Footwear Assessment

Affordable Footwear

Ken Wong (OT)
Price of Wales Hospital
Introduction

Fall risk factors

• Intrinsic factors
  – Poor lower limb proprioception
  – Visual impairment
  – Decreased reaction time
  – Decreased lower limb muscle strength etc.

• Extrinsic factors (Menz HB et al. 2000)
  – Environmental hazards (insufficient lighting, poor housekeeping etc.)
  – Unsafe footwear

• Footwear is a potentially modifiable factor that play a role in some falls (Thomson et al. 2004)
• Inappropriate footwear has been contributed to 45% of falls (Menant J. C. 2008)

• Shoes alter the interface between the foot and the ground (Menz HB et al., 1999)
Fall (slip / trip)

• **Slip**
  - a *sudden loss of grip*, in the presence of liquid or solid contaminants
  - results in *sliding of the foot* on a surface

• **Trip**
  - *sudden interruption of the foot* in the *swing phase* by uneven surfaces or with obstacles on the floor

(Gronqvist Q et al. 2001)
Fall mechanism

- Forward falls / lateral falls (less common)

- Backward falls involve pelvic impact due to slipping after heel contact (most common)
A conceptual framework of a foot slide leading to backward fall

<table>
<thead>
<tr>
<th>Normal activity</th>
<th>Perturbation</th>
<th>Preceding events</th>
<th>Contact event</th>
<th>Injury event</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walking</td>
<td>Onset</td>
<td>Control of balance lost</td>
<td>Outstretched hand, hip or head strikes ground</td>
<td>Fracture to ankle, pelvis, shoulder or head</td>
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<td></td>
<td></td>
<td>(fall recovery)</td>
<td></td>
<td>(sprained wrist, low-back pain)</td>
</tr>
</tbody>
</table>

- 0 sec
- 0.2 sec
- 0.3 sec
- 0.5 sec
- 0.7 sec
- 0.9 sec

Dry, clean surface

Wet, greasy spot causes slip initiation ($\mu_s$)

Drainage and draping incomplete ($\mu_k$)

Deformation and damping insufficient ($\mu_k$)

Foot slide accelerates, traction lost (fall unavoidable)

Measurement of slipperiness

- Center of mass (COM)
  - Balance maintained
  - Body COM over BOS (COP)
  - Balance challenged
  - Body COM approaches boundaries of BOS
  - Balance lost
  - Body COM outside boundaries of BOS

(Gronqvist Q et al. 2001)
Two critical gait moment

- Heel contact and toe-off
- Heel contact phase is more challenging for stability, as the forward momentum maintains the body weight on the leading foot causing a forward slide of foot (Redfern et al. 2001)

Front and rear part of sole in contact
Friction Coefficient

\[ u = \frac{F_u}{F_N} > \frac{F_H}{F_V} \]

- Interaction between an elastic shoe sole, an interfacial contaminant and the floor surface.

- Preventing slip, resisting friction force should be higher than the horizontal component of the force (Gronqvist Q et al. 2001)
Friction Coefficient

• Excessive slip resistance of shoe may lead to fall
  - when pivoting the upper body to perform a ADL tasks, friction between the shoe and the contact surface restricted the feet from pivot, resulting in loss of balance (Connell BR, 1997)
  - Uncommon
How to select an appropriate footwear?
Features of footwear
Features of shoe design that have an impact on balance

- Heel height
- Heel-collar height
- Heel-collar stiffness
- Sole hardness
- Bevelled heel
- Slip resistance of the outer sole
- Sole geometry
- Fixation
Heel height

- High heel shoe (4.5cm) impaired balance
  - Heel elevation shifts the body COM anteriorly, modifying posture and plantar pressure distribution.
  - Lead to lateral instability because of a smaller critical tipping angle compared to lower heel shoes
Collar Height

- High collar ✓
- Low collar ✗
  - Circumferential ankle pressure (tactile stimulus)
    - Enhances joint position sense
    - Improve stability

Robbins SE, 1995
Heel collar stiffness

- Stiff heel collar assist in controlling heel movement
Sole hardness

• Hard / thin sole shoes ✓

Thick / soft sole shoes ✗

- Thick soft sole shoes impaired joint position sense and balance
  • reduce transmission of tactile sensory input to the feet and delayed CNS to respond accordingly to control balance.

- Cushioning properties in the mid-sole attenuate normal perception of impact and prevent normal impact-moderating behaviors
A conceptual framework of a foot slide leading to backward fall

- Normal activity: Walking
- Perturbation: Onset, Foot slide starts
- Preceding events: Control of balance lost, (fall recovery)
- Contact event: Fall, Outstretched hand, hip or head strikes ground
- Injury event: Fracture to ankle, pelvis, shoulder or head, (sprained wrist, low-back pain)

Measurement of slipperiness:
- Center of mass (COM): Balance maintained, Body COM over BOS, (COP)
- Base of support (BOS): Balance challenged, Body COM approaches boundaries of BOS
- Balance lost, Body COM outside boundaries of BOS

(Gronqvist Q et al. 2001)
Bevelled heel

- Bevelled heel provided a greater coefficient of friction than a shoe with a squared-edged heel.
- Improve slip resistance by increasing the surface contact area at heel strike.

(Menz HB et al., 1999)
Sole geometry

- **Midsole flare**
  - difference between the width of the midsole at the level of the upper and its width at the level of the outsole

- **A flared sole enhanced stability by**
  - providing a [larger base of support](https://example.com) - significantly associated with [lower risk of fall](https://example.com) (Allan F et al., 2004)
  - [longer moment arm (X) for eversion](https://example.com) offered better base of support

(Lord SR, 1994)
Tread pattern

- Wider tread groove results in higher COF values
- Shoe sole with deep cleat and well defined tread pattern can improve slip resistance
- Linear grooves disperse fluid from under the shoe
- Wear flat shoes maximize the area of contact with the floor
- Outsole material hardness increase, coefficient of friction decrease

(Menz HB et al., 1999)
Fixation

- Shoe without proper fixation promote unsteady gait and are more likely to be separated from the foot when walking (Menz HB et al., 1999)

- Lace, velcro, zip, elastic lace with pop-lock
  - Velcro is easy to fasten
  - Lace have more room for adjustment
Appropriate Slippers?
• Similar principles and features
• Slipper use at home only
Size – too large / small
Slide inside slipper
- sock with slipper
- insole material
Humidity ~ Slipper
Non-slip sole

VS

X

✓
Size of slipper cover ~ Fixation
Footwear selection for elderly with various foot problems
Hammer toes

- Toes are squashed by wearing poorly fitting shoes for long time or high heel
  - **Toe boxes**
    - Soft
    - spacious with sufficient width and height
  - A **harder shoe sole**
    reduce painful dorsiflexion
    at the first MTP joint
Hallux Valgus

• If shoes press against the bunion. The bursa may become inflamed and painful

  – Choosing shoes with a soft upper and medial cover will reduce pressure and friction on the bunion

  – Avoid oversized shoe

    • prevent foot slide with rubbing on the bunion
Diabetic foot

- Footwear has been implicated as an extrinsic cause of foot ulcers in people with diabetes (Gayle E et al. 2002).
- Footwear must be smooth on the inside.
- Individuals with sensation loss tend to buy shoes that are too small because they can feel the shoe in fitting.
- Do wear sock to fit shoe.
Point to note when selecting shoe

• **Upper**
  - Soft, flexible and ideally waterproof
  - A smooth lining

• **Toe box**
  - Should be deep enough to allow you to wriggle your toe

• **Sole**
  - Strong and flexible for good grip

• **Heel**
  - Broad base for stability
  - Should be no higher than 4cm

• **Fastening**
  - Provide stable fit and some flexibility to allow for unusually shaped feet or swelling

• **Try shopping for shoes later in the afternoon**
Perception of elderly towards footwear

• Oversea survey

• Older people based their footwear choice on comfort rather than safety (Catherine, 2003)

• In a survey of 147 subjects with fall history – 73% reported that comfort, not safety was the primary concern (Menz HB et al. 1999)
A survey on footwear among patient with history of fall in PWH

- **Local survey**
- **Selection criteria**
  - 68% price
  - 54% non-slippery performance
  - 31% outlook
- 40% able to report at least 3 criteria of an appropriate footwear
- 27% able to select an appropriate footwear in 3 demo. shoe
Conclusion

• Inappropriate footwear is a risk factor of elderly fall
• Footwear is a potentially modifiable factor that play a role in some falls
• Education on the selection of appropriate footwear should be a part of fall prevention program
The End
Thank you
Reference

- Allan F et al. 2004, Biomechanical Properties of Shoes and Risk of Falls in Older Adults. JAGS 52: 1840-1846