Workplace Physical Demands and Musculoskeletal Injury Surveillance

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Disclaimer: This content represents the views of the presenters and does not necessarily represent any policy or position of the National Institute for Occupational Safety and Health.
Objectives

• Provide industrial exoskeleton developers, users, policy-makers, and stakeholders with background on data sources characterizing occupational musculoskeletal/overexertion injury burden.
  • Surveillance-driven approach to workplace intervention
  • Exoskeletons as an injury prevention control technology

• Emphasis on the data sources
Background - All Industry Injury Cost Summary

Top 10 Causes and Direct Costs of the Most Disabling U.S. Workplace Injuries

- Overexertion involving outside source: 24.4% ($15.08 billion)
- Falls on same level: 16.4% ($10.17 billion)
- Falls to lower level: 8.7% ($5.40 billion)
- Struck by object or equipment: 8.6% ($5.31 billion)
- Other exertions or bodily reactions: 6.7% ($4.15 billion)
- Roadway incidents involving motorized land vehicle: 4.8% ($2.96 billion)
- Slip or trip without fall: 3.8% ($2.35 billion)
- Caught in/pressed by equipment or objects: 3.2% ($1.97 billion)
- Struck against object or equipment: 3.0% ($1.85 billion)
- Repetitive motions involving micro-tasks: 2.9% ($1.82 billion)

Total cost of the most disabling workplace injuries: $61.88 billion
Cost of top 10 most disabling workplace injuries: $51.06 billion

2016 Liberty Mutual Workplace Safety Index (based on 2013 injury data)
Background

Where (in what industries, occupations) is greatest injury burden in which to apply exoskeleton technologies?

• Injury burden $\cong$ musculoskeletal symptoms, pain, lost work time, medical costs. Also include job physical demands as risk factors.

• Data Sources:
  - Symptoms/Pain
    - NIOSH Quality of Work Life (QWL)
  - Lost work time
    - Workers Compensation Systems (state based systems, examples: OH, WA)
  - Medical costs
  - Job physical demands
    - Occupational Requirements Survey (BLS-ORS)
Quality of Work Life (QWL) Survey

- NIOSH survey of risk factors for musculoskeletal disorders (MSDs)
- Supplement to the General Social Survey (GSS) of U.S. residents
- In-person interview by National Opinion Research Center
- U.S. adults over 18 years, random selection, English speaking
- N ≈ 1,500
- GSS survey methods: [http://gss.norc.org/About-The-GSS](http://gss.norc.org/About-The-GSS)
QWL - ratings of physical effort by occupation
QWL (musculoskeletal) – symptoms of back pain/arm pain

<table>
<thead>
<tr>
<th>Occupation</th>
<th>“Back Pain” %</th>
<th></th>
<th></th>
<th></th>
<th>“Pain in Arms” %</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>2002</strong></td>
<td><strong>2006</strong></td>
<td><strong>2010</strong></td>
<td><strong>2014</strong></td>
<td><strong>2002</strong></td>
<td><strong>2006</strong></td>
<td><strong>2010</strong></td>
<td><strong>2014</strong></td>
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<tr>
<td>Construction and extraction</td>
<td>38.3</td>
<td>28.2</td>
<td>40.9</td>
<td>32.0</td>
<td>37.0</td>
<td>38.5</td>
<td>38.6</td>
<td>36.0</td>
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<td>Transportation and material moving</td>
<td>33.3</td>
<td>30.4</td>
<td>27.1</td>
<td>31.3</td>
<td>33.3</td>
<td>45.6</td>
<td>33.9</td>
<td>35.9</td>
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<td>Production occupations</td>
<td>30.1</td>
<td>30.0</td>
<td>24.1</td>
<td>24.0</td>
<td>34.6</td>
<td>33.6</td>
<td>33.3</td>
<td>28.8</td>
</tr>
<tr>
<td>Installation, maintenance, and repair</td>
<td>33.9</td>
<td>36.9</td>
<td>32.3</td>
<td>29.0</td>
<td>30.8</td>
<td>30.8</td>
<td>32.3</td>
<td>26.3</td>
</tr>
<tr>
<td>Service occupations</td>
<td>33.5</td>
<td>29.9</td>
<td>30.4</td>
<td>25.5</td>
<td>30.0</td>
<td>28.1</td>
<td>31.9</td>
<td>25.6</td>
</tr>
<tr>
<td>Sales and related</td>
<td>21.5</td>
<td>33.3</td>
<td>27.3</td>
<td>21.7</td>
<td>20.9</td>
<td>30.2</td>
<td>22.7</td>
<td>23.6</td>
</tr>
<tr>
<td>Office and administrative support</td>
<td>25.4</td>
<td>35.7</td>
<td>26.8</td>
<td>24.5</td>
<td>26.0</td>
<td>36.1</td>
<td>30.0</td>
<td>23.1</td>
</tr>
<tr>
<td>Professional and related</td>
<td>23.6</td>
<td>20.7</td>
<td>19.8</td>
<td>17.0</td>
<td>26.7</td>
<td>18.6</td>
<td>19.8</td>
<td>19.2</td>
</tr>
<tr>
<td>Management, financial and business</td>
<td>25.5</td>
<td>21.8</td>
<td>21.9</td>
<td>20.3</td>
<td>24.5</td>
<td>17.5</td>
<td>26.6</td>
<td>18.6</td>
</tr>
<tr>
<td>Overall</td>
<td>28.1</td>
<td>28.0</td>
<td>25.8</td>
<td>22.8</td>
<td>28.1</td>
<td>27.8</td>
<td>27.7</td>
<td>23.9</td>
</tr>
</tbody>
</table>
Workers’ Compensation (WC) - Injury Causation/Outcomes

• Automated text mining approaches to code WC claims
• NIOSH method
  • Based on claim narrative, injury/illness category (ICD diagnoses)
  • Fast, accurate, reliable
  • Codes claims as three causation types
    • Ergonomic (ERGO) - Musculoskeletal disorders caused by one or more ergonomic risk factors: excessive force, awkward postures, repetitive motion, contact stress, vibration
    • Slip/Trip/Fall (STF) - Fall from height, on level
    • Others (OTH) - Struck by/against, caught between, motor vehicle, etc.
• NIOSH will share SAS code (contact: cwcs@cdc.gov)
Top 10* Lost Time (LT) Injury Categories for ERGOs by cause, 2001–2011 (Ohio WC)

<table>
<thead>
<tr>
<th>LT Claim Count</th>
<th>% LT Claims</th>
<th>Injury Category</th>
<th>ERGO</th>
<th>OTH</th>
<th>STF</th>
</tr>
</thead>
<tbody>
<tr>
<td>44,713</td>
<td>14.91</td>
<td>Sprains-Back</td>
<td>66%</td>
<td>12%</td>
<td>22%</td>
</tr>
<tr>
<td>34,175</td>
<td>11.4</td>
<td>Sprains - upper extremity</td>
<td>58%</td>
<td>16%</td>
<td>26%</td>
</tr>
<tr>
<td>23,565</td>
<td>7.86</td>
<td>Disc Disorders</td>
<td>63%</td>
<td>14%</td>
<td>23%</td>
</tr>
<tr>
<td>17,443</td>
<td>5.82</td>
<td>Soft tissue/Enthesopathy</td>
<td>66%</td>
<td>14%</td>
<td>20%</td>
</tr>
<tr>
<td>7,283</td>
<td>2.43</td>
<td>Hernia of abdominal cavity</td>
<td>96%</td>
<td>1%</td>
<td>3%</td>
</tr>
<tr>
<td>5,510</td>
<td>1.84</td>
<td>Carpal Tunnel Syndrome</td>
<td>95%</td>
<td>3%</td>
<td>2%</td>
</tr>
<tr>
<td>30,419</td>
<td>10.14</td>
<td>Sprains - lower extremity</td>
<td>14%</td>
<td>8%</td>
<td>79%</td>
</tr>
<tr>
<td>13,649</td>
<td>4.55</td>
<td>Dislocation</td>
<td>23%</td>
<td>8%</td>
<td>69%</td>
</tr>
<tr>
<td>8,485</td>
<td>2.83</td>
<td>Sprains - Neck</td>
<td>29%</td>
<td>50%</td>
<td>21%</td>
</tr>
<tr>
<td>2,208</td>
<td>0.74</td>
<td>Sprains - other</td>
<td>86%</td>
<td>5%</td>
<td>9%</td>
</tr>
</tbody>
</table>
ERGO injury claim rates (Lost Time) by Industry* (2001–2010, OH)
### Top 10* NAICS subgroups for Lost Time ERGOs (OH)

1. 6231-Nursing Care Facilities
2. 3363-Motor Vehicle Parts Manufacturing
3. 6233-Community Care Facilities for the Elderly
4. 3315-Foundries
5. 6219-Other Ambulatory Health Care Services
6. 4931-Warehousing and Storage
7. 3262-Rubber Product Manufacturing
8. 4248-Beer, Wine, and Distilled Alcoholic Beverage Merchant Wholesalers
9. 4841-General Freight Trucking
10. 4842-Specialized Freight Trucking

*Among single-location, private employers
## WA State, 2002-2010 WC, Overexertion claim injuries (by Industry classification)

<table>
<thead>
<tr>
<th>Industry</th>
<th>NAICS</th>
<th>Claim</th>
<th>Claim</th>
<th>Median</th>
<th>Median</th>
<th>Severity</th>
<th>Rate</th>
<th>Count</th>
<th>Overall PI</th>
</tr>
</thead>
<tbody>
<tr>
<td>CON 2381</td>
<td>Foundation, Structure, and Building Exterior Contractors</td>
<td>425</td>
<td>30.9</td>
<td>$9,134</td>
<td>46</td>
<td>5,042</td>
<td>2</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>CON 2361</td>
<td>Residential Building Construction</td>
<td>474</td>
<td>25.4</td>
<td>$7,922</td>
<td>42</td>
<td>4,050</td>
<td>5</td>
<td>1</td>
<td>2</td>
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<tr>
<td>CON 2383</td>
<td>Building Finishing Contractors</td>
<td>379</td>
<td>23.5</td>
<td>$8,453</td>
<td>42</td>
<td>3,559</td>
<td>9</td>
<td>4</td>
<td>3</td>
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<tr>
<td>TWU 4841</td>
<td>General Freight Trucking</td>
<td>218</td>
<td>24.3</td>
<td>$7,993</td>
<td>43</td>
<td>3,348</td>
<td>7</td>
<td>10</td>
<td>4</td>
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<tr>
<td>TWU 4842</td>
<td>Specialized Freight Trucking</td>
<td>152</td>
<td>32.5</td>
<td>$6,521</td>
<td>33</td>
<td>3,029</td>
<td>1</td>
<td>19</td>
<td>5</td>
</tr>
<tr>
<td>CON 2389</td>
<td>Other Specialty Trade Contractors</td>
<td>270</td>
<td>21.9</td>
<td>$9,350</td>
<td>47</td>
<td>3,507</td>
<td>13</td>
<td>7</td>
<td>5</td>
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<tr>
<td>CON 2382</td>
<td>Building Equipment Contractors</td>
<td>472</td>
<td>17.1</td>
<td>$8,428</td>
<td>34</td>
<td>2,232</td>
<td>20</td>
<td>2</td>
<td>7</td>
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<tr>
<td>SER 5617</td>
<td>Services to Buildings and Dwellings</td>
<td>323</td>
<td>16.8</td>
<td>$6,582</td>
<td>41</td>
<td>2,425</td>
<td>22</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>CON 2362</td>
<td>Nonresidential Building Construction</td>
<td>190</td>
<td>17.4</td>
<td>$7,983</td>
<td>32</td>
<td>1,610</td>
<td>19</td>
<td>14</td>
<td>9</td>
</tr>
<tr>
<td>MNF 3371</td>
<td>Household and Institutional Furniture and Kitchen Cabinet Manufacturing</td>
<td>97</td>
<td>23.7</td>
<td>$6,184</td>
<td>19</td>
<td>2,548</td>
<td>8</td>
<td>29</td>
<td>10</td>
</tr>
</tbody>
</table>

*rate per 10,000 FTE

## WA State, 2002-2010 WC, Overexertion claim injuries (by Occupational Risk Class)

<table>
<thead>
<tr>
<th>Risk Class</th>
<th>WIC Industry</th>
<th># Claims</th>
<th>Claim Rate</th>
<th>Median Cost</th>
<th>Median days TL</th>
<th>Severity TL</th>
<th>Severity Cost</th>
<th>Rate Rank</th>
<th>Count Rank</th>
<th>TL days rank</th>
<th>cost rank</th>
<th>PI rank</th>
<th>Expanded PI rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>0510</td>
<td>Wood Frame Building Construction</td>
<td>417</td>
<td>42.1</td>
<td>$7,243</td>
<td>43</td>
<td>6,963</td>
<td>$1,443,499</td>
<td>11</td>
<td>2</td>
<td>11</td>
<td>10</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>0302</td>
<td>Masonry Construction</td>
<td>83</td>
<td>60.0</td>
<td>$9,082</td>
<td>43</td>
<td>13,392</td>
<td>$3,606,536</td>
<td>4</td>
<td>44</td>
<td>1</td>
<td>11</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>0507</td>
<td>Roofing Work - Construction and Repair</td>
<td>112</td>
<td>47.4</td>
<td>$6,283</td>
<td>54</td>
<td>8,403</td>
<td>$1,637,653</td>
<td>7</td>
<td>31</td>
<td>6</td>
<td>9</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>0516</td>
<td>Carpentry, N.O.C.</td>
<td>171</td>
<td>33.5</td>
<td>$6,869</td>
<td>38</td>
<td>5,238</td>
<td>$1,173,373</td>
<td>15</td>
<td>13</td>
<td>15</td>
<td>15</td>
<td>2</td>
<td>4</td>
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<tr>
<td>7117</td>
<td>Temporary Help - Machine Operation</td>
<td>70</td>
<td>76.8</td>
<td>$5,371</td>
<td>29</td>
<td>12,136</td>
<td>$2,094,603</td>
<td>1</td>
<td>52</td>
<td>2</td>
<td>12</td>
<td>5</td>
<td>5</td>
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<tr>
<td>0540</td>
<td>Wallboard Installation - Discounted Rate</td>
<td>64</td>
<td>66.6</td>
<td>$8,723</td>
<td>53</td>
<td>12,098</td>
<td>$2,644,363</td>
<td>3</td>
<td>56</td>
<td>3</td>
<td>2</td>
<td>16</td>
<td>6</td>
</tr>
<tr>
<td>0518</td>
<td>Non Wood Frame Building Construction</td>
<td>173</td>
<td>32.3</td>
<td>$6,799</td>
<td>54</td>
<td>3,841</td>
<td>$1,362,659</td>
<td>19</td>
<td>11</td>
<td>25</td>
<td>12</td>
<td>3</td>
<td>7</td>
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<tr>
<td>0217</td>
<td>Concrete Work - Foundations and Sidewalks</td>
<td>119</td>
<td>31.7</td>
<td>$7,393</td>
<td>44</td>
<td>7,213</td>
<td>$1,384,313</td>
<td>20</td>
<td>26</td>
<td>10</td>
<td>11</td>
<td>10</td>
<td>7</td>
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<tr>
<td>6907</td>
<td>Moving and Storage Companies</td>
<td>88</td>
<td>69.1</td>
<td>$5,524</td>
<td>33</td>
<td>5,309</td>
<td>$1,040,169</td>
<td>2</td>
<td>39</td>
<td>14</td>
<td>17</td>
<td>7</td>
<td>9</td>
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<tr>
<td>1102</td>
<td>Trucking, N.O.C.</td>
<td>245</td>
<td>30.2</td>
<td>$7,629</td>
<td>43</td>
<td>4,017</td>
<td>$831,636</td>
<td>27</td>
<td>4</td>
<td>23</td>
<td>27</td>
<td>5</td>
<td>10</td>
</tr>
</tbody>
</table>
Occupational Requirements Survey (ORS)

- Commissioned by Social Security Administration
- Conducted by the Bureau of Labor Statistics' (BLS) National Compensation Survey program
- Collection of job-related estimates: physical demands, environmental conditions, mental and cognitive demands, vocational preparation requirements
- Purpose is disability adjudication. Also a resource of occupational requirements
- 654 total estimates
ORS – Data Collection

- ORS is establishment-based survey; national sample design
- # of occupations and occupational detail to increase until full sample size (~30,000 establishments)
- Data in 2016 release - 5,800 private industry and 600 state and local government establishments First full data release in three phases
  - First - December 2016 (187 occupations)
  - Second - November 2017
  - Third - October 2018
- BLS estimates 450 occupations after three years (~80% of occupations in the national economy)
- After first 3-year collection cycle BLS will start the second cycle
Potential Relevance to Exoskeleton Use

(Note: down-select of potentially relevant variables done by the presenter)

- Sitting vs. standing/walking at will is (not) allowed
- Reaching overhead
- Reaching at/below the shoulder
- Pounds maximum weight lifted/carried, mean
- Lifting/carrying none is required
- Lifting/carrying > 10 lbs and ≤ 20 lbs required
- Lifting/carrying > 20 lbs and ≤ 50 lbs required
- Lifting/carrying > 50 lbs and ≤ 100 lbs required
- Lifting/carrying > 100 lbs required
- Pushing/pulling with hands/arms
- Pushing/pulling with feet/legs
- Stooping
- Crawling
- Pushing/pulling is required, one hand/arm
- Pushing/pulling is required, both hands/arms
- Pushing/pulling is required, one foot/leg
- Pushing/pulling is required, both feet/legs
- Pushing/pulling with feet only
- Pushing/pulling with feet only required, one foot
- Pushing/pulling with feet only required, both feet
- Strength is required, sedentary
- Strength is light work, medium work, heavy work, very heavy work

Preliminary data for illustrative purposes only.
Example – Physical demands, *reaching overhead*

<table>
<thead>
<tr>
<th>Occupation</th>
<th>Hours of <em>reaching overhead</em>, mean</th>
<th>% of workers where <em>reaching overhead</em> is required, both hands</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricians (SOC 47-2111)</td>
<td>1.63</td>
<td>96</td>
</tr>
<tr>
<td>Bus and Truck Mechanics and Diesel Engine Specialists</td>
<td>1.61</td>
<td>92.9</td>
</tr>
<tr>
<td>Construction and Extraction Occupations</td>
<td>1.34</td>
<td>81.8</td>
</tr>
<tr>
<td>Emergency Medical Technicians and Paramedics</td>
<td>1.06</td>
<td>98.2</td>
</tr>
<tr>
<td>Middle School Teachers, Except Special and Career/Technical Education</td>
<td>0.82</td>
<td>47.6</td>
</tr>
<tr>
<td>First-Line Supervisors of Construction Trades and Extraction Workers</td>
<td>0.78</td>
<td>69.3</td>
</tr>
<tr>
<td>Dishwashers</td>
<td>0.75</td>
<td>66.3</td>
</tr>
<tr>
<td>Cooks, Restaurant</td>
<td>0.73</td>
<td>62.8</td>
</tr>
<tr>
<td>Bartenders</td>
<td>0.64</td>
<td>39.9</td>
</tr>
<tr>
<td>Shipping, Receiving, and Traffic Clerks</td>
<td>0.61</td>
<td>62.5</td>
</tr>
</tbody>
</table>

Preliminary data for illustrative purposes only.
Example – Physical demands, *maximum weight lifted/carried*

<table>
<thead>
<tr>
<th>Occupation</th>
<th>Maximum weight lifted/carried, mean (lbs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emergency Medical Technicians and Paramedics (SOC 29-2041)</td>
<td>128</td>
</tr>
<tr>
<td>Police Patrol Officers</td>
<td>91</td>
</tr>
<tr>
<td>Telecommunications Equipment Installers and Repairers, Except Line Installers</td>
<td>76</td>
</tr>
<tr>
<td>Protective Service Occupations</td>
<td>74</td>
</tr>
<tr>
<td>Construction Laborers</td>
<td>72</td>
</tr>
<tr>
<td>Carpenters</td>
<td>71</td>
</tr>
<tr>
<td>Construction Carpenters</td>
<td>70</td>
</tr>
<tr>
<td>Bus and Truck Mechanics and Diesel Engine Specialists</td>
<td>69</td>
</tr>
<tr>
<td>Maintenance and Repair Workers, General</td>
<td>67</td>
</tr>
<tr>
<td>Construction and Extraction Occupations</td>
<td>66</td>
</tr>
</tbody>
</table>

Preliminary data for illustrative purposes only.
Example: Physical demands that *might* preclude technology, *crawling required*

<table>
<thead>
<tr>
<th>Occupation</th>
<th>Percent of workers where <em>crawling</em> is required*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Police Patrol Officers (SOC 33-3051)</td>
<td>95.7</td>
</tr>
<tr>
<td>Telecommunications Equipment Installers and Repairers, Except Line Installers</td>
<td>88.4</td>
</tr>
<tr>
<td>Bus and Truck Mechanics and Diesel Engine Specialists</td>
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<tr>
<td>Carpenters</td>
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<td>Electricians</td>
<td>70.6</td>
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<tr>
<td>Maintenance and Repair Workers, General</td>
<td>67.5</td>
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<tr>
<td>Childcare Workers</td>
<td>62.5</td>
</tr>
<tr>
<td>Maintenance Workers, Machinery</td>
<td>61.3</td>
</tr>
<tr>
<td>Installation, Maintenance, and Repair Occupations</td>
<td>60.1</td>
</tr>
<tr>
<td>Construction and Extraction Occupations</td>
<td>52.1</td>
</tr>
</tbody>
</table>

*But, few reported mean hours of crawling

Preliminary data for illustrative purposes only.
ORS - Lifting/carrying, load and frequency

- Interaction of load/frequency to define risk

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<th>Seldom (up to 2% of the day)</th>
<th>Occasionally (2% up to 1/3 of a day)</th>
<th>Frequently (1/3 up to 2/3 of a day)</th>
<th>Constantly (2/3 or more of a day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 10 lbs</td>
<td>&lt; 10 lbs</td>
<td>&lt; 1 lbs</td>
<td>None</td>
</tr>
<tr>
<td>11 – 20 lbs</td>
<td>11 – 20 lbs</td>
<td>&lt; 10 lbs</td>
<td>&lt; 1 lbs</td>
</tr>
<tr>
<td>21 – 50 lbs</td>
<td>21 – 50 lbs</td>
<td>11 – 25 lbs</td>
<td>&lt; 10 lbs</td>
</tr>
<tr>
<td>51 – 100 lbs</td>
<td>51 – 100 lbs</td>
<td>26 – 50 lbs</td>
<td>11 – 20 lbs</td>
</tr>
<tr>
<td>&gt; 100 lbs</td>
<td>&gt; 100 lbs</td>
<td>&gt; 50 lbs</td>
<td>&gt; 20 lbs</td>
</tr>
</tbody>
</table>
Summary/Further Consideration

• Surveillance data (injury/illness) to define injury prevention needs
• Difficult to get data across industries/occupations
• Leverage existing and forthcoming data sources
  • Workers’ Compensation Systems – Injury causation, outcomes, burden
  • Occupational Requirements – Physical demands
• ORS physical demands – identify stakeholder groups (occupations) and system requirements
Comments/Suggestions/Other input?

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