Interpreting Lateral Dynamic Weight Shifts using a Simple Inverted Pendulum Model

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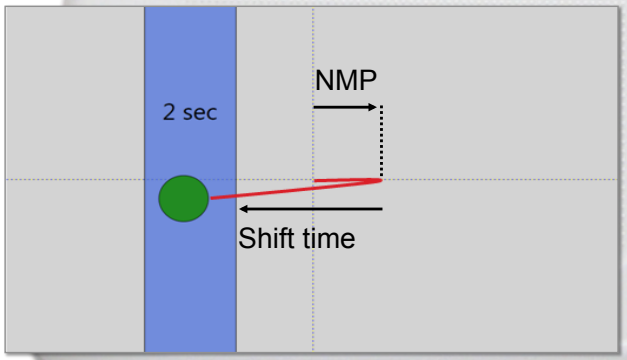
Background

- Lateral weight shifting is an important task in balance rehabilitation because of its correlation with fall probability.
- Most modeling research to date has focused on static sagittal balance rather than dynamic lateral weight shifting.
- Static sagittal balance has been modeled as inverted pendulum with feedback control.

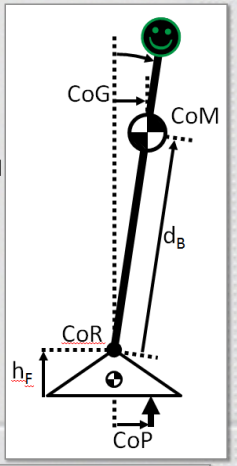
Methods

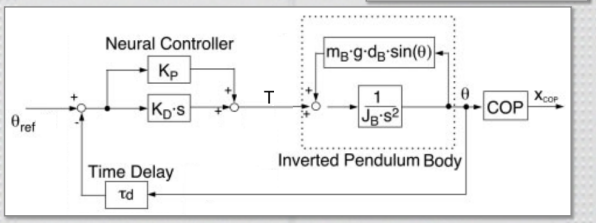
- Dynamic lateral weight-shifting activity
  - Randomized left/right offset targets
  - Return to symmetric stance after each target
- 75 healthy subjects using WeHab[1] system
- Metrics
  - Non-minimum phase (NMP) distance – CoP initially moves opposite of weight shift direction
  - Shift time from max NMP shift to target region entry

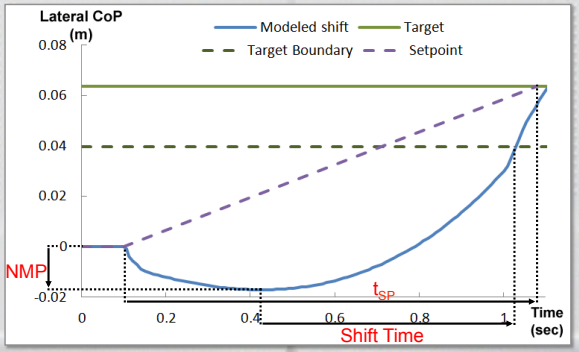


Methods, cont.

- Frontal plane inverted pendulum model
  - Parameters based on subject height/weight and Winter's[2] anthropometric data
    - m_B: Shifted body mass
    - m_F: Static body mass (feet)
    - h_F: Height of CoR (ankle)
    - d_B: Distance from CoR to CoM
    - J_B: Body moment of inertia about CoR
- PID control
  - Control parameters
    - K_P: Proportional gain
    - K_D: Derivative gain
    - t_{SP}: Setpoint shift time

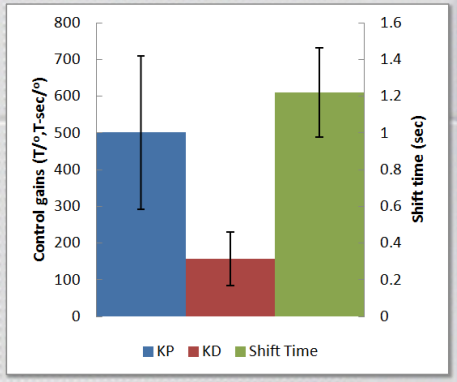






Results

- Matching modeled shifts to subject data
  - Close match for data from 74 subjects
    - 0.44% error in shift time (average)
    - 0.09% error in NMP distance (average)
  - Failed to meet error threshold for 1 subject
    - 3.8% error in shift time
    - 1.29% error in NMP distance
  - Average control parameter values (± std. dev.)
    - K_P: 502 (± 209); K_D: 157 (± 73)
    - t_{SP}: 1.22 (±0.24)



Future Work

- Application to neurotrauma patient data
  - Evaluate model robustness
  - Compare modeled control parameter values between healthy and neurotrauma populations

1) Kennedy et al. (2011) Enhanced feedback in balance rehabilitation using the Nintendo Wii Balance Board. *HealthCom 2011*.
2) Winter, D.A. (1990) *Biomechanics and Motor Control of Human Movement*, 2nd edition. New York: Wiley.

Locomotion & Biomechanics Lab

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