Investigating Mechanisms of Fall Risk during Everyday Tasks on Ladders

Erika M. Pliner[1,2], Daina L. Sturnieks[2], Stephen R. Lord[2]

[1]Department of Bioengineering, University of Pittsburgh

[2]Falls Balance and Injury Centre, Neuroscience Research Australia

NSW Falls Prevention Network Forum – 11th May 2018

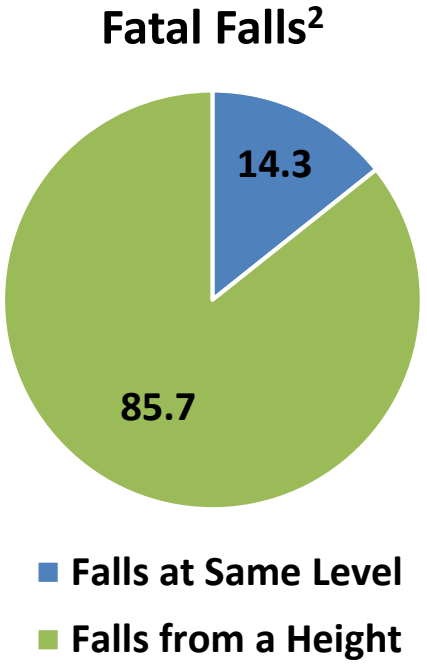
Injury Data on Falls

Falls: most common cause of a disabling injury[1]

- 27% of disabling injuries

Fall at Same Level

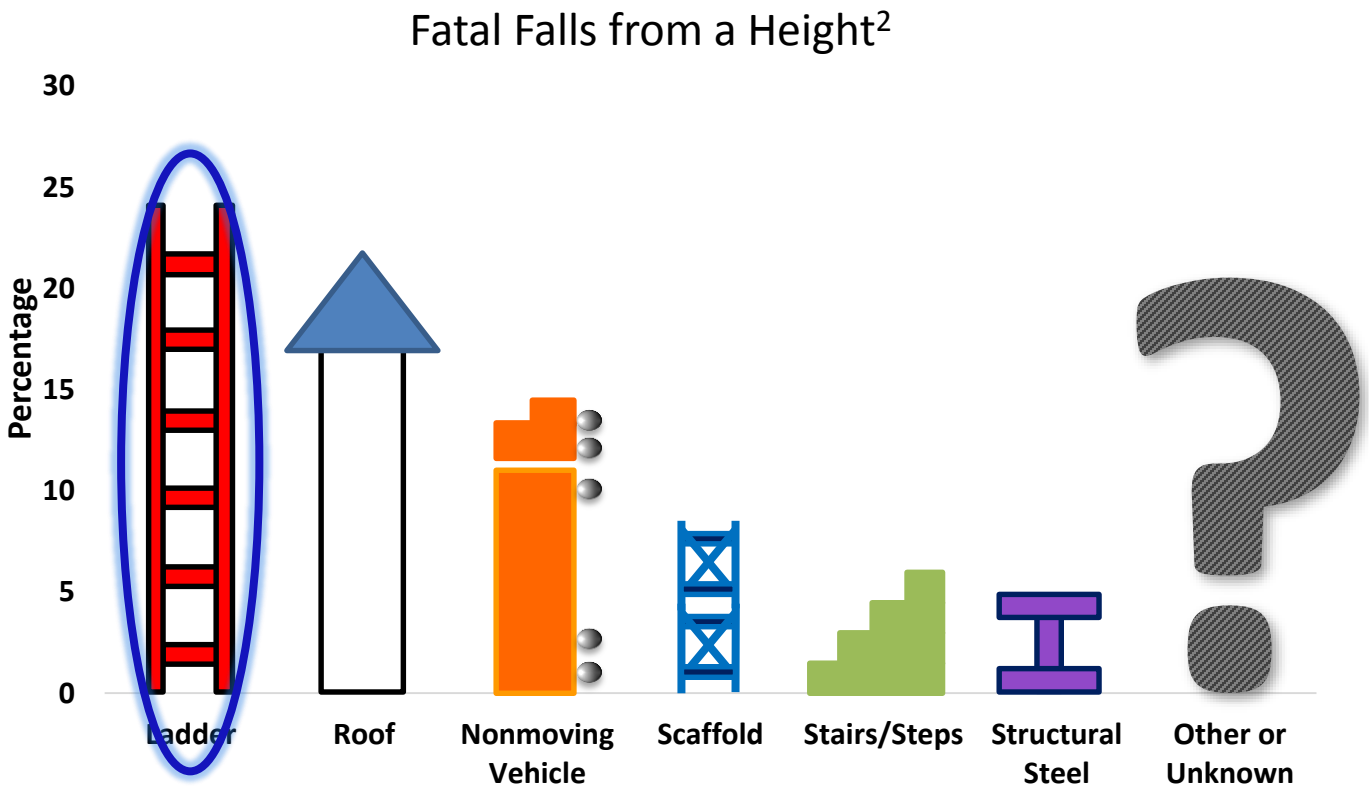
Fall from a Height



[1]Liberty Mutual Research Institute for Safety. (2012). *from Research to Reality*.

[2]BLS. (2012). Census of Fatal Occupational Injuries Charts (Ed.).

Fatal Falls from a Height



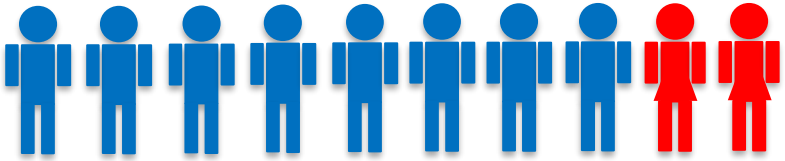
[2]BLS. (2012). Census of Fatal Occupational Injuries Charts (Ed.).

Ladder Falls

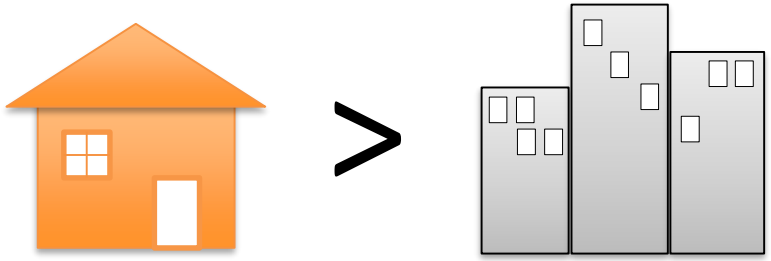
Multi-country epidemiology reports on ladder fall incidence

Australia[3], Denmark[4], Finland[5], Spain[6], Sweden[7], United Kingdom[8] and United States[9]

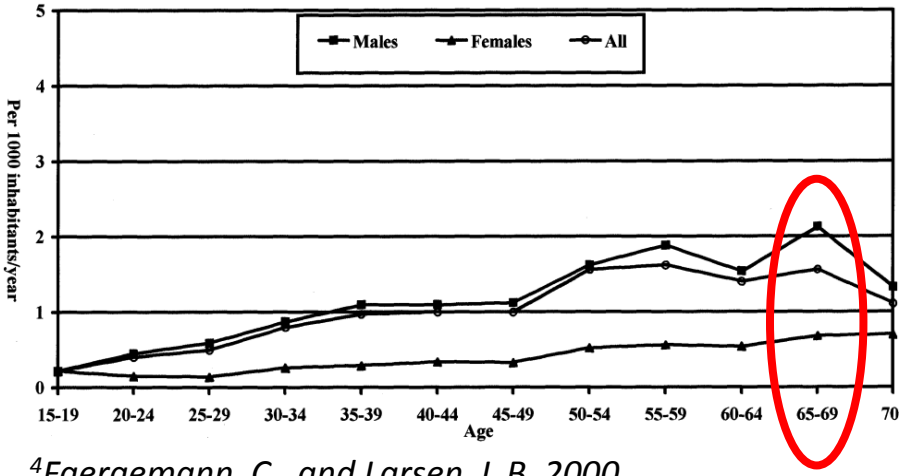
72%-87% of falls among men[3,4]



Majority in non-occupational setting[3,4,8,9]



Highest rates among older adults[4]



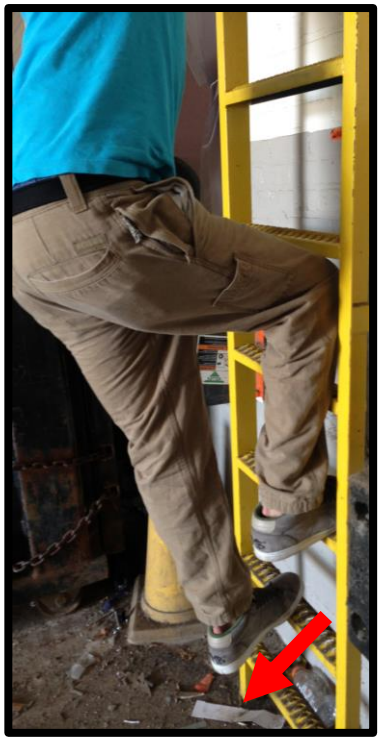
[4]Faergemann, C., and Larsen. L.B. 2000

[3]Ackland, H. M., et al. (2015). *Injury.*
[4]Faergemann, C., & Larsen, L. B. (2000). *Accident Analysis and Prev*.
[5]Hakkinen, K. K., Pesonen, J., & Rajamaki, E. (1988). *J Occupational Accidents*.
[6]Lopez, M. A., et al. (2011). *J Safety Research*.
[7]Bjormstig, U., & Johnsson, J. (1992). *J Safety Research*.
[8]Muir, L., & Kanwar, S. (1993). *Injury.*
[9]D'Souza, A. L., et al. (2007). *Amer. J Prev. Med*.

Causes of Ladder Falls

Investigated?

Sliding of base



Foot slipping

Over-reaching

Loss of balance

Mechanisms Causing Ladder Falls

Setup angle[10]

Sliding of base

75° from horizontal

Restricted foot placement[11]

Foot slipping

Increase toe gap distance

Mechanism?

Over-reaching

Recommendation?

Mechanism?

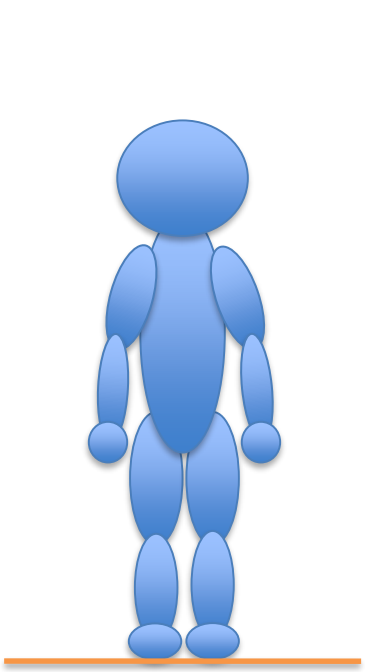
Loss of balance

Recommendation?

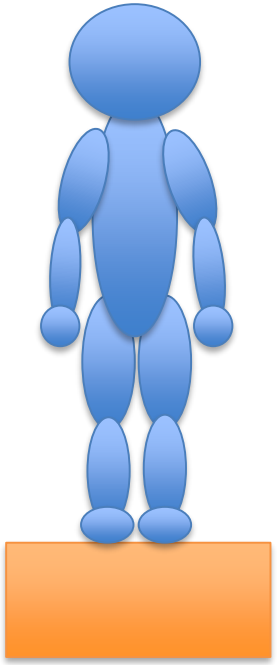
[10]Chang, C-C., et al. (2005). *Safety Science.* [11]Pliner, E.M., et al. (2014). *Ergonomics.*

Potential Mechanisms of Ladder Fall Risk

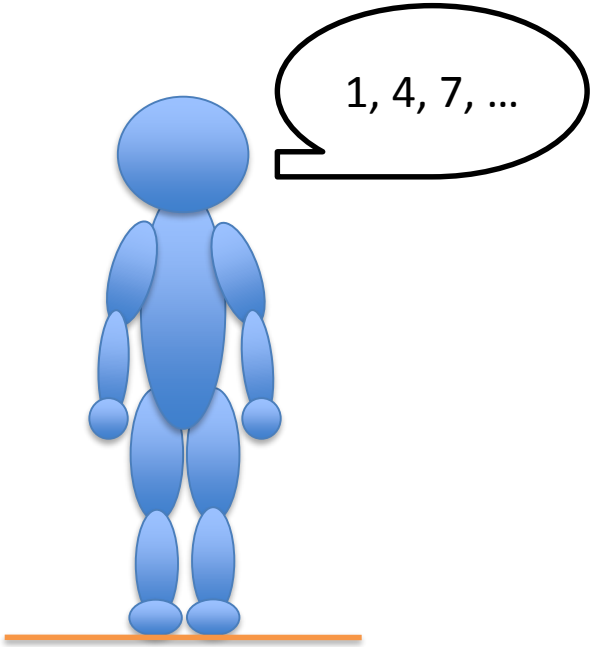
Physiological, Psychological, *&* ***Cognitive*** *abilities influence*



Balance[12]



Balance at Elevated Levels[13]



Balance While Performing a Secondary Task[14]

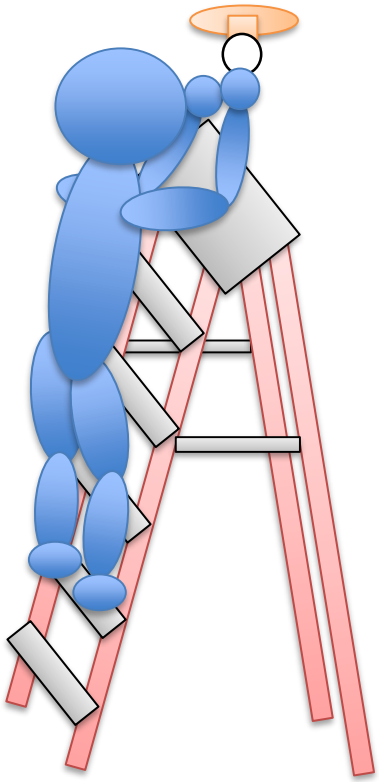
[12]Lord, S.R., et al. (2003). *Physical Therapy.*

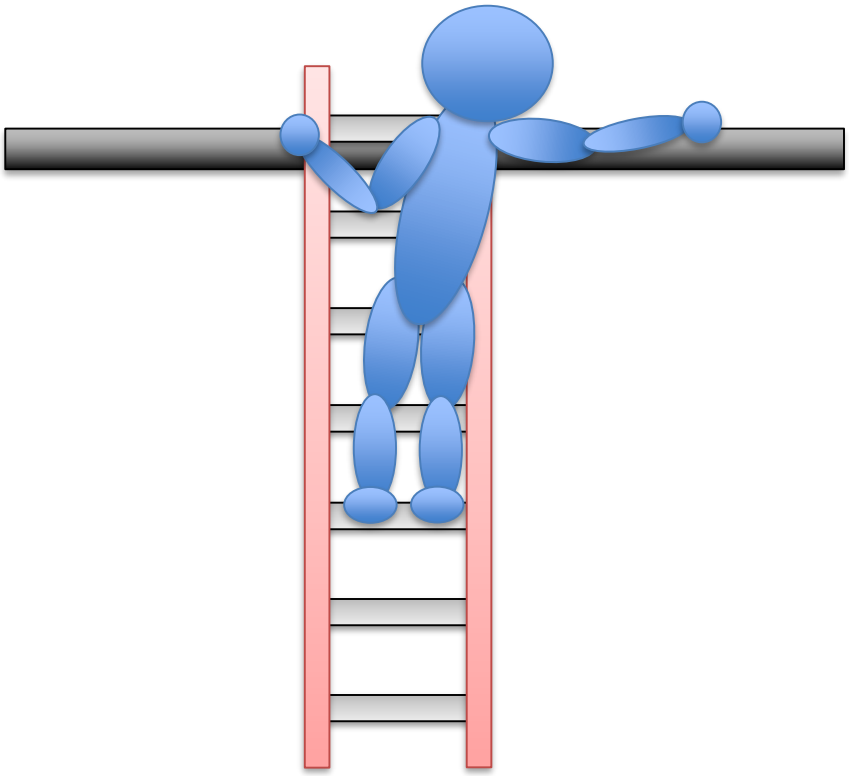
[13]Sturnieks, D.L., et al. (2016). *Human Movement.*

[14]Brown, L.A., et al. (2002). *Gerontology.*

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*

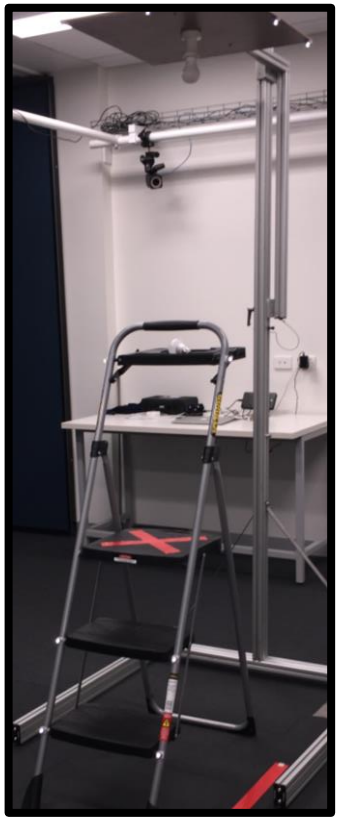
Unstable ladder user dynamics: *loss of balance and over-reaching*

Ladder Experiments

Ladder Experiments

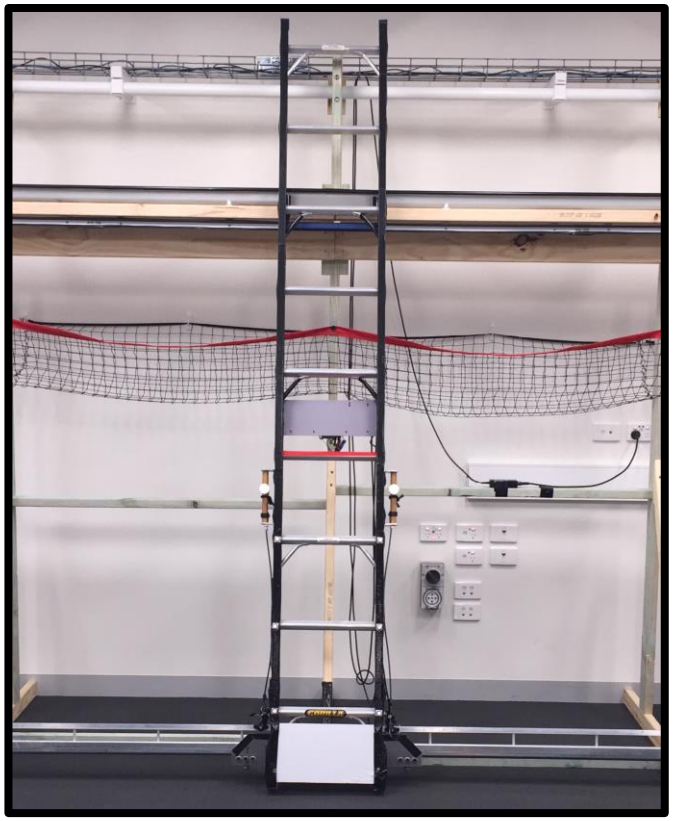
Washing
the windows

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

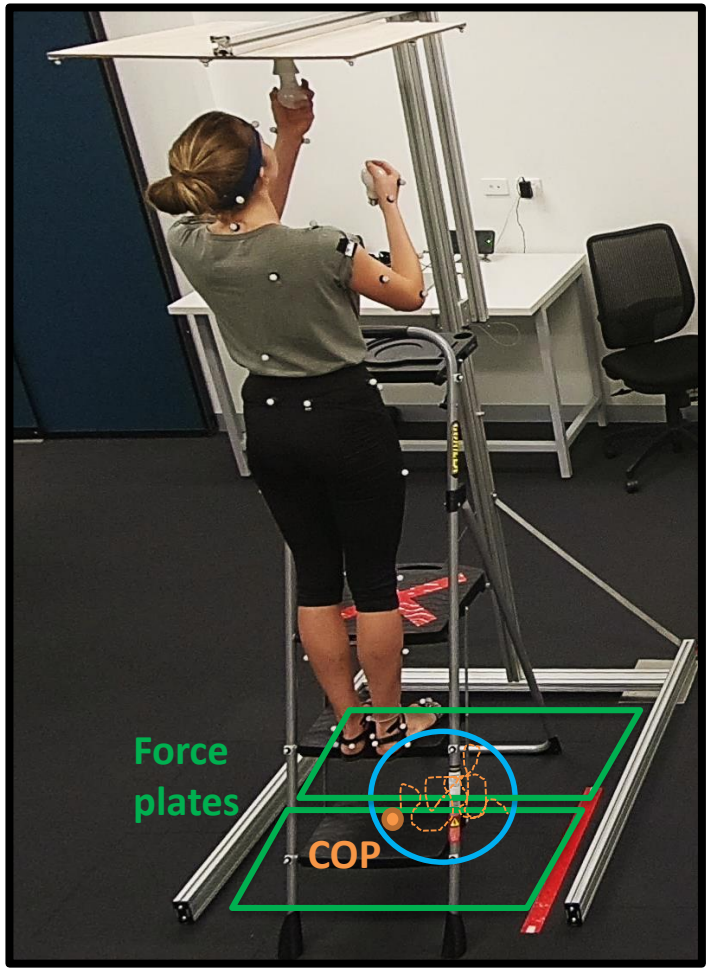
- Likelihood of the ladder tipping

$$\sum M_o = RF * \left(\frac{Width_L}{2} cos\,\theta\right) - W_L\left(\frac{Height_L}{2} sin\theta\right) - W_C(Height_C sin\theta + COM_{MaxDis} cos\theta)$$

Changing a Light Bulb

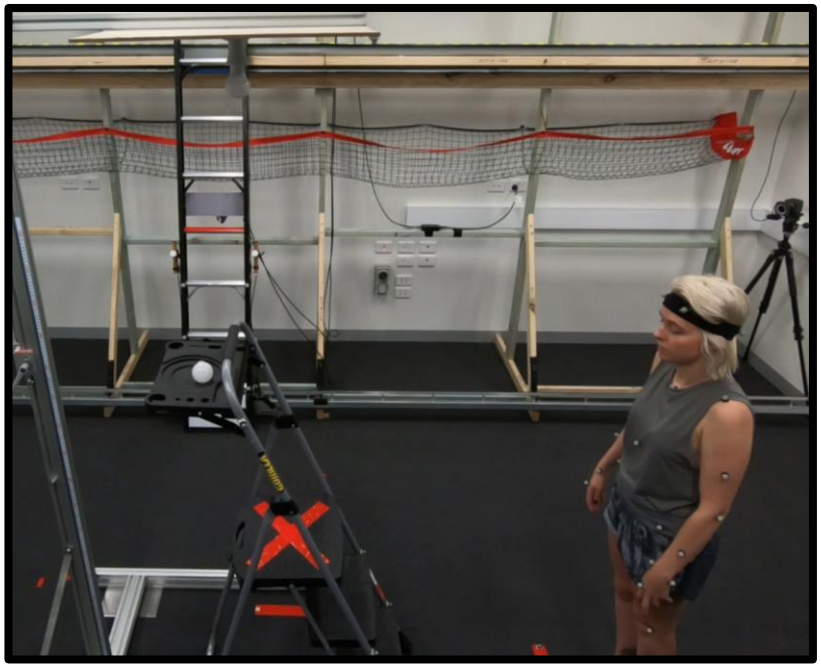
- **Complete twice**
  - Naming animals
  - No cognitive distraction
- ***"As <u>quickly</u> and <u>safely</u> as possible"***
- **Fall risk measure:**

  Task performance
  - Completion time
  - Stability on ladder

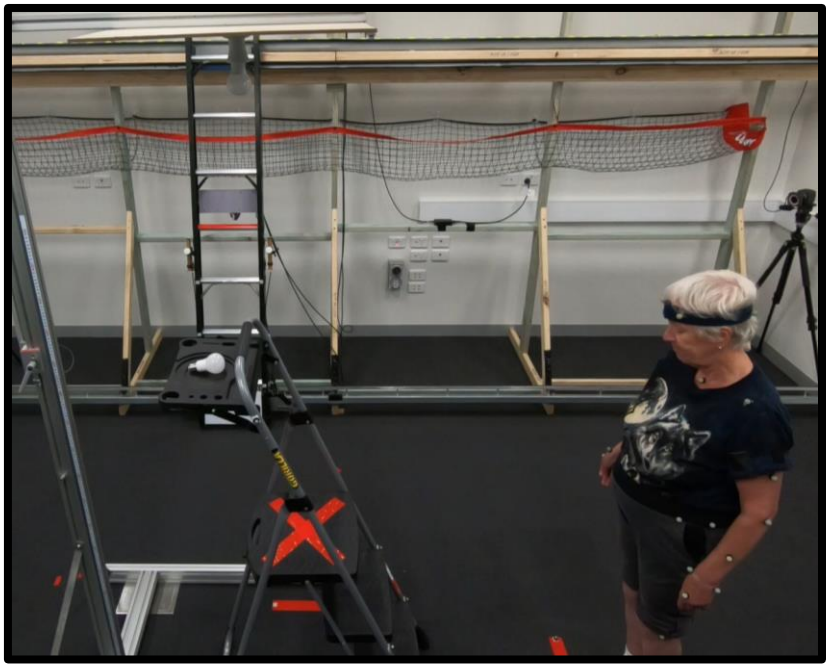


COP = Center of Pressure

Changing a Light Bulb



Younger adult



Older adult

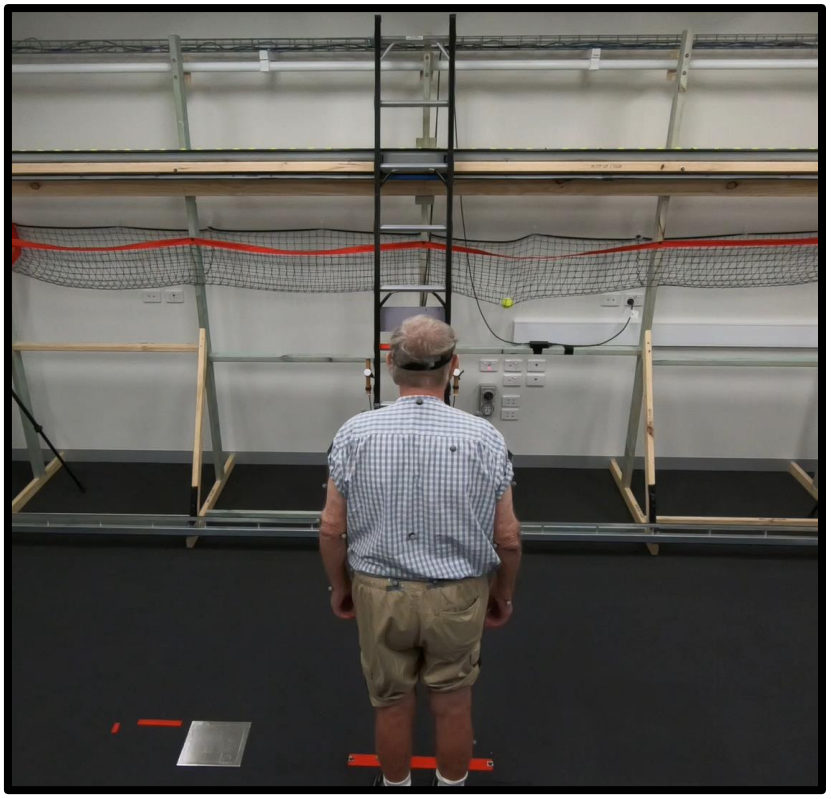
Cleaning a Gutter

- ***"How many times do you think you need to move the ladder to clean the gutter?"***
- **Complete once**
- ***"As <u>quickly</u> and <u>safely</u> as possible"***
- **Fall risk measure:**

Judgment error =
$Percieved\ Moves - Actual\ Moves$

Cleaning a Gutter

Younger adult

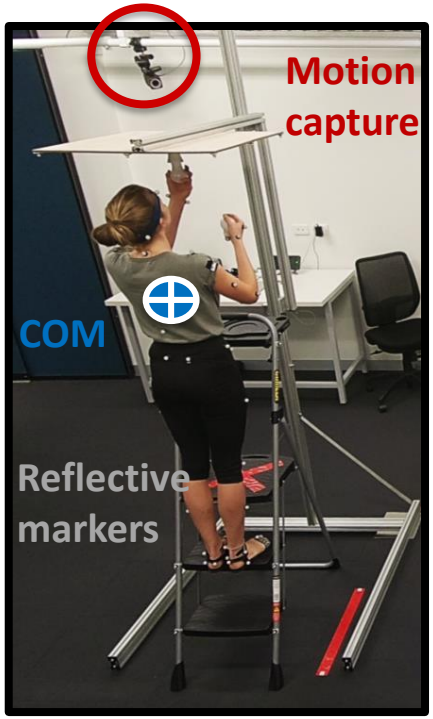


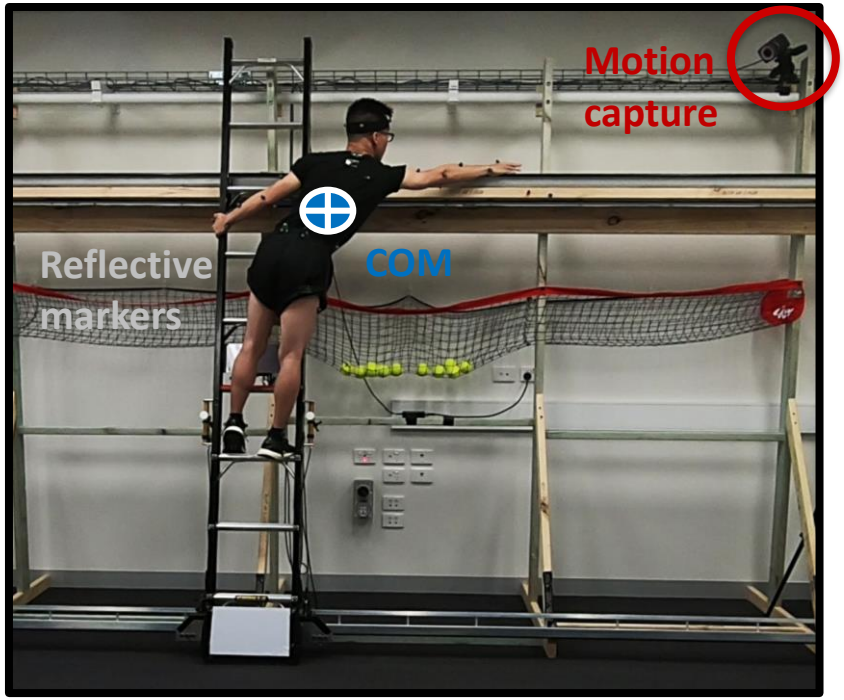
Older adult

Risk of Climber Falling and Ladder Tipping

Risk of Climber Falling – Motion Data

$$\frac{\textit{Maximum COM displacement in experiments}}{\textit{Maximum COM displacement in baseline lean and reach tests}}$$





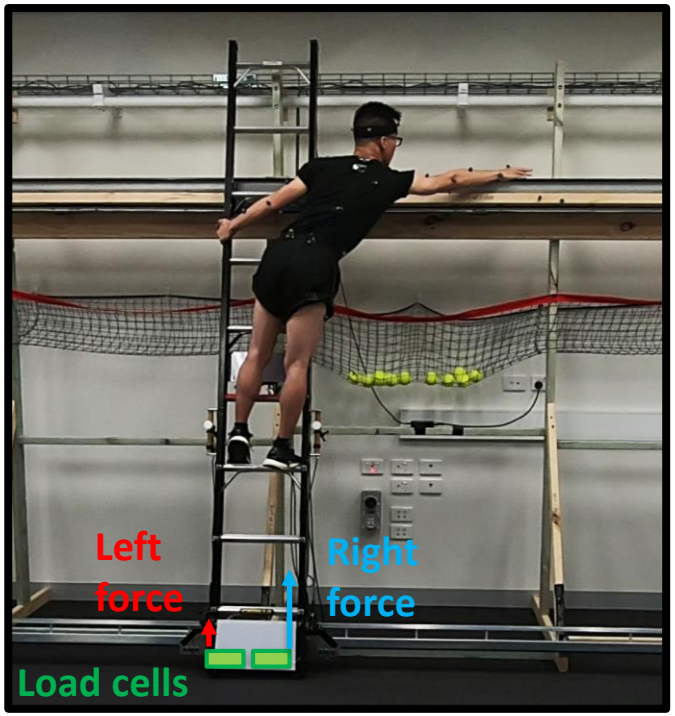
Greater value is associated with greater probability of the climber falling

Value > 1 *indicates the climber would fall without holding onto an external object*

Risk of Ladder Tipping – Force Data

$\boldsymbol{Medial - lateral}$ $\boldsymbol{COP}$ *displacement*

$|\boldsymbol{left\ force - right\ force}|$



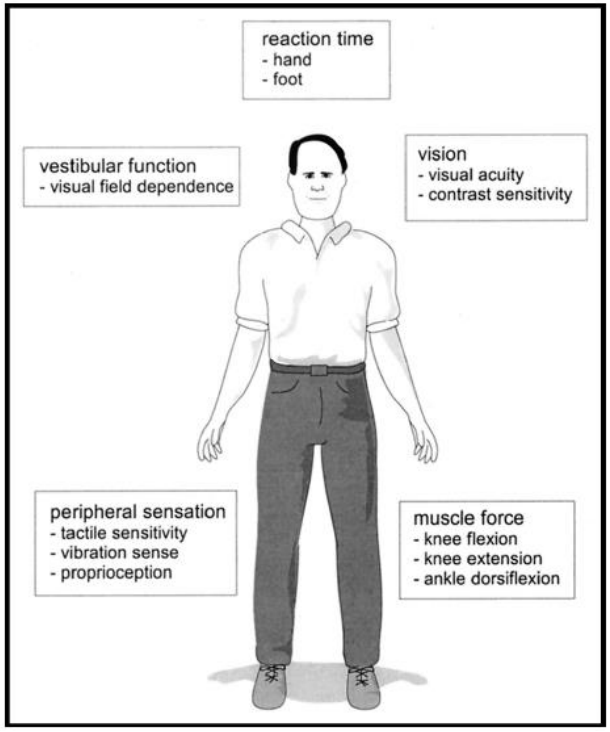
Greater medial – lateral COP displacement will indicate greater probaility of the ladder tipping

Greater difference between load cell forces will indicate greater probaility of the ladder tipping

Individual Factors

Assessments of Individual Factors

Physiological



[12]*Lord, S.R., et al. 2003*

- Physiological Profile Assessment (PPA)[10]
- Upper limb PPA

[12]Lord, S.R., et al. (2003). *Physical Therapy.*

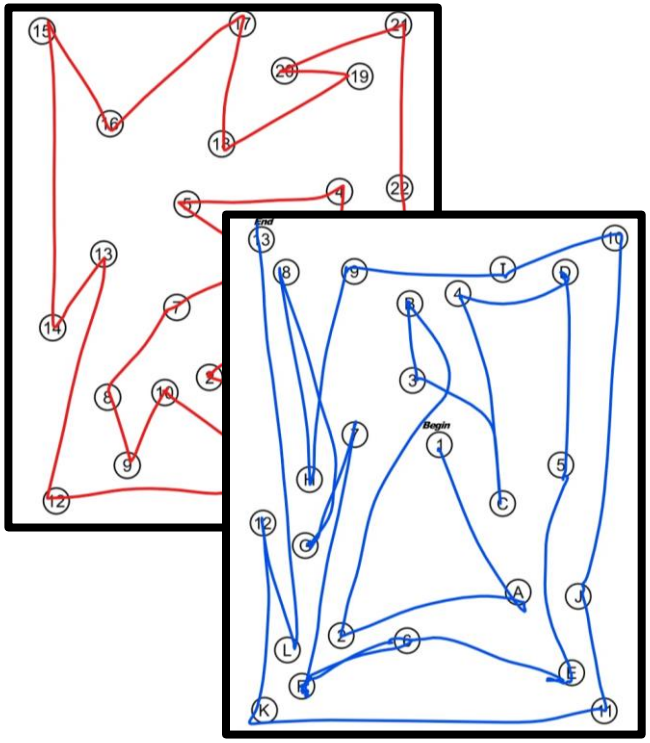
Psychological

[17]*Delbaere, K., et al. 2010*

- Risk-taking assessment[13]
- Anxiety assessment (GAD)[16]
- Iconographical Falls Efficacy Scale[17]

[15]Butler, A.A., et al. (2015). *Gerontology.*
[16]Spitzer, R.L., et al. (2006). *Arch. Intern. Med.*
[17]Delbaere, K., et al. (2010). *Gerontology.*

Cognitive

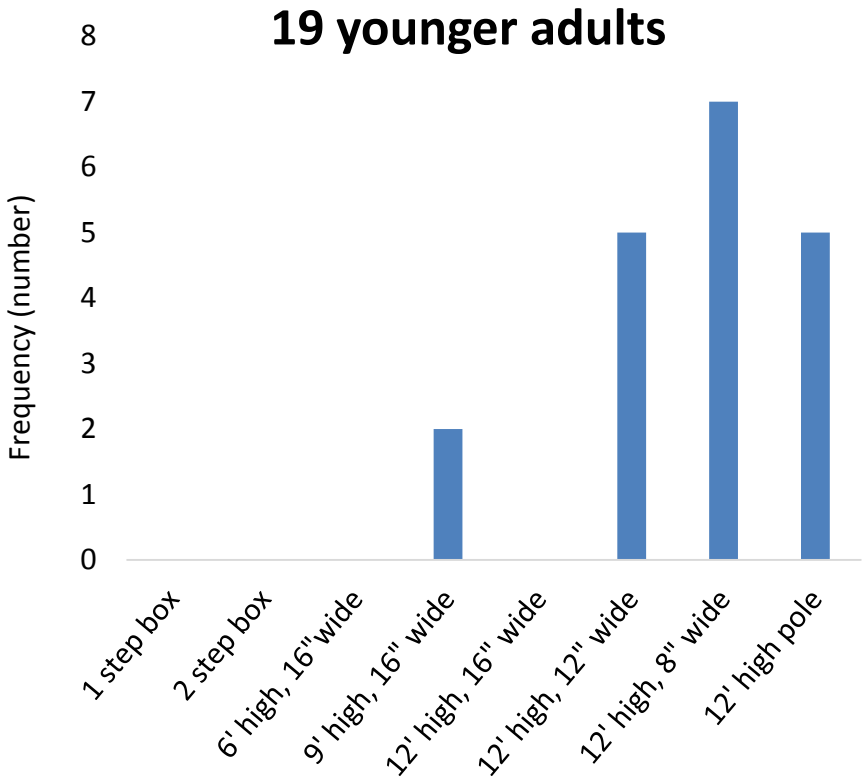


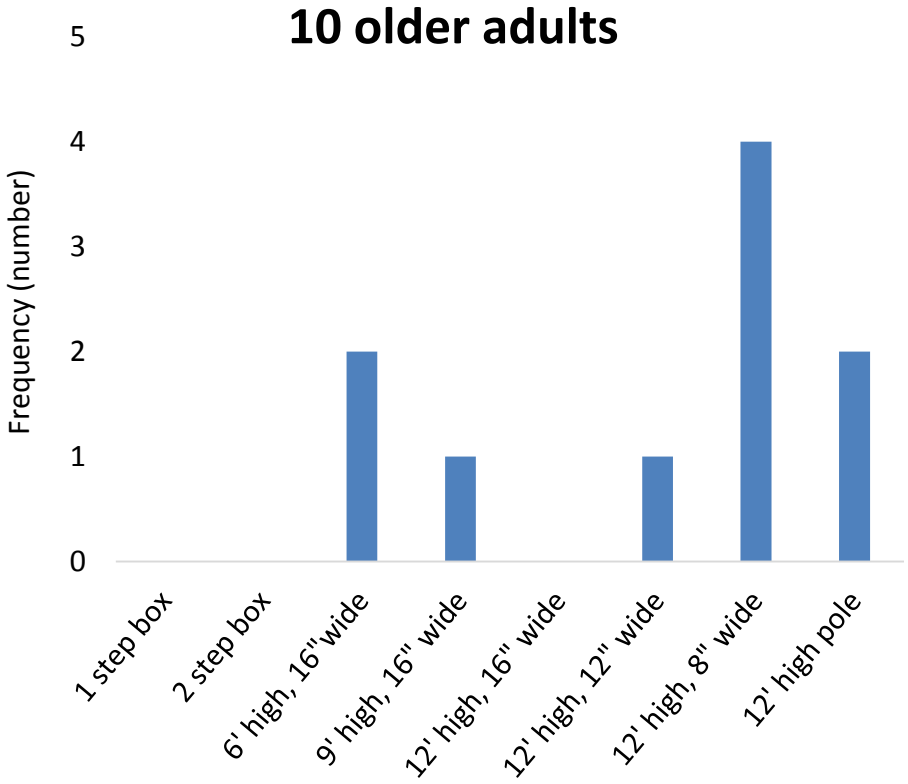
- Trail making test A & B[18]

[18]Reitan, R.M., (1958). *Percep. Motor Skills.*

Preliminary Data

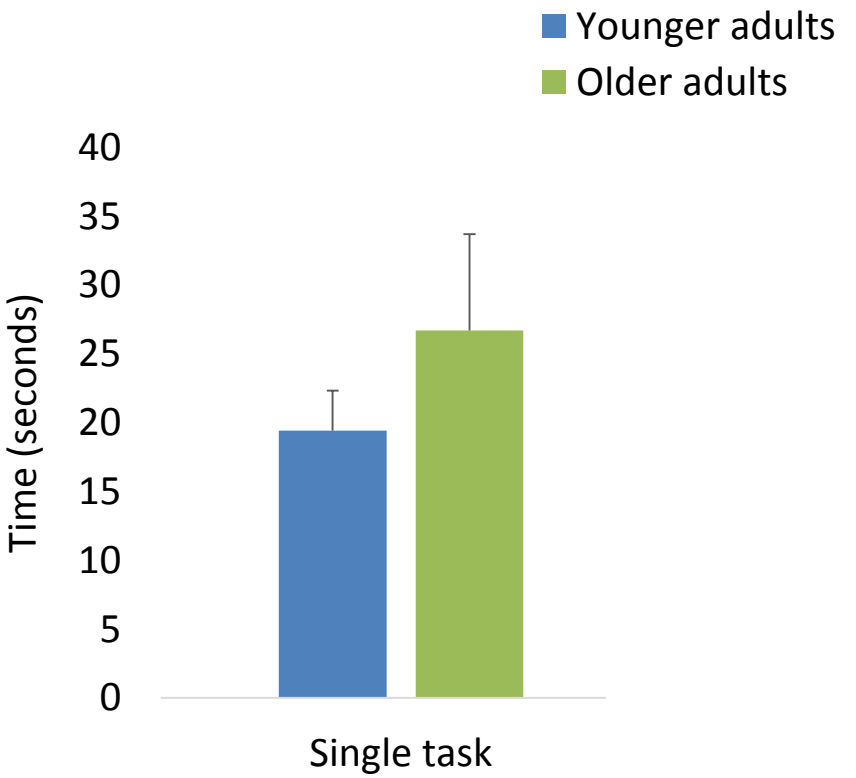
Washing the Window – Behavioral Risk





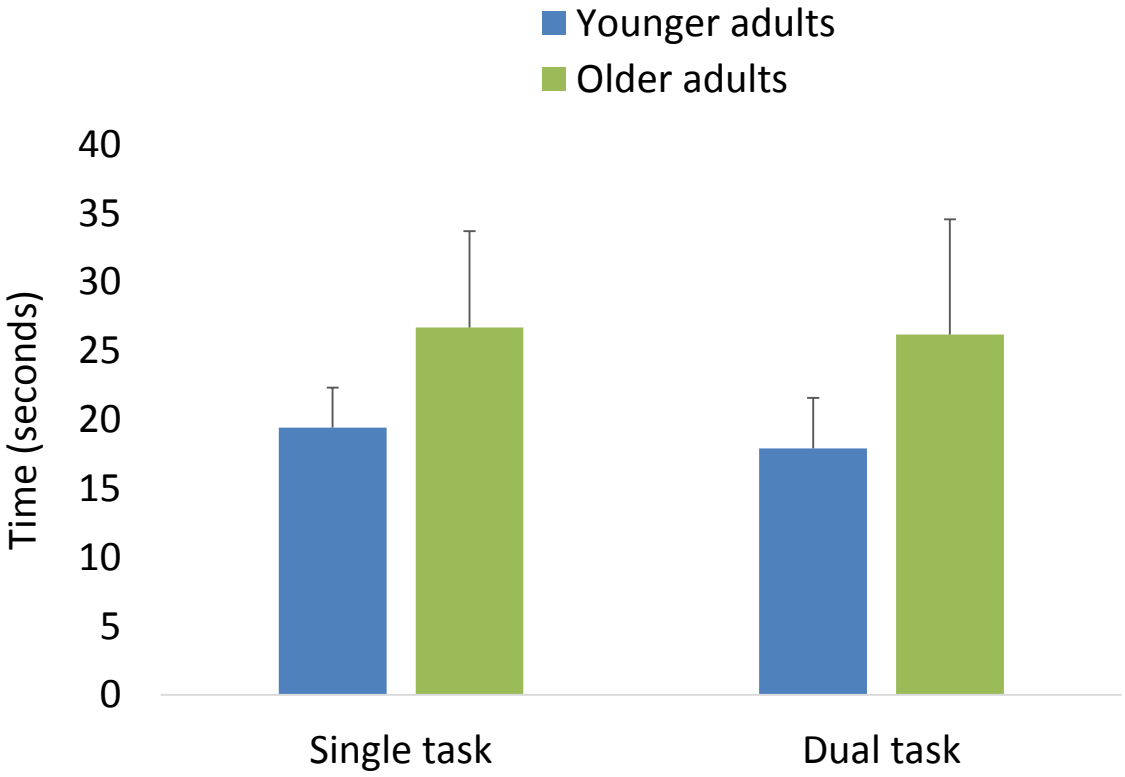
Riskiest ladder chosen to wash a window

Changing the Light Bulb – Task Performance



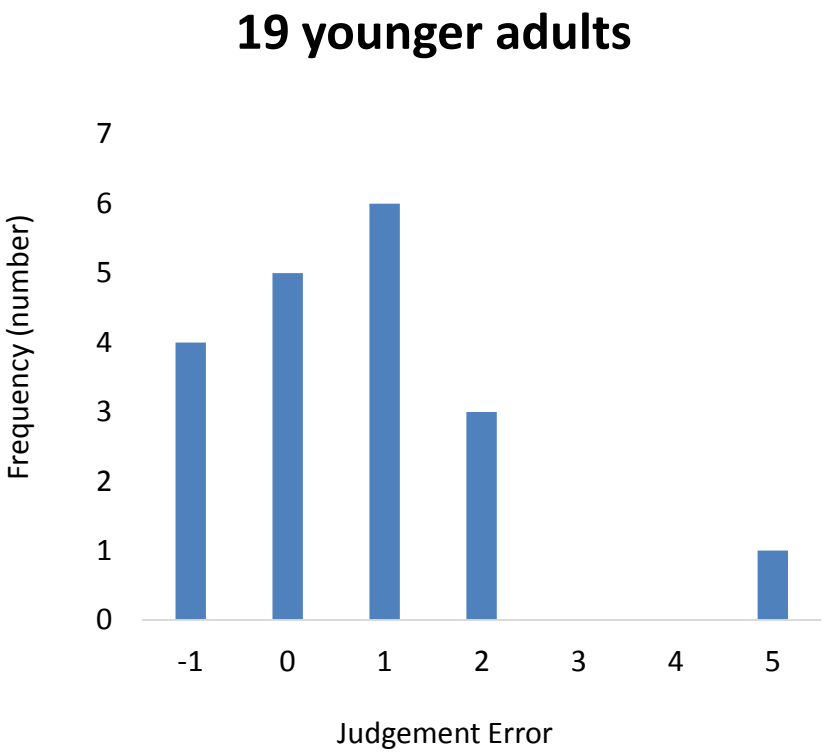
Time taken to change a light bulb

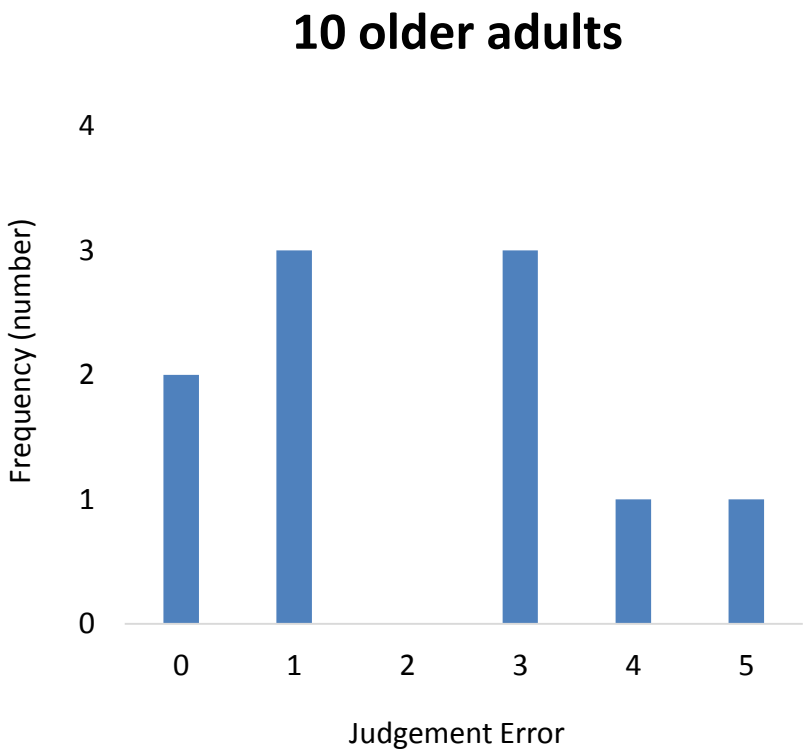
Changing the Light Bulb – Task Performance



Time taken to change a light bulb

Cleaning the Gutter – Judgement Error





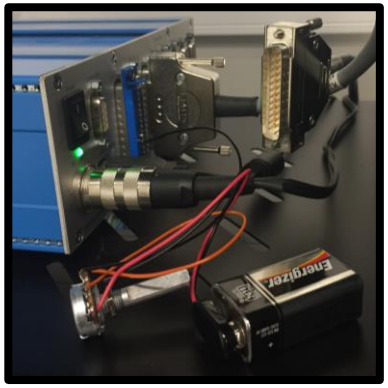
Difference in perceived and actual climbs taken to clean a gutter

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***

Thanks & Acknowledgments

Whitaker International Program



Special Thanks!

Mentors
- Stephen Lord
- Daina Sturnieks

Study setup
- Hilary Carter
- Artemij Iberzanov

Testing assistants
- Brandon Tan
- Yun Xuan Khoo
- Ruiyi Liu

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

	Hypothesis	Statistical Test	Dependent variable	Predictor variables
Aim 1	Biomechanical analysis of the climber or ladder falling will be associated with greater ladder fall risk measures	Linear regression	Task performance	Risk of ladder tipping Risk of climbing falling
		Linear regression	Judgement error	
Aim 2	Physical, psychological and cognitive measures will predict ladder fall risk	Stepwise regression	Task performance	Physical measures Psychological measures Cognitive measures
		Stepwise regression	Judgement error	
		Stepwise regression	Behavioral risk	
Aim 3	Ladder use will vary by low and high ladder fall risk groups	Chi-squared test	Use by ladder type	Ladder fall risk group
		Chi-squared test	Ladder use behavior	
		Chi-squared test	Fall history	