a discussion should occur about goal achievement.
- Patients will use this information to help them understand how much walking activity they performed during certain daily activities, like walking to the mailbox or walking laps around their home, and how that added to their total steps per day.
- The PT's role in this discussion is as a ***facilitator***
- Utilize techniques from Motivational Interviewing:
  - The goal of MI is to strengthen the importance of change <u>from the patient's perspective</u> *(Burke, Arkowitz, & Menchola, 2003)*

Four basic principles to enhance motivation from MI *(Miller & Rollnick, 2002):*

(a) expression of empathy,
(b) development of discrepancy,
(c) rolling with resistance, and
(d) the support of self-efficacy

Examples:

- "From what you have been sharing with me, I know you feel as though it will be difficult to walk more, but what ARE ways in which you think you can improve your daily walking activity?"
- "I understand that you feel as though it's much harder to physically walk since you've had a stroke. We are working to build your endurance week by week and goal by goal with the aim being that you walk more by the end of the monitoring program."
- "You did a nice job meeting your current goal, how will you tackle meeting the advanced goal for next week? I know in bad weather you choose to walk at the mall. If it rains this week like projected, will you do more laps in the mall as opposed to the track, like you have been doing?"

Clinical Practice Guidelines for Improving Locomotor Function Following Acute-onset Neurological Injury

T. George Hornby, PT, PhD
Professor, Locomotor Recovery Lab
Dept PMR and Physical Therapy
Indiana University School of Medicine

Darcy Reisman, PT, PhD
Professor, Associate Chair
Dept of Physical Therapy
University of Delaware

Irene Ward, PT, NCS
Brain Injury Clinical Research Coordinator
Kessler Institute of Rehabilitation,
West Orange, NJ

Patty Scheets, PT, DPT, NCS, MHS
Director of Quality and Clinical Outcomes
Infinity Rehab,
Portland, OR

Allison Miller, PT, DPT, NCS
Inpatient Rehabilitation
Kessler Institute of Rehabilitation,
West Orange, NJ

Introduction

- Multiple varied interventions utilized to treat patients with neurological injury with multiple physical impairments (Lang 2007, 2009, Kimberly-Jones 2011, Moore 2010, Zbogar 2016)

Research to provide answers?

- Hundreds of studies have evaluated the efficacy of specific interventions to improve function
  - Many demonstrate positive results
  - Available meta-analyses suggest positive outcomes for many interventions
- Clinical Practice Guidelines may provide a mechanism to delineate specific recommendations to guide clinical practice

APTA Clinical Practice Guidelines

- Strategic objective: CPGs enable PTs and PTAs to understand the state of evidence in an effort to:
  - Decrease unwarranted variations in practice
  - Minimize the knowledge translation gap
  - Optimize movement
- Reframing the CPG question
  - Typical focus: What interventions facilitate improvements in function in patients with neurological injury?
  - Current focus: What interventions optimize performance of a specific function?

CPG for Locomotor Outcomes

- Application for Locomotor Clinical Practice Guidelines to APTA
  - Goal: provide **concise recommendations** supported by **systematic literature review** of the efficacy of **specific interventions to improve locomotor function** in persons **> 6 months following stroke, traumatic brain injury (TBI) or incomplete spinal cord injury (SCI)**
  - Timeline:
    - CPG workshop at APTA (Alexandria, VA) – July 2014
    - CPG application submission - March 2015
    - CPG application acceptance – July 2015
    - Anticipated end date – June 2018

Selected patient populations – SCI, TBI, CVA

- Acute-onset episode resulting in partial damage to supraspinal or spinal pathways influencing motor function
- Rationale for combining diagnoses
  - Common pathways and mechanisms underlying motor performance, adaptation and learning *(Dobkin 2008, Holleran 2018)*
    - Improved performance/learning may rely on plasticity in spared neural networks vs discrete mechanisms within separate diagnoses
    - Similar mechanisms underlying muscular and cardiopulmonary plasiticity

Selected patient populations – chronic stages post injury

- Attempts to minimize contributions of spontaneous neurological resolution
- Minimize variability in recovery patterns

Consideration of Evidence: study selection

- Decision to accept only randomized clinical trials
  - Many interventions show a positive effect on function (Duncan 1998, 2003, 2011)
  - Non-randomized trials provide little indication of optimal intervention
- Evaluation of the treatment groups?
  - What were the experimental and control interventions?
  - Unequal duration therapies
    - No intervention or intervention unlikely to improve locomotion
    - Additional therapy (X intervention + PT vs PT only)

Consideration of Evidence: intervention categories/search terms

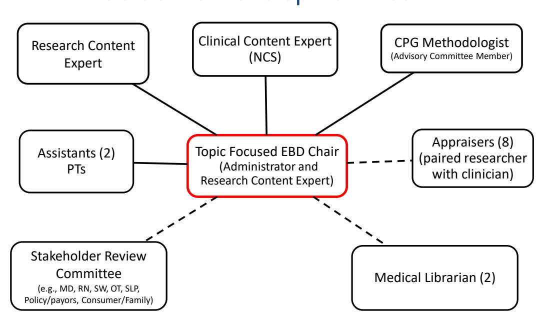
- Evaluation of the types of activities performed during therapies *(Lang 2007, 2009, Kimberly-Jones 2011, Moore 2010, Hornby 2016, Zbogar 2016)*
- Survey results:

1. Over-ground walking (91%)
2. Balance (64%)
3. Treadmill (40%)
4. Strengthening (27%)
5. Neurofacilitation (26%)
6. Functional electrical stimulation (18%)
7. Aerobic training (13%)
8. Robotic-assisted walking (8%)
9. Circuit training (4%)
10. Tai-Chi (1%)
11. Aquatic (0%)
12. Vibration platform (0%)

Methodology

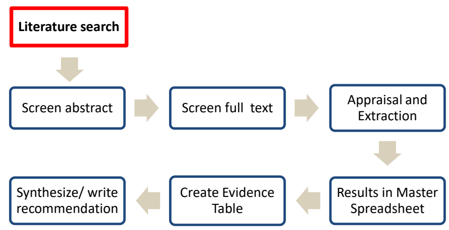
- CPG development follows a formal process and a rigorous methodology
  - Ensure completeness
  - Meet a standard criteria (AGREE II)
  - Transparency
- ANPT Evidence-based Document Manual
  - Released 2015
  - Updated based on APTA recommendations 2018

Guideline Development Team



CPG update

Summary of Methodology



CPG update

First Literature Search

- Ensure CPG on this topic does not currently exist
- Refine scope of CPG
  - Identify PICO questions (Patient, Intervention, Comparison/Control, Outcomes)
  - Development of key conceptual and operational definitions
- Ensure sufficient information exists on this topic

CPG update

Second (formal) Literature Search

- Database (Pubmed, CINAHL, Embase, CENTRAL)
  - RCTs from 1995- 2016
  - 4778 articles after de-duplication
  - using intervention search term: locomotor/exercise/treadmill/overground = 2483
- Systematic Reviews and Meta-analysis – screening for additional appropriate articles

CPG update

Development of Appraisal Process

- APTA Critical Appraisal Tool for Experimental Interventions (CAT-EI v. 2016)
  - Part A: contextual information
  - Part B
    - Items 1-12: overall quality of the study
    - Items 13-20: individual outcomes of the study
  - Part C: impact of the study
- Piloted appraisal on 9 strength articles
  - Identified items for extraction
  - Developed database
  - Developed manual for appraisers

Score on B section indicates Level of Evidence

CPG update

Appraiser Training

- 8 appraisers successfully completed training
- Training:
  - Review criterion manual for article evaluation
  - View CAT-EI training module
  - Appraise 1 sample article with answer key
  - 2 test articles
    - "Easier" vs "harder" article
    - 90% cut-off score
- Appraisers paired based on primary role
  - Researcher-clinician paired
  - If not consensus, provide both scores (~1 pt difference in B score)

CPG update

Grading Levels of Evidence

I. Evidence obtained from high-quality diagnostic studies, prognostic or prospective studies, cohort studies or **randomized controlled trials**, meta analyses or systematic reviews (**critical appraisal score ≥50% of criteria, B score ≥ 10**).

II. Evidence obtained from lesser-quality diagnostic studies, prognostic or prospective studies, cohort studies or **randomized controlled trials**, meta analyses or systematic reviews (eg, weaker diagnostic criteria and reference standards, improper randomization, no blinding, <80% follow-up) (critical appraisal score **<50% of criteria, B score < 10**).

~~III. Case-controlled studies or retrospective studies~~

~~IV. Case studies and case series~~

~~V. Expert opinion~~

CPG update

Evidence Table

- Evidence for a specific intervention
  - Article, level/score, diagnoses (CVA, SCI, TBI)
  - Outcomes (10 m, 6 min) –
    - **"-"** not tested
    - **"0"** – not significantly different between groups
    - **"+"** – significantly different between groups
  - Intervention (Experimental v Comparison)
    - no or matched vs. unmatched intervention
    - FITT parameters
  - Other findings – additional significant outcomes

CPG update

Example Evidence Table (strength)

Strengthening exercises									
	Article	Level	Score	Dx	6 MWT	10 MWT	Intervention	Control	Other Findings
Strengthening vs no exercise	Flansbjer 2008	1	13	CVA	0	0	2X 6 to max reps 80% 1RM, 2X/wk, 10 wks	no intervention	strength, TUG
Strengthening vs other exercise									
Etc.									

CPG update

Strength of Recommendation

Grade	Level of Obligation	Definition
A	Strong	-moderate to high level of certainty of moderate to substantial benefit, harm, risk or cost (most Level 1 or 2)
B	Moderate	-moderate to high level of certainty of slight to moderate benefit, harm, risk or cost (based on most Level 2)
C	Weak	-weak level of certainty for moderate to substantial benefit, harm, risk or cost (Level 2-5)
R	Research	-an absence of research on the topic or disagreement among conclusions from higher-quality studies on the topic

CPG update

Benefit-Harm Assessment

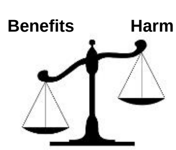
•Improves walking function (greater efficacy)

• Cost of equipment or additional personnel
• Time/travel
•Alternative intervention available
•Increased physiological monitoring

CPG update

Use of "should" recommendation

- Strength of Recommendation: **A** (Strong) or **B** (Moderate)
  - moderate to high level of certainty of benefit
- Intervention ***should be performed***
  - Mostly better than conventional or alternative therapy
  - >66% studies show benefit



CPG update

Use of "may" recommendation

- Strength of Recommendation: **C** (Weak)
  - weak level of certainty of benefit
- Intervention ***may be considered***
  - Sometimes better than conventional therapy (33-66% studies show benefit)
  - Mostly better than no intervention (>66% show benefit)

CPG update

Use of "should not" recommendation

- Strength of Recommendation: **A** (Strong) or **B** (Moderate)
  - moderate to high level of certainty of harm, risk or cost
- Intervention ***"should not" be performed***
  - Mostly not better than conventional therapy or alternative strategy (< 33% show benefit)

Benefits **Harm**

CPG update

Examples of evidence from 2 categories of intervention

CPG update

Walking- Aerobic

- 12 Level I articles
  - High intensity vs low intensity (5 articles)
    - high intensity: HIIT or 70-85% HRR/VO_2 peak
    - Low intensity: 40-50% HRR
  - High intensity vs passive/no intervention (5 articles) –
    - 60-80/85% HRR or age predicted HR_{max}
    - stretching, passive exercise, some balance, massage
  - Fast vs slow walking (2 articles) – fast as safely possible vs self-selected speed

CPG update

	Article	Level	Score	Dx	6 MWT	10 MWT	Intervention	Comparison
Hi intensity vs stretching/ massage/passive exercise	Globas, 2012	1	15	CVA	+	+	TM, 60-80% HRR, 3x/week, 3mo	Passive stretch, balance
	Gordon, 2013	1	14	CVA	+	__	OG walking, 60-85% HRmax, 3x/wk, 12 ks	Light massage
	Luft, 2008	1	13	CVA	+	O	TM, 40 min, 60-80% HRR, 3x/week, 6mo	Passive stretch
	Moore, 2010	1	13	CVA	O	O	TM, 80-85%HRmax, 20x/wk, 4 wks	no intervention
	Macko, 2005	1	13/12	CVA	+	O	TM, 60-80 HRR, 40 min, 3x/week, 6mo	Low intensity, 30-40% HRR, stretch
Higher vs lower intensity walking training	Boyne, 2016	1	18	CVA	O	+	TM, HIIT(30 s max, <60 s rec) 3x/wk, 4 wks	TM, 45% HRR, 3x/week, 4 weeks
	Ivey, 2015	1	11	CVA	O	O	TM, 30 min, 80-85% HRR, 3x/week, 6mo	TM, 30 min, <50% HRR, 3x/week, 6mo
	Munari, 2016	1	16	CVA	+	+	TM, HIIT 1 min ints; 85% Vo2pk, 3 min 50% Vo2pk), 3x /wk, 3mo	TM, 50-60 min, 40-60% VO2 peak, , 3x /week, 3mo
	Holleran, 2015	1	12	CVA	+	O	TM&OG, 30min, 70-80% HRR, 3x/week, 4 weeks	TM&OG, 30min, 30-40% HRR, 3x/week, 4 weeks
	Yang, 2014	1	12	SCI	+	O	TM, 60min, 5x/week, 2mo, faster than SSV	precision training OG 5x/week, 2mo
Fast vs slow speed	Awad, 2016	1	13/14	CVA	O	O	TM&OG, Fastest speed 40min, 3x/week, 12 weeks,	TM&OG, SSV40mi, n, 3x/week, 12 weeks
	Sullivan, 2002	1	11	CVA	-	O	TM, 2.0mph, 20 min, 12 sessions over 4-5 weeks	TM, 0.5mph, 20 min, 12 sessions over 4-5 weeks

CPG update

Summary: Walking- Aerobic

Aggregate Evidence Quality:

- **High intensity walking vs passive exercise/stretching – 4/5 showed greater benefit**
- **High intensity walking vs low intensity walking- 4/5 showed greater benefit**
- **Fast walking vs slow walking (no measure of intensity) -2/2 showed no differences**

Action Statement: Clinicians *should use* moderate to high intensity walking training interventions for improving locomotor function in patients with chronic CNS injury *(Level 1, Grade A).*

Risks, harm, costs: Potentially increased risk of cardiovascular events during higher intensity training walking training without appropriate cardiovascular monitoring

CPG update

Walking- Body weight supported treadmill training (BWSTT)

- 9 articles met criteria (6 level I, 3 level II)
  - BWSTT vs over ground walking (3 Level I, 3 Level II)
  - BWSTT + conventional PT vs conventional PT (1 Level I)
  - BWSTT vs conventional PT (1 Level I)
  - BWSTT vs no intervention (1 Level I)
- FITT categories
  - Type – all BWS with PT assist as needed vs overground or other
  - Frequency/time – indication of duration/frequency
  - Intensity – HR parameters rarely described, detail of amount of BWS and PT assist

UNIVERSITY OF DELAWARE

CPG update

	Article	Level	Score	Dx	6 MWT	10 MWT	Intervention	Comparison
BWSTT vs overground	Alexeeva, 2011	1	12	SCI	-	0	TM, 30%BWS, 3x/week, 60 min, 13 weeks, SSV	2 CTRL groups – conventional PT & OG BWS training, 3x/week, 60 min, 13 weeks, 30%BWS, SSV
	Brown, 2005	2	7	TBI	0	0	TM, 30% BWS, 2x/wk, 14 wks +30 min exercise, 1-3 PT asst kinematics	OG, 2x/wk, 14 wks +30 min exercise
	Combs-Miller, 2014	1	15	CVA	0	+	TM, 30% BWS, 5x/wk, 2 wks, PT asst kinematics	OG walking, 5x/wk, 2 wks, walk fast, not to exceed mod intensity
	Suputtitada, 2004	2	7	CVA	-	0	TM, 30% BWS decr, 5x/wk, 4 wks, 0.44 m/s, increased as tolerated, 2 PT assist	OG walking, 15 min, 5x/week, 4 weeks
	Middleton, 2014	1	11	CVA	0	0	TM, <50% BWS , 10days, PT asst kinematics + 2 hours balance, strength, ROM, coordination	OG walking, , 60 min, 10days, + 2 hours balance, strength, ROM, coordination exercises
	Lucarelli, 2011	2	7	SCI	-	∅	TM, 40% BWS decr, 2x/wk, 30 sess, SSV, 2 PT asst kinematics + passive stretch/joint mobs,	OG walking, 2x/week, 30 sessions, SSV, + passive stretching and joint mobs, session time = 30 min
BWSTT vs conventional PT	Yen, 2008	1	10	CVA	-	+	TM <40% BWS, 3x/wk, 4 wks, 1-2 PTs asst kinematics, + 2-5x/wk general PT	2-5x/wk general PT
	Ribeiro, 2013	1	10	CVA	-	0	TM, 30% BWS,3x/week, 4 weeks, 2 PTs asst kinematics, BWS decr < PT assist needed, SSV	PNF, 3x/week, 30 min, 4 weeks
BWSTT vs no control	Takao, 2015	1	11	CVA	-	+	TM, 20% BWS, 3x/week, 4 weeks, fastest p speed	no intervention

UNIVERSITY OF DELAWARE

CPG update

	Article	Level	Score	Dx	6 MWT	10 MWT	Intervention	Comparison
BWSTT vs overground	Alexeeva, 2011	1	12	SCI	-	0	TM, 30%BWS, 3x/week, 60 min, 13 weeks, SSV	2 CTRL groups – conventional PT & OG BWS training, 3x/week, 60 min, 13 weeks, 30%BWS, SSV
	Brown, 2005	2	7	TBI	0	0	TM, 30% BWS, 2x/wk, 14 wks +30 min exercise, 1-3 PT asst kinematics	OG, 2x/wk, 14 wks +30 min exercise
	Combs-Miller, 2014	1	15	CVA	0	+	TM, 30% BWS, 5x/wk, 2 wks, PT asst kinematics	OG walking, 5x/wk, 2 wks, walk fast, not to exceed mod intensity
	Suputtitada, 2004	2	7	CVA	-	0	TM, 30% BWS decr, 5x/wk, 4 wks, 0.44 m/s, increased as tolerated, 2 PT assist	OG walking, 15 min, 5x/week, 4 weeks
	Middleton, 2014	1	11	CVA	0	0	TM, <50% BWS , 10days, PT asst kinematics + 2 hours balance, strength, ROM, coordination	OG walking, , 60 min, 10days, + 2 hours balance, strength, ROM, coordination exercises
	Lucarelli, 2011	2	7	SCI	-	∅	TM, 40% BWS decr, 2x/wk, 30 sess, SSV, 2 PT asst kinematics + passive stretch/joint mobs,	OG walking, 2x/week, 30 sessions, SSV, + passive stretching and joint mobs, session time = 30 min
BWSTT vs conventional PT	Yen, 2008	1	10	CVA	-	+	TM <40% BWS, 3x/wk, 4 wks, 1-2 PTs asst kinematics, + 2-5x/wk general PT	2-5x/wk general PT
	Ribeiro, 2013	1	10	CVA	-	0	TM, 30% BWS,3x/week, 4 weeks, 2 PTs asst kinematics, BWS decr < PT assist needed, SSV	PNF, 3x/week, 30 min, 4 weeks
BWSTT vs no control	Takao, 2015	1	11	CVA	-	+	TM, 20% BWS, 3x/week, 4 weeks, fastest p speed	no intervention

UNIVERSITY OF DELAWARE

CPG update

	Article	Level	Score	Dx	6 MWT	10 MWT	Intervention	Comparison
BWSTT vs overground	Alexeeva, 2011	1	12	SCI	-	0	TM, 30%BWS, 3x/week, 60 min, 13 weeks, SSV	2 CTRL groups – conventional PT & OG BWS training, 3x/week, 60 min, 13 weeks, 30%BWS, SSV
	Brown, 2005	2	7	TBI	0	0	TM, 30% BWS, 2x/wk, 14 wks +30 min exercise, 1-3 PT asst kinematics	OG, 2x/wk, 14 wks +30 min exercise
	Combs-Miller, 2014	1	15	CVA	0	+	TM, 30% BWS, 5x/wk, 2 wks, PT asst kinematics	OG walking, 5x/wk, 2 wks, walk fast, not to exceed mod intensity
	Suputtitada, 2004	2	7	CVA	-	0	TM, 30% BWS decr, 5x/wk, 4 wks, 0.44 m/s, increased as tolerated, 2 PT assist	OG walking, 15 min, 5x/week, 4 weeks
	Middleton, 2014	1	11	CVA	0	0	TM, <50% BWS , 10days, PT asst kinematics + 2 hours balance, strength, ROM, coordination	OG walking, , 60 min, 10days, + 2 hours balance, strength, ROM, coordination exercises
	Lucarelli, 2011	2	7	SCI	-	∅	TM, 40% BWS decr, 2x/wk, 30 sess, SSV, 2 PT asst kinematics + passive stretch/joint mobs,	OG walking, 2x/week, 30 sessions, SSV, + passive stretching and joint mobs, session time = 30 min
BWSTT vs conventional PT	Yen, 2008	1	10	CVA	-	+	TM <40% BWS, 3x/wk, 4 wks, 1-2 PTs asst kinematics, + 2-5x/wk general PT	2-5x/wk general PT
	Ribeiro, 2013	1	10	CVA	-	0	TM, 30% BWS,3x/week, 4 weeks, 2 PTs asst kinematics, BWS decr < PT assist needed, SSV	PNF, 3x/week, 30 min, 4 weeks
BWSTT vs no control	Takao, 2015	1	11	CVA	-	+	TM, 20% BWS, 3x/week, 4 weeks, fastest p speed	no intervention

UNIVERSITY OF DELAWARE

CPG update

Summary: Walking- BWSTT

Aggregate Quality Evidence:

- BWSTT vs over ground walking - 6/6 no greater benefit of BWSTT and 1 showed over ground better
  - lower intensity of BWSTT?
  - BWS, PT assistance, limited speed with increased focus on kinematics
- BWSTT compared to PT or no intervention
  - 1 study showed benefit of *additional* BWSTT (BWSTT + PT vs PT alone)
  - 1 study found no greater benefit of BWSTT vs PT
  - 1 study found BWSTT better than no intervention

UNIVERSITY OF DELAWARE

Summary: Walking- BWSTT (con't)

Action Statement:

A. Clinicians *should not* perform body weight supported treadmill training in lieu of over ground training for improving locomotor function following chronic CNS injury *(Level 1, Grade A).*

B. Clinicians *may* use body weight supported treadmill training interventions as an adjunctive intervention for improving locomotor function following chronic CNS injury *(Level 1, Grade C).*

Risks, harm, costs: Body weight-support systems are expensive, assistance from multiple therapists costly and often not feasible.

UNIVERSITY OF DELAWARE

CPG update

Implementation

- ANPT Practice Committee
- Recruited and selected Implementation team:
  - Co-Chairs: Casey Holleran & Lisa Goodwin
  - Committee members: Meredith Banhos, Estelle Gallo, Allison Miller, Sue Peters, Meghan Bretx, Lauren Szot

Collaboration

LAB – Past and Present

Undergraduate fellows

- Stacey Cifelli
- Jen Breithupt
- Chris Wagner
- Jill McElligott
- Shreya Jammula
- Dana McCoy
- Lucas Brady
- Menki Chen
- Jen Byrnes
- Justin Pepper
- Ania Lipat
- Emmeline Oltmanns

LAB