Investigating Mechanisms of Fall Risk during Everyday Tasks on Ladders

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Injury Data on Falls

**Falls:** most common cause of a disabling injury\(^1\)
- 27% of disabling injuries

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Fatal Falls from a Height

Fatal Falls from a Height\(^2\)

- Ladder
- Roof
- Nonmoving Vehicle
- Scaffold
- Stairs/Steps
- Structural Steel
- Other or Unknown

\(^2\)BLS. (2012). Census of Fatal Occupational Injuries Charts (Ed.).
Ladder Falls

Multi-country epidemiology reports on ladder fall incidence

Australia³, Denmark⁴, Finland⁵, Spain⁶, Sweden⁷, United Kingdom⁸ and United States⁹

72%-87% of falls among men³,⁴

Majority in non-occupational setting³,⁴,⁸,⁹

Highest rates among older adults⁴

Causes of Ladder Falls

Investigated?

- Sliding of base
- Foot slipping
- Over-reaching
- Loss of balance
Mechanisms Causing Ladder Falls

- **Setup angle**
  - Sliding of base
    - 75° from horizontal

- **Restricted foot placement**
  - Foot slipping
    - 75° from horizontal
  - Increase toe gap distance

- **Mechanism?**
  - Over-reaching
  - Loss of balance

**Recommendation?**


Potential Mechanisms of Ladder Fall Risk

**Physiological, Psychological, & Cognitive abilities influence**

1. Balance
2. Balance at Elevated Levels
3. Balance While Performing a Secondary Task

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Potential Mechanisms of Ladder Fall Risk

Physiological, Psychological, & Cognitive abilities may influence

Balance while performing tasks on ladders
Goal of Study

To determine individual factors that influence ladder fall risk from unstable ladder user dynamics

**Individual factors:** physiological, psychological and cognitive abilities

**Ladder fall risk:** behavioral risk, task performance, and judgement error

**Unstable ladder user dynamics:** loss of balance and over-reaching
Ladder Experiments
Ladder Experiments

Washing the windows

Behavioral Risk

Changing a light bulb

Task Performance

Cleaning a gutter

Judgment Error
Washing the Windows

• “Are you willing to climb this ladder today to wash the window?”
  – From 1 step box to the riskiest ladder
  – Until response is “no”
  – Will not actual climb ladder

• Fall risk measure:
  Behavioral Risk
  • Likelihood of the ladder tipping

\[
\sum M_o = RF \ast \left( \frac{\text{Width}_L}{2} \cos \theta \right) - W_L \left( \frac{\text{Height}_L}{2} \sin \theta \right) - W_C (\text{Height}_C \sin \theta + COM_{\text{MaxDis}} \cos \theta)
\]
Changing a Light Bulb

- **Complete twice**
  - Naming animals
  - No cognitive distraction

- "**As quickly and safely as possible**"

- **Fall risk measure:**
  Task performance
  - Completion time
  - Stability on ladder

\[ \text{COP} = \text{Center of Pressure} \]
Changing a Light Bulb

Younger adult

Older adult
Cleaning a Gutter

• “How many times do you think you need to move the ladder to clean the gutter?”

• Complete once

• “As quickly and safely as possible”

• Fall risk measure:
  
  Judgment error = Perceived Moves – Actual Moves
Cleaning a Gutter

Younger adult

Older adult
Risk of Climber Falling and Ladder Tipping
Risk of Climber Falling – Motion Data

Maximum COM displacement in experiments
Maximum COM displacement in baseline lean and reach tests

Greater value is associated with greater probability of the climber falling
Value $> 1$ indicates the climber would fall without holding onto an external object
Risk of Ladder Tipping – Force Data

**Medial – lateral COP displacement**

Greater medial – lateral COP displacement will indicate greater probability of the ladder tipping.

**|left force – right force|**

Greater difference between load cell forces will indicate greater probability of the ladder tipping.
Individual Factors
Assessments of Individual Factors

**Physiological**
- Physiological Profile Assessment (PPA)
- Upper limb PPA

**Psychological**
- Risk-taking assessment
- Anxiety assessment (GAD)
- Iconographical Falls Efficacy Scale

**Cognitive**
- Trail making test A & B

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Preliminary Data
Washing the Window – Behavioral Risk

19 younger adults

Riskiest ladder chosen to wash a window

10 older adults

Riskiest ladder chosen to wash a window
Changing the Light Bulb – Task Performance

**Time taken to change a light bulb**

- **Younger adults**
- **Older adults**

*Time (seconds)*

**Single task**
Changing the Light Bulb – Task Performance

Time taken to change a light bulb

Time (seconds)

Younger adults
Older adults

Single task
Dual task

Time taken to change a light bulb
Cleaning the Gutter – Judgement Error

**19 younger adults**

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<th>Judgement Error</th>
<th>Frequency (number)</th>
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**10 older adults**

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*Difference in perceived and actual climbs taken to clean a gutter*
Expected Outcomes

• Risk of the climber falling and ladder tipping
  – *We expect lower task performance and greater judgement error to be associated with greater probability of the climber falling or ladder tipping*

• Individual abilities to be predictors of ladder fall risk
  – *We expect a combination of physical, psychological and cognitive measures to influence ladder fall risk measures*
    • Lower and upper body stability, anxiety, executive function

• Interventions to reduce number of ladder fall injuries
  – *Health screenings*
  – *Training programs*
  – *Ladder redesign*
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Recruitment
• Smart Step study research assistants

Falls, Balance and Injury Research Members
APPENDIX
Study Aims

To determine individual factors that influence ladder fall risk from unstable ladder user dynamics

Aim 1: Biomechanically validate measures of ladder fall risk

Aim 2: Determine individual factors that predict ladder fall risk

Aim 3: Investigate ladder use between low and high ladder fall risk groups
Statistical Analysis
# Statistical Analysis

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<th>Statistical Test</th>
<th>Dependent variable</th>
<th>Predictor variables</th>
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<td><strong>Aim 1</strong></td>
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<td>Biomechanical analysis of the climber or ladder falling will be associated with greater ladder fall risk measures</td>
<td>Linear regression</td>
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<td>Risk of ladder tipping</td>
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<td>Use by ladder type</td>
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