Pushing the Limits: Novel Balance Approaches in Aging and Stroke

Combined Sections Meeting, February 18, 2015, Anaheim, CA

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Objectives for the Session

- Describe the current status of balance assessment and intervention
- Describe the use of neural probes and biomechanical methods to assess balance control
- Discuss novel training approaches to improve balance control, biomechanical and functional outcomes for the elderly and post stroke populations
- Describe potential ways to translate research findings into clinical practice
Session Schedule

• Lateral Instability and Falls in Aging     Rogers

• Integration of Reaching and Postural Control      McCombe Waller

• Reactive and Voluntary Stepping in the Elderly     Savin

• Reactive and Voluntary Stepping Post Stroke     Gray

• Question and Answers
Advances in Balance Assessments & Interventions

- Protective stepping
- Muscle composition & balance
- Assessing cortical & brainstem mechanisms of balance
- Role of startle
- Vulnerability to lateral instability
- High-intensity balance perturbation training
- Integrated arm & balance training after stroke
- Functional task training vs. balance perturbation training

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Lateral Instability and Falls in Aging

Mark W. Rogers PT, PhD, FAPTA

University of Maryland, School of Medicine, Department of Physical Therapy and Rehabilitation Science
Protective Stepping

• Aging changes in balance and gait are associated with neuromechanical impairments consistently linked with falls (Tinetti et al., 1988; Studenski et al., 1991; Guralnik et al., 1995).

• Stepping is normally a pervasive balance stabilizing action for physiological protection against falls.

• Induced reactively by external perturbations to balance or executed voluntarily in anticipation against a fall.

• Older people have an increased reliance on stepping rather than other actions to maintain balance (Luchies et al., 1994; McIlroy & Maki, 1996; Pai et al., 1998; Mille et al., 2003).
Lateral Instability is Accentuated with Aging

• **> M-L sway:** associated with past & future falls (Maki et al., 1994; Lord et al., 1999)

• **Forward perturbations:** step more laterally with multiple side-steps & fallers > lateral body motion (McIlroy & Maki, 1996; Rogers et al., 2001)

• **Lateral perturbations:** more recovery steps & inter-limb collisions (Maki et al., 2000; Mille et al., 2005; 2013)

• **Obstacle crossing:** > lateral body motion (Chou et al., 2002; McFadyen et al., 2002)

• **Gait:** > stride-width with fear of falling & future falls (Maki, 1997)

• **Video surveillance:** living community highlights sideways falls (Robinovitch et al., 2013)
**Balance & Falls in Aging Research Agenda**

1) To determine protective stepping patterns for multidirectional perturbations of standing balance in aging.

2) To determine the effects of aging on: i) hip joint AB-AD torque capacity; and ii) hip kinetic profiles for lateral stability.

3) To relate key M-L stepping and neuromechanical variables to the prospective risk of falls.

4) To design and assess the effectiveness of therapeutic interventions targeting lateral balance function to prevent falls.
Hip Abductor-Adductor Control is the Predominant Neuromechanical Contributor to Lateral Balance Stability

Representation of the theoretical joint moment control to move the COP to the left: Horizontal arrows under the feet indicate the maximum COP movement that can be produced by the individual joint moments. (Adapted from Rietdyk et al.,1999)
Lateral Stepping Strategies
(Mille et al., 2005)

Two major stepping strategies when lateral balance is perturbed.
Is there a Directional Vulnerability to Lateral Instability and Falls with Ageing?  
(Rogers & Mille, 2003; Mille et al., 2013)

Young (n=26) 23.5 Yrs.
Older NF (n=30) 72.5 Yrs.
Older FL (n=19) 75.2 Yrs.

• 12 perturbation directions at 30 degree intervals
• 5 randomly applied waist-pulls/direction
• Pulls at 22.5 cm; 31.5 cm/s; 900 cm/s
• Kinematic and kinetic recordings
Number of Steps Differ with Age & Fall Risk Especially in Lateral Directions (Mille et al., 2013)

A

1 Steps

2 Steps

3 Steps or more

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Inter-Limb Collisions Increase with Age & Fall Risk in the Lateral Direction  
(Mille et al., 2013)

• Older subjects 80 collisions vs. 4 for Young: 86.25% involved perturbations approaching the frontal plane(0° ±30° or 180° ±30°) with 53.75% of these for purely lateral perturbations.

• Fallers accounted for 57.5% of the collisions.
First Step Type & Adaptive Control Differ in Lateral Direction with Age & Fall Risk

(Mille et al., 2013)

**A**

- **Step duration (ms)**
  - Young: n=17
  - Non-Fallers: n=23
  - Fallers: n=14

**B**

- **Step clearance (%BH)**

**C**

- **Step length (%BH)**

**Legend:**
- LS= Loaded limb side-steps
- US= Unloaded limb steps

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Multiple Lateral Recovery Steps & First Step Length Differentiate Older Fallers from Nonfallers

*K-W: p < 0.018

Multiple Lateral Recovery Steps & First Step Length Differentiate Older Fallers from Nonfallers

% Multiple Steps

Global Step Length (cm)

Fallers (n=19)
NonFallers (n=32)

Fallers
NonFallers

M-L Stepping Responses of Older Adults

M-L Stepping Responses of Older Adults

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Hip AB-AD Isokinetic Joint Torques (60/s) are Reduced with Age

(Johnson et al., 2003)

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# Predictors of Fall Risk after One-year Prospective Falls Reporting

(Hilliard Johnson, et al, 2008)

<table>
<thead>
<tr>
<th>Predictor Variable</th>
<th>Odds ratio</th>
<th>95 % CI</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Multiple M-L Steps</td>
<td>6.16</td>
<td>1.74 - 21.84</td>
<td>0.005</td>
</tr>
<tr>
<td>M-L Step Length</td>
<td>2.03</td>
<td>1.23 - 3.34</td>
<td>0.006</td>
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<tr>
<td>Peak Isokinetic Hip AB Torque</td>
<td>1.79</td>
<td>1.13 - 2.82</td>
<td>0.012</td>
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</tbody>
</table>

Sensitivity: 63% - 74%    Specificity: 66% - 77%
Gluteal Muscle Composition Differentiates Older Adult Fallers from Non-Fallers (Inacio et al., 2014)

Representative computed tomography (CT) scans from an older adult showing A) abdominal scan; B) hip scan; C) thigh scan. 1. Psoas; 2. Gluteus Medius/Minimus; 3. Gluteus Maximus; 4. Rectus Femoris; 5. Vastus Lateralis; 6. Hamstrings compartment; 7. Adductor Magnus/Longus.
Fallers Have Lower Muscle Attenuation (Density) Than Non-Fallers

(Inacio et al., 2014)

Comparisons (Mean ± SEM) * p < 0.05.

✓ Age, height, weight & BMI were not different between groups.
✓ Muscle CSA not different between groups for any muscle.
% IMAT Discriminates Between Older Adult Fallers & Non-Fallers Especially for Gluteal Muscles (Inacio et al. 2014)
Normalized peak isokinetic torque differed between the groups only for hip abduction > nonfallers (0.53 ± 0.02) than fallers (0.41 ± 0.03, p = 0.01).

Hip abduction torque positively associated with muscle attenuation (r = 0.53, p < 0.01) and inversely associated with gluteus medius/minimus % IMAT infiltration (r = −0.49, p < 0.01).

Increased IMAT in the proximal hip muscles, particularly the hip abductors, associated with increased gait variability and poorer balance.
Acute Improvements in Protective Stepping with Practice Training in Older Adults

(Yungher et al., 2012)

Pull Intensity Relative to Balance Tolerance Limit = BTL
**Intervention to Enhance Lateral Balance Function & Prevent Falls in Aging: Randomized Clinical Trial**

1. **Subject Recruitment & Telephone Screening**
   - Ineligible or Decline to Participate

2. **Eligible & Willing to Participate - Medical Screen**
   - Ineligible due to Medical Reasons

3. **Medically Eligible & Consent to Participate**

4. **Baseline Assessments of Induced Stepping Performance, Hip AB Strength, Clinical Assessments**

5. **Stratified Randomization of 160 Subjects (Low Fall Risk - High Fall Risk)**

6. **Induced Step Training (IST)**
7. **Hip AB Strength Training (HST)**
8. **Induced Step & Hip AB Strength Training (IST + HST)**
9. **Flexibility & Relaxation Exercises (SFR) (Control)**

   - 3 times/week for 12 weeks

10. **Immediate post-test and begin home maintenance exercise program & 12-month fall diary sent in to project coordinator monthly**

11. **3 month post-test**

12. **Complete 12-month fall follow-up**

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Integration of Postural Control and Goal Directed Upright Reaching in Patients with Chronic Stroke

Sandy McCombe Waller PT, PhD, NCS

University of Maryland, School of Medicine
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Rehabilitation Challenge

Many traditional rehabilitation approaches for the upper extremity post stroke focus only on the arm and fail to address the multifactorial problems that more fully contribute to overall disability.

Anticipatory postural adjustments (APAs) of the legs precede and accompany the goal directed arm movement, followed by responses that stabilize postural control and prevent falling.

Pai et al., 1994, Massion, 1992, Massion et al., 2004
Proposed Mechanisms Integration of Postural Control and Goal Directed Reaching

Primary Motor Cortex

Premotor Cortex

Cortico-cortical Tracts

Corticospinal Tract

Voluntary REACH

Primary Motor Cortex

Anticipatory Postural Adjustment Preceding Reach

Ponto-Medullary Junction

Corticoreticular Tract

Reticulospinal Tract

Anticipatory Postural Adjustment Accompanying Reach

Massion, 1992, Massion et al., 2004, Drew et al., 2004
Expected Events with Integrated Postural Responses (APA) and Goal Directed Movement (Reach)

- **Tonic soleus activity** is inhibited accompanied by TA burst that moves COP posteriorly.
- Force plate shows posterior displacement of COP.
- Soleus then bursts to move COP anteriorly as the hand/arm reaches forward to target.

Diagram showing:
- **Go Signal**
- **Soleus**
- **Tibialis Anterior**
- **COP**
- **Arm/Hand**
Loud Acoustic Stimulus as a Measurement of Movement Planning and Preparation

Classic Startle Response (At Rest)
• An unexpected loud stimulus (> 110 dB) evokes rapid, bilateral, involuntary, generalized, motor responses in eyes, neck, trunk, limbs
• The rapid latency (< 100ms) implies a subcortical pathway too fast for a conscious, voluntary, transcortical reaction
  Valls-Sole et al., 1995

StartReact Response (Prepared movements)
• The planned movement can be triggered by loud acoustic stimulus at a latency too fast to be a voluntary reaction time (80 to 100 ms).
• The “released movement” has the characteristics of the planned movt
• Permits assessment of movement preparation and planning

Valls-sole et al., 1999; Rothwell et al., 2002; Carlsen et al., 2004, 2010
Video of StartReact Response
Experimental Design

Prep Cue: Planning ------→ Go Cue: Reach Execution

Two responses are modulated planned/ prepared over the time course from Prep Cue to Movement Execution
1) anticipatory postural responses
2) goal directed reach

S = timing relative to “GO” cue, -1500, -1000, -500, -200, 0 ms (Startle Induced Response)

Graphics courtesy of Don Yungher
Prep Cue: “Get ready to move”

Go Cue: “Reach for the ball as quickly as you can”

LAS Burst at -1500, -1000, -500, -200, 0, ms relative to the “go” cue
<table>
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<tr>
<th>Sub #</th>
<th>Age (yrs)</th>
<th>Gender</th>
<th>Type of Stroke and Side</th>
<th>Hand Dom</th>
<th>Wolf Time (sec)</th>
<th>Wolf Funct.</th>
<th>UE Fugl Meyer</th>
<th>Baseline Balance Scores</th>
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<tr>
<td>01</td>
<td>63*</td>
<td>M</td>
<td>L Cortical /SCWM</td>
<td>R</td>
<td>68.13</td>
<td>2.30</td>
<td>36</td>
<td>53 90</td>
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<td>L Cortical</td>
<td>R</td>
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<td>1.35</td>
<td>18</td>
<td>40 65</td>
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<td>76</td>
<td>F</td>
<td>R Cortical</td>
<td>R</td>
<td>17.15</td>
<td>2.13</td>
<td>49</td>
<td>30 70</td>
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<td>L Cortical/SCWM</td>
<td>R</td>
<td>69.88</td>
<td>1.26</td>
<td>20</td>
<td>30 70</td>
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<td>05</td>
<td>55*</td>
<td>M</td>
<td>L Cortical/SCWM</td>
<td>R</td>
<td>72.85</td>
<td>1.61</td>
<td>23</td>
<td>37 50</td>
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<tr>
<td>06</td>
<td>64*</td>
<td>F</td>
<td>L Cortical/SCWM</td>
<td>R</td>
<td>62.25</td>
<td>1.5</td>
<td>22</td>
<td>30 70</td>
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<tr>
<td>07</td>
<td>67</td>
<td>M</td>
<td>R Cortical</td>
<td>R</td>
<td>36.35</td>
<td>2.17</td>
<td>36</td>
<td>40 70</td>
</tr>
<tr>
<td>08</td>
<td>61</td>
<td>F</td>
<td>R Cortical /SCWM</td>
<td>R</td>
<td>26.84</td>
<td>2.68</td>
<td>59</td>
<td>40 72</td>
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<tr>
<td>09</td>
<td>50*</td>
<td>F</td>
<td>L Cortical</td>
<td>R</td>
<td>68.32</td>
<td>2.5</td>
<td>38</td>
<td>53 87</td>
</tr>
<tr>
<td>10</td>
<td>55*</td>
<td>F</td>
<td>R Cortical</td>
<td>L</td>
<td>64.82</td>
<td>1.48</td>
<td>36</td>
<td>55 90</td>
</tr>
</tbody>
</table>

SCWM-subcortical white matter; Dom-dominance; BERG- Berg Balance Scale; ABC-Activities Balance Confidence Scale
Measures/ Outcomes

Functional outcomes measures for the UE

Anticipatory Postural Response
  Center of Pressure (CoP) Onset
  EMG Onset Anterior Tibialis, Soleus

Reach Response
  Onset of forward motion of hand marker
  EMG Onset Ant Deltoids, Middle Deltoids, Biceps

Primary Outcome
  • Presence of StartReact Response: Measure of motor planning
  • Upper extremity function

Secondary Outcomes:
  • Posterior excursion of CoP
  • Lag between CoP onset and hand forward motion: measure of temporal coordination
  • EMG onset for ankle muscles coordination of postural response
Arm Training in Standing with Implicit Balance Training

3x’s week for 6 weeks; one hour sessions

All cues related to the arm task with NO explicit cueing of balance/weight shift
StartReact Responses Largely Absent in Individuals With Stroke: Motor Planning Deficits

Startle induced responses were seen in 70% of trials with controls but only 14% of trials of stroke subjects.
Delayed and Diminished APA in Stroke

**Posterior Displacement of CoP Onset (ms)**

- Stroke
- Control

**Posterior Displacement of CoP (cm)**

- Stroke
- Control

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Delayed Reach Onset Further Delayed by LAS

Reach Onset of Hand Forward Displacement (ms)

Stroke

Control

Lag Between CoP Onset & Reach Onset (ms)

Stroke

Control

Impaired Temporal Coordination of APA-Reach Sequence
Post Training Results

**Posterior Displacement of CoP (cm)**

- Stroke PRE
- Stroke Post
- Control

**Lag Between CoP Onset & Reach Onset (ms)**

- Stroke Pre
- Stroke Post
- Control

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## Upper Extremity Outcomes

<table>
<thead>
<tr>
<th>Functional Outcome</th>
<th>PRE</th>
<th>POST</th>
<th>Mean Absolute Change</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fugl Meyer (UE)</strong></td>
<td>32.11±13</td>
<td>38.55±13</td>
<td>6.44 points</td>
<td>p&lt;.01*</td>
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<tr>
<td><strong>Wolf Time (sec): All items</strong></td>
<td>75.12±20.37</td>
<td>65.25±18.43</td>
<td>9.87 secs</td>
<td>p&lt;.05*</td>
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<tr>
<td><strong>Wolf Time (sec): Only tasks completed by all subjects</strong></td>
<td>10.28±6.33</td>
<td>6.31±3.43</td>
<td>3.97 secs</td>
<td>p&lt;.05*</td>
</tr>
<tr>
<td><strong>Wolf Weight (lbs)</strong></td>
<td>5.25±3.45</td>
<td>8.75±4.65</td>
<td>3.5 lbs</td>
<td>p&lt;.06 (trend)</td>
</tr>
<tr>
<td><strong>UMAQs</strong></td>
<td>17±5.2</td>
<td>24±7.4</td>
<td>7 points</td>
<td>p&lt;.05*</td>
</tr>
<tr>
<td><strong>Box and Blocks</strong></td>
<td>14±17</td>
<td>19±19</td>
<td>5 blocks</td>
<td>p=.23</td>
</tr>
</tbody>
</table>
Summary of Results

Compared to Age-matched Healthy Controls:

- Subjects with stroke have deficits in the planning/preparation of a forward reach as evidenced by a lack of StartReact Responses.

- The impact on movement execution includes:
  - Later onsets of anticipatory postural responses (APA) compared to controls.
  - Reduced posterior displacement of the CoP.
  - Great lag between the postural response and initiation of reaching.
  - Later onsets of Reach.
Arm Training in Standing resulted in:

- Gains in upper extremity function on standard post stroke functional outcome measures
- Improved planning and preparation during a forward reach (StartReact responses)
- Movement execution gains including:
  - Earlier postural responses
  - Increased posterior displacement of CoP
  - Reduced lag between postural response and reach
Conclusions

Upper extremity function in standing involves postural responses that are integrated with goal directed movement of the arms

After stroke interactions between the two systems are impaired

Arm training in standing may be one approach to address training of both UE function while also implicitly training postural control (the natural way in which these two systems work)
Reactive and Voluntary Stepping Assessment and Intervention in the Elderly

Doug Savin, PT, PhD

University of Maryland, School of Medicine, Department of Physical Therapy and Rehabilitation Science
How do People Fall?

- ~15% due to external event that would cause most to fall

- ~15% due to a single identifiable cause

- ~70% due to multiple factors
  (La Grow et al., 2006)

- Most frequent cause of falls: Slips and trips while walking
  (Downton and Andrews, 1991; Li et al., 2006)
Current Clinical Standard of Care Lacking

• Most balance/fall interventions emphasize voluntary, pre-planned movements

• Balance/fall interventions effective 17% - 35% of the time

• Lack of training for primary cause of falls: unexpected balance challenges
Do We Adequately Train?

• Falls by their nature are primarily unexpected, suggesting the response contains a reflexive component

• Reflexes slow with aging (Chung et al., 2005)

• How well do we address delayed reflexes/reactions in fall-risk older adults?
Control of Balance

• Balance control during intended movements
  – Cortical and subcortical mechanisms (Yakovenko & Drew, 2009; Caeyenberghs et al., 2010)

• Balance control during unpredictable challenges
  – Brainstem (PMRF) and spinal cord mechanisms (Schepens, Stapley & Drew, 2008)
Reactive Balance Training

- Slip from sit to stand (Pai et al., 2003, 2010)
  - Slip training may inoculate against falls in elderly

- During walking (Wang et al., 2011; Pai et al., 2014)
  - Gait-slip training can decrease prospective falls

- Sudden release from forward lean (Mansfield et al., 2011)
  - Decreased fall risk in post-stroke hemiparesis

- Unexpected waist pulls (Yungher et al., 2012)
  - Decreased number of recovery steps with training

- Motorized treadmill (Grabiner et al., 2012; Patel & Bhatt 2015)
  - Increased stability largely due to reactive improvements
Pilot Training Balance Reactions

• Compare traditional with reactive training:
  – Control of balance during internally generated movements (Volitional Balance Training - VBT)
  – Control of balance during unexpected movements (Reactive Balance Training – RBT)

• SA 1: Determine if each balance intervention improves balance control in fall-risk older adults.

• SA 2: Determine between group differences in response to intervention.

• Overall Hypotheses:
  – Different neuromotor, biomechanical, and behavioral responses to VBT versus RBT in fall-risk older adults.
Study Design

• Enroll 14 elderly (60 – 85 y/o) fall risk participants
  – ≥ 1 fall in the past year
  – No significant neurological or orthopedic Hx
• Randomly assign to progressive volitional or reactive balance training program
  – Trainings dose matched (2x/wk X 8 wks)
• Pre/post clinical measures of balance performance
  – Berg Balance Scale
  – Falls Efficacy Scale
  – 5 Item Physiological Profile Assessment
• Pre/post laboratory tests corresponding to a VBD & RBD
  – RBD: Random waist-pull perturbations
  – VBD: Standing Forward Reach
Waist Pull to Induce Stepping

• Can deliver unexpected balance perturbation
  – M/L and A/P depending on participant orientation

• Outcomes include:
  – Length of first recovery step
  – Step type (cross forward, cross back, medial, side)
  – Percentage of challenges requiring multiple recovery steps
Predictive Control of Balance

Standing Reach Test: Reaching to a target following a visual cue

- Excursion of net COP
- Relationship of net COP excursion to BOS
- Ankle co-contraction index
Volitional Balance Training

• Progressive, active exercises designed to challenge predictive control of balance
  – Gait
    • Tandem forward and backward, braiding right and left
  – Dynamic Training
    • Reaching (within available ROM) right/left, high/low
    • Standing leg exercises: hip flexion, extension, abduction
    • Alternating touch to step/stool
• Duration: 45 – 50 minutes per session
Reactive Balance Training

- Progressive, randomized support surface perturbations designed to challenge reactive balance control
  - ActiveStep© Treadmill
    - Anterior/posterior and medial/lateral perturbations
    - Magnitude of perturbations progressive
    - Direction and magnitude randomized
- Duration 45 – 50 minutes
RBT Increases First Recovery Step Length
Participants Generally Take Fewer Recovery Steps Post-Training
RBT May Decrease Falls Prospectively

*1 or more non-study related falls during training

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Reactive Training Increases COP Excursion

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Conclusions

• Reactive balance training:
  – Improves overall balance control
  – Decreases fall risk
  – Is well tolerated

• Translation to clinical practice
  – Lean and release
  – Therapist delivered unexpected challenges
  – Motorized treadmill (ActiveStep)

• Future directions
  – Combine reactive and volitional training
  – Low-cost, reactive balance community intervention
Reactive Step Training in Chronic Stroke

Vicki Gray PT, PhD

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Introduction

- Sensorimotor impairments from the stroke impact ability to recover from a loss of balance, whether movement is voluntary or from an external force
- Falls:
  - 73% in first 6 months after a stroke (Forster & Young, 1995), with more falls reported in the home and during walking and transferring (Forster and Young, 1995)
  - equal number of falls from internal and external factors (Mansfield et al., 2013)
Introduction

- Lateral instability:
  - Weight bearing asymmetry (Gray et al. 2012)
  - Reduced limits of stability on paretic side (Au-Yeung et al. 2003)
  - Reduced response from medial lateral muscles of the hip (Kirker et al. 2000)
Stepping after stroke

What we know about impairments in stepping after stroke:

- Steps initiated voluntarily are slow and the muscle activity is altered (Gray et al. 2012)
- Steps from external perturbations are initiated more frequently by the paretic leg (Lakhani et al., 2011; Martinez et al., 2011)
Preliminary Study

- The efficacy of reactive step training on balance and falls in chronic stroke.
Methods: Subjects

- > 50 years with hemiparesis from a stroke >6 months post stroke, able to stand unsupported for 5 minutes and can ambulate 10 meters with or without a gait aid
- Excluded if cardiac, respiratory or neuromuscular conditions precluding participation or health conditions impacting ability to walk beyond effects of stroke
Methods: Outcomes

Step Testing
1. Lateral perturbations: lateral waist pull 24 randomly applied (2 sides X 3 trials X 4 magnitudes)
2. Voluntary Steps: choice reaction in response to a light cue, 10 lateral steps (2 sides X 5 trials)

Outcome measures: step count, step type, step length, step initiation time

Figure 1: Experimental set up of the lateral waist pull perturbation system and harness support system.
Methods: Outcomes

Clinical Outcome Measures
- Activities Specific Balance Confidence Scale
- Community Balance & Mobility Scale
- Chedoke McMaster Stroke Assessment (leg+foot)

Testing:
- Baseline, post training, retention (1 month after post test)

Falls
- 6 months pre training vs 6 months post training
Methods: Intervention

- 1 hour 3 times per week for 6 weeks (18 sessions)
- Protocol
  - used the Active Step
  - max. of 80 steps
  - 80% lateral perturbations, 20% forward/backward
  - perturbations velocity was increased
  - training progressed based on participant's ability and tolerance;
  - emphasized use of the paretic leg
## Results: Demographics

<table>
<thead>
<tr>
<th></th>
<th>Gender</th>
<th>Age</th>
<th>Yrs post stroke</th>
<th>Paresis</th>
<th>Paretic Cutaneous Sensation</th>
<th>CMSA (/14)</th>
<th>ABC</th>
<th>CBM</th>
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<tr>
<td>1</td>
<td>M</td>
<td>72</td>
<td>11.8</td>
<td>Right</td>
<td>diminished light touch</td>
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<td>88</td>
<td>56</td>
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<td>diminished protective sensation</td>
<td>8</td>
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<tr>
<td>3</td>
<td>M</td>
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<td>6.2</td>
<td>Right</td>
<td>deep pressure sensation only</td>
<td>6</td>
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<td>4</td>
<td>F</td>
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<td>8.0</td>
<td>Left</td>
<td>deep pressure sensation only</td>
<td>5</td>
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<td>5</td>
<td>M</td>
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<td>5.4</td>
<td>Left</td>
<td>normal</td>
<td>9</td>
<td>73</td>
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<td>6</td>
<td>M</td>
<td>54</td>
<td>11.9</td>
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<td>diminished light touch</td>
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<td>76</td>
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</table>

CMSA, Chedoke McMaster Stroke Assessment; ABC, Activities Balance Confidence Scale; CBM, Community Balance and Mobility Scale

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Type of Recovery Steps

Passive loaded
Passive unloaded

Lateral  Crossover  Medial
Step Type

Paretic Side Pull

Non-paretic Side Pull

Percentage of trials

Step Type

Medial  | Lateral  | Crossover

Medial  | Lateral  | Crossover

Base     | Post     | Retention

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Number of recovery steps

Paretic Side Pull

Non-paretic Side Pull

Percentage of trials

Number of recovery steps

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Step length and initiation time

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Motor Recovery: Chedoke McMaster Stroke Assessment

Leg Score

<table>
<thead>
<tr>
<th></th>
<th>Base</th>
<th>Post</th>
<th>Retention</th>
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<tbody>
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<td>Score</td>
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Foot Score

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</table>

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Results: Confidence & Balance

Activity Balance Confidence Scale

Community Balance & Mobility Scale

Base | Post | Retention

Base | Post | Retention
Results: Falls

- 6 months Pre training
- 6 months Post training

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Discussion

• All subjects except one was able to use their paretic leg at least 50% of the time during training
• Step Type: medial steps decreased and lateral steps increased (both directions)
• Step Number: single steps increased, with reduced 3+ steps
Discussion

- CMSA: trend for improvements in foot scale
- Community Balance & Mobility Scale: improved
- ABC: no significant
- Falls: trend for a reduction in the number of falls
Conclusion

• Reactive training
  – feasible for improving the use of the paretic limb
  – Improve motor recovery
  – Improve balance
  – Reduce the number of falls
Conclusions

• Reactive balance training:
  – Improves overall balance control
  – Decreases fall risk
  – Is well tolerated

• Translation to clinical practice
  – Lean and release
  – Therapist delivered unexpected challenges
  – Motorized treadmill (ActiveStep)

• Future directions
  – Combine reactive and volitional training
  – Low-cost, reactive balance community intervention


References for Dr. Gray


