Balance and aging
Alan Wing
Falls

- 7th leading cause of death in people over 75 years of age
- 40% of people over the age of 65 experience a fall at least once a year (Campbell et al., 1981; Tinetti et al., 1988)
- 20% of elderly experiencing a serious fall die within the next 6 months
- 50% of them need hospitalization for the rest of their life (Sattin et al., 1990)
- Over the age of 85: mortality from fall related injuries is greater than that from cerebro-vascular diseases (Drought, 1997)
- Fear of falling seriously limits older person’s physical activity and function (Tinetti et al., 1996)
Balance and aging - lecture overview

- 1. Biomechanics and motor control
  - Muscles, coordination; quantifying balance
  - Motor changes
- 2. Sensory function
  - Tactile, proprioceptive, visual pathways
  - Sensory changes
- 3. Attention and balance
  - Transitions project
Part 1

1. Biomechanics and motor control
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Standing balance

- Inverted pendulum
- Centre of mass in front of ankle
  - Body sways forward
- Ankle plantarflexion
  - Acts against ground reaction
- Measurement
- Sway
- Centre of pressure
  - Static and dynamic components
  - Multiple segments

Anterior

Posterior

L

R
Multiple segments

- **Sources of Forces (torques)**
  - AP (Ankles, knees, hips)
  - LR (Ankles, hips)
Quantifying balance - reactive

† Horak and Nashner

Context dependence of postural reflex

Normal vs short support base

Other recovery strategies

Using the hand

Stepping

Forward sway

Backward sway

Support translation

Forward

Sequence

Long latency

Fwd sway

Backward

Support translation

Normal vs short support base
Lateral balance

- Sideways push
- Hip ab/adductors
- Ground reaction forces

Kirker, Simpson, Jenner, Wing 2000
Feedback control

- Desired trajectory (posture)
- Motor command update
  - Negative feedback
- Delay
  - Instability (oscillation)
  - Damping (slowing) vs prediction
Predictive control of balance

- Pull - Inertial load
- Self perturbation of balance
- Grip and force plate measures
  - Predictive grip force (PGF)
  - Anticipatory postural adjustment (APA)
- Correlations
  - APA, PGF

Wing, Flanagan and Richardson 1997
- Dynamic model predicts state
- Early (predictive) correction of motor command
Coordination

- Multiple forward models
  - Arm - load
  - Hand - grip

- Hierarchy

BBS-SyMoN
Clinical assessment of balance

- Response to push
- Berg balance scale
- Berg et al 1992
- Functional reach test
- Duncan et al 1990
- In hemiparetic stroke correlates .78 with Berg balance scale
- Smith et al 2004

Berg Balance Scale

<table>
<thead>
<tr>
<th>Balance Item</th>
<th>Score (0–4)</th>
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<tbody>
<tr>
<td>1. Sitting unsupported</td>
<td></td>
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<tr>
<td>2. Change of position: sitting to standing</td>
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<tr>
<td>3. Change of position: standing to sitting</td>
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<td>4. Transfers</td>
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<td>5. Standing unsupported</td>
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<td>6. Standing with eyes closed</td>
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<td>7. Standing with feet together</td>
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<td>8. Tandem standing</td>
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<td>9. Standing on one leg</td>
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<td>10. Turning trunk (feet fixed)</td>
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<tr>
<td>11. Retrieving objects from floor</td>
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<td>12. Turning 360 degrees</td>
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<tr>
<td>13. Stool stepping</td>
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<tr>
<td>14. Reaching forward while standing</td>
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</tbody>
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Interpretation

0–20, wheelchair bound
21–40, walking with assistance
41–56, independent
Musculoskeletal changes

- Decrease in skeletal muscle mass (cross-sectional area decreases by 20-25%); decrease in number of motor units (25%); motor output produced by surviving motor units increases
  - Doherty et al 1993, Narici et al 1991
- Loss of spinal flexibility - shrinkage of intervertebral disks; older means shorter (5.5-7.5 cm.)
  - Studenski et al 1991, Lewis and Bottomley 1990
- Joints; decreased range of motion
- Bones; decrease in calcium deposits and bone density, fragile
Muscle action changes

- Reduced rate of force development; unsteadiness during isometric contraction
  - Galganski et al. 1993
- Decrease in muscle strength is more evident in lower limbs
  - Kauffman 1985, Wilmore 1991
- Decrease in muscle moment during Knee extension and plantarflexion
  - Larsson et al. 1979, Gerdle and Fugl-Meyer 1985
- Greater agonist – antagonist co-contraction
  - Spiegel et al. 1996
Postural changes

- Thoracic curvature increased – alters upper limb posture
- Head position changed – visual and vestibular input changed
- Lumbar extension increased – position of pelvis altered
- Knee flexion – greater muscle effort in walking
- CoP backwards – less stable
Aging response to perturbation

- Disrupted recruitment order, increased co-activation (Nashner et al., 1983)
- Increased use of hip strategy (Horak et al., 1989, Manchester et al., 1989)
- Slowed onset latencies (Woollacott and Moore, 2001)
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Somatosensation

- Touch
- Cutaneous
  - Slow vs Fast adapting
  - Small vs large receptive field
  - Ruffini, Merkel
    - Pressure
  - Meissner, Pacinian
    - Vibration
- Muscle (proprioceptive)
  - Afferent as well as efferent
  - Spindle
  - Static, dynamic
    - Kinesthesis
Somatosensory system

- **Primary somatosensory cortex**
  - S-I: 3a (muscle), 3b (skin)
  - 1, 2
  - early sensory processing

- **Secondary somatosensory cortex**
  - S-II
  - attention to touch

- **Posterior parietal cortex**
  - PPC: 5,7
  - higher level processing
  - multimodal integration
Vestibular sensation

- **Semicircular canals**
  - head angular acceleration

- **Otoliths:** saccule, utricle
  - static head tilt
Vision

- Functional distinction
  - parvocellular vs magnocellular pathway
  - ventral vs dorsal stream (perception vs action)
- Stereopsis, optic flow, occlusion
Multiple sensory systems

- Sensory ambiguity
  - Ankle proprioception alone - sloping surface or leaning forward?
  - Vestibular alone - head or body inclined?
  - Visual alone - own sway or the surround moving?
- Resolving ambiguity - multiple sensory inputs
Testing sensory systems

- Sensory organisation test (SOT)

Woollacott et al 1986
Sensory system changes: vision

- Loss and decline of sensory fibers innervating peripheral receptors cause decline in
  - Vibratory sensation (Kenshalo 1979)
  - Fine touch (Bruce 1980)
  - Pressure sensation
- 40% loss of vestibular hair and nerve cells (Rosenhall & Rubin 1975)
- Vision
  - Decline in visual acuity (Felson et al 1989),
  - Loss of visual field (Paulus et al 1984)
  - Loss of peripheral vision
  - Perception of verticality (Tobis et al 1981)
  - Impaired visual motion perception (Warren et al 1989)
  - Deficits in spatial orientation (Tang & Woollacott 1995)
Aging effects on balance

- Relatively greater effect of loss of somatosensory input in sensory organisation test
  - Woollacott et al 1986
- Greater slowing of reaction time in secondary task with loss of vision
  - Teasdale et al 1993
- Changing lighting conditions: Lights on/off: elderly difficulty
  - Teasdale et al 1991
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Attention

- Central processing
  - Task difficulty defines the demand on central resources
  - Flexible deployment over range of tasks
- Limited capacity - attention
  - Increase in resources for one task results in decrease in resources for another
  - Performance disrupted if task demands exceed resource limit
Balance - Controlled vs automatic

- **Controlled**
  - Top down, slow, sequential, capacity limited, subjectively demanding

- **Automatic**
  - Bottom-up, fast, parallel, unlimited (no competition) resources, subjectively effortless

- **Dual task methodology**
  - Concurrent cognitive task used to probe capacity
Domain-specific process interference

- Kerr et al. (1985)
  - secondary task: working memory
  - no change in postural performance (tandem Romberg: CoP sway)
Quiet stance

- Greater sway (especially ML) and more affected by memory load
  - Maylor et al 2001
- Latency slowed by addition of secondary task in elderly not young
  - Rankin et al 2000
BBSRC project

- With Zoe Kourtzi, Leif Johanssen
- Attentional demands of state transitions in posture and balance
  - Transitions between dynamic postural states involve attention-demanding cognitive mechanisms governing sensory motor transformations for control of balance.
  - Inefficient handling of the fluctuations in cognitive demand in the elderly contributes to impaired balance
- Background
  - Elderly groups more vulnerable in balance: Increased sway, Falls
  - Impaired sensory and motor function: More interference between cognition and balance
  - Difficulty in coping with change
Transitions project

- Different modes of postural oscillation will be imposed on the participants
  - Implicitly: entrain body sway to visual or mechanical oscillation
  - Explicitly: ask participants to perform voluntary oscillatory body movements (periodic swaying) synchronized to a metronome.

- These states require monitoring of sensory motor relations. We will examine transition between oscillatory states in terms of attention demands
  - Adaptation of postural stability to abrupt transitions between body sway entrainment states as a function of cross-modal interference
  - Age-related effects on transitions between postural states as a function of additional demands of attentional resources
  - Brain imaging of periodic ankle torque control and entrainment with an oscillatory visual stimulus
Summary

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Balance and aging
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Balance - Interventions

- Strengthening
- Fitness (Walking)
- Coordination (GLASS)
- Sensory calibration (light touch)
- Prediction (vs reaction)
- Generalisation (vs specific training)
- Distributed (vs massed) practice
- Motivation (Danzon)