Proprioception and Better Balance

Jason Wingert, PT, PhD
UNC-Asheville
Today’s talk

• Discuss risk factors for falling
• Discuss lab findings related to proprioception and balance
• Specific prevention strategies
Impact of Falls

Who falls?

• Amongst people 65+:
  – ~35% fall each year\(^1\)
  – 16% fell in the past 3 months\(^2\)
• Those who fall are 2-3 times more likely to fall again\(^3\)
• ~1 in 3 falls causes serious injuries\(^2\)

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• FALLING IS **NOT** A NORMAL PART OF AGING!

• As we get older, there may be more things that put us at risk for a fall, but

FALLS ARE PREVENTABLE!
Risk Factors: Behavioral

- History of falling
  - Greatest predictor of future fall
- Two types of people tend to fall
  - Those with muscle/bone weakness (frail)
  - Risk takers (vigorous)
    - Climbing on step stools or rushing

Age Adjusted Fatal Fall Injury Rates Among Men and Women Aged 65 Years and Older, United States, 1994–2003; from the CDC
Risk Factors: Behavioral

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Age Adjusted Fatal Fall Injury Rates Among Men and Women Aged 65 Years and Older, United States, 1994–2003; from the CDC
Risk Factors: Physical

• Physical difficulty with daily activities
  – Walking 2-3 blocks
  – Climbing 10 steps
  – Preparing meals
  – Heavy household chores
  – Shopping
• Poor balance
• Dizziness upon standing (orthostatic hypotension)
• Poor vision
Modifiable Risk Factors

**Biological**
- Muscle weakness*
- Walking & balance problems*
- Poor vision*
- Orthostatic hypotension

**Behavioral**
- 4+ medications
- Inactivity
- High risk behaviors
- Fear of falling

**Environmental**
- Tripping hazards
- No railings or grab bars
- Poor lighting
- Weather

Rubenstein, *Age & Aging*, 2006
Slide adapted from NC Falls Prevention Coalition
Risk Factors: Polypharmacy

Any medication that causes an adverse effect can amplify fall risk, including:

- Unsteadiness of increased postural sway (imbalance)
- Dizziness
- Sedation/drowsinessness
- Incontinence
- Muscle weakness
- Overall impaired functional mobility

Galloway, *GeriNotes*, 2011
Risk Factors: Polypharmacy

- Talk with your doctor
- Dose-response
- Medication half-life
- Monitor changes
- Better medication or combination?

Galloway, GeriNotes, 2011
Risk Factors: Environmental

- Majority of falls happen outside
- Inside falls tend to happen in the bedroom and kitchen
- Dark stairways
- Obstacles
- Edge of steps

Painter & Hudson, *J of Community Health*, 2006
Risk Factors: Fear

- Many people who fall, even those who are not injured, develop a fear of falling
  - prevalent among 22-54% of community-living adults whether or not they have fallen¹
- Fear of falling may cause activity limitations, leading to reduced mobility and physical fitness, and increasing actual risk of falling¹,²

Risk Screening

American Geriatrics Society guidelines
• All adults 65+ should be screened for falls
• If person reports fall in past year, in-depth screen is warranted

Quick fall risk screen:
• Have you had a fall in past year? (yes/no)
• Are you having difficulty walking or with balance? (yes/no)
• Balance test...

If positive, thorough balance testing is needed.
Full Assessment?

Clinical assessment

Review and manage medications

Exercise for strength and balance

Improve home safety

Maximize vision

Slide adapted from NC Falls Prevention Coalition
Balance

• Balance relies on contributions from:
  – Vision
  – Vestibular sense
  – Proprioception
  – Muscle strength & flexibility
  – Reaction time

When one component of these sensory, motor, central processing systems is deficient:
• There is greater reliance on the remaining components
• Increased challenge for balance control

Proprioception

- The body's sense of how it is positioned or moving in space
- A complex somatosensory modality utilizing inputs from muscle, skin afferent fibers, and joints

Input from lower limb is most important somatosensory input for standing balance
Proprioception

- Loss of peripheral sensation (proprioception) from:
  - Diabetes mellitus
  - Alcohol misuse
  - Vitamin B12 deficiency
  - Chemotherapy and some other medications
  - Aging???
Falls and Fractures

Most fractures among older adults are caused by falls\(^1\)

- **Wrist fracture** most often with forward/backward falls\(^2\)
  - Mostly controlled by ankle strategy\(^3\)
- **Hip fractures** most often with lateral falls\(^2\)
  - Mostly controlled by hip strategy\(^3\)

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Participants

We tested 102 people total

- **Inclusion criteria**
  - Independent, community ambulation

- **Exclusion criteria**
  - Diagnosis of diabetes, peripheral neuropathy, or neurological disease

<table>
<thead>
<tr>
<th></th>
<th>Younger</th>
<th>Mid-age</th>
<th>Older</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>34 (22 females)</td>
<td>34 (23 females)</td>
<td>34 (24 females)</td>
</tr>
<tr>
<td>Age, mean (range in years)</td>
<td>24.6 (19-37)</td>
<td>53.3* (40-64)</td>
<td>76.3*† (65-94)</td>
</tr>
<tr>
<td># of falls - 12 months, mean (95% CI)</td>
<td>0.7 (0.0 to 1.4)</td>
<td>0.6 (0.3 to 1.0)</td>
<td>0.9 (0.1 to 1.7)</td>
</tr>
<tr>
<td>ABC scale, mean (95% CI)</td>
<td>91.1 (87.3 to 94.9)</td>
<td>89.9 (87.1 to 92.7)</td>
<td>86.5 (81.3 to 91.6)</td>
</tr>
<tr>
<td>Mini-BESTest score, mean (95% CI)</td>
<td>96.0 (94.7 to 97.2)</td>
<td>87.0* (80.7 to 93.4)</td>
<td>73.8*† (67.8 to 79.8)</td>
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<tr>
<td>Physical Activity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ACSM guidelines, Yes (%)</td>
<td>32</td>
<td>44</td>
<td>26</td>
</tr>
<tr>
<td>Balance activity, Yes (%)</td>
<td>24</td>
<td>32</td>
<td>18</td>
</tr>
</tbody>
</table>

*p ≤ 0.05, compared to Younger* and Mid† group. SD = standard deviation

Proprioception Device

Proprioception error

*Proprioception error

*p < 0.00625, Bonferroni-corrected for multiple comparisons.

1. Wingert et al., Arch Physical Med Rehabil., 2014
Proprioception and age

The Pearson correlation test revealed that JPS error increases with age ($r = 0.60$, $p < 0.0001$).

Proprioception summary

1. Wingert et al., Arch Physical Med Rehabil., 2014
Older adults performed the kinesthesia task significantly less accurately than younger adults with the dominant leg (p=0.0002) and non-dominant leg (p=0.0021). *p < 0.00625, Bonferroni-corrected for multiple comparisons.
Are balance and proprioception related?

People with proprioception loss had significant decreases in dynamic balance.

Older adult participants with higher proprioception scores had significantly higher mini-BESTest scores. There was no such relationship for the ABC Scale.

Regular physical activity, as defined by the American College of Sports Medicine (e.g., minimum 150 min/wk of endurance activity), had no effect on proprioception error.
Does exercise protect proprioception?

Participants engaging in regular balance-specific physical activity have lower JPS error (*p=0.02).
Balance Training-Exercise

Most activity we do is in the sagittal plane (forward-backward), offering no protection for lateral (side-to-side) falls

Many older people at risk for falls have particular difficulties with successfully stepping sideways as a protective response to loss of balance in the lateral direction

- Balance training should include lateral movements

2. Yungher et al., Clin Biomech., 2012
Balance Training-Exercise

• So what works best for reducing fall risk?
  – Activity
  – Tai Chi (SL Wolf et al)
  – Dance
  – Yoga?

• Balance training programs
  – Improve balance\(^1\)
  – Decrease fear of falling\(^2\)
  – Prevent falls\(^3\)

1. Sihvonen et al., *Gerontol*, 2004a
3. Sihvonen et al., *Gerontol*, 2004b
Balance Training-Exercise

All risk factors must be addressed first!

Minimum 50 hours over a period of 4 months\textsuperscript{1-3}
– Can be done in:
  • Home
  • Class
  • Clinic

1. Campbell et al., BMJ, 1997
3. Li et al., J Gerontol A Biol Sci, 2005
*Balance Training-Exercise*¹

- Static activities
  - Exercise that challenges the center of mass
    - Reaching while standing
  - Exercise that practices a narrow base of support
    - Tandem stance
    - Single-leg stance

*Should be done with trained supervision*

*Balance Training-Exercise\(^1\)

- **Strength training**
  - Leg (hip and knee) extension
    - Standing squats → lunges forward/side
  - Hip abduction
  - Chair raises
  - Toe raises

- **Effective with balance training**

\(^\ast\)Should be done with trained supervision

*Balance Training-Exercise¹

- Strength training
  - Leg (hip and knee) extension
    - Standing squats → lunges forward/side
  - Hip abduction
  - Chair raises
  - Toe raises

- Effective with balance training

*Should be done with trained supervision

¹Shubert TE. J Geriatr Phys Ther. 2011
**Balance Training-Exercise**

- Dynamic activities
  - Exercise that challenges the center of mass while the feet are in motion
    - Reaching
    - Stair-stepping
    - Tai-chi

*Should be done with trained supervision*

*Balance Training-Exercise*¹

- Dynamic walking and Dual task training
  - Dancing
  - Cognitive task while walking
    - Conversing while focusing on maintaining speed
  - Backwards walking
  - Heel/toe walking

*Should be done with trained supervision*

Balance Training - Exercise

• Hip Abduction muscle strengthening: abduction glide
Balance Training-Exercise

- Hip Abduction muscle strengthening: weighted step-up
Balance Training-Exercise

- Hip Abduction muscle strengthening: Abduction with band
Balance Training-Exercise

- Hip Abduction muscle strengthening: Abduction with wall
Balance Training-Exercise

- Hip Abduction muscle strengthening: Bridging with abduction
Balance Training-Exercise

• Hip Abduction muscle strengthening: Wall slides with abduction
Balance Training-Exercise

- Hip Abduction muscle strengthening: Side lunges
Balance Training - Exercise

• Hip Abduction muscle strengthening: Abduction agility
Conclusions

• Age-related proprioception declines are related to balance changes.
• Balance-specific activity and hip abduction strengthening protect against age-related declines in balance.

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Anxiety networks

Meditation networks

Sylvester et al., *Trends in Neurosci*, 2012

Proprioception

Role in control of voluntary movement:
1. Calibrating limb position in space\(^1\)
2. Sustaining constant muscle force/movement\(^2\)
3. Discriminating object weights\(^2\)
4. Performing targeted movements\(^3,4\)
5. Coordinating gait patterns\(^5\)
6. Timing of muscle firing in multi-joint movements\(^6\)
   – Complex intersegmental dynamics
7. Critical source of sensory feedback for standing balance\(^7\)

\(^1\) Teasdale et al., *Acta Pshcol.*, 1993
\(^2\) Rothwell et al., *Brain*, 1982
\(^3\) Messier et al., *Exp. Brain Res.*, 2003
\(^5\) Lajoie et al., *Neurol.*, 1996
\(^6\) Sainburg et al., *J Neurophysiol.*, 1995
\(^7\) Fitzpatrick et al., *J Physiol.*, 1994a,b
Force Platform

- Quantitative assessment of posture balance
- Force platforms can be predictive of future falls
- Especially the following parameters:
  - Higher ML sway amplitude (EO and EC)\(^1\)
  - Higher ML COP speed (EO)\(^1\)
  - Higher RMS values for ML COP displacement (EC)\(^2\)
  - Higher amplitude of ML COP movement (indoor falls only)\(^3\)
  - Higher ML movement during dual-tasks (injurious falls)\(^4\)

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1. Maki et al., *J Gerontol*, 1994
Normal motor control of stance

- Anteroposterior control: distal to proximal
  1. Ankle strategy
  2. Hip strategy for larger, faster perturbations

- Mediolateral control: proximal to distal
  1. Hip
  2. Ankle

Proprioception and force platform

- Age-related great toe proprioception deficits have been positively correlated with increased tandem standing sway\(^1,2\)
- Older adults with very poor knee and ankle kinesthesia have increased sway\(^3\)

Fear of Falling Scales

• Activities-Specific Balance Confidence (ABC) Scale
  – Reliable and valid\(^1\)
  – Differentiates older adults who avoid activity due to fear\(^2\)
  – Predicts falls\(^3\)

Other Scales
• Falls Efficacy Scale (FES)
  – Home-bound/low-functioning
• Modified Falls Efficacy Scale (mFES)
  – Added outdoor activities/Higher functioning

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3. Lajoie & Gallagher, *Arch Gerontol Geriatr*, 2004
Human and animal aging research has shown:¹

- Decreased muscle spindle diameter
- Decreased muscle spindle sensitivity
- A fewer total number of intrafusal fibers
- Altered, decreased number, and mean density of cutaneous mechanoreceptors (Meissner and Pacinian corpuscles)
- Decreased number of joint mechanoreceptors (Ruffini, Pacinian, and Golgi tendon receptors)

No direct mechanisms have been made for proprioception loss in older adults.

¹. For review see Goble et al., *Neurosci. and Behav. Rev.*, 2009
Proprioception and Age

Proprioception is typically tested in two ways
1. Ipsilateral remembered matching tasks
   – Affected by decreased memory abilities\(^1\)
2. Contralateral concurrent matching
   – Affected by decreased interhemispheric communication (corpus callosum)\(^2\)

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Proprioception and Age

There is significant joint position sense deterioration with age

- Elbow, knee, ankle, big toe\(^1\)
- Not true for the hip (only one study)\(^2\)

There is kinesthesia deterioration with age

- Knee and ankle\(^1\)
- Has not been assessed for hip

1. For review see Goble et al., *Neurosci. and Behav. Rev.*, 2009
Proprioception

Role of proprioception in control of voluntary movement:\(^ {1-7}\):

- Affects the degree of movement accuracy
- Assesses muscle force/movement
- Coordinates gait patterns, body and limb segments to self and environment
- Critical source of sensory feedback for standing balance

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2. Rothwell et al., *Brain*, 1982
5. Lajoie et al., *Neurol.*, 1996
7. Fitzpatrick et al., *J Physiol.*, 1994a,b
Risk Factors: Polypharmacy

Over half of adults 65+ use 5 or more meds\(^1\)

- Psychotropics: medications active on the nervous system (seizures, anxiety, sleep)
  - Anti-depressants (fluoxetine)
  - Sedative-hypnotics (benzodiazepines)
  - Antiepileptics/antipsychotics
- Antiarrhythmics (disopyramide)
  - Digoxin
- Antihypertensives
  - Diuretics (HCTZ)
  - ACE inhibitors
- NSAIDs (aspirin)

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Galloway, *GeriNotes*, 2011