Presentation Overview

• Fatality statistics for fall-related incidents, 2012-2017
• Construction-related regulations – Subpart M
• Fall Protection
  • Personal fall-arrest system
  • Swing-fall research
  • Suspension Intolerance
• Fall Prevention
  • Slide-guard system
  • NIOSH-developed guardrail system
• Ladder Usage
  • NIOSH Ladder Safety App
• Summary
Fall-related fatality statistics, 2012-2017
## Fatality Data, 2012-2017

(Publicly accessible data from BLS, Census of Fatal Occupational Injuries, [www.bls.gov/iif](http://www.bls.gov/iif))

<table>
<thead>
<tr>
<th>Category</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
<th>2016</th>
<th>2017</th>
<th>% Incr ‘12–’17</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total U.S. occupational fatalities</td>
<td>4628</td>
<td>4585</td>
<td>4821</td>
<td>4836</td>
<td>5190</td>
<td>5147</td>
<td>11%</td>
</tr>
<tr>
<td>Total U.S. occupational fatal falls to lower level</td>
<td>570</td>
<td>595</td>
<td>660</td>
<td>648</td>
<td>697</td>
<td>713</td>
<td>25%</td>
</tr>
<tr>
<td>Total Construction fatalities</td>
<td>806</td>
<td>828</td>
<td>899</td>
<td>937</td>
<td>991</td>
<td>971</td>
<td>21%</td>
</tr>
<tr>
<td>Total Construction fatal falls to lower level</td>
<td>279</td>
<td>291</td>
<td>345</td>
<td>350</td>
<td>370</td>
<td>366</td>
<td>31%</td>
</tr>
<tr>
<td>Construction fatal falls, roof edge only</td>
<td>51</td>
<td>46</td>
<td>54</td>
<td>50</td>
<td>65</td>
<td>56</td>
<td>10%</td>
</tr>
<tr>
<td>Ladder-related fatal falls in construction</td>
<td>29</td>
<td>26</td>
<td>45</td>
<td>45</td>
<td>44</td>
<td>45</td>
<td>55%</td>
</tr>
</tbody>
</table>

Note: (Pct of “Total Construction fatal falls to lower level”) (ext’n, step, and straight)
Fall-related Regulations for Construction
Fall Protection Regulations

- OSHA regulations for Construction are 29 CFR 1926
- Fall protection regs for Construction are discussed in Subpart M, 1926.500 to 1926.503 plus Appendices A thru E

- 1926.501 Duty to have fall protection – (b)(1) *Unprotected sides and edges*: Each employee on a walking/working surface with an unprotected side or edge which is 6 feet or more above a lower level shall be protected from falling by the use of guardrail systems, safety net systems, or personal fall arrest systems.
Fall Protection Research

Project Officer: Hongwei Hsiao, Ph.D.
Fall protection vs. Fall prevention

- Fall protection – worker falls and is saved by the personal fall arrest system (PFAS)
- PFAS is required to be worn when working at elevations; worker still has to be rescued
- Fall prevention – the worker is prevented from falling in the first place
Workers come in different sizes; so should harnesses

Riddleberger, C., “What Happens After a Fall is Arrested? Suspension Trauma and the Importance of Having a Rescue Plan” CPWR Webinar, June 27, 2019
Body Scanner

Test Postures
Test Subject Standing and Suspended
Subjects standing in fall-arrest harnesses
Subjects suspended while wearing the harnesses

Harn019b  Harn020b  Harn031b  Harn032b  Harn035b
Harn037b  Harn038b  Harn058b  Harn062b  Harn063b
Harn067b  Harn096b  Harn101b  Harn102b  Harn108b
No Photo
Same 15 Subjects, grouped by body size (height & weight)

Small, Medium, Large, XL, and XXL

A search on-line shows at least one company has 7 sizes – from X Sm to 3 XL

This research has been conducted in cooperation with harness manufacturers, and has contributed to many more sizing choices for men and women.


Swing-Fall Research

Project Officer: Tony McKenzie, Ph.D., P.E.
Worker Tied Off on High Steel

Request to investigate this situation was received from the ANSI/ASSP Z359 Committee
Swing-Fall Test Apparatus
Load Cell Location Specified by Z359 Standard

Figure 11: 12 ft. Free Fall Lanyard Performance Testing
ANSI/ASSP Z359.13, pg. 38

Figure 6: Example Test Weight
ANSI/ASSE Z359.13 pg. 33
Desired Weight (282 lbs.)
Load Cell and Harness Tie-off Location
Test Manikin with Markers to Track Movement
Multiple Tests Result in a Swing-Fall Zone

Cone is the Swing-Fall Zone
Cube is the Safe Zone

Follow-on research determined the fall-arrest forces & the decelerations of the manikin compared to the round test weight.

Results have been shared with the ANSI/ASSP Z359 Committee.
“Arresting Forces: Manikin vs the Weight Specified by ANSI/ASSP Z359”

“NIOSH: Swing Fall Analysis of Below D-Ring Anchorage”
E. A. “Tony” McKenzie, Jr. Ph.D., P.E. and Thomas G. Bobick, Ph.D., P.E., CSP, CPE; Presented at the 2018 ASSP Professional Development Conference, San Antonio, TX, June 4, 2018
Suspension Intolerance

Project Officer: Nina Turner, Ph.D.
Suspension Intolerance: rapid loss of consciousness (can lead to death) due to inadequate circulation from motionless vertical suspension

Venous pooling of blood in the legs due to gravity

Riddleberger, C., “What Happens After a Fall is Arrested? Suspension Trauma and the Importance of Having a Rescue Plan” CPWR Webinar, June 27, 2019
Postures from Subject Testing

Typical postures for the Chest, Back, and the Harness Accessory suspension tests. For the Back Suspension test, the mean back angle from vertical was 41°.
## Suspension Times for Front, Back, and Accessory Medical Reason

<table>
<thead>
<tr>
<th>Medical Reason</th>
<th>Mean ± s.d.</th>
<th>Range</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>(Both Male &amp; Female Subjects)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chest Attachment, n = 36</td>
<td>24 ± 13 min</td>
<td>5 – 60</td>
<td>25</td>
</tr>
<tr>
<td>(1 subj @ 5 min, 9 within 15 min)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Back Attachment, n = 37</td>
<td>29 ± 12 min</td>
<td>5 – 56</td>
<td>30</td>
</tr>
<tr>
<td>(1 subj @ 5 min, 6 within 15 min)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Harness Accessory, n = 26</td>
<td>58 ± 6 min</td>
<td>39 – 60</td>
<td>0</td>
</tr>
<tr>
<td>(85% (22/26) completed 60-min suspensions)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Medical Reasons:** (1)↓Sys BP > 20 mm Hg;  (2)↓Dia BP > 10 mm Hg;  (3)↑HR > 28 bpm; (4)↓HR > 10 bpm;  (5) Pulse Pressure (*i.e.*, difference between Sys & Dia) < 18 mm Hg

“To ensure that no more than 5% of workers would experience [suspension intolerance] symptoms, rescue would have to occur in ... 11 min for a back attachment point.”

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Project Officer

Dr. Nina Turner, Ph.D.
Physiologist
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Worker Rescue:

*(No NIOSH research conducted on this topic, but important to mention)*
Suspended Work Platform Failure

Kassman, M., “What Happens After a Fall is Arrested? Suspension Trauma and the Importance of Having a Rescue Plan” CPWR Webinar, June 27, 2019
Have to Plan for Emergencies:
1. Day before work starts, discuss possible events that may occur – such as emergency access
2. What type of rescue equipment is available? (on-site or local FD?)
3. Emergency contact info needed by work crew and building owner
4. After rescue – know proper procedure to deal with victim

Kassman, M., “What Happens After a Fall is Arrested? Suspension Trauma and the Importance of Having a Rescue Plan” CPWR Webinar, June 27, 2019
Fall Prevention – Slide Guard System

Project Officer: Thomas Bobick, Ph.D., P.E., CSP, CPE
Typical Real World Usage

Typical slide guard arrangement:
2” x 6” boards supported by 2” x 4” boards;
system nailed to roof every two feet.
Evaluate a slide guard system at the roof edge

Evaluate effectiveness of slide guard set-up for preventing a test manikin from sliding over the roof edge of two roof slopes

Test manikin served as a surrogate for an unconscious worker
34° slope test roof (8-in-12)

45° slope test roof (12-in-12)
34° Roof Slope
45° Roof Slope
## Summary of 16 Manikin Slides

<table>
<thead>
<tr>
<th>Material</th>
<th>34° Slope</th>
<th>45° Slope</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Manikin stayed on roof / M. went off roof</td>
<td>M. stayed on roof / M. went off roof</td>
</tr>
<tr>
<td>OSB</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Went over SG like speed bump</td>
</tr>
<tr>
<td>Plywood</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Went over SG like speed bump</td>
</tr>
<tr>
<td>Green Board</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Went over SG like speed bump</td>
</tr>
<tr>
<td>No. 30 Felt Paper</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Went over SG like speed bump</td>
</tr>
<tr>
<td>Synthetic Material A</td>
<td>No</td>
<td>Knocked SG off roof</td>
</tr>
<tr>
<td>Synthetic Material B</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Synthetic Material C</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Synthetic Material D</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Went over SG like speed bump</td>
</tr>
</tbody>
</table>
Take Home Message

• A slide guard system installed at the eave of a roof slope of 34° (8-in-12) or shallower can be an effective *supplement* to a company’s overall fall-protection plan, but should not be considered as the sole means to achieve work site fall protection compliance.

• Using a slide guard system on a roof slope of 45° (12-in-12) would most likely *not* be an effective fall protection supplement to a company’s overall fall-protection plan.
Project Officer

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Research Safety Engineer
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Fall Prevention – Guardrail System

Project Officer: Thomas Bobick, Ph.D., P.E., CSP, CPE
Background

• Pilot project evaluated the strength of two commercial guardrails and compared them to job-built guardrails made of 2-by-4 lumber

• A unique design was developed that was adjustable from flat thru seven different roof slopes

• Develop an adjustable, securely fastened, durable, guardrail system to prevent workers from:
  • sliding or falling off roof edges
  • falling thru unprotected roof/floor holes & existing skylights
  • falling into stairwells
  • falling from balconies and decks
 Started with a commercially available design

Slide Guard

Walking-Working Surface

Range = Flat, 6/12, 8/12, 10/12, 12/12, 15/12, 18/12, 24/12 (A-frame)

27° 34° 40° 45° 51° 56° 63°
Top rail – adjustable

Mid-rail – adjustable
2" x 4" holder, initial design (4" x 6" x 6")

Toe Board – adjustable

Level Working Surface

Slide Guard

Upper surface can be used for material storage (with no vertical poles) or used as a working surface (install vertical poles and cross rails)

Current design for 2" x 4" holder is (4" x 6" x 1")

Accepts 48" vertical pole with supports for top and mid-rails

Flat Base

Vertical Base

Vertical Offset Base
Flat bases used on curved staircase

... and two unguarded edges on second floor

Field testing by a Morgantown, WV Contractor
Morgantown, WV Contractor started using the guardrail system in 2012
One of the owners commented, “We like the system ... it’s now part of our daily routine”

Photo taken May 2015

Follow-up phone call to the Contractor in July 2019: still using the system & very satisfied → seven years of usage & still functional!
Guardrail System was awarded the NIOSH Bullard-Sherwood r2p (research to practice) award in 2015
Fall Prevention Successes

- Three known saves
- All originated more than 20 ft above concrete or asphalt surfaces
- Prevented workers from having severe, or perhaps, fatal injuries

NIOSH has established a non-exclusive licensing agreement with a distributor to commercialize this guardrail system

Licensee Information provided:
Reese Wholesale
Indianapolis, IN
317-800-8444
Jesse Lindstrom

www.reesewholesale.com/safety/protector-guardrails.html

(Component photos and prices are listed)

Ladder Research

Project Officer: Peter Simeonov, Ph.D.
The NIOSH Ladder Safety App

Released: June 2013
- 283,669 downloads

Based on NIOSH research and patented safety device

Developed in partnership with ALI and ANSI A14

The NIOSH Ladder Safety App

Free on iOS/Android phones in English and Spanish
Easy to use interactive tool; designed to promote the safe use of straight, extension, and step ladders

Can be used in the field and in the classroom as training tool

The app features:
a tool to quickly and easily set a ladder at a safe angle,
guide for ladder selection, inspection, positioning, and safe use
The NIOSH Ladder Safety App

Selection tool

- **Recommended Ladder Grade Required**
- **Warning:**
  - Metal rungs
  - Loose rungs

Light Duty Flosselard

- **Ladder Height Required**
- **Load for**
  - Ladders
  - Ladder strength

- **Use: 145 lbs**
- **Use: 155 lbs**
- **Use: 165 lbs**

Measuring tool

- **Position the ladder**
  - Hold the phone flat against the side rail next to front edge
  - Move the ladder until you hear a beep sound
- **To check the angle**
  - Align phone on top of side rail
  - Optimal angle is shown by green arrow and beeping sound

Proper use tool

- **Face the ladder**
  - Going up and coming down
- **Keep centered between rails**
  - And avoid leaning, stretching, or making moves that could throw you off balance

Setup tool

- **Place base of ladder 1 foot away from support for every 4 feet of working length of the ladder**
- **4:1 Ratio**
- **To use**
  - Upper support adjust
  - Base

Accessories tool

- **Ladder Levelers**
- **Stabilizers and Standoffs**
The NIOSH Ladder Safety App

Awards:
- 2014 DHHS Innovation Award – HM
- 2014 Hamilton Engineering Award
- 2014 Bullard-Sherwood r2p Award
- 2015 Federal Health IT Innovation Award
- 2015 Digital Health Merit Award

Additional Information:
Website: [https://www.cdc.gov/niosh/topics/falls/mobileapp.html](https://www.cdc.gov/niosh/topics/falls/mobileapp.html)
Get the Ladder Safety App

Learn more:
www.cdc.gov/niosh/topics/falls
Project Officer

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Summary
Summary

- Fall-related research has been conducted by NIOSH – Division of Safety Research for the past 15 – 20 years

- Both fall protection and fall prevention research projects have been conducted and have provided positive impact on worker safety
  - Harness sizing
  - Rescue times for suspension in a PFAS
  - Commercial guardrail system
  - Widely distributed ladder app

- Future projects will include the use of artificial intelligence (AI) and Robotics in the construction industry to reduce worker exposures to hazardous conditions
Thank You – Any Questions or Comments?

hhsiao@cdc.gov – Harness Sizing

tmckenzie@cdc.gov – Swing Fall

nturner@cdc.gov – Harness Suspension

tbobick@cdc.gov – Slide Guard & Guardrail Systems

psimeonov@cdc.gov – Ladder App

For more information, contact CDC
1-800-CDC-INFO (232-4636)

Mention of any company or product does not constitute endorsement by NIOSH.
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