Locomotor control and recovery following neurological injury

T. George Hornby, PT, PhD
Associate Professor, Dept of Physical Therapy
University of Illinois at Chicago
Research Scientist
Sensory Motor Performance Program
Rehabilitation Institute of Chicago

Outline

• Case studies – what do you see/what would you do?

• Normal and impaired gait in neurologic patients
  • Definitions and measures
  • Biomechanical principles
  • Kinematics and kinetics, muscular and metabolic requirements

• Strategy for clinical interventions

Case 1: History

• 52 year old male; L ICH (subcortical, ICH)
  • hypertension, dysphagia, aphasia, acute kidney failure
  • medications:: simvastatin, nifedipine, dilatin, digoxin, phenobarbital, clozapine, metoprolol

• Social hx:
  • Lived alone prior to stroke
  • Admitted to nursing home after medically stable post-stroke/minimal rehabilitation

• Started intensive rehabilitation (study) 4 months post-stroke

• Baseline assessments
  • FIM: Mod assist for all transfers and ambulation
  • 5 x sit to stand: unable
  • Berg Balance Scale Score: 5/56
  • self-selected gait speed: 0 m/s (unable to ambulate)
  • 6 minute walk distance: 0 feet (unable to ambulate)
Case 2: History

- 59 year old male (> 300 lbs); L thalamic/BG stroke; mass effect/midline shift
  - acute renal insufficiency/hydronephrosis, HTN, CHF, a-fib, asthma, LE venous stasis ulcers
  - Medications: Protonix, Tobradex, Norvasc, Vasotec, Keppra, Hydralazine

- Social hx:
  - Admitted to nursing home after medically stable post-stroke
  - Family unable to assist patient; lived with wife prior

- Assessments
  - FIM: Mod assist for all transfers and mobility items
  - Self – selected gait speed: 0 m/s (unable to ambulate)
  - Berg Balance Scale Score: 7/56
  - 6 minute walk distance: 0 feet (unable to ambulate)
  - 5 x sit to stand: unable

Basic definitions of walking

- Most natural means of moving from one location to another over a short distance

- Rhythmic alternating movements of the trunk & limbs which result in the forward progression of the center of gravity

- “Controlled falling”
  - Forward progression/stance stability requires energy from muscles, trunk lean to give passenger unit sufficient momentum
  - Conservation of energy
    - cyclic exchange between gravitational and kinetic energy
    - efficient redirection of “falling” into steady state forward progression

Passenger vs Locomotor Units

- Passenger unit – head ,neck, trunk, arms, pelvis
  - 70% BW, responsible for it’s own postural integrity
  - Aligned with forward tilt/provides momentum

- Locomotor Unit – legs, pelvis
  - 11 articulations, 57 muscles, bony “levers”
  - Alternating limb function:
    - Support/progress the passenger unit
    - With relief of BW, swings to new “position”

- Biomechanical subcomponents of gait (Kuo and Donelan 2010 PTJ)
  - Forward Progression
  - Stance Stability
  - Energy Conservation
Locomotor function – **forward progression**

- **Propulsion**
  - redirecting COM gravitational energy to kinetic energy
  - Inverted pendular motion
  - Shock absorption redirected to propulsion

- **Limb swing**
  - Progression of non-wt bearing limb – pendular motion
  - Preparation to accept weight

---

Locomotor function – **forward progression**

- **Propulsion**
  - redirecting COM gravitational energy to kinetic energy
  - Inverted pendular motion
  - Shock absorption redirected to propulsion

---

Locomotor function – **Stance Stability**

- **Stance Stability**
  - Maintain upright posture
    - reliance on passive (skeletal) vs active (muscular) structures to support weight
  - Reduce center of mass movement outside of lateral base of support
Passive walking devices

- [http://www.youtube.com/watch?v=e2Q2Lx8O6Cg&feature=related](http://www.youtube.com/watch?v=e2Q2Lx8O6Cg&feature=related)
- [http://www.youtube.com/watch?v=_2pAMe_5VeY&feature=related](http://www.youtube.com/watch?v=_2pAMe_5VeY&feature=related)

Locomotor function – Energy Conservation

- Inverted pendulum of stance, pendulum motion of swing
  - E.g., stance knee kinematics
    - Low costs with slight knee flexion during stance
    - Excessive knee flexion increases cost
  - E.g., swing knee kinematics
    - Knee flexion largely passive – interaction torques
    - Knee extension – knee flexors not extensors to decelerate shank

Energetics of Locomotion

- Redirecting COM (step-to-step transitions)
  - Stance: Energy costs of braking
    - Initial contact (eccentric)
    - Rebound (slight return of knee ext)
  - Propulsion:
    - Energy cost of redirecting “up”
    - Push-off from opposite limb
  - Swing:
    - Increase speed by increasing step frequency
    - High frequencies also increase costs

Energetics of Locomotion

- Walking speeds and spatiotemporal patterns at lowest metabolic costs
  - Increases in both step frequency and stride length to minimize costs
Energetics of Locomotion

- Stability
  - Relatively stable in A-P plane: small perturbations accounted for by altered collision and propulsive forces
  - Less stable in frontal plane: small perturbations = large disturbances
    - Active stability control
      - Position of torso – hip activity
      - Ankle inversion/eversion
      - Lateral foot placement (minimized by stabilizing pelvis during gait)

- Progression
  - Propulsion (42-48%)
  - Swing (10-20%)

- Stance Stability
  - Stance/body weight support (25-28%)
  - Lateral Stability (6%)

- Residual – work of lungs/heart

Spatiotemporal Descriptions

- Spatial: Stride vs step length; step width
- Temporal: Cadence: steps/min (inverse of step time)
- Gait velocity
  - Standardized measures: 10 m walk (speed); 2-12 min walk (distance)
  - Correlates with fall risk, fear of falls, quality of life, strength, balance, participation, community ambulation

Pelvis
- Limited movement
Hip
- Kinematics
  - Stance
    - Heel strike
    - Flexion at heel strike
  - Swing
    - Extends during midstance
      - 30° flexion
      - Peak flexion during swing (about 60°), shortens limb

- Muscle activity/power
  - Stance/loading
    - Hip ext
  - Swing
    - Initiation - not much (hip flex)
    - Termination - knee ext and flex

Knee
- Stance
  - Flexion at heel strike
  - Body moves over fixed foot to peak extension (10° prior to toe off)
  - Swing
    - Flexion begins during terminal stance
    - Peak flexion during swing (about 60°), shortens limb

- Muscle activity/power
  - Stance/loading
    - Hip flex
  - Swing
    - Initiation - hip flex
    - Termination - hip ext

- Stance/loading
  - Knee ext
  - Swing
    - Initiation - not much (knee flex)
    - Termination - knee ext and flex

Ankle
- Stance
  - Dorsiflexion during loading response
  - Plantarflex during midstance to toe-off
  - Swing - DF to neutral position
    - Dorsiflexes to neutral position during swing

- Muscle activity/power
  - Stance/loading
    - DFs initially, PF for pushoff
  - Swing
    - Initiation - DFs
    - Termination - DFs

Gait Kinetics
- Measured by force plate (stance)
- Estimated by joint accelerations (swing)
- Forces
  - Vertical
  - Anterior/posterior
  - Medial lateral

- Vertical
  - Anterior/posterior
  - Medial lateral
Kinematics and Kinetics

- Joint angles
  - Extension
  - Flexion

- Joint moments
  - Extension
  - Flexion

- Joint powers
  - Generation
  - Absorption

Energetics and total activity

- Muscular forces generated rapidly, off quickly (minimal co-activation)

- Transmission from potential-kinetic energy (inverted pendulum)

- Reliance on “interaction”, non-muscular torques
  - Knee flexion early-swing largely passive
  - Knee extension late-swing also passive (hamstrings “brakes”)
  - Reliance on passive tissues during stance

What happens following neurological injury?

- Decreased stability (stance, anterior-posterior or lateral COM over BOS)
  - Decreased gait speed/distance and balance
  - Increased risk for falls
  - Reliance on devices/braces

- Altered gait kinematics
  - Decreased sagittal motion
  - Increased frontal plane movements

- Decreased speed/gait velocity
  - Decreased power generation at more impaired muscles (ankle < hip)
  - Compensate with less impaired joints
What happens following neurological injury?

- Decreased efficiency/endurance
  - Biomechanical (inefficient potential to kinetic energy transfer or extraneous movements) – step-length asymmetry increased cost?
  - Muscular activity (co-activation, stiffening for posture/stability)?
  - Muscle metabolic properties (decreased oxidative capacity)
- Post-stroke
  - < 0.9 m/s; ~0.35 ml O2/kg/m; Moore et al 2010)
  - Stroke – 2500-4000 steps/day
- Post- incomplete SCI (Saraf et al 2010)
  - “community walkers” - ~0.37 ml O2/kg/m – 4000 steps/day
  - non-community walkers – ~1.0 ml O2/kg/m – 1000 steps/day
  - Intact subjects —0.20-0.25 ml O2/kg/m; 6000-8000 steps/day

Mulroy et al 2010 – STEPS trial

Changes with walking training

- Improved gait efficiency (Moore et al 2010, Awad et al 2015)

Changes in kinematics with walking training

- Sagittal kinematics scale with speed
  - Improved temporal symmetry, some spatial symmetry
  - ankle dorsiflexion/plantarflexion ROM (in higher functioning)
  - hip flexion/ext ROM – often compensatory for smaller ankle changes
- Increased knee flexion/ROM – combined interventions?
  - SCI (Field-Fote and Tepavac 2002 vs Noojien et al 2009)
  - Stroke (Daly et al 2004)
- Circumduction difficult as well (Lewek et al 2009)
Strategies for Interventions?

- Focus on gait function (speed/distance)?
  - Primary biomechanical determinants (stance, propulsion, swing, lateral stability)
  - Spatiotemporal patterns, selected hip/ankle sagittal kinematics/kinetics scale

- Focus on gait kinematics?
  - Knee flexion, circumduction, ankle dorsiflexion recalcitrant
  - Contributions to gait function, biomechanical subcomponents?
  - Effectiveness of strategies to normalize kinematics?

- Patient’s goals?

Outline

- Case studies – what do you see/what would you do?

- Normal and impaired gait in neurologic patients
  - Definitions and measures
  - Biomechanical principles
  - Kinematics and kinetics, muscular and metabolic requirements

- Strategy for clinical interventions
Evolution of Rehabilitation Strategies

Carey L. Holleran MPT, DHS, NCS
Clinical Practice Leader – Neurologic Physical Therapy
Sensory Motor Performance
Rehabilitation Institute of Chicago

Agenda
• Evolution of rehabilitation strategies
• Evidence behind strategies
• Walking recovery literature

Evolution of Rehabilitation Approaches

1900s
Sherrington

1960-1970s
PNF

1980-1990s
Task oriented training

1940-1970s
Neurodevelopmental Approaches

1990s
Neuroplasticity

Evolution of Rehabilitation Approaches

• Traditional approach commonalities
  – Efforts directed towards minimizing spasticity
  – Avoidance of exertion to prevent augmentation of spasticity
  – Abnormal movement must be minimized in order to retrain normal movement patterns
Evolution of Rehabilitation Strategies

- Task oriented or Motor relearning (Schumway-Cook & Wollacott, 2012)
  - Functional tasks relating to mobility
    - Gait training with BWS and TM
    - Progression of functional tasks
    - Strength, flexibility, balance, and cardiovascular endurance

  - Stability
  - Limited variability
  - Constrained environment

  ->

  - Mobility
  - Increased variability
  - Unconstrained environment

Evolution of Rehabilitation Approaches

- Neuroplasticity (Kleim & Jones, 2008)
  - Brain encodes experience and learns new behaviors
  - Damaged brain relearns lost behavior

- Nudo et al, 1996
  - Cortical stimulation pre and post training
  - UE task

Agenda

- Evolution of rehabilitation strategies
- Evidence behind strategies
- Walking recovery literature

Evidence - EBRSR

- Langhammer et al, 2000

Conclusion: The restorative (Bobath) approach results in longer lengths of stay and offers no advantage over other therapy approaches.
Evidence – systematic reviews

- Verbeek et al 2004
  - “strong evidence favoring intensive high repetitive task-oriented and task-specific training in all phases post-stroke”
  - “strong evidence for unfavorable effects of NDT on motor function (synergy), gait speed, spatiotemporal gait pattern functions…”

Evidence

- Focus on progression along development sequence or focus on impairments
  - Multicenter Post-stroke Rehabilitation Outcomes Project (PSROP) (Horn 2005)
    - 177 people in inpatient rehab with severe stroke and admission Locomotion/walk level 1
    - Gait training time in 1st block of therapy predicted progression to improvement to Locomotion FIM ≥4

Evidence

- Principles of Neuroplasticity (Kleim & Jones, 2008)
  1. Use it or lose it
  2. Use it and improve it
  3. Specificity matters
  4. Repetition matters
  5. Intensity matters
  6. Time matters
  7. Salience matters
  8. Age matters
  9. Transference
  10. Interference
Evidence

Evidence – Specificity

- Specificity – Type of practice
  - Non-stepping practice
    - Balance training improves balance (Au-Yeung, Hui-Chan et al 2009)
    - Strength training improves strength (Patten et al 2004; Jayaraman et al 2013; Damiano et al 1998;2010)
    - Smaller effects on walking
    - Preparatory activities (pre-gait) (Weinstein, 1989)

Evidence – Specificity and amount

- Lang et al, 2009
  - IP/OP post-stroke rehabilitation
  - Multiple activities aimed at body/structures and activity level

<table>
<thead>
<tr>
<th>Category</th>
<th>Repetitions (mean)</th>
</tr>
</thead>
<tbody>
<tr>
<td>UE Functional</td>
<td>32</td>
</tr>
<tr>
<td>LE Functional</td>
<td>6</td>
</tr>
<tr>
<td>Steps</td>
<td>357</td>
</tr>
<tr>
<td>Stairs</td>
<td>38</td>
</tr>
<tr>
<td>Transfers</td>
<td>11</td>
</tr>
<tr>
<td>Balance</td>
<td>27</td>
</tr>
</tbody>
</table>

Evidence

- Moore et al 2010
  - Tracked individuals in PT
  - Trained individuals in forward stepping on treadmill up to 85% of max HR for 4 weeks
**Evidence – Specificity and amount**

- UE Exercise (11%)
- Transfers (1%)
- Stretches (8%)
- Active LE Exercise (27%)
- Gait (34%)
- Balance (15%)

Moore et al, 2010

**Contributions of Amount of Practice**

- Repetition - Amount of stepping practice
  - Traditional treadmill training with BWS provides large amounts of stepping (Barbeau et al, 2003; Dean et al, 2010, Ada et al, 2010)
  - Dose appears to be related to responses (Moore, 2010; Holleran et al, 2014; Hornby et al, 2015a; Hornby et al, 2015b)
    - Dose: ~ 4000 steps
  - Faster is better (Pohl et al, 2002, Sullivan et al, 2002)

**Evidence – Repetition**

- Repetition - Amount of stepping practice
  - Traditional treadmill training with BWS provides large amounts of stepping (Barbeau et al, 2003; Dean et al, 2010, Ada et al, 2010)
  - Dose appears to be related to responses (Moore, 2010; Holleran et al, 2014; Hornby et al, 2015a; Hornby et al, 2015b)
    - Dose: ~ 4000 steps
  - Faster is better (Pohl et al, 2002, Sullivan et al, 2002)
Agenda

• Evolution of rehabilitation strategies
• Evidence behind strategies
• Walking recovery literature

Improving walking after injury

• Use residual descending, spinal and afferent circuits to facilitate reinforcement of synaptic connectivity of locomotor circuits
  – Walking training (gait training, locomotor training) has been shown to be superior to “non-walking” interventions (i.e. NDT, PNF – Hesse et al 1995, Wernig et al 1995, Pohl et al 2002)
  – How do you do this?!?!?!

Theories of how to provide walking training

• Guidelines for Locomotor Training
  – Derived and translated from findings in basic science on neurobiological control of walking
  – Sensory input associated with locomotion provided to the neural axis and circuitry generates stepping response (Behrman and Harkema 2000; Wernig et al 1995)

EMG mimicking “normal” locomotor activity

Patients can generate locomotor pattern similar to “normal”, but may not always recover volitional stepping overground and/or don’t walk normally.
Theory for providing walking training

Guidelines for Locomotor Training (Behrman/Harkema):

1. Maximize loading on LEs
2. Provide sensory input consistent with walking activity
3. Optimize posture and kinematics for each task.
4. Maximize independence and recovery of movements/ minimize compensation


Theory for providing walking training

1. Maximize loading on LE’s
   a) Dietz et al, 1995; Harkema et al, 1997
2. Provide sensory input consistent with walking activity
   a) DeLeon 1998, 1999
   b) How precise does the sensory input need to be?
3. Optimize posture and kinematics for each task.
   a) Kinematics and posture related to sensory, guiding them reduces intensity (Hornby et al, 2008; Israel et al, 2006)
4. Maximize independence and recovery of movements/ minimize compensation


Evidence - Walking

• No explicit focus on kinematics
  – Significant improvements in measures including
    • Gait speed
    • Balance
    • Timed distance
    • Peak treadmill speed
    • Peak metabolic capacity

• Explicit focus on kinematics and progress to adaptability
  – Significant improvements in measures including
    • Gait speed
    • Balance
    • Timed distance
    • Peak treadmill speed
    • Peak metabolic capacity

• Yagura et al, 2006
  – BWS vs BWS plus facilitation
  – Facilitation did not add significantly to locomotor outcomes
  – Required more therapists’ assistance
Evidence Summary

1. Motor learning approach superior to traditional approaches
2. Data indicates a stepwise progression in difficulty of tasks may not be superior to practicing higher order tasks
3. Repetition is important, but difficult to account for importance of intensity

Specificity vs amount

- Ada et al, 2010
  - Subacute stroke
  - Overground vs treadmill walking
  - Results: TM walking safe, feasible, and resulted in more people walking independently and earlier

- Amount *may* be more important earlier

Specificity vs amount

- Combs-Miller et al, 2014
  - Overground vs BWS treadmill
  - Chronic stroke (> 1 year) with the ability to walk
  - Results: OG significantly greater improvements than TM in comfortable walking velocity post-training and at follow-up

- Specificity *may* be more important later

Walking training
Incorporating Intensity into Walking Interventions
Patrick Hennessy, PT, MPT, NCS
Adapted from original lecture by T George Hornby, PT, PhD
Spinal Cord Injury Service
Locomotor Recovery Lab, Sensory Motor Performance Program
Rehabilitation Institute of Chicago

Presentation objectives
- Part I:
  - Provide frequently used definitions of intensity
  - Discuss the physiological rationale for high intensity practice
  - Display supportive data and training parameters for high-intensity training post-stroke
- Part II:
  - Concerns regarding high intensity practice post-stroke
  - Summary and re-emphasis on available data

What is the definition of intensity?
- Amount of time focused on each training procedure (Winstein et al 2003)
- Number of hours of consecutive therapy in a day (Page, 2003)
- Number of training sessions per week (Hesse, 2011)
- Frequency of repetitions of desired movement in a session (Tanaka, 2004)

“Biomechanical” definition
- Webster’s: Magnitude of a quantity (as force or energy) per unit of area, charge, mass, or time
- Exercise prescription - Power required to perform an activity (workload)
  - work per unit time
  - force x velocity
- Speed of action performed (if mass is same)
- Increase force (if speed is same)
As Defined in Exercise Prescription

- **Changing muscular demands during anaerobic or aerobic exercise**
  - Increasing load (weight) or same load moved faster
  - Changing power (speed, incline, resistance – bike/UBE)

**Expected Physiologic Response to Increased Exercise Intensity**

- Increases in VO\(_2\) driven by increases in cardiac output (CO) and \(O_2\) extraction from blood
  - Increase CO
    - driven by \(\uparrow\)HR and \(\uparrow\) Stroke Volume
    - \(\uparrow\) systolic BP
  - Increase \(O_2\) extraction
    - driven by \(\uparrow\) perfusion (vasodilation) and muscle metabolism
    - similar diastolic BP

- Increase ventilation
- Increase body heat/sweat production
Monitoring Intensity and Exercise Response

- Frequency
- Intensity
  - heart rate reserve (HRR)
  - heart rate max (HRmax)
  - rate of perceived exertion (RPE)
- Time
- Type (Specificity)

**Principles of Neuroplasticity:** (Kleim & Jones, 2008)
**FITT Principle** (Ayers and Sariscany, 2011)

Monitoring Intensity and Exercise Response

- Heart Rate Reserve
  - Training heart rate = [(HRmax – HRrest) * %training intensity] + Hrrest
- HRmax – significant inter-individual variability
  - 220-age
  - 208-(.7xage) (Tanaka et al 2001)
  - All prediction equations often reveal large inaccuracies in some patients (> 10 beats/min)
  - %HRmax does not consider resting HR
- Borg RPE - ratings of “exertion” vs “difficulty”

High intensity exercise protocols following neurological injury

- Task-specific aerobic treadmill training (Macko et al. 2005)
  - Experimental: 40 minutes on TM (60-70% HRR)
  - Control: 35 minutes stretching, 5 minutes on TM (30-40% HRR)

- Task-oriented training vs “therapeutic exercise” (Outermans et al. 2010)
  - E: Repeated walking-related “work stations” (70-80% HR reserve)
  - C: matched therapy time, lower workload, less repetitions

- Fast vs slow-walking or vs equivalent duration control

- **Separating practice/repetition from intensity**
  - Holleran et al. 2015 - intensity manipulated by adding resistance during treadmill walking at matched speed
  - Ivey et al. 2015 – low intensity group trained longer to match workload
  - Hornby et al. 2008 – Robotic vs therapist assisted walking

Repetition vs Intensity

- Robotic assisted stepping vs therapist assisted interventions (Hornby et al. 2008, Hidler et al. 2009)
  - Greater improvements in therapist-assisted training in gait speed and walking function
  - More or equivalent stepping practice during robotic-assisted training
  - **Why?**
Metabolic muscle activity during robotic vs therapist-assisted walking

Protocol I – “Just walk”:
- Large differences in metabolic costs of walking
- Reduced hip flexor muscle activity

Protocol II: “walk as hard as you can”
- Equivalent metabolic cost early, but a quick drop-off

“Principle of Laziness” – AD Kuo
(Israel et al 2006)

LEAPS TRIAL

- Early and Late LT vs Home-based PT programs
  - Similar frequency and duration of sessions
  - Experimental: LT including treadmill stepping with BWS
    - 20-30 minutes per session on treadmill, up to 3.2 km/hr (2 mi/hr)
    - 15 minutes overground after 4th week
    - LT groups progressed in duration, BWS, assistance
  - No differences in outcomes measures at 6 months
    - Ave max speed during LT = 3.2 kmph; minimum BWS was 11%
    - mean midpoint HR of each session
      - Locomotor training (early) = 90 beats/min
      - RPE < 13, HR < 110 beats/min (BMC Methods paper, LEAPS CSM presentation 2011) (Duncan, 2011)

HR data during 6 min walk test

- 17 subjects with subacute or chronic stroke, < 0.9 m/s overground walking speed
- HR collected each minute during 6 min walk at self-selected pace

HR data during 6 min walk test

- 17 subjects with subacute or chronic stroke, < 0.9 m/s overground walking speed
- HR collected each minute during 6 min walk at self-selected pace
HR data during 6 min walk test

- 17 subjects with subacute or chronic stroke, < 0.9 m/s overground walking speed
- HR collected each minute during 6 min walk at self-selected pace

Comparison of intensity of other studies to LEAPS interventions

  - Investigation of task-specific aerobic treadmill training
  - Aerobic walking exercise (60-70% heart rate reserve)
- Outermans et al 2010
  - Investigation of task-oriented training
  - Repeated walking-related work stations (70-80% HR reserve)
- Pang et al 2005
  - Investigation of community based fitness program
  - Instructed to stay within HR zone (70-80% HR reserve)
- Fast vs slow-walking and/or vs control
  - Progressive training of speeds based on HR
  - Pohl et al 2002, Moore et al 2010, Hornby et al 2008 (up to 85% HRmax)

Aerobic Exercise vs Control

- Pang et al 2013: Meta-analysis of RCTs comparing aerobic training to control group
- Aerobic training favored for improved
  - VO2 peak
  - 6MWT
  - gait speed

Case Video

- Reggie video

  - Intensive variable stepping protocol (Holleran et al 2013)
  - Target training zone of 70-80%HRR or 15-18 Borg RPE
Presentation objectives

• Part I:
  – Provide frequently used definitions of intensity
  – Discuss the physiological rationale for high intensity practice
  – Display supportive data and training parameters for high-intensity training post-stroke

• Part II:
  – Concerns regarding high intensity practice post-stroke
  – Summary and re-emphasis on available data

Potential drawbacks of high intensity training

• Neuromuscular concerns
  – Re-enforcing abnormal movement patterns and
  – Increased spasticity

• Cardiovascular concerns

Potential drawbacks of high intensity training: supportive findings

Increasing spasticity
• Increased spasticity for the short term during training is expected (Kline et al 2007)

• Spasticity may reduce over time with training or does not change (Wirz et al 2005)

• BWSTT has been shown to reduce spasticity in chronic SCI as compared to tilt table (Hicks 2011)

Re-enforcing abnormal movements
• Evidence for improved gait pattern over long term (Kuys 2010, Hornby 2008)

• Improved muscle timing/activation patterns is not linked to improved walking function (Den Otter et al 2006)

• Increased risk of cardiovascular event or repeat stroke
ACSM recommendations for cardiovascular disease (CVD)

- Adverse responses to discontinue exercise
  - DBP ≥ 110 mm Hg
  - SBP > 10 mm Hg during exercise with workload increase
  - Significant ventricular or atrial arrhythmias
  - Second or third degree heart block
  - Signs/symptoms of exercise intolerance including angina, marked dyspnea, and ECG changes suggesting ischemia

ACSM contraindications to initiating training in CVD

- Unstable angina
- Uncontrolled hypertension — resting systolic blood pressure (SBP) > 180 mm Hg and/or resting diastolic BP (DBP) > 110 mm Hg
- Orthostatic BP drop of > 20 mm Hg with symptoms
- Significant aortic stenosis
- Uncontrolled atrial or ventricular arrhythmias
- Uncontrolled sinus tachycardia (> 120 beats/min)
- Uncompensated heart failure
- Third-degree atrioventricular (AV) block without pacemaker
- Active pericarditis or myocarditis
- Recent embolism
- Acute thrombophlebitis
- Acute systemic illness or fever
- Uncontrolled diabetes mellitus
- Severe orthopedic conditions that would prohibit exercise
- Other metabolic conditions, such as acute thyroiditis, hypokalemia, hyperkalemia, or hypovolemia (until adequately treated)

Cited Recommendations in Training Intensity

- AHA Scientific Statement
  - Recommendation of graded exercise test with ECG (typically treadmill protocols)
  - 40-70% HRR/50-80% HR max
  - 20-60 min sessions, 3-7 days/week
  - RPE 11-14
  - Without exercise ECG “lighter intensity exercise should be prescribed”

- ACSM guidelines - RPE 14-16 (lower in early stages of cardiac rehab)
  - *include ACSM exercise HR

  - Graded exercise training performed 60-70% HRR
  - Community setting: 70-80% HRR
  - Gradually work towards 3-5, 40 minute sessions/week

Risk for cardiovascular event?

Pang et al 2013 – no increase in risk to patient post-stroke following high intensity training as compared to low intensity control conditions (primarily in chronic stroke)

Hornby 2015 – no increase in risk in the inpatient subacute stroke population as compared to standard rehabilitation interventions

AHA Recommendations for ECG graded exercise stress testing prior to training
Motor Adaptations and Aftereffects – making patients look worse to look better?

T. George Hornby, PT, PhD
Associate Professor, Dept of Physical Therapy
University of Illinois at Chicago
Research Scientist
Sensory Motor Performance Program
Rehabilitation Institute of Chicago

Major Points

1. Motor adaptation and aftereffects - learning a new sensorimotor task
2. Variability and trial and error practice is important for motor learning.
3. Elimination of errors during practice may limit improvements in patient’s with neurologic damage/disease.
4. Patients with a variety of neurologic diagnoses can utilize trial and error practice to adjust movement.

Definitions of changes in motor behavior

• Transitions
  • Immediate change in behavior
  • Driven by prior experience and the ability to predict that new demands will exceed “current state” (feed-forward strategies)

• Adaptations
  • Gradual change in behavior that results from experience (“feedback strategies”)
  • Driven by demands that exceed “current state”

• Learning
  • Relatively permanent changes
  • Resulting from repeated exposure (adaptation may be a precursor)

Adaptation to a visual perturbation

• Prisms inserted into eyeglasses
  • Displace visual field
  • Leads to initial errors in movement accuracy
Aftereffects in pts with cerebellar damage

Prism adaptation

- T. Thach (Martin et al. 1996)
  - Black – prior to prism exposure
  - White – during prism exposure
  - Gray – removal of prism

"see" direction
"throw" direction

With extensive training, throwing with wedge prisms can become a skill.

Repeated adaptation results in learning which allow faster transitions

Role of Cerebellum as a “Comparator”

- Efferent copy of feedforward motor command
- Afferent copy of peripheral feedback
- Generate feedback motor correction and new feedforward command on next movement attempt
Major Points

1. Motor adaptation and aftereffects - learning a new sensorimotor task

2. Variability and errors in movement and learning.

3. Elimination of errors during practice may limit improvements in patient's with neurologic damage/disease.

4. Patients with a variety of neurologic diagnoses can utilize trial and error practice to adjust movement.

“Variability” and allowing errors in more common movements

“Variability” and allowing errors: simple examples

“Variability” and allowing errors: simple examples

Improved free throws with a lot of variable practice
Other factors?

- Errors and variability may be important in learning
  - Variable vs Constant Practice
  - Random vs Blocked Practice (i.e., Contextual Interference)
  - Greater errors associated with allowing variability

Contributions of errors and variability to learning

- Types of variability
  - Kinematic variability (Cai 2007; Hornby 2008, Lewek 2009)

---

**Gait speed (less impaired subjects)**

Therapist-assisted

Robotic-assisted

Post-4 weeks

6 month follow-up


**Gait speed (more impaired subjects)**

Therapist-assisted

Robotic-assisted

Post-4 weeks

6 month follow-up


**Paretic single limb stance time (% gait cycle)**

Therapist-assisted

Robotic-assisted

Post-4 weeks

6 month follow-up


**Step length symmetry (%)**

Therapist-assisted

Robotic-assisted

Post-4 weeks

6 month follow-up

Augmenting errors during learning may enhance magnitude/accelerate learning (split-belt treadmill stepping; Bastian 2006, Reisman 2010)

If errors are good . . . .

Application of error augmentation – Split belt treadmill for step-length asymmetry post-stroke

During walking on split-belt treadmill

How to we get more errors?

- Types of variability
  - Kinematic variability (Cai 2007; Hornby 2008, Lewek 2009)
  - Environmental variability – overground/stairs (van den Brand 2012)
  - Task variability – forward vs sideways vs backwards (Shah 2012)

- What types of variability/errors are appropriate for patients?
Trial and error practice – specifications

- Goal-directed, salient task (Bastian et al. 2006)
  - Be able to detect their error
    - May be compromised in those with memory or sensory deficits (Alzheimer's or Liu 2012, sensory: Ghez et al. 1995)
    - Learning is enhanced if subjects self-evaluate movement form or outcome (Swinnen et al. 1990; Liu & Wrisberg, 1997)
- Ability to recalibrate
  - Compromised with specific cerebellar lesions
- Must have an adaptation to have an aftereffect

Error Augmentation

\[ \text{Degree of Skill Acquisition} \]

Error

Assistance

Guidance

Trial-and-error practice

Error augmentation

Differences in theoretical frameworks of locomotor training paradigms

Copyright Rehabilitation Institute of Chicago
Trial and Error Practice

• Clinical implication
  – Increasing intensity may also increase error
  – May use external forces to increase error

• Determine whether the patient can adapt to the “error”
  – Application to specific diagnoses
  – Setting patient up for success
  – Read patient-specific psychological response to trials with error

• Explain to the patient that they may look worse before they look better

Using objects in the environment to create errors (high steps, unsteady surfaces, etc)
Major Points

1. Trial and error practice is important for motor learning.

2. Patients with a variety of neurologic diagnoses can utilize trial and error practice to adjust movement.

3. Elimination of errors during practice may limit improvements in patient’s with neurologic damage/disease.
Development and Application of a Walking Training Program

T. George Hornby, PT, PhD
Carey L. Holleran, PT, DHS, NCS
Sensory Motor Performance Program
Rehabilitation Institute of Chicago

Walking Training Paradigm

- Large Amounts of Task Specific Practice
  - Focus on continuous reciprocal stepping
  - Focus only on continuous reciprocal stepping

- Aerobic intensity
  - Training HR zone (THR) = 70-80% Heart Rate Reserve (HRR)
  - 15-18 BORG Ratings of Perceived Exertion (RPE)

- Variability
  - Multidirectional stepping
  - Multiple environments
  - Random order practice

Walking Training Paradigm

- Biomechanical subcomponents of walking
  - Limb swing advancement
  - Propulsion
  - Stance control
  - Lateral/frontal stability

- Defining Successful walking
  - Positive step length
  - Directional advancement
  - Preventing limb/trunk collapse
  - Maintain upright

Success = Continuous stepping
Failure = 3-5 consecutive errors
Gait kinematics were not a primary concern
(Holleran, NNR 2014, appendix)

Progressing Biomechanical Subcomponents of Walking
Examples of increasing variability/difficulty

• Swing phase completion
  – Guidance/Assist as needed:
    • If cannot swing limb independently, provide manual/elastic assistance (Hesse et al 1995, Gottschall and Kram 2005)
    • Reduce assistance as tolerated
  – Trial and error/Error augmentation:
    • Add leg weights/stepping over objects/elastic resistance (Lam et al 2008, 2009, Sevin et al 2009)

Examples of increasing task variability/difficulty

• Weight bearing
  – Guidance/Assist as needed:
    • If cannot bear weight during stepping (e.g., knee “buckles”) provide body weight support (Visintin et al 1998)
    • Reduce weight support as tolerated (Barbeau and Visintin 2003, Grabowski et al 2005)
    • Assistive devices
  – Trial and error/Error augmentation:
    • Add weighted vest – increases neuromuscular activity to maintain upright posture (Umberger et al 2010)
    • Reduce use/change assistive device
Progressing Biomechanical Subcomponents of Walking

Limb Advancement  Stance Control  Propulsion  Stability & Balance

Examples of increasing task variability/difficulty

• Propulsion
  – Guidance/Assist as needed:
    • Assistance at pelvis to ensure forward progression (treadmill or overground)
  – Trial and error/Error augmentation:
    • Resisted walking (elastic resistance at pelvis/trunk)
    • Adding mass increases propulsive demands

Progressing Biomechanical Subcomponents of Walking
Examples of increasing task variability/difficulty

• Lateral/sagittal stability
  – Guidance/Assist as needed:
    • Provide stabilization of trunk if cannot maintain upright posture
    • Physical assistance, elastic assistance (hold hips forward/in place; Sullivan et al 2002)
    • Assistive device (Chen et al 2005)

• Trial and error/Error augmentation
  • unstable or narrow surfaces (Domingo and Ferris, 2008, 2009)
  • backward/sidestepping, running (Ada et al 2003)
  • obstacles, dual physical tasks
  • externally applied horizontal forces (Gottschall and Kram 2003)

Outline

• Introduction – Theory and Rationale

• Development and Application
  – Walking Training Paradigm
  – Randomized Clinical Trial – Very Intensive Early Walking post-Stroke (VIEWS)

• Knowledge Translation

• Implementation

Randomized Controlled Trial

• Subjects
  – Subacute*
  – Age 18-75
  – Single unilateral stroke
  – MMSE ≥ 23
  – mod A or ambulate < 0.9 m/s (SSV)
  – Stratification prior to randomization (walking speed)*
  – N=32 required from effect sizes

• Intervention
  – ≤ 40 1hour sessions over 8-10 weeks
  – 1 week forward TM training
  – 7 weeks variable training

• Outcomes assessment
  – Primary: SSV & 6MWT
  – Secondary: 5X sit-to-stand, Berg Balance Scale

(Homby et al, 2015)
VIEWS: Design

**Control**
- Encouraged to continued physical therapy
- Supplemental sessions to achieve 40 sessions
- Multiple activities, limited practice of any single task (Lang, 2009)
  - Balance, Strength, PROM, Transfers
  - Walking: 800-1000
  - steps/session = 200 + 1500 steps (initial walking speeds) (Moore, 2010)
- 30-40% HRR (Mackay-Lyons 2003)

**Experimental**
- No concurrent physical therapy
- Focused stepping training up to 40 1 hr sessions
- High aerobic intensity (70-80% HRR)
- Skilled variable task practice on treadmill and over ground

VIEWS: Group Comparisons

<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>Experimental</th>
<th>Control</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demographics</td>
<td>N=15</td>
<td>N=17</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>57±12</td>
<td>60±9.2</td>
<td></td>
<td>0.31</td>
</tr>
<tr>
<td>Days post-stroke</td>
<td>114±56</td>
<td>89±44</td>
<td></td>
<td>0.16</td>
</tr>
<tr>
<td>Impairments</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LE Fugl-Meyer</td>
<td>20±5.8</td>
<td>21±6.2</td>
<td></td>
<td>0.63</td>
</tr>
<tr>
<td>PHQ-9</td>
<td>4.3±3.5</td>
<td>3.2±3.3</td>
<td></td>
<td>0.74</td>
</tr>
</tbody>
</table>

VIEWS: Group Comparisons

Significant difference in walking measures (p<0.01)

- Self-selected velocity (0.27±0.22 vs 0.09±0.09 m/s)
- Fastest possible velocity (0.28±0.20 vs 0.11±0.15 m/s)

Between group differences well above MCID for walking outcomes
VIEWS: Results

No significant between group difference in changes in non-walking measures

Only control group practiced transfers and balance, but demonstrated no greater gains than experimental group

Relationship between stepping dosage vs outcomes

Amount of practice related to improvements in walking

VIEWS: Results

Relationship between peak training intensity vs outcomes

Intensity of practice related to improvements in walking

“What about their quality of gait?”

Greater hip flexion (30° ± 12° to 37° ± 14° *)
Greater knee flexion (37° ± 15° to -43° ± 21° *)
Greater total hip ROM – knee and ankle vary

Changes in frontal plane deviations
- Hip abduction – 2.8°*
- Hip hiking (2°)*
- Circumduction (4 cm)
“What about their quality of gait?”

- Peak hip abduction
  - 5 of 23 patients demonstrated Δ hip abduction > 5°
  - Positively correlated with peak treadmill speed, stride length
  - Negatively correlated with baseline lower extremity Fugl-Meyer
  - Do they even have the neuromuscular substrate to walk normally?

**Case 1: History**

- 52 year old male; L ICH (subcortical, ICH)
  - Hypertension, dysphagia, aphasia, acute kidney failure
  - Medications: simvastatin, nifedipine, dilatin, digoxin, phenobarbital, clozapine, metoprolol

- Social hx:
  - Lived alone prior to stroke
  - Admitted to nursing home after medically stable post-stroke/minimal rehabilitation

- Started intensive rehabilitation (study) 4 months post-stroke

- Baseline assessments
  - FIM: Mod assist for all transfers and ambulation
  - 5 x sit to stand: unable
  - Berg Balance Scale Score: 5/56
  - Self-selected gait speed: 0 m/s (unable to ambulate)
  - 6 minute walk distance: 0 feet (unable to ambulate)

**Case 2: History**

- 59 year old male (> 300 lbs); L thalamic/BG stroke; mass effect/midline shift
  - Acute renal insufficiency/hydronephrosis, HTN, CHF, a-fib, asthma, LE venous stasis ulcers
  - Medications: Protonix, Tobradex, Norvasc, Vasotec, Keppra, Hydralazine

- Social hx:
  - Admitted to nursing home after medically stable post-stroke
  - Family unable to assist patient; lived with wife prior

- Assessments
  - FIM: Mod assist for all transfers and mobility items
  - Self – selected gait speed: 0 m/s (unable to ambulate)
  - Berg Balance Scale Score: 7/56
  - 6 minute walk distance: 0 feet (unable to ambulate)
  - 5 x sit to stand: unable

Baseline testing
Outline

• Introduction – Theory and Rationale

• Development and Application
  – Walking Training Paradigm
  – Randomized Clinical Trial – Very Intensive Early Walking post-Stroke (VIEWS)

• Knowledge Translation

• Implementation
Clinical Decision-Making for Walking Training Interventions
Patrick Hennessy, PT, NCS, Jane Woodward, PT, NCS, Carey Holleran, PT, NCS, T. George Hornby, PT, PhD

Lecture Outline
• Prognostic literature for walking recovery in stroke and SCI
• Strategies for locomotor training
  – Reviewing biomechanical subcomponents of gait
  – Discussing grading challenge of task
• Considerations for implementation
• Case Studies

Is walking appropriate for my patient?
A review of prognostic factors & clinical prediction rules in post-stroke walking function
Prediction rules for locomotor recovery following stroke

- Veerbeek et al (NNR), 2011
- The EPOS Study

Patients’ independent sitting balance and leg strength in first 3 days predicted walking function at 6 months

- 98% walked independently (FAC>4) at 6 months with M2>25 or
  1. Independent sitting edge of bed for 30 seconds (TCT-sitting)
  2. Visible contraction in hip flexors, knee extensors and dorsiflexors OR Manual resistance against one of the muscles
- 27% walked independently if criteria not met at 3 days post-stroke
- 10% walked independently if criteria not met at 9 days post-stroke

Systematic Review of Stroke Predictors

- Preston et al 2011
- Initially non-ambulatory stroke patients managed in rehabilitation or acute care units
- Probability of independent walking
  - 60% (95% CI 47-74%) at 3 months (9 studies)
  - 65% (95% CI 53%–77%) at 6 months (3 studies)
  - 91% (95% CI 81%–100%) at 12months (1 study)

Systematic Review of Stroke Predictors

Kwakkel and colleagues suggested predictors (1996)

- age
- previous stroke
- urinary continence
- consciousness at onset
- disorientation in time and place
- severity of paralysis
- sitting balance
- admission ADL score
- level of social support
- metabolic rate of glucose outside the infarct area in hypertensive patients

Meijer and colleagues (2003)

- insufficient quality of data to provide predictions
- some evidence for poorer outcomes with:
  - low initial ADL functioning
  - high age
  - cognitive disturbance
  - paresis of the limbs
  - reduced initial level of consciousness
  - previous hemiplegia
  - homonymous hemianopia
  - visual extinction
  - constructional apraxia
  - no admission to a stroke unit
  - non-lacunar stroke
  - visuospatial construction problems
  - urinary incontinence
  - female gender
Clinical take-home from available stroke literature?

- Lower initial functional status has been identified as having lower probability of achieving independent walking at discharge from inpatient rehab or in long term follow-up
- Available body of literature has not tracked interventions received during rehabilitation
- “differences in objectives and heterogeneity in stroke patients responsible for the lack of accuracy in predicting functional outcome, but also the methodological flaws in published prognostic research”

Predictors for locomotor recovery following SCI

**Initial AIS exam**
- Sacral Sparing (Oleson)
- Anal sensation (Marino 2004)
- LE pinprick (Oleson)
- LEMS scores
  - Quadriceps (Crozer)
  - Hip flexors (Hussey)

**Limitations**
- Small sample sizes
- Not cross-validated
- Cannot identify probability of walking based on individual exam findings

Clinical prediction rule for locomotor recovery following SCI

AIS testing administered within 15 days and 1 year post-injury
Independent walking (SCIM) used as primary outcome

1. Lower Extremity Motor Scores (0-5) for quadriceps and plantarflexors
2. Sensory scoring (light touch) for L3 and S1 dermatomes (0 = none, 1 = impaired, 2 = normal)
3. Age (> or < 65)

<table>
<thead>
<tr>
<th></th>
<th>Range</th>
<th>Weighted Coefficient</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age ≥65 years</td>
<td>0-1</td>
<td>-10</td>
<td>-10</td>
<td>0</td>
</tr>
<tr>
<td>Motor L3</td>
<td>0-5</td>
<td>2</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>Motor S1</td>
<td>0-5</td>
<td>2</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>Sensory L3</td>
<td>0-2</td>
<td>5</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>Sensory S1</td>
<td>0-2</td>
<td>5</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>-10</td>
<td>40</td>
</tr>
</tbody>
</table>

Patient Case Example

- 34 yo male **T12 AIS B SCI** s/p pedestrian vs car
- 9 days post SCI to admission (AIS exam 10 days post)
- 24 days post SCI to initiating walking

<table>
<thead>
<tr>
<th></th>
<th>Range</th>
<th>Weighted Coefficient</th>
<th>CPR Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age ≥65 years</td>
<td>0</td>
<td>-10</td>
<td>0</td>
</tr>
<tr>
<td>Motor L3</td>
<td>0</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Motor S1</td>
<td>0</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Sensory L3</td>
<td>1</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Sensory S1</td>
<td>2</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td><strong>15</strong></td>
</tr>
</tbody>
</table>

(van Middendorp, 2011)
Patient Case Example

• 4-5x/week up to 45 minutes of walking with target training intensity
• Weekly LEMS re-assessment
• Lower extremity motor return identified 8 days post initiating walking training
• Discharged from inpatient rehab ambulating >200’ with supervision + AD/bracing (Mod I in Community within 4 months post-SCI
• Considerations

Lecture Outline

• Prognostic literature for walking recovery in stroke and SCI
• Strategies for locomotor training
  – Reviewing biomechanical subcomponents of gait
  – Discussing grading challenge of task
• Considerations for implementation
• Case Studies

Video example 1

What gait variables do you manipulate?

Grading challenge within the context of stepping training
Biomechanical Subcomponents of Walking

- Limb Swing
- Stance control
- Propulsion
- Stability & Balance

Graph showing the relationship between Degree of Skill Acquisition and Error Augmentation.
Considerations

- Cognition/language
  - Feedback and Communication strategies

- Anticipated discharge setting/plans
  - POC carryover after discharge
  - Training family/caregivers
  - Patient advocacy/direction of care

- Other medical issues
  - Cardiovascular, respiratory, metabolic status
  - Skin and wounds

- Line/medical equipment management
  - PEG, trach, vent, IV,
  - Padding/modifying harness for PEG,
  - Catheter considerations

Orthopedic concerns
Orthotics & Assistive Devices

- Cervical/thoracic orthoses (Halo, Somi, TLSO, etc.) and other orthopedic considerations

- Lower extremity bracing
  - Trial vs permanent bracing
  - Bracing changes for high intensity training

- Upper extremity considerations
  - Slings, Giv-Mohr, shoulder cuff -
  - Finger/grasp function without pain (strapping to handrails)

Lecture Outline

- Prognostic literature for walking recovery in stroke and SCI

- Strategies for locomotor training
  - Reviewing biomechanical subcomponents of gait
  - Discussing grading challenge of task

- Considerations for implementation

- Case Studies

Case Study: Inpatient Rehab

- 63 yo male
- Right intracerebral thalamic and basal ganglia hemorrhage with IVH
- PMH: HTN
- Work-up: EF 60% mild LVH and mild atrial enlargement

- Impairments:
  - 0 to 2-/5 LLE strength
  - Light touch and proprioception: Absent
  - Impaired dynamic sitting balance

- Goals: Household ambulation and stairs
### Video

- [Image of a video showing a person walking with a walker.](image)

### Outcome Measures

<table>
<thead>
<tr>
<th></th>
<th>FIM Transfer</th>
<th>FIM Amb</th>
<th>FIM Stairs</th>
<th>6MWT</th>
<th>10MWT</th>
<th>BBS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Week 1</td>
<td>Max A</td>
<td>17’ TA</td>
<td>NT</td>
<td>NT</td>
<td>NT</td>
<td>4/56</td>
</tr>
<tr>
<td>Week 1.5</td>
<td></td>
<td></td>
<td>60’ max A, hemi-W</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Week 2</td>
<td>Mod A</td>
<td>Max A</td>
<td>12 steps mod A</td>
<td>114’ max A, hemi-W</td>
<td>.13 m/s max A</td>
<td>7/56</td>
</tr>
<tr>
<td>Week 3</td>
<td>Min A</td>
<td>Mod A</td>
<td>12 steps mod A</td>
<td>185’ mod A, LBQC</td>
<td>.18 m/s Mod A</td>
<td>10/56</td>
</tr>
<tr>
<td>Week 4</td>
<td>CS</td>
<td>Min A</td>
<td>28 steps mod A</td>
<td>227’,min A, LBQC</td>
<td>.23 m/s Min A</td>
<td>14/56</td>
</tr>
<tr>
<td>6 month f/u</td>
<td></td>
<td></td>
<td></td>
<td>311’ CS, SBQC</td>
<td>.27 m/s CS</td>
<td>28/56</td>
</tr>
</tbody>
</table>

### FITT Principle

- **Week 1 and 2**
  - **Frequency:** 4-5x/week
  - **Intensity:**
    - Goal target HR range: 104-127bpm (70-85% HRmax) adjusted for beta-blocks, RPE ≥14
    - Actual HR range: 75-102bpm (50-68% HRmax), RPE 12-15
  - **Time:** 30 or 60 min sessions
    - Amb 15-20 mins
  - **Type:**
    - Treadmill: First 5 training sessions (6 total)
    - Stairs: 2 sessions
    - Overground: 1 session

### HR Calculator

- [Image of a HR calculator with data points and formulas.](image)
FITT Principle

• Week 1 and 2
  – Frequency: 4-5x/week
  – Intensity:
    • Goal target HR range: 100-124bpm (70-85%) adjust for beta-blocks, RPE ≥ 14
    • Actual HR range: 75-102bpm (50-68%), RPE 12-15
  – Time: 30 or 60 min sessions
    • Amb 15-20 mins
  – Type:
    • Treadmill: 6 training sessions
    • Stairs: 2 sessions
    • Overground: 1 session

Treadmill and Overground

Outcome Measures

<table>
<thead>
<tr>
<th></th>
<th>FIM Transfer</th>
<th>FIM Amb</th>
<th>FIM Stairs</th>
<th>6MWT</th>
<th>10MWT</th>
<th>BBS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Week 1</td>
<td>Max A</td>
<td>17' TA</td>
<td>NT</td>
<td>NT</td>
<td>NT</td>
<td>4/56</td>
</tr>
<tr>
<td>Week 1.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>60' max A, hemi-W</td>
<td></td>
</tr>
<tr>
<td>Week 2</td>
<td>Mod A</td>
<td>Max A</td>
<td>12 steps mod A</td>
<td>114' max A, hemi-W</td>
<td>.13 m/s</td>
<td>7/56</td>
</tr>
<tr>
<td>Week 3</td>
<td>Min A</td>
<td>Mod A</td>
<td>12 steps mod A</td>
<td>185' mod A, LBQC</td>
<td>.18 m/s Mod A</td>
<td>10/56</td>
</tr>
<tr>
<td>Week 4</td>
<td>CS</td>
<td>Min A</td>
<td>28 steps mod A</td>
<td>227', min A, LBQC</td>
<td>.23 m/s Min A</td>
<td>14/56</td>
</tr>
<tr>
<td>6 month f/u</td>
<td></td>
<td></td>
<td></td>
<td>311' CS, SBQC</td>
<td>.27 m/s CS</td>
<td>28/56</td>
</tr>
</tbody>
</table>

FITT Principle

• Week 3 and 4
  – Frequency: 7-12x/week
  – Intensity:
    • Goal target HR range: 100-124bpm (70-85%) adjust for beta-blocks, RPE ≥ 14
    • Actual HR range: 80-120bpm (54-81%), RPE 13-16
  – Time: 30 or 60 min sessions
    • Amb 26 mins
  – Type:
    • Treadmill: 4 sessions
      – Variable/error adaptation
    • Stairs: 5 sessions
    • Overground: 11 sessions
      – Variable/error adaptation
    • Family Training: 4 sessions
### Outcome Measures

<table>
<thead>
<tr>
<th></th>
<th>FIM Transfer</th>
<th>FIM Amb</th>
<th>FIM Stairs</th>
<th>6MWT</th>
<th>10MWT</th>
<th>BBS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Week 1</strong></td>
<td>Max A</td>
<td>17' TA</td>
<td>NT</td>
<td>NT</td>
<td>NT</td>
<td>4/56</td>
</tr>
<tr>
<td><strong>Week 1.5</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>60' max A, hemi-W</td>
<td></td>
</tr>
<tr>
<td><strong>Week 2</strong></td>
<td>Mod A</td>
<td>Max A</td>
<td>12 steps</td>
<td>114’ max A, hemi-W</td>
<td>.13 m/s max A</td>
<td>7/56</td>
</tr>
<tr>
<td><strong>Week 3</strong></td>
<td>Min A</td>
<td>Mod A</td>
<td>12 steps</td>
<td>185’ mod A, LBQC</td>
<td>.18m/s Mod A</td>
<td>10/56</td>
</tr>
<tr>
<td><strong>Week 4</strong></td>
<td>CS</td>
<td>Min A</td>
<td>28 steps</td>
<td>227’, min A, LBQC</td>
<td>.23 m/s Min A</td>
<td>14/56</td>
</tr>
<tr>
<td><strong>6 month f/u</strong></td>
<td></td>
<td></td>
<td></td>
<td>311’ CS, SBQC</td>
<td>.27 m/s CS</td>
<td>28/56</td>
</tr>
</tbody>
</table>

### Key Factors

- Supportive Family
- Consistent gait training strategies amongst PT team
- Patient motivation
  - Explicit goals
  - Additional PT sessions
- Early implementation of gait training

### Video

### Case Study 2: Outpatient

- 67 yo female
- 1 year post R MCA infarct
  - 20 days acute inpatient rehab
  - SNF ~4 months prior to discharge home
- **PMH:** HTN, HLD
- Left neglect and visual field cut
Baseline Testing

Outcome Measures

<table>
<thead>
<tr>
<th></th>
<th>SXSTS</th>
<th>BBS</th>
<th>6MWT (SSV)</th>
<th>GaitMat SSV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>unable</td>
<td>17/56</td>
<td>158’ with SBQC, CGA</td>
<td>.08m/s</td>
</tr>
<tr>
<td>Post 4 Weeks</td>
<td>28.9 sec</td>
<td>31/56</td>
<td>266’ with SBQC, CGA</td>
<td>.31m/s</td>
</tr>
<tr>
<td>Post 8 Weeks</td>
<td>13.1 sec</td>
<td>34/56</td>
<td>423’ with SBQC, CGA</td>
<td>.28m/s</td>
</tr>
<tr>
<td>6 Month Follow-up</td>
<td>unable</td>
<td>26/56</td>
<td>345’ with SBQC, CGA</td>
<td></td>
</tr>
</tbody>
</table>

Intervention

- **Frequency:** 4-5x/week

- **Intensity:**
  - Goal target HR range: 133-143bpm (70-80%HRR) adjust for beta-blocks, RPE ≥14
  - Actual HR range: 138-145bpm RPE 15-17

- **Time:** 60 min sessions
  - Amb up to 40 mins

- **Type:**
  - Treadmill speed-dependent (25%)
  - Treadmill variable (25%)
  - Stairs (25%)
  - Overground variable (25%)
### Outcome Measures

<table>
<thead>
<tr>
<th></th>
<th>5XSTS</th>
<th>BBS</th>
<th>6MWT (SSV)</th>
<th>GaitMat SSV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>unable</td>
<td>17/56</td>
<td>158’ with SBQC, CGA</td>
<td>.08m/s</td>
</tr>
<tr>
<td>Post 4 Weeks</td>
<td>28.9 sec</td>
<td>31/56</td>
<td>266’ with SBQC, CGA</td>
<td>.31m/s</td>
</tr>
<tr>
<td>Post 8 Weeks</td>
<td>13.1 sec</td>
<td>34/56</td>
<td>423’ with SBQC, CGA</td>
<td>.28m/s</td>
</tr>
<tr>
<td>6 Month Follow-up</td>
<td>unable</td>
<td>26/56</td>
<td>345’ with SBQC, CGA</td>
<td>.20m/s</td>
</tr>
</tbody>
</table>

### Key factors:

- Additional strategies needed for:
  - Fear of falling
  - Apprehensive of new challenges
  - Deconditioned and required rests
  - Additional time to complete tests
- Motivation?
- Supportive family

### Questions??

### References:

- Domingo A, Ferris DP. The effects of error augmentation on learning to walk on a narrow balance beam. Exp Brain Res. 2010 Oct;206(4):359-70
- Grabowski A et al. Independent metabolic costs of supporting body weight and accelerating body mass during walking. Journal of Applied Physiology February 1, 2005 vol. 98 no. 2 579-583
References:


Knowledge Translation Strategies

Jennifer Moore PT, DHS, NCS
Clinical Practice Leader, Neurologic Physical Therapy
Rehabilitation Institute of Chicago

Knowledge Translation (KT)

“the dynamic and iterative process that includes the synthesis, dissemination, exchange and ethically sound application of knowledge to improve health, provide more effective health services and products, and strengthen the health care system.”

- Canadian Institute of Health Research

Evidence-Based Practice (ebp)

Evidence-Based Practice (EBP)

“integration of the best research evidence with clinical expertise and patient values and circumstances to make clinical decisions.”

The Challenge of Knowledge Translation (KT)

• > 17 years for evidence to be used clinical practice (Morris, 2011)

• KT is multi-faceted (Strauss, 2009)
  • Patient
  • Individual Clinician
  • Organizational leaders/stakeholders
  • Political
  • Economic
Translation to clinical practice:

Challenges and solutions towards implementing training interventions in the clinical setting.
Identify the problem: Tips

• Start with a clear statement of the problem
• Engage representatives from stakeholder groups
• Determine process to identify problem
  • Chart audits
  • Surveys (current practice, perspectives, organizational climate)
  • Observation
  • Competency assessment (skills or knowledge questionnaires)
  • Focus groups

High Intensity Training for Stepping (HITs)

Problem: Are patients admitted to inpatient rehabilitation:
  • Assessed with a standard gait and balance assessment battery?
  • Treated with a high intensity gait training intervention that:
    • Maximizes stepping practice
    • Achieves high aerobic intensities
    • Provides variability in stepping tasks with progression of activities
  • Monitored with an outcome measurement battery?

Identify the problem

• Define the problem
  • Current Practice
    • 10% of patients had an outcome measurement administered (Moore et al, 2010)
    • 357 steps/session (Lang et al, 2019); 886 steps/session (Moore et al, 2010)
  • Desired Practice (Moore et al, 2010; Holleran et al, 2014; Straube et al, 2014)
    • Routine administration of outcome measures
    • Maximize high intensity stepping
    • Variability of locomotor tasks

• Define measurable objectives for the project

HITs Objectives

• Identify barriers to providing HITs in inpatient rehabilitation
• Implement KT interventions targeting the identified barriers
• Determine the impact of HITs on clinicians’ behaviors & patient outcomes
• Specific intervention goal:
  • Maximize the number of steps (counted by pedometers)
  • Achieve high aerobic intensity with 70-85% HR Max (documented)
Adapt Knowledge to Local Context

**Considerations**
- Protect integrity of evidence
- Engage stakeholders
- Transparent reporting of limitations

**Examples**
- Application to inpatient populations:
  - Communication impairments
  - Increased number of comorbidities
  - Impaired cognition

Multilevel Approach to Examining Facilitators and Barriers

- **Innovation**: Advantages, limitations, feasibility
- **Individual**: Attitude, motivation to change
- **Social**: Opinions of colleagues, culture, leadership
- **Organizational**: Resources, capacity

Facilitators to HITs

**Facilitators**:
- Organizational and social:
  - Vision
  - Initially implemented in “ability lab”
  - Stakeholder involvement
- Individual:
  - Clinicians knew expectations/vision
  - Patients expected a “novel” treatment

Barriers to HITs

- **Knowledge & skills**:
  - General application
  - Medically complex and very impaired patients
- **Difference in practice beliefs**: Focusing sessions on gait training
- **Logistics**:
  - Scheduling
  - Readiness for PT when session starts
  - Time lost setting patients up
  - Streamlined documentation
Select KT Interventions

- KT interventions: not rigorously studied
  - Professional interventions
  - Patient directed interventions
  - Organizational interventions
  - Financial incentive

- Target stated barriers and facilitators

- Multiple component KT interventions

 Straus, Tetroe and Graham, 2013

HITs KT Interventions

<table>
<thead>
<tr>
<th>Barrier</th>
<th>KT Intervention</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knowledge &amp; skills</td>
<td>Education sessions</td>
</tr>
<tr>
<td></td>
<td>Clinician driven case study presentation</td>
</tr>
<tr>
<td></td>
<td>Facilitation by PT with dual clinical/research role</td>
</tr>
<tr>
<td></td>
<td>Consultations, structured meetings, and problem-solving</td>
</tr>
<tr>
<td>Current practice &amp; culture</td>
<td>Maximize dose using gait groups</td>
</tr>
<tr>
<td></td>
<td>Family training on walking</td>
</tr>
<tr>
<td>Logistics</td>
<td>Scheduling mechanism</td>
</tr>
<tr>
<td></td>
<td>Rehab aide/nursing assist in setting patients up</td>
</tr>
<tr>
<td></td>
<td>EMR modified for streamlined documentation</td>
</tr>
</tbody>
</table>

Evaluate Outcomes at Various Levels

- Patient
  - Improvement in functional outcome
  - Length of stay
  - Satisfaction

- Clinician
  - Changes in decision-making / practice behaviors
    - Observation
    - Chart audits
    - Efficiency

- Organizational or process level
  - Overall patient outcomes
  - Reimbursement

**HITs outcomes will be presented by Carey Holleran**

Monitor knowledge use

- Conduct surveys, focus groups, discussions, or observations
  - Changes in knowledge, understanding, attitudes
  - Actual changes in behavior or practice

- HITs Examples:
  - Observation and monitoring of measurements and stepping activity
  - Case discussions and problem solving
  - Compliance during team conference reporting:
    - Outcome measures
    - Patient response to HITs program
Strategies to Sustain Use

- Leadership
  - Organizational goals/vision for implementation of evidence
  - Interviewing strategies:
    - “Tell me about the OMs you use in practice. How did you learn about them? How do they impact your decision-making?”
    - “Tell me about the last intervention study you read. Did it impact your practice? Why or why not?”

- Financial supports: Desired change as component of merit increases

- Integrate into routine clinical practices/processes
  - Team conference reporting and mandatory documentation
  - Journal and education inservices on the topic

Tips for Success

- Collaboration between stakeholders to implement project

- Clearly stated vision by leadership

- Tailored KT interventions to address barriers

- Ongoing monitoring and measurement of outcomes

Knowledge-to-Action Framework

For more information:

Implementation of a high intensity stepping program in inpatient post-stroke rehabilitation

Carey L. Holleran MPT, DHS, NCS
Clinical Practice Leader for Neurologic Physical Therapy
Rehabilitation Institute of Chicago

Acknowledgements

- Locomotor Recovery Laboratory
  - Principal Investigator
    - T. George Hornby PT, PhD
  - Staff
    - Abi Leddy, DPT, MSCI, NCS
    - Patrick Hennessy MPT, NCS
    - Jane Woodward, DPT, NCS
    - Christopher Thompson DPT, PhD
    - Kristan Leech DPT, PhD
    - Mark Connolly, BS
    - Catherine Kinnaird, MS
    - Gordhan Mahtani, MS

- RIC Physical Therapists
  - Nicole Williams, DPT
  - Ryan Pelo, DPT
  - Raquel Santiago, DPT
  - Mike Klonowski, DPT, PCS
  - Heather Scholten, DPT
  - Holly Paczan, DPT
  - Deb Tobias, DPT

- Administrators/Physicians
  - Elliot Roth, MD
  - Richard Harvey, MD
  - Linda Lovell, BS
  - Kara Kozub, MS
  - Jennifer Smith, MS
  - Nicole Sedam, OTL/R

Agenda

- Theory and rationale

- Implementation Methods
  - Structure and planning
  - Data analysis

- Results
  - Characteristics of sample
  - Outcome assessment changes
  - Correlation and regression analyses

Walking recovery

Specificity

Intensity

Repetition
Walking Recovery

- Specificity – Type of practice


  - Non-stepping practice
    - Balance training improves balance (Hui-Chan et al 2009)
    - Strength training improves strength (Patten et al 2004; Jayaraman et al 2013)
    - Smaller effects on walking

- Repetition - Amount of stepping practice

  - Traditional BWS provides large amounts of stepping (Barbeau, 2003)

  - Dose appears to be related to responses (Moore, 2010)
    - Dose : ~ 4000 steps

  - Faster is better (Pohl et al 2002, Sullivan et al, 2002)

- Intensity - Workload or power output estimated by heart rate (HR)

  - Definition of intensity varies – NOT treatment time or repetition

  - Treadmill walking 60-70% heart rate reserve (HRR) (Macko et al, 2005), up to 85% HR max (Moore et al, 2010)

- Types of variability

  - Kinematic variability (Hornby 2008)

  - Environmental variability – overground/stairs (VanDen Brand et al, 2012)

  - Task variability – forward vs sideways vs backwards (Shah 2012)
Conclusions

- Current practice patterns demonstrate...
  - Lack of task specific training related to goals
  - Small amount of repetitions
  - Reduced intensity

Clinicians' concerns

- "I won’t have time to practice transfers."
- "My patients won’t be prepared for discharge."
- "Don’t my patients need to learn to stand first?"
Outcomes from IP Rehab

• Horn SD et al, 2005  (Post-Stroke Rehabilitation Outcomes Project Database)
  – Greater minutes in PT gait activities significantly associated with higher discharge (DC) FIM scores
  – Greater minutes in bed mobility and sitting consistently associated with lower DC FIM scores

Project Goals

• Prioritization of activities to maximize amount and aerobic intensity of stepping practice
• Feasibility of number and intensity of stepping related activities
• Evaluate potential associations of stepping activity with locomotor and non-locomotor outcomes

Agenda

• Theory and rationale
  – Walking recovery
  – Current practice patterns
  – Goals of project

• Implementation Methods
  – Structure and planning
  – Data analysis

• Results
  – Characteristics of sample
  – Outcome assessment changes
  – Correlation and regression analyses

Implementation - Intervention

• Prioritization of stepping practice
  – Task specificity - Stepping on treadmill and overground
  – Intensity - 60-85% HR max, 14-17 RPE
  – Variability - Multiple directions, obstacles, stairs, uneven/compliant surfaces, curbs

• Weekly assessments – consistent documentation of mobility outcomes

• Family training
Timeline of Activities

January 2012
- Combined research and clinical pilot floor opens at RIC
- Therapists interested in translation of evidence to clinic hired to PT team
- Clinical and research team assembled
- Developed research proposal for Henry Betts Innovation Grant Award

March 2012
- Project selected as Innovative Award Winner
- Weekly collaborative meetings of clinicians and researchers initiated

April 2012
- Training of rehabilitation aide within clinical environment
- Defined goals and purpose of stepping program
- Changes to electronic documentation for extraction

May 2012
- Developed tools for collection of data
- First patient began program

October 2012
- Implementation on second floor

Study Sample and Design

- Retrospective data analysis
  - Implementation of clinical initiative over 16 month period
  - No control group

- Inclusion
  - Initial diagnosis of stroke (<6 months)
  - 18-89 years of age

- Exclusion
  - Pregnant
  - HIV or AIDS
  - Incarceration
  - Lower extremity fracture or amputation

Implementation – Clinician Driven

- Physical Therapy Staff
  - Prioritizing walking
  - Perform outcome measurements

- Occupational Therapy
  - Repetitive task specific UE training
  - Continuing to address transfers

- Therapy Aides
  - Assist with increased stepping under PT guidance

- Nursing/PCT Staff
  - Consistently ready for therapy
  - Carry over of transfers

- Administrative/Physician Support
  - Group scheduling
  - Moral support

- Research Support
  - Assisted with initiation of program and performed data analysis

Implementation - Stepwatch

- StepWatch3™
  - Worn 7:30 am to 5:00 pm
  - Paretic leg
  - Matched with medical records and de-identified for research analysis
**Implementation - Environment**

**Equipment**

- 4 Treadmills with BWS
- Use of two inpatient floors
  - Overhead trolley
  - Lite gait
  - Rifton tram
  - Hoyer lift
- Rotating stairs

**Data Extraction**

Extracted by clinical staff and de-identified for research staff analysis

- Demographic Information
  - Gender
  - Age
  - Duration post-stroke
  - Lesion side
  - Type (ischemic/hemorrhagic)
  - Adverse events during length of stay
  - Distribution

**Data Extraction**

- Outcome assessments (Admit and D/C)
  - 6 MWT
  - 10 MWT
  - FIM (Bed, Toilet, Walk, Combined Motor, Combined Cognitive)
  - BERG balance scale

- Training parameters
  - Peak HR & duration
  - Peak RPE & duration

- Stepping Activity

**Analysis**

Out, liar!

Your theory is wrong!
Research Related Questions

- Did demographic, impairment measures, and training parameters contribute to mobility-related outcomes?
- Independent contributions of stepping to mobility outcomes?
- Adverse consequences of augmented stepping activity?
- Primary determinants (variables) that best predict walking without physical assistance at DC?
- Primary determinants of DC to home?

Data Analysis

- Correlation analysis
  - Baseline impairments, demographics
  - Training – amount of PT, stepping activity
  - Outcomes – 6MWT, BBS, FIM scores
- Relative contributions of independent predictors to outcomes
  - Primary predictors 6MWT/BBS improvements? (stepwise linear regressions)
  - Primary predictors of assistance at DC, location of DC? (conditional logistic regression)

Agenda

- Theory and rationale
  - Walking recovery
  - Current practice patterns
  - Goals of project
- Implementation Methods
  - Structure and planning
  - Data analysis
- Results
  - Characteristics of sample
  - Outcome assessment changes
  - Correlation and regression analyses

Demographics & Baseline Characteristics

- Nonparametric data distribution – median, interquartile range
- Demographics
  - N = 201
  - Age: 64 (55-75)
  - Days post-stroke: 13 (8-25)
- Baseline Characteristics
  - FIM level: 1 (1-2)
  - BERG balance: 5 (4-22)
### Results - PT Interventions

<table>
<thead>
<tr>
<th>Training characteristics</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>length of stay (days)</td>
<td>28 (21-35; 201)</td>
</tr>
<tr>
<td>PT sessions/day</td>
<td>1.1 (0.94-1.3; 201)</td>
</tr>
<tr>
<td>PT min/session (min)</td>
<td>54 (52-56; 201)</td>
</tr>
<tr>
<td>peak HR/session (% max)</td>
<td>70 (62-76; 161)</td>
</tr>
<tr>
<td>peak RPE/session</td>
<td>16 (15-17; 160)</td>
</tr>
<tr>
<td>mean % session RPE &gt; 13</td>
<td>38 (31-44; 157)</td>
</tr>
<tr>
<td>daily stepping (steps/day)</td>
<td>1516 (594-2645; 201)</td>
</tr>
</tbody>
</table>

### Results - Stepping Activity

#### Daily Stepping Activity During Length of Stay

- **1516 steps**

#### Adverse Events

- **7 Cardiovascular events**
- **7 Non-cardiovascular events requiring discharge**
- **10 returned to inpatient – all data utilized**
- Percentage consistent with normative values (Langborne et al., 2000) and echoes recent meta-analyses (Pang et al., 2013)
Outcomes

- Delivered more steps than observational reports demonstrate (1516 vs 249; Lang et al 2009)
- Achieved higher intensity than previous inpatient observational studies (38% vs 5% duration of PT; MacKay-Lyons 2002)
- Performed in individuals with severe deficits
- Focused delivery of high-intensity stepping resulted in no increased risk of adverse events

Results

Outcome measures | Admission | Discharge | N (%)
--- | --- | --- | ---
6 min walk test (m) | 15 (3.0-67) | 146 (44-281) | 166 (83)
6 min level of assistance | 3 (2-4) | 5 (4-5) | 166 (83)
Berg Balance Scale | 5 (4-22) | 34 (13-46) | 173 (86)
FIM-Bed mobility | 2 (1-3) | 5 (3-5) | 201 (100)
FIM-Toilet transfers | 2 (1-3) | 4 (3-5) | 201 (100)
FIM-Walk | 1 (1-2) | 4 (3-5) | 201 (100)

All p = <0.0001

Correlations with DC 6MWT

- Demographics and impairments relate to mobility outcomes
  - Admit Berg Balance Scale: 0.62*
  - Admit 6MWT: 0.64*
  - Paretic leg strength: 0.53*
  - Duration post stroke: - 0.26*
  - Age: -0.07
- Training characteristics
  - Steps/day: 0.87*
  - Pt minutes/day: 0.34*
  - Average HR % max: 0.39*
  - Length of stay: -0.31*

Results - Correlations

![Correlation Plot](image)
Results - Correlations

- Primary predictors for DC 6MWT and DC BBS
  - DC 6MWT = 59[steps/1000/day] + 0.32 [admission 6MWT] – 1.6 [age] – 14.7 [paretic limb strength] + 109
  - DC BBS = 6.0[steps/1000/day] + 0.28 [admission BBS] + 4.7 [cortical] – 0.09 [duration] + 16

- Hierarchical linear regression – steps/day independently accounts for 20% of variance of DC 6MWT (r² = 0.20)

- Other outcomes
  - Steps/day was primary predictor for Δ6MWT, DC and ΔBBS (independent r²=10-31% of variance)
  - DC FIM - walking, - toilet transfers, - bed mobility

Results - Stepping and Initial LoA

<table>
<thead>
<tr>
<th>Admit LOA</th>
<th>Median steps/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total A</td>
<td>589.8 (383-1662)</td>
</tr>
<tr>
<td>Max A</td>
<td>816.1 (486-1540)</td>
</tr>
<tr>
<td>Mod A</td>
<td>1587.3 (961-2436)</td>
</tr>
<tr>
<td>Min A</td>
<td>2266.1 (1438-2968)</td>
</tr>
<tr>
<td>CGA or better</td>
<td>3280.3 (2151-4342)</td>
</tr>
<tr>
<td>Mod I</td>
<td>N/A</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Discharge LOA</th>
<th>Median steps/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total A</td>
<td>212 (145-340)</td>
</tr>
<tr>
<td>Max A</td>
<td>482 (429-506)</td>
</tr>
<tr>
<td>Mod A</td>
<td>419 (369-615)</td>
</tr>
<tr>
<td>Min A</td>
<td>1016 (539-2010)</td>
</tr>
<tr>
<td>CGA or better</td>
<td>2053 (1293-2880)</td>
</tr>
<tr>
<td>≥Mod I</td>
<td>4471 (3253-4619)</td>
</tr>
</tbody>
</table>

Cut-off: ~1000 steps
Sensitivity 56% Specificity 85%

Cut-off: ~1000 steps
Sensitivity 87% Specificity 90%
What the heck does that mean?

Functional Level

Steps/day

Conditional logistic regression

Admit BERG

CGA or better (LoA ≥ 5)

Steps/day

Conditional logistic regression

CGA or better (LoA ≥ 5)

DC Home vs. Other

Conditional logistic regression

Admit BERG

CGA or better (LoA ≥ 5)

Steps/day

DC Home vs. Other
Results

- The amount of steps could affect your patient’s ability to walk without assist
- This could be related to whether or not they can go home

Summary

- Stepping - 1516 steps/days, 5-6 x greater than published reports (Lang et al, 2009; Scrivner et al, 2012)
- Adverse events consistent with normative data (Langhorne et al, 2000)
- Correlations echo other data (Moore et al 2010, Holleran et al, 2014) with stepping demonstrating strongest correlation to outcomes
- Stepping activity possible predictor of LoA at discharge and discharge location (home vs other facility)
- Effects on both locomotor and non-locomotor outcomes

Limitations and Future Direction

- Limitations
  - No control group
  - No long-term follow up

- Future Directions
  - Assess comparative effectiveness