Maintenance of Balance with Aging: Choose Your Steps Carefully

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Motion Analysis

Modeling & Simulation

Dynamic Imaging
Clinical Applications

- Aging and Sensorimotor Control of Balance
- Imaging of Tendon Mechanics
- Early Onset Osteoarthritis Following ACL Injury
- Treatment of Pediatric Gait Disorders
Falls in the Elderly

- $19 billion in direct medical costs in 2000
- 1:3 older people fall each year
- 1:5 falls cause a serious injury
- 95% of hip fractures caused by falls
Falls in the Elderly

Potential energy of a fall

\[ PE = mgh \]

Energy required to fracture an average elderly femur

10x greater!

Which is greater?

Fractures most often result of landing on side

Maintenance of Balance

Controller:
Central Nervous System

Plant:
Musculoskeletal System

Command:
Stay Upright

Output:
Body Position

Sensors:
Somatosensory, Vestibular, Vision
Maintenance of Balance

Controller: Central Nervous System

Command: Stay Upright

Plant: Musculoskeletal System

Output: Body Position

Sensors: Somatosensory, Vestibular, Vision
Bipedal Robots: Honda Asimo Walks and Runs

- Human like?

https://www.youtube.com/watch?v=_kzqk4Rnpqc
Energetic Cost of Transport

\[ c_{et} = 3.2 \quad \text{and} \quad c_{et} = 0.2 \]

\[ C_{et} = \frac{\text{total energy used}}{\text{weight} \times \text{distance traveled}} \]
Efficient Walking Robots

- No actuators
- No sensors

• Simple control
• Ankle push off at heel strike
Energetic Cost of Transport

\[ C_{et} = \frac{\text{total energy used}}{\text{weight} \times \text{distance traveled}} \]

- \( c_{et} = 3.2 \)  
- \( c_{et} = 0.2 \)  
- \( c_{et} = 0.2 \)  
- \( c_{et} = 0.25 \)

Collins et al., Science 2005
Maintenance of Balance

Command: Stay Upright

Output: Body Position
Does Coordination Change due to Sarcopenia and Muscle Weakness

- Loss of muscle mass (20-40%)
- Lipid infiltration of muscle tissue
- Reduced force-generating capacity of leg muscles
Changes in Coordination with Aging

**Older adults:**
- *Push off less vigorously with ankles*
- *Rely more on hips to power walking*

Judge et al. 1996, DeVita and Hortobagyi 2000
Age and the Biomechanics of Uphill vs. Level Walking

Healthy and active subjects
~10 Young (18-35 years)
~10 Old (65+ years)

Franz and Kram, J Biomech 2013
Old adults have an underutilized propulsive reserve

Biofeedback can strategically call upon this reserve

Franz and Kram, Clinical Biomech 2014
The Spring in your Step

- Gastrocnemius
- Soleus
- Achilles tendon

Tendons act as a spring storing and releasing energy with each step!
Tracking of Achilles Tendon Motion in Gait

Motion Capture

Ultrasound Imaging

Instrumented Treadmill

Franz et al., Gait Posture In Press
Achilles tendon behavior

The aging Achilles tendon appears more compliant with adhesions potentially restricting sliding between sub-tendons

Franz et al. *J Apply Phys* 2015
Maintenance of Balance

Command: Stay Upright

Output: Body Position
Maintenance of Balance

Command: Stay Upright

Output: Body Position

Aging degrades sensory feedback!
How Can One Measure Effects of Sensory Feedback on Balance?

Eyes Open  Eyes Closed
Investigate whether old adults rely more on visual feedback than young adults

Virtual Reality System to Perturb Optical Flow
Motion of Old Adult

Normal

Visual Perturbation
RESULTS

Francis et al., Gait and Posture, 2015
Age-Related Prioritization of Visual Feedback

Young Adults
Integration of reliable sensory feedback

AGING?

Impaired Somatosensation

Old Adults
Visual Reliance

Advanced Age Brings a Greater Reliance on Visual Feedback to Maintain Balance During Walking
Maintenance of Balance

Command: Stay Upright

Output: Body Position

Aging degrades sensory feedback!

Goal: Improve Somatosensation
Signal Detection Problem in Neurons

Leads to Diminished Postural Feedback!

Wells et al, 2003. *J Gerontology*
Stochastic Resonance to improve Balance

VIBRATING SOLES: Electric motors embedded in gel insoles produce noisy vibrations that improve balance.

Harry et al. 2005. Spectrum, IEEE.
Stochastic resonance – Bottom of Feet

Effect of Stochastic Resonance on Balance

Harry et al. 2005. *Spectrum, IEEE.*
Effect of Stochastic Resonance on Balance

Been Shown to improve balance in:

- Healthy elderly adults (Priplata 2003)
- Patients with diabetic neuropathy (Priplata 2006)
- Patients with stroke (Priplata 2006)
- In elderly people with recurrent falls (Galica 2009)

So why hasn’t this been done already?
So why hasn’t this been done already?

Hijimans et al. 2015. *Int J of Rehab Res.*

Lipsitz et al. 2015. *Arch Phys Med & Rehab.*
Stochastic Resonance about the Ankle
Pilot Testing on Stochastic Resonance at Ankle

- 52 year old, Female
- Lower limb neuropathy due to viral infection in the brain stem
- Chronic balance impairment and reported dizziness
Results

Stochastic resonance OFF

Stochastic resonance ON
Simple targeted interventions may hold promise for maintaining mobility and preventing falls

1. Biofeedback for Gait Retraining

2. Environmental Modifications to Enhance Visual Input

3. Devices to enhance somatosensory Input
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Interested in participating as a research subject?
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