Gait and Cognition in Older Adults

Can impairments in walking and thinking be linked?
In our younger years, walking and thinking are automatic....
Are walking and thinking linked, and in what ways?

How do we keep these processes automatic in our older years?
The need....

Lustig, 2009

• Aging is associated with cognitive changes that can limit functional capacity
• Many people are reaching the age at which those changes will become a concern
Population 65+ by Age: 1900-2050
Source: US Bureau of the Census
Therapist to patient: “What does normal walking look like?”

“Automatic”
“Smooth”
“Reciprocal”
“Speed about 1.2m/s”
“Sufficient endurance”
“Pain-free”
“Independent”
Review of Normal Gait Cycle
“Normal” or not?
“Normal” or not?
### System contributions to gait

<table>
<thead>
<tr>
<th>Musculoskeletal</th>
<th>Neuromotor</th>
</tr>
</thead>
<tbody>
<tr>
<td>ROM</td>
<td>Motor control – central and peripheral contributions</td>
</tr>
<tr>
<td>Strength</td>
<td></td>
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<td></td>
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<tr>
<td>Cardiopulmonary</td>
<td>Neurocognitive</td>
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<tr>
<td>Sufficient endurance</td>
<td>Central processing</td>
</tr>
<tr>
<td>Normal responses to</td>
<td>Response to challenges</td>
</tr>
<tr>
<td>exercise challenges</td>
<td></td>
</tr>
</tbody>
</table>
Recent Evidence – Linking Thinking and Walking

Complex walking problems (Ferrucci et al, 2001)

• Multiple systems contribute to walking:
  – nervous, musculoskeletal, cardiopulmonary
  – integrated, coordinated for efficient mobility
• Age-related, progressive walking disability
  – system redundancy for gait;
  – compensation for deficits in one by greater function of another
Recent Evidence – Linking Thinking and Walking

The brain, motor skill and gait

- Brain areas associated with age-related changes in gait overlap brain areas that subserve the selection, execution and learning of goal-directed motor skills (VanSwearingen et al, 2010; Baezner et al, 2008; Seidler et al, 2008; Rosano et al, 2007; Baloh et al, 1995;)

- Learning and using motor routines is a primary function of the basal ganglia linked with sensorimotor cortex, ‘cortical-striatal circuits’ (Doyon et al 2009, 2010; Krietzer et al 2008)
Recent Evidence – Linking Thinking and Walking

- Changes in executive function measures...
  - Are associated with brain white and grey matter volumes. (Madden et al, 2004; Longstreth et al, 1998)
  - Contribute to stance time variability and curved path walking (Brach et al, 2006; Hess et al, 2009 [press]; Robertson et al, 2009)


- Pattern of gait changes with tasks, training and perception (Schneider & Capaday, 2003; Capaday, 2002)
Recent Evidence – Linking Thinking and Walking

Brain grey matter volume and intervention outcomes

- Brain areas associated with age-related changes in gait overlap brain areas that subserve the selection, execution and adaptation (learning) of motor programs for well-learned, goal-directed motor skills, such as walking. (Baloh et al, 1995; Baezner et al, 2008; Rosano et al, 2007, Seidler et al, 2008)

- brain grey matter volume in regions related to task-related motor sequence performance influenced skill acquisition and response to different training strategies in young adults. (Erickson et al, 2010)
Recent Evidence – Linking Thinking and Walking

Brain and clinical manifestations of subsyndromal gait and cognitive problems

- Subsyndromal gait and cognitive problems co-occur more often than by chance among older adults.

- The risk of disability and poor health-related quality of life is greater with both gait and cognitive problems, while good mobility or cognition can serve as a resource and reduce or delay disability or health risks. (Inouye et al, 2007; Tas et al, 2007)

- Some brain regions have roles in both gait and cognition, and interventions for one problem can impact the other – exercise improves gait and cognition. (Wood et al, 2005; Fitzpatrick et al, 2007; Colocombe et al, 2007)
Recent Evidence – Linking Thinking and Walking

Brain and clinical manifestations of subsyndromal gait and cognitive problems

• Co-occurring subsyndromal gait and cognitive problems compared to gait alone, was associated with lower region-specific grey matter volumes and poorer physical function and activity.

• Lower grey matter volume in brain regions related to motor planning and spatial navigation may underlie the poorer physical function and activity in older adults with subsyndromal gait and cognitive problems compared to those with slow gait alone.

(VanSwearingen et al, 2010 Gait & Mental Function, abstract)
Biomechanical Factors
- Increased Trunk Flexion
- Reduced Hip Extension
- Reduced push-off

Motor Control Factors
- Generalized muscle activation
- Diminished Stepping Signal
- Asynchrony of limbs

Brain Processing

Gait Dysfunction
- Increased variability
- Decreased speed

Decreased Walking Confidence

Inability to Adapt to a challenge

Increased Energy Cost of Walking

Decreased Physical Activity

VanSwearingen, 2011
Informing Fall and Fear Reduction Interventions: Gait, Physical Function, Cognitive Function and White Matter Disease by Falls and Fear of Falling Status

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Jennifer Brach, PhD, PT, David Wert, MPT, Jessie VanSwearingen, PhD, PT

School of Health and Rehabilitation Sciences
Department of Physical Therapy
RESEARCH QUESTION:

Does gait, physical function cognitive function and brain burden differ by combined falls and FOF status?

How might these differences inform our interventions?
METHODS

Subjects:

50 older adults with slow and variable gait:

• Gait speed between .6m/s and 1.0m/s
• Step length coefficient of variation (CV) >4.5% or step width CV <7% or >30%
• Participated in a RCT of interventions to improve gait.
Methods

Measures:

• Fear of Falling (FOF)
• Fall Status
• Gait speed (m/s) (Walsh, 1995; Brach, 2001)
• Survey of Activities and Fear of falling in the Elderly (SAFFE): activity restriction sub-scale (Lachman, 2003)
• Gait Efficacy Scale (GES) (Rosengren, et al, 1998)
• Late Life Function and Disabilities Index (LLFDI) (Haley, 2002)
Measures (cont.)

- **Cognitive Function**
  
  Basic
  
  Mini Mental State Examination (MMSE) (Folstein, 1997)

  Executive function
  
  Trail-Making B (Trails B) (Reitan, 1958)


- **White Matter Disease (WMD)**
  
  Structural MRI of the Brain – graded as 1-3, higher grade = worse disease (Fazekas, et al 1987)
Methods

Data Analysis

• Gait, physical function, cognitive function and WMD across groups defined by combinations of falls and fear of falling status analyzed using one-way ANOVA

• Post-hoc tests for between group comparisons
## RESULTS

### Participant Characteristics

<table>
<thead>
<tr>
<th>Measure</th>
<th>Mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, years</td>
<td>76.78 (5.40)</td>
</tr>
<tr>
<td>Gait Speed, m/s</td>
<td>.87 (.15)</td>
</tr>
<tr>
<td>Gait Variability, SD of stance time</td>
<td>.041 (.013)</td>
</tr>
<tr>
<td>Step Length, m</td>
<td>.52 (.08)</td>
</tr>
<tr>
<td>LLFDI total</td>
<td>54.40 (6.17)</td>
</tr>
<tr>
<td>LLFDI – BLE</td>
<td>63.20 (9.21)</td>
</tr>
<tr>
<td>LLFDI – ALE</td>
<td>44.27 (9.49)</td>
</tr>
<tr>
<td>GES</td>
<td>70.98 (16.98)</td>
</tr>
<tr>
<td>SAFFE</td>
<td>3.52 (2.66)</td>
</tr>
<tr>
<td>MMSE</td>
<td>28.66 (1.39)</td>
</tr>
<tr>
<td>TrailsB, s</td>
<td>136.58 (65.74)</td>
</tr>
<tr>
<td>DSST</td>
<td>45.12 (9.62)</td>
</tr>
<tr>
<td>WMD, 1-3 (median)</td>
<td>1.70 (.71)</td>
</tr>
</tbody>
</table>
# Gait by Falls and Fear of Falling Status

<table>
<thead>
<tr>
<th></th>
<th>No Falls</th>
<th></th>
<th>Falls</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No Fear</td>
<td>Fear</td>
<td>No Fear</td>
</tr>
<tr>
<td></td>
<td>N=10</td>
<td>N=17</td>
<td>N=7</td>
</tr>
<tr>
<td>Gait Speed (m/s)</td>
<td>.93 (.14)</td>
<td>.90 (.18)</td>
<td>.88 (.14)</td>
</tr>
<tr>
<td>Gait Variability</td>
<td>.049 (.016)</td>
<td>.035 (.011)</td>
<td>.044 (.013)</td>
</tr>
<tr>
<td>(SD of Stance Time)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Step Length (m)</td>
<td>.55 (.06)</td>
<td>.50 (.10)</td>
<td>.56 (.07)</td>
</tr>
</tbody>
</table>

Across group comparisons: gait variability $p < .05$
### Physical function by falls and fear of falling status

<table>
<thead>
<tr>
<th></th>
<th>No Falls</th>
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<tbody>
<tr>
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<td>No Fear N=10</td>
<td>Fear N=17</td>
</tr>
<tr>
<td></td>
<td>No Fear N=7</td>
<td>Fear N=16</td>
</tr>
<tr>
<td>LLFDI Total</td>
<td>56.58 (5.48)</td>
<td>54.31 (1.58)</td>
</tr>
<tr>
<td>LLFDI Basic LE Function</td>
<td>68.09 (9.63)</td>
<td>63.28 (10.20)</td>
</tr>
<tr>
<td>LLFDI Advanced LE Function</td>
<td>45.0 (7.67)</td>
<td>43.79 (9.29)</td>
</tr>
<tr>
<td>GES</td>
<td><strong>83.50 (11.07)</strong></td>
<td><strong>68.12 (19.65)</strong></td>
</tr>
<tr>
<td>SAFFE Restriction (# of activities)</td>
<td>1.5 (2.01)</td>
<td>3.35 (2.69)</td>
</tr>
</tbody>
</table>

- Across group comparisons: GES and SAFFE  \( p < .05 \)
- Post-hoc group comparisons: GES differs from 2 groups; \( p < .05 \)
### Cognition by falls and fear of falling status

<table>
<thead>
<tr>
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<th>No Falls</th>
<th>Falls</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>No Fear</td>
<td>Fear</td>
</tr>
<tr>
<td>N=10</td>
<td>29.10</td>
<td>28.76 (1.15)</td>
</tr>
<tr>
<td>N=17</td>
<td>27.29 (2.22)</td>
<td>28.88 (1.09)</td>
</tr>
<tr>
<td>MMSE</td>
<td>118.55(76.23)</td>
<td>147.44(72.74)</td>
</tr>
<tr>
<td>Trails B (s)</td>
<td>154.08(74.16)</td>
<td>128.66(47.17)</td>
</tr>
<tr>
<td>DSST (s)</td>
<td>45.20(7.52)</td>
<td>49.12(9.11)</td>
</tr>
<tr>
<td>WMD (1-3)</td>
<td>1.56 (.53)</td>
<td>1.80 (.68)</td>
</tr>
<tr>
<td></td>
<td>2.4 (.89)</td>
<td>1.43 (.65)</td>
</tr>
</tbody>
</table>

- **Across group comparisons:** MMSE and WMD  p< .05
- **Post-hoc group comparisons:** WMD differs from all 3 other groups; p<.05
- **Post-hoc group comparisons:** MMSE differs from 2 groups; p<.05

* +2 SD below age-adjusted norms
**DISCUSSION**

Those who have fallen, but do not report FOF, have lower scores on the MMSE and increased brain burden, as well as lower-than-age-adjusted norms on the Trails B and DSST.

Some aspect of cognitive decline may contribute to a lack of fear, i.e. poorer judgment

FOF may be more likely in those without cognitive decline or white matter disease because they:

• recognize the need to be more careful

• are still able to divide their attention between walking and potential distractors (Alexander and Hausdorff, 2008)
CLINICAL RELEVANCE

Among those older adults who have fallen but who do not report fear of falling:

• Lack of fear may be an early red flag for poor judgment or decline in cognition

• They may be mobility “risk-takers”

• They may need a different approach to fall prevention
  – Implicit strategies for gait and functional training
  – Reduce fall risks associated with the environment
Relevant Tests and Measures
Gait Speed

- Measure of mobility
- Timed-walk over a known distance (3-20 m)
- Test-retest reliability r > .89
- Sensitivity and Specificity for recurrent fall risk
  - Sensitivity = .72; Specificity = .74
  - Cutoff score = .56 m/s (VanSwearingen et al, 1998)
- Meaningful change (Perera et al, 2006)
  - Small = 0.04-0.06 m/s (best estimate 0.05 m/s)
  - Substantial = 0.08 – 0.14 m/s (best estimate .10 m/s)
Gait Speed and Outcomes

- Disability
- Nursing home placement
- Survival
- Falls
- Hospitalization
- Dementia
Meaningful Values of Gait Speed

Superior
≥ 1.4 m/s

1.4 m/s
> 1.3 m/s – extremely fit
1.2 to 1.3 m/s - usual adult gait speed
1.22 m/s - speed required to cross intersection in allotted time (guidelines for street development)
> 1.2 m/s - exceptional life expectancy
1.06 m/s – median speed to safely cross street in a larger community, population > 95,000
> 1.0 m/s – low risk for disability, health events and better survival

Normal
1.0 to 1.4 m/s

1.0 m/s
1.0 m/s - survival that is longer than expected for age and gender
0.98 m/s – median speed to safely cross street in a moderate community, population 10,000 to 40,000
0.80 m/s - predicted years of remaining life at the median life expectancy for most ages for each gender
0.80 m/s - community walker
0.74 m/s - median speed to safely cross street in a small community, population <10,000

Mildly Abnormal
0.6 to 1.0 m/s

0.60 m/s
0.60 m/s - poor health outcomes
0.56 m/s – related to a history of falls
0.50 m/s - mean gait speed in a hospital setting
<0.42 m/s – functional dependence
0.30 to 0.35 m/s - in-hospital independent walking
0.23 m/s - mean gait speed in geriatric rehabilitation setting
<0.15 m/s – institutionalization

Seriously Abnormal
<0.60 m/s

Values below 0.60 m/s indicate serious abnormalities

<0.42 m/s – functional dependence
0.30 to 0.35 m/s - in-hospital independent walking
0.23 m/s - mean gait speed in geriatric rehabilitation setting
<0.15 m/s – institutionalization

Hornyak et al, 2011
Curved Path Walking: Figure of 8 Walk

Clinical measure of walking skill

- time to complete, s
- # of steps to complete
- smoothness, 0-3
Screening for Cognitive Function

**MMSE**

**Picture 1 – Mini mental state examination (MMSE)**

| Temporal orientation (5 points) | What is the approximate time?  
| What day of the week is it?  
| What is the date today?  
| What is the month?  
| What is the year?  |
| Spatial orientation (5 points) | Where are we now?  
| What is this place?  
| In what district are we or what is the address here?  
| In which town are we?  
| In which state are we?  |
| Registration (3 points) | Repeat the following words: CAR, VASE, BRICK  
| Attention and calculation (5 points) | Subtract: 100-7 - 93-7 = 86-7 = 79-7 = 72-7 = 65  
| Remote memory (3 points) | Can you remember the 3 words you have just said?  
| Naming 2 objects (2 points) | Watch and pen  
| REPEAT (1 point) | "NO IFS, ANDS OR BUTS"  
| Stage command (3 points) | "Take this piece of paper with your right hand, fold it in half, and put it on the floor"  
| Writing a complete sentence (1 point) | Write a sentence that makes sense  
| Reading and obey (1 point) | Close your eyes  
| Copy the diagram (1 point) | Copy two pentagons with an intersection  

Screening for Cognitive Function
Montreal Cognitive Assessment (MOCA)

<table>
<thead>
<tr>
<th>VISUOSPATIAL / EXECUTIVE</th>
<th>NAME</th>
<th>Date of birth</th>
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<tbody>
<tr>
<td>Copy cube</td>
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<td></td>
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<tr>
<td>Draw clock (Ten past eleven)</td>
<td>(3 points)</td>
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<table>
<thead>
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<th>NAMING</th>
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<table>
<thead>
<tr>
<th>MEMORY</th>
<th>FACE</th>
<th>VELVET</th>
<th>CHURCH</th>
<th>DAISY</th>
<th>RED</th>
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<tbody>
<tr>
<td>Read list of words, subject must repeat them. Do so 2 times. No recall after 5 minutes.</td>
<td>No points</td>
<td></td>
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</table>
# MOCA Scores

<table>
<thead>
<tr>
<th></th>
<th>Normal Controls (NC)</th>
<th>Mild Cognitive Impairment (MCI)</th>
<th>Alzheimer’s Disease (AD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of subjects</td>
<td>90</td>
<td>94</td>
<td>93</td>
</tr>
<tr>
<td>MoCA average score</td>
<td>27.4</td>
<td>22.1</td>
<td>16.2</td>
</tr>
<tr>
<td>MoCA standard deviation</td>
<td>2.2</td>
<td>3.1</td>
<td>4.8</td>
</tr>
<tr>
<td>MoCA score range</td>
<td>25.2 – 29.6</td>
<td>19.0 – 25.2</td>
<td>21.0 – 11.4</td>
</tr>
<tr>
<td>Suggested cut-off score</td>
<td>≥26</td>
<td>&lt;26</td>
<td>&lt;26ψ</td>
</tr>
</tbody>
</table>

ψ Although the average MoCA score for the AD group is much lower than the MCI group, there is overlap between them. The suggested MoCA cut-off score is thus the same for both. The distinction between AD and MCI is mostly dependent on the presence of associated functional impairment and not on a specific score on the MoCA test.

http://www.medpagetoday.com/MeetingCoverage/ANA/42322
Executive Function Measures

Speed of Processing Domain:

• Digit Symbol Substitution Test (DSST) (WAIS III; Longstreth et al, 1998)
  – Replace the letter with the symbol shown above
  – # completed in 90s
Executive Function Measures

Set-Shifting Domain:
• Trail Making Test B (Trails B) (Reitan, 1958)
  – ‘connect the dots’ alternating numbers and letters
  – time to complete
  – Normal, age-adjusted values: 45s to 247s
  – Low average to impaired 112-192s (Ahsendorf, 2008)
Challenging Gait – Physical, Mental or Both?
What about Dual-tasking?

Walking while talking
...while carrying objects
...while reciting lists
....while doing calculations
...while performing other movements

Luria Motor Sequences
The idea of reserve...
Intervention Ideas

Studenski in NYT (June, 2012)

Engine – tune up the cardiopulmonary system
Chassis – tune up the musculoskeletal system
Steering – tune up the nervous system

Tune up the thinking?
Tune up the motor learning?
Case Studies

Each participant will get one of two cases
Form small discussion groups
Discuss the main features of the case...
    what other tests might be helpful?
Make recommendations for intervention

We will re-group and discuss our ideas
Wrap-Up / Debriefing