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Biomechanics of ladder falls: Informing fall prevention efforts

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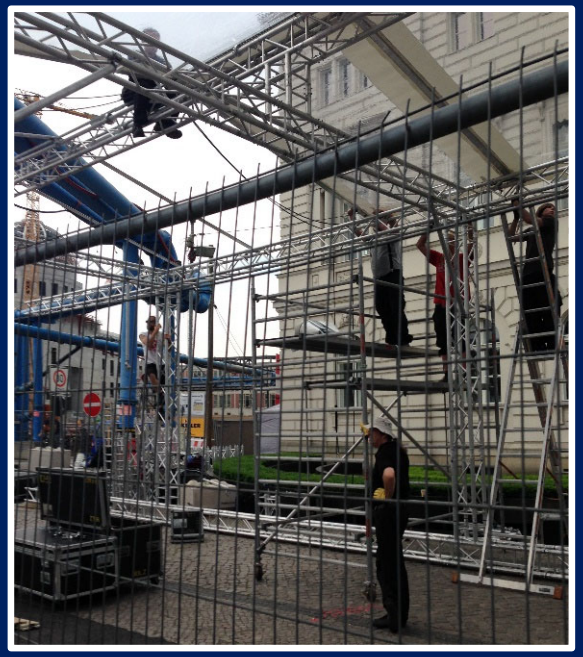
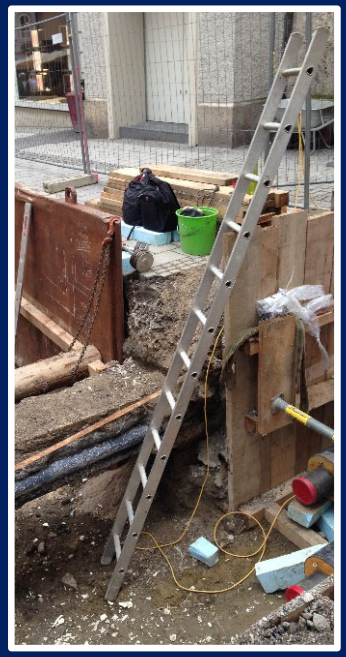
Falls to lower Levels

Ladders are associated with:

- **15,000 non-fatal falls**
- **113 fatal falls**

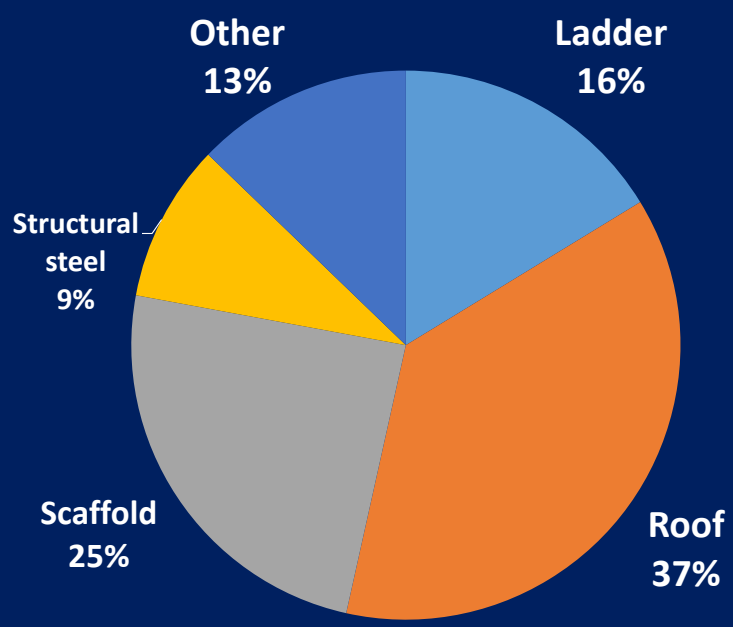
Median of 20 days away from work for ladder-related falls



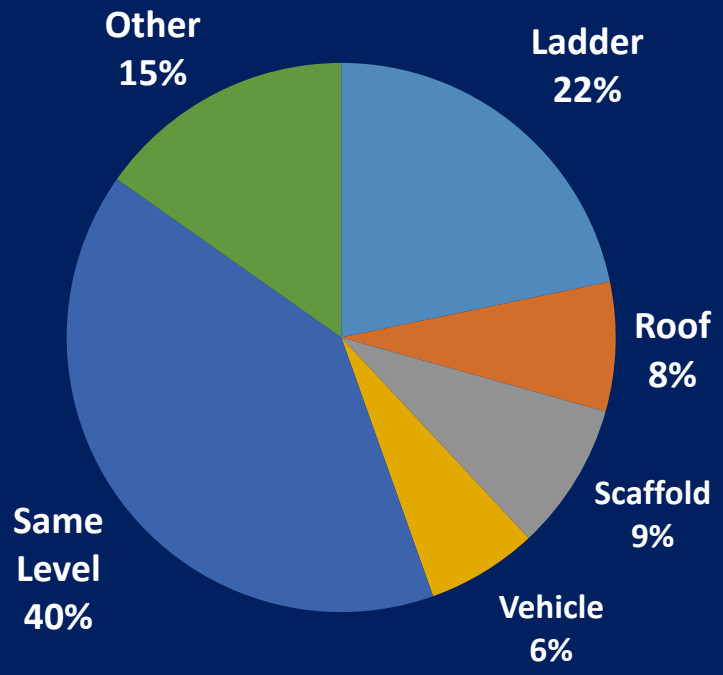


[1]Socias, C.M., et al.. (2014). *Morbidity and mortality weekly report.*

Ladders are frequently involved in fatal and disabling falls in the workplace



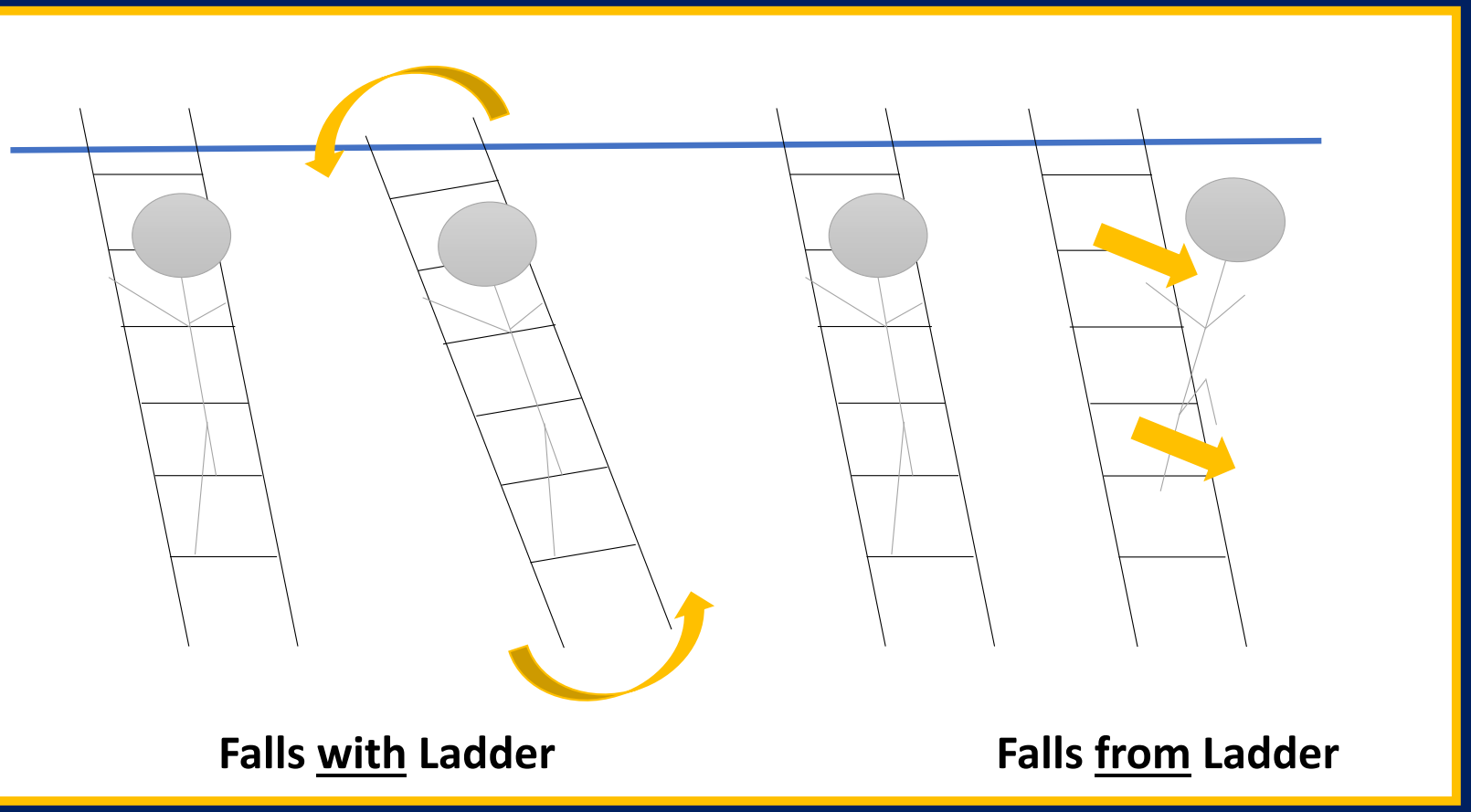
Fatal Falls



Disabling Falls

U.S DoL- BLS, *New Data Highlight Gravity of Construction Falls*, 1996: Washington, D.C.

Ladder Fall Type



[3]Shepherd, G.W., et al. (2006). *Ergonomics.*

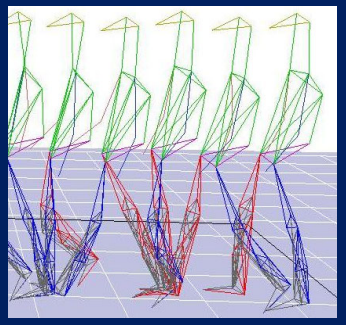
Slips commonly cause occupational ladder fall events

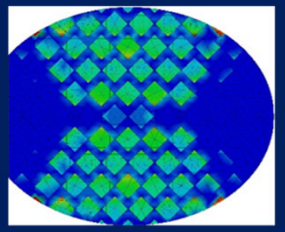
- **“Slip on rungs” was the initiating event for 14% of ladder-related fatalities[1]**

- **“Slipped/lost balance” was the initiating event for 25% of occupational non-fatal falls [2,3]**

[1]Shepherd, G. W., Kahler, R. J., & Cross, J. (2006). Ergonomic design interventions–a case study involving portable ladders. *Ergonomics, 49*(3), 221-234.
[2]Smith, G. S., Timmons, R. A., Lombardi, D. A., Mamidi, D. K., Matz, S., Courtney, T. K., & Perry, M. J. (2006). Work-related ladder fall fractures: identification and diagnosis validation using narrative text. *Accident Analysis & Prevention, 38*(5), 973-980.
[3]López, M. A. C., Ritzel, D. O., González, I. F., & Alcántara, O. J. G. (2011). Occupational accidents with ladders in Spain: Risk factors. *Journal of Safety Research, 42*(5), 391-398.

Research philosophy



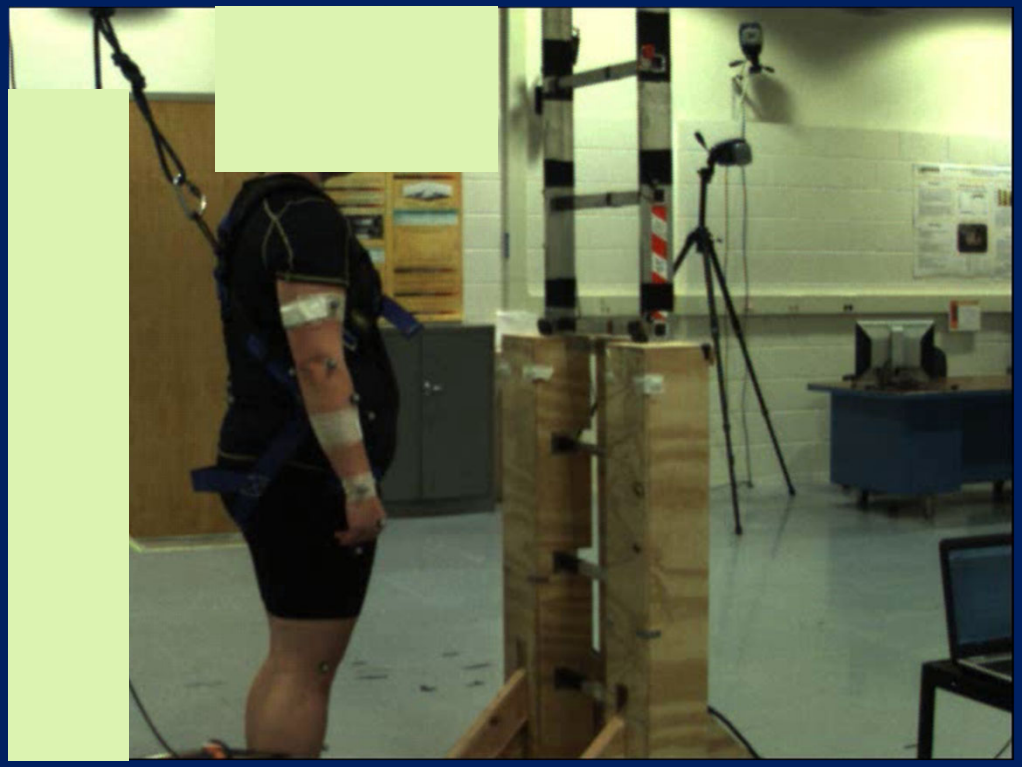


Engineering mechanics analyses

Human motion

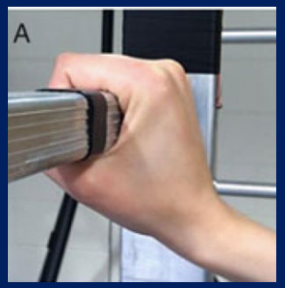
Ergonomic interventions

What happens during a slip?



Impact of ergonomic design and human factors on slipping risk

Controlled grasping



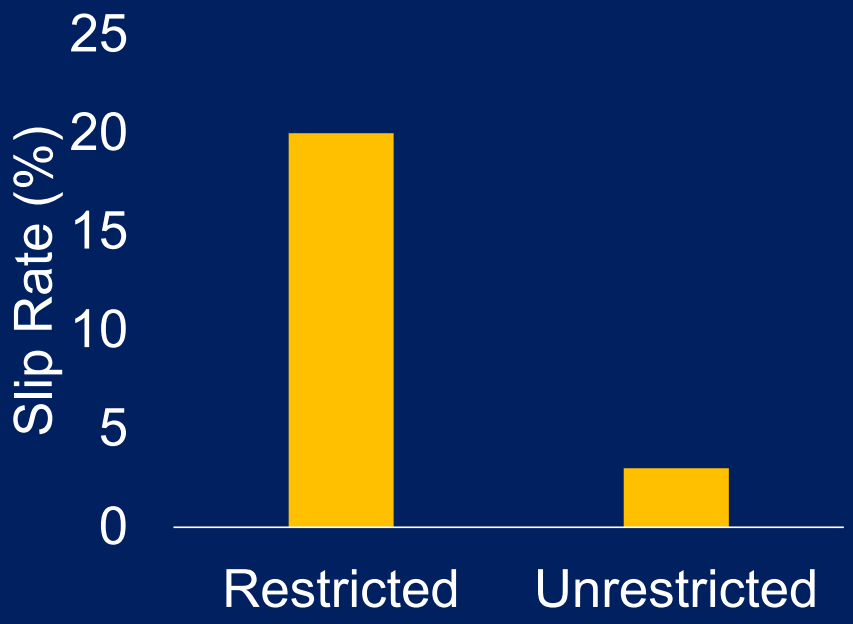
Controlled foot placement

Pliner, E. M., Campbell-Kyureghyan, N. H., & Beschorner, K. E. (2014). Effects of foot placement, hand positioning, age and climbing biodynamics on ladder slip outcomes. *Ergonomics*, *57*(11), 1739-1749.

Environmental factors: restricted foot placement

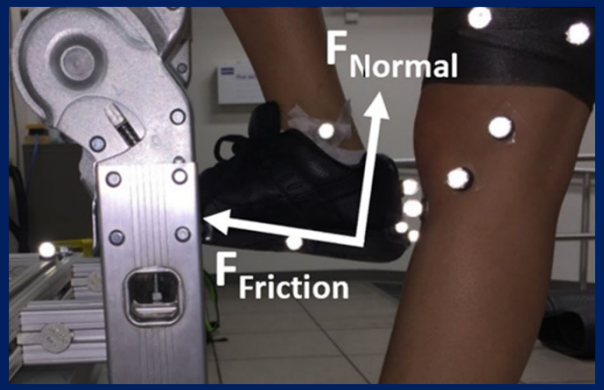
Restricted

Unrestricted

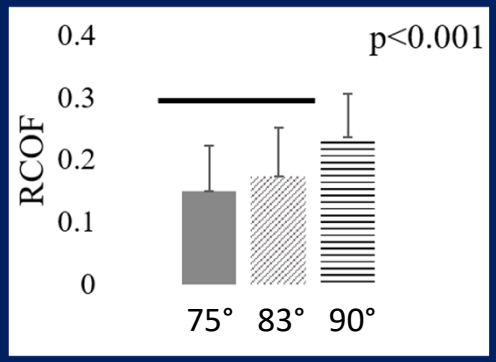


Pliner, E. M., Campbell-Kyureghyan, N. H., & Beschorner, K. E. (2014). Effects of foot placement, hand positioning, age and climbing biodynamics on ladder slip outcomes. *Ergonomics*, *57*(11), 1739-1749.

Environmental factors: Ladder angle



Higher slip risk



Martin, Ellen R., Erika M. Pliner, and Kurt E. Beschorner. "Characterizing the shoe-rung friction requirements during ladder climbing." *Journal of Biomechanics* 99 (2020): 109507.

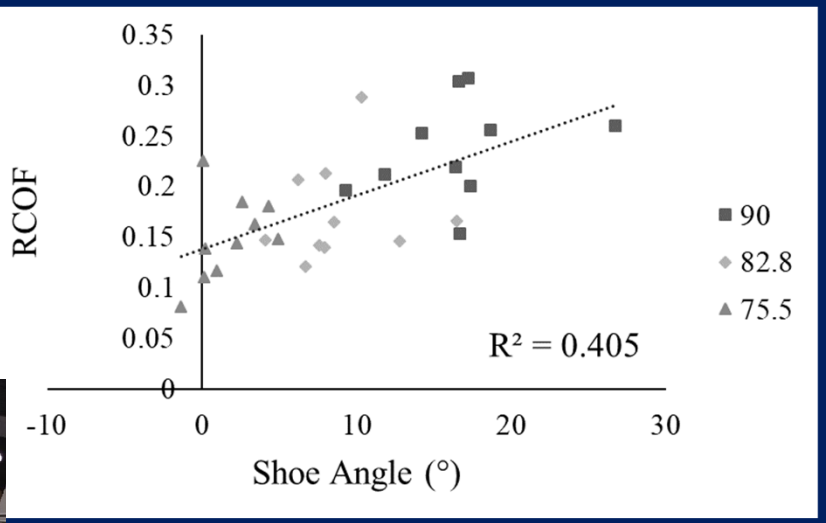
Ladder Climbing Observed in Power Plants

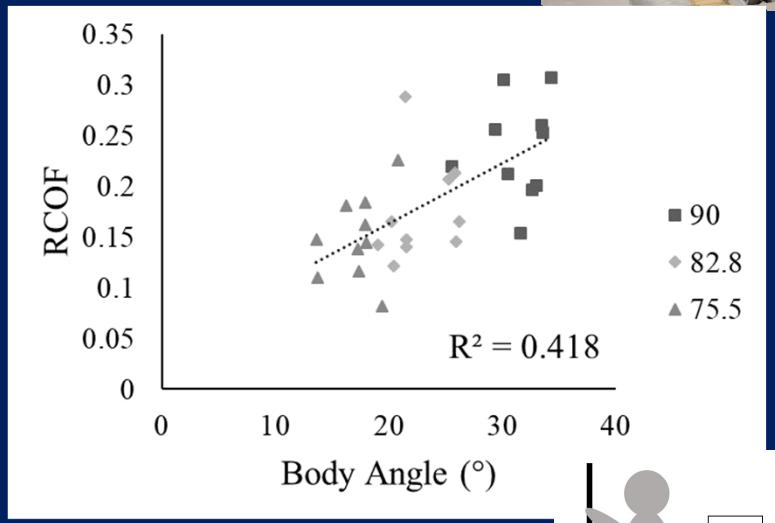
Human Factors: Foot and body positioning influence slip risk

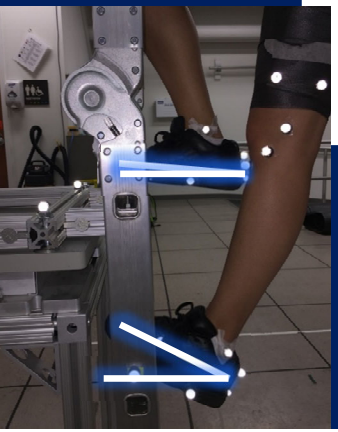
Shoe angle

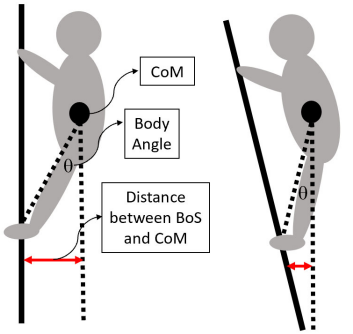
Body angle

Higher slip risk





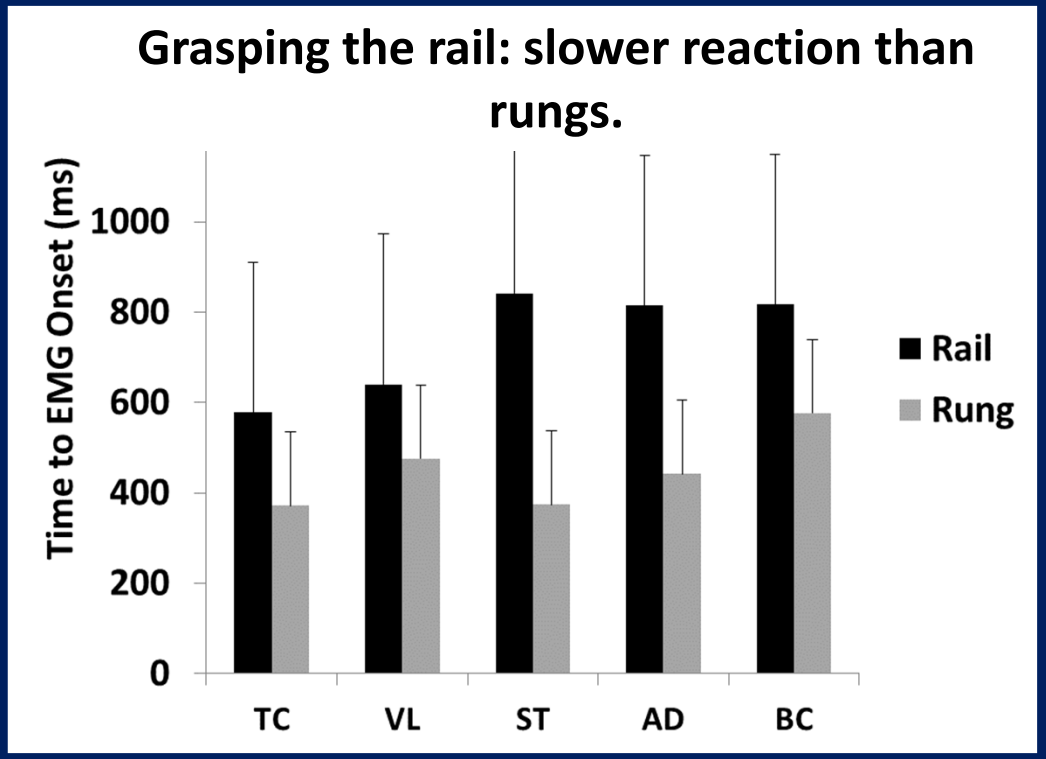




Martin, Ellen R., Erika M. Pliner, and Kurt E. Beschorner. "Characterizing the shoe-rung friction requirements during ladder climbing." *Journal of Biomechanics* 99 (2020): 109507.

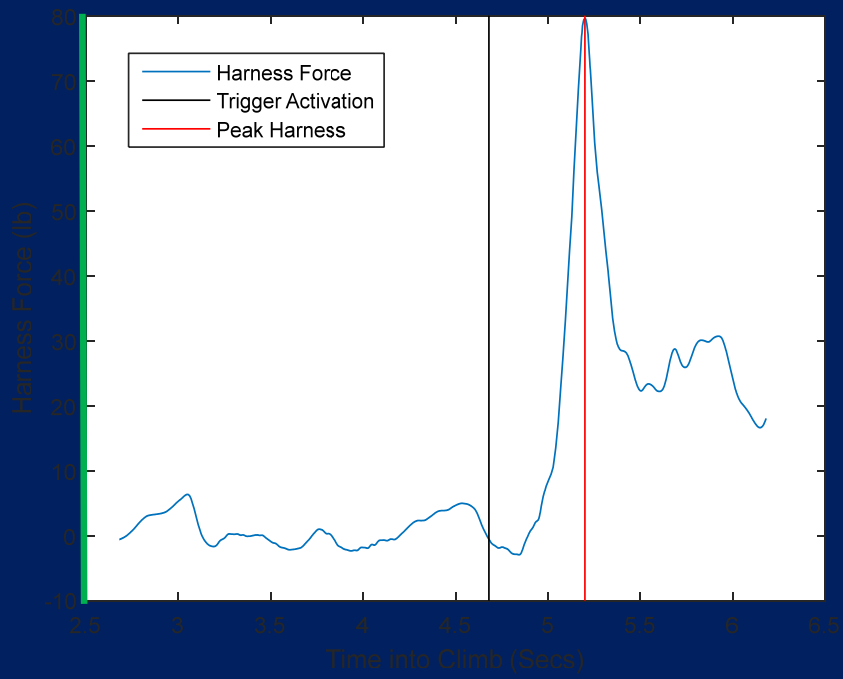
Experiment 2: Recovering from a ladder “misstep”

Human factors: Influence of grasp location on response speed

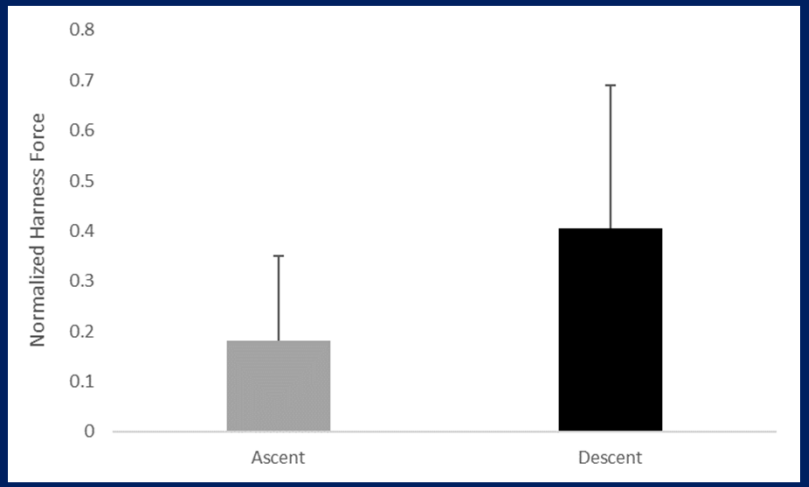


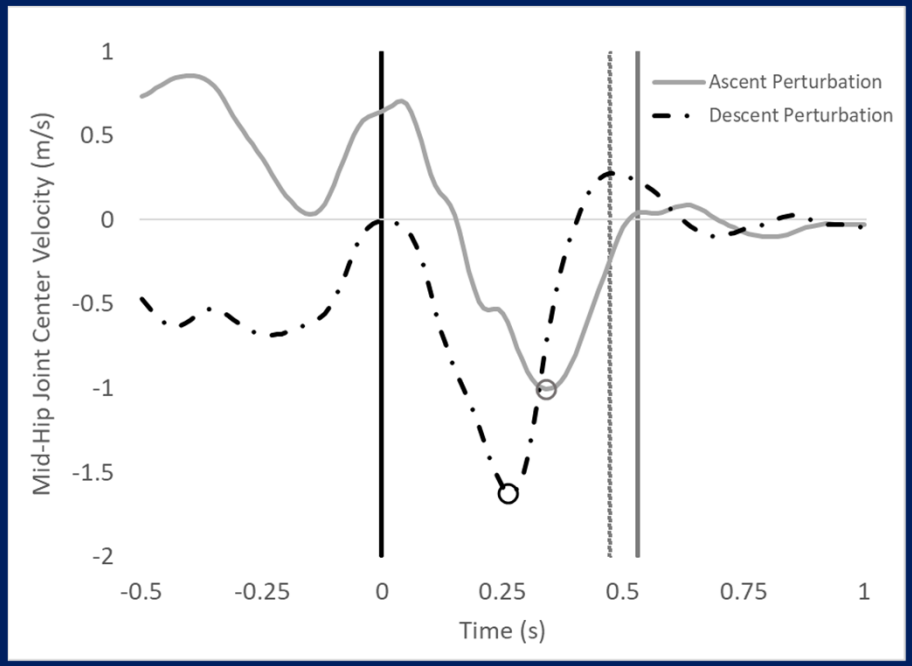
Schnorenberg, A.J., Campbell-Kyureghyan, N.H., Beschorner, K.E., 2015, Biomechanical Response to Ladder Slipping Events: Effects of Hand Placement, *Journal of Biomechanics* 48 (14), 3810-3815.

Ladder perturbation – video



Environmental factors: Ladder descent increases fall risk compared to ascent

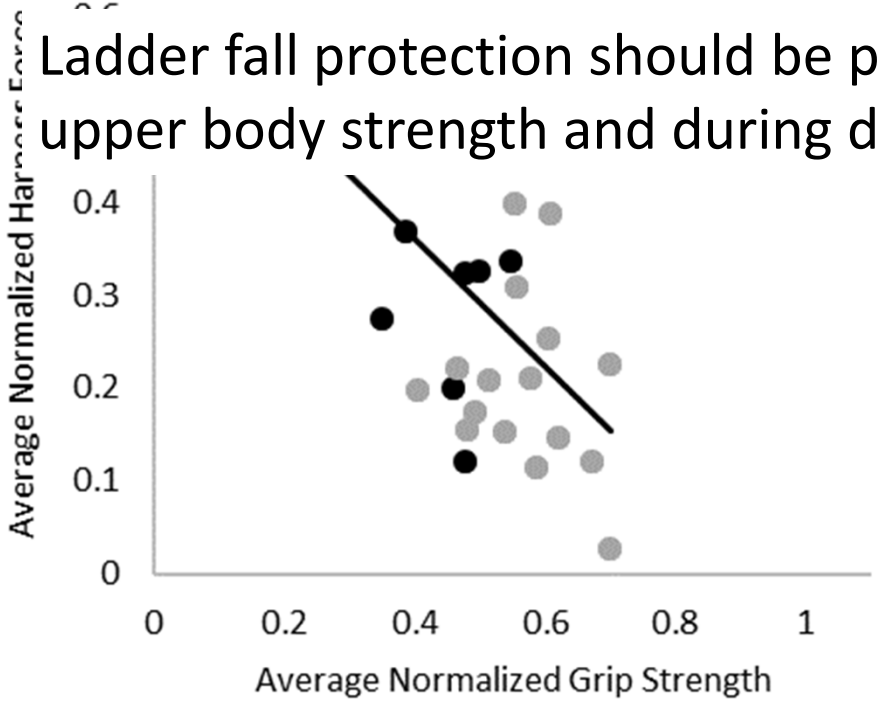


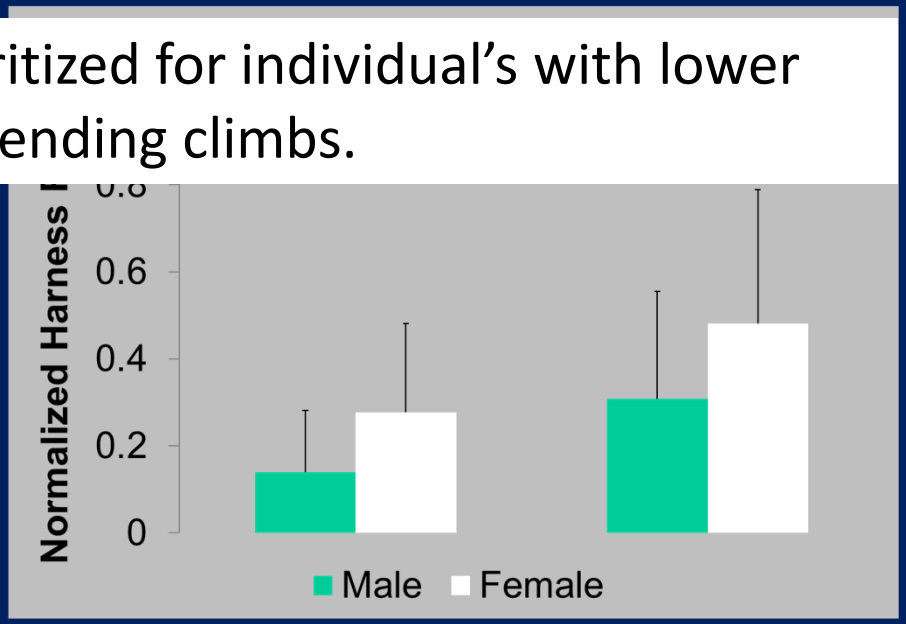


Pliner, E. M., Seo, N. J., Ramakrishnan, V., & Beschorner, K. E. (2019). Effects of upper body strength, hand placement and foot placement on ladder fall severity. *Gait & posture*, *68*, 23-29.

Human factors: Sex and grip strength can predict recovery from a ladder

Ladder fall protection should be prioritized for individual's with lower upper body strength and during descending climbs.





Pliner, E. M., Seo, N. J., Ramakrishnan, V., & Beschorner, K. E. (2019). Effects of upper body strength, hand placement and foot placement on ladder fall severity. *Gait & posture*, *68*, 23-29.

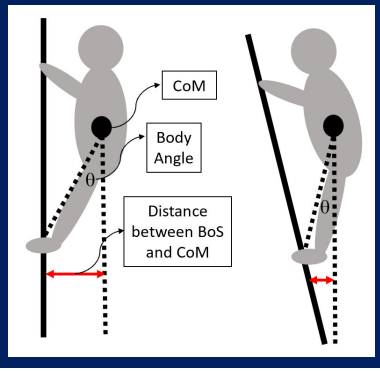
Factors associated with greater safety

Environmental

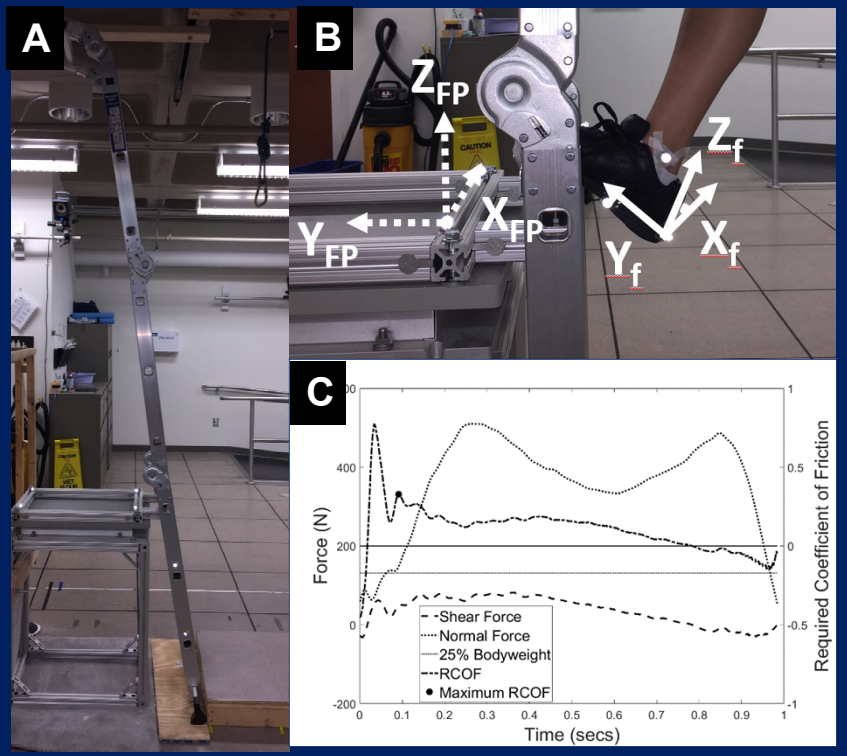
- Unrestricted foot placement
- Non-vertical ladders (~75°)
- Extra precautions for descent
- Ladders that enable better foot contact

Human factors

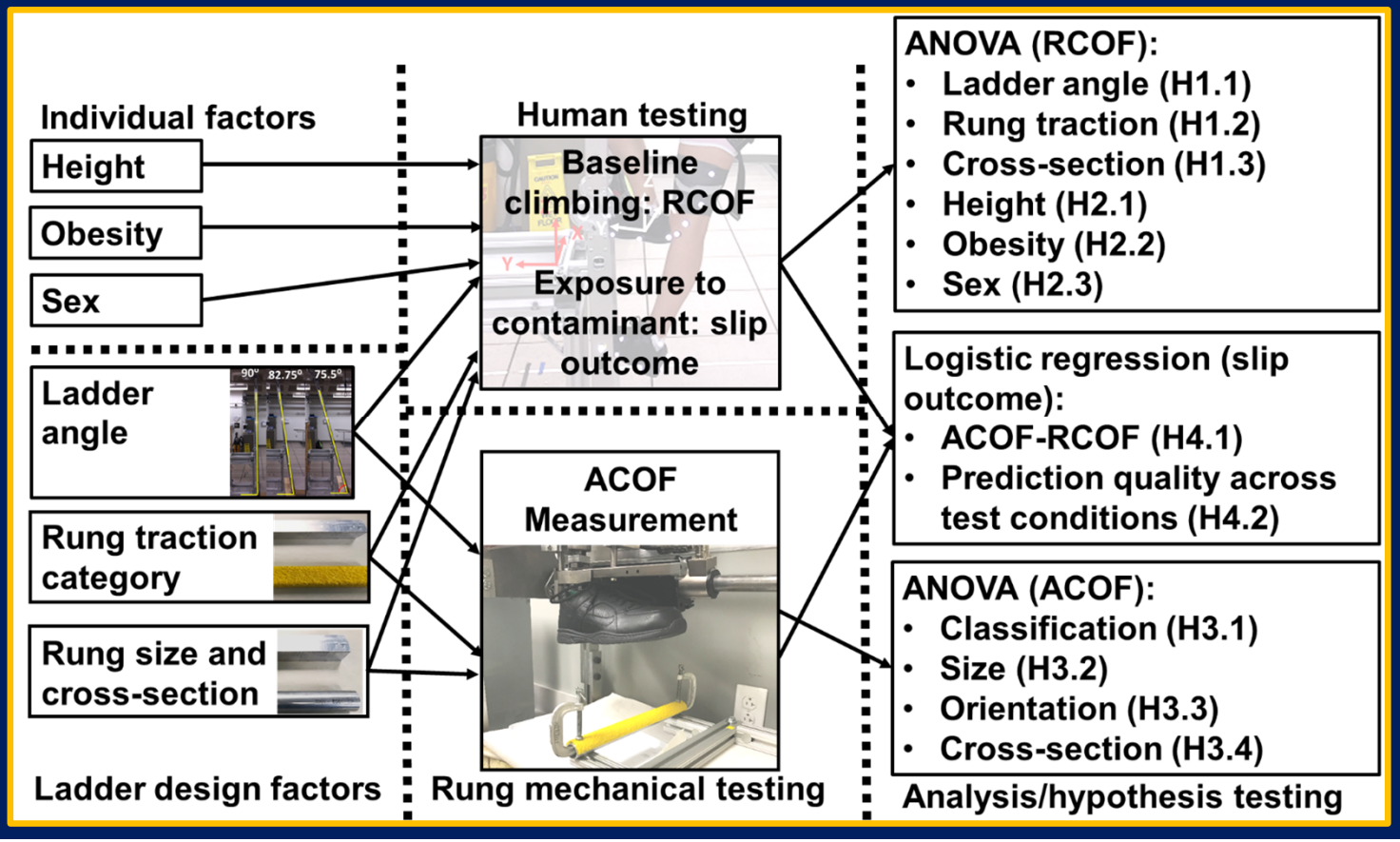
- Grasping rungs instead of rails
- Keeping body weight over feet
- Maintaining level feet
- Accommodating lower upper body strength individuals



Next phase of research: Influence of individual and ladder design factors on slipping events



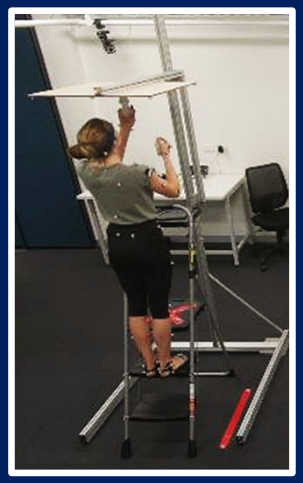
NIOSH: R01OH011799: Predicting slips during ladder climbing: novel methods for assessing shoe-rung friction



Additional factors identified since funding that are being considered

- **Ladder-to-roof transition (and vice versa)**
- **Base-to-fly transition during descent**
- **Carrying an object**
- **Exposure of rung surfaces to coatings (paint, tar, etc.)**
- **Role of footwear**

Also keep on eye out for aging and ladder fall research from Erika Pliner and Stephen Lord


- Pliner, E. M., Sturnieks, D. L., & Lord, S. R. (2020). Individual factors that influence task performance on a straight ladder in older people. *Experimental Gerontology*, 111127.
- Pliner, E.M., Sturnieks, D.L., Beschorner, K.E., Redfern, M.S., Lords, S.R., Individual factors that influence task performance on a stepladder, Safety Science, in review.

Put our research into action!

- **Links to full access articles are shared on:**
  - **LinkedIn: “Kurt Beschorner”**
  - **Twitter: @kurt_beschorner**
  - **E-mail me at beschorn@pitt.edu**

Partner with us!

- **We are always recruiting industry partners to help with our research**
- **Share stories of ladder slip and fall events (beschorn@pitt.edu)**
- **We will be recruiting participants in Fall, 2021.**
- **Benefits of being a partner:**
  - **Ensuring research results are relevant to your workers**
  - **Early access to research results**
  - **Flexible testing times → no interruption to work**
  - **Worker's get reimbursed for their time**

Acknowledgements:

- **NIOSH R01 OH 011799: Predicting slips during ladder climbing: novel methods for assessing shoe-rung friction**
- **NIOSH R21 OH 010038: Quantifying the Recovery Response and Role of Hand Strength During Ladder Falls**
- **NIOSH T42 OH 008672: Effects of Hand and Foot Positions on Ladder Slip and Fall Outcomes**
- **OSHA SH-24880-13-60-F-55: Safety and Ergonomics for Renewable Energy**

Thank You!

Put our research into action!

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