Neuromechanics of the foot and footwear

Dr. Stephen Perry, PhD

Department of Kinesiology and Physical Education, Wilfrid Laurier University
Dept. of Physical Therapy & Grad Dept. of Rehabilitation Science, University of Toronto
Toronto Rehab Institute

Areas of Research

Hallux Valgus
Functional Flat Foot
Footwear Characteristics
Plantar Surface Sensation

Balance Control

Falls

On average 1/3 of persons over the age of 65 fall at least once per year resulting in 270,000 hip fractures per year (US)

It is estimated 1.5 million elderly individuals will fall more than three times a year (Nazarko, 2006)

Most reported falls are linked to (Rubenstein, 2006):
- Environment
- Weakness
- Gait / Balance disorders

Key Terms

COM – Centre of Mass (body motion)
BOS – Base of Support (environment contact)
Standing

BOS

Walking

BOS

BOS

BOS

BOS

BOS

Balance Control system

Mechanical Perturbation

Musculoskeletal System
Muscles
Bones
Joints

Central Nervous System
Brain
Nerves
Reflexes

Physiological Perturbation

Sensory Systems
Vision
Vestibular (inner ear)
Somatosensory
(touch, joint sense)

Informational Perturbation

Hallux Valgus (Bunions)

Measurement of great toe deformity

Current Study
Controls (n=5) 14°
Hallux valgus (bunion) (n=5) 24°
Functional Flatfoot

Functional Flatfoot (FFF)
• A complete loss or a significant reduction of the medial longitudinal arch of the foot while weight bearing
Measurement of Stability

Foot and Footwear Role and Function

Sensory Role

Mechanical Role

How footwear characteristics influence balance control

Midsole Hardness
Influence of footwear midsole material hardness on dynamic balance control during unexpected gait termination. (Gait & Posture, 2007)

\[ F_{\text{wt}} = 700 \text{ N} \]
\[ d_1 = 0.05 \text{ m} \]
\[ d_2 = 0.15 \text{ m} \]
\[ F_{\text{GRF}} = 233 \text{ N} \]

Insole Friction

Perry SD, Radtke A, Goodwin, CR. Influence of footwear midsole material hardness on dynamic balance control during unexpected gait termination. (Gait & Posture, 2007)
Sensory Systems
Cutaneous (touch) and muscle

Zehr & Stein (1999) Progress in Neurobiology
Plantar mechanoreceptors
Age-related changes

- Density of dermal mechanoreceptors
- changes in receptor morphology
- rigidity and inelasticity of surrounding dermal tissue
- changes in peripheral nerve conduction
Method of Perturbation

- Moveable platform
- Unpredictable perturbations
  - Random time of onset
  - Random direction and magnitude
  - Random waveforms
Gait Termination

Reduced sensation effects

Second step of termination

A

D

Loading rate

C

Step during which signal to terminate gait is given

First step of termination

Walking Direction

Perry et al., Brain Research 2001: 913 (1) 27-34

Efficacy of a balance-enhancing shoe insert

Supported by a Proof of Principle grant from:

Inssoles can be purchased at www.balancepro.ca
Improving Sensation

Top view

Bottom view

Results (falls data)

A total 14 subjects experienced a fall
- 9 of 14 fallers were wearing the blank insole
- 5 of 14 fallers were wearing the facilitatory insole

Therefore 45% of subjects that wore the blank insoles fell, whereas only 25% of subjects wearing the facilitatory insoles fell.

Follow-up questionnaire

<table>
<thead>
<tr>
<th>Number of Falls</th>
<th>Blank</th>
<th>Facilitatory</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>&gt; 2</td>
<td>0</td>
<td>2</td>
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<table>
<thead>
<tr>
<th>Reason for Falls</th>
<th>Blank</th>
<th>Facilitatory</th>
</tr>
</thead>
<tbody>
<tr>
<td>slipped on ice</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>tripped</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>missed step</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>no info</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

Number of subjects

Number of falls

COM-BOS Analysis

Maximum COM-BOS

Minimum COM-BOS

“Stability Margin”

End of single stance

Start of single stance

Lateral BOS
Take Home Message

Follow-up on any plantar-surface sensory (tingling, calluses) issues

Footwear fit, integrity and interface (cushioning, sock-insole, impingements)

Identify and treat mechanical foot misalignments with all of this taken into consideration

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