Independent effects of sleep duration and body mass index on the risk of a work-related injury: Evidence from the US National Health Interview Survey (2004-2010)

Presentation by David A. Lombardi, PhD 1,2
Co-Authors: Anna K. (Wirtz) Arlinghaus, Dipl. Psych., PhD 1, Joanna L. Willets, MS 1, Simon Folkard, PhD, DSc (Lond) 1,2
1Liberty Mutual Research Institute for Safety, Center for Injury Epidemiology, Hopkinton, MA, USA
2Department of Environmental Health, Harvard School of Public Health, Boston, MA, USA
3Institut de Psychologie, Université Paris Descartes, France
4Department of Psychology, Swansea University, UK

Liberty Mutual Research Institute for Safety
American Public Health Association (APHA), 2012 Annual Meeting
October 27-31, San Francisco, CA

---

Presenter Disclosures

David A. Lombardi, PhD

(1) The following personal financial relationships with commercial interests relevant to this presentation existed during the past 12 months:

No relationships to disclose

---

Sleep and Safety

"Fatigue is a biological drive for recuperative rest" (Safe recovery)

- Slowed reaction times
- Lapses of attention
- Errors of omission
- Compromised problem solving ability
- Sleep homeostasis

### Sleep and Health

- Sleep deficits (and excess) may lead to adverse outcomes with changes in endocrine, metabolic and immune pathways. (Cappuccio et al., 2010)
  - Mortality (U-shaped), cardiovascular disease, hypertension, diabetes, and depression (Hysy et al., 2007, Bajwa et al., 2015, Hebert et al., 2009, Patel et al., 2018)
  - Obesity (measured as BMI) in cross-sectional and longitudinal studies (Singh et al., 2005, Gangwisch et al., 2006, Gotleib et al., 2005, Patel et al., 2006)
  - Traffic "accidents", work-related injuries and "accidents (Connor et al., 2002, Dembe et al., 2006; Folkard and Lombardi, 2005, Lombardi et al., 2010)

### BMI and Safety

- Higher BMI and obesity have been shown to increase injury risk in vehicle drivers (Whitlock et al., 2003)
  - Obese workers (BMI ≥ 30) were reported to have a higher risk of falls, sprains and strains, and general occupational injury (Chau et al., 2004)

- However:
  - Systematic reviews of the literature have reported mixed findings
  - Suggesting further examination of the association between obesity and injury risk using studies with sufficient sample size and control for confounding variables (Pollack & Cheskin, 2007)

### Trends in Sleep Duration in the US

#### Men

| Age (yr) | 1982-94 | 1999-00 | 2004-4 | <6 hrs per 24 hrs, %
|----------|---------|---------|--------|-----------------
| 18-24    | 40.5    | 40.0    | 41.0   | 1.50            |
| 25-34    | 45.0    | 43.5    | 45.5   | 1.75            |
| 35-44    | 47.5    | 46.0    | 47.5   | 2.00            |
| 45-54    | 49.0    | 47.5    | 49.0   | 2.25            |
| 55-64    | 50.5    | 49.0    | 50.0   | 2.50            |
| 65-74    | 52.0    | 50.5    | 52.0   | 2.75            |
| 75+      | 53.5    | 52.0    | 53.5   | 3.00            |

#### Women

| Age (yr) | 1982-94 | 1999-00 | 2004-4 | <6 hrs per 24 hrs, %
|----------|---------|---------|--------|-----------------
| 18-24    | 37.5    | 36.0    | 37.5   | 1.25            |
| 25-34    | 41.0    | 39.5    | 41.5   | 1.50            |
| 35-44    | 43.5    | 42.0    | 43.5   | 1.75            |
| 45-54    | 46.0    | 44.5    | 46.0   | 2.00            |
| 55-64    | 48.5    | 47.0    | 48.5   | 2.25            |
| 65-74    | 50.0    | 48.5    | 50.0   | 2.50            |
| 75+      | 51.5    | 50.0    | 51.5   | 2.75            |

Change in Obesity in the US

Of the ~2/3rds of adults in the United States who are overweight; 
>1/2 of them (more than 72 million) are considered obese

Study Objective

• Short sleep and high BMI have been associated with an increase in work-related injury risk in separate studies, however,
  - it has not been examined whether these two factors independently affect work injury risk? (e.g., exhibit an additive effect) or
  - if BMI modifies the effect of short sleep on injury risk or vice-versa (e.g., interactive effect)

Study Design

• Seven years of pooled data (2004-2010) from US National Health Interview Survey (NHIS)
• Since 1957, annual, nationwide, cross-sectional sample survey of ~33,300 households and ~86,000 persons (varies by year/budget)
  - Multistage area probability design creates a representative sampling of all US households
    [Vital Health Stat 2, 2000; Moriarity, 2002]
  - Each person has a known non-zero probability of selection
  - Weighted for over-sampling adjustments for gender, age, race/ethnicity, and non-response
  - Sum of the weights is the size of the US civilian non-institutionalized population
Study Design

- In-home face-to-face interview by trained Census Bureau interviewers
  - Advance letter and informed consent
- Inclusion / Exclusion Criteria
  - Non-institutionalized civilian population
  - 18 - 75 years of age (analysis only)
  - 50 states and the District of Columbia
  - Excludes military, long-term care facilities, prisons
  - U.S. nationals living in foreign countries

Work Injury Assessment* (Outcome)

- Medically attended, self or proxy-reported injury during 3 month period prior to interview
  - Phone call or visit to doctor
  - Visit to hospital, clinic, ER (outpatient)
  - Multiple injury reports captured
- Work related
  - What were you doing when the injury happened? = “Working at a paid job”
- Verbatim text
  - ICD-9CM injury cause and nature coding


Sleep Duration Assessment

- "Usual" Daily Sleep
  - Question asking about "usual" number of hours of sleep, first introduced in the Sample Adult Core in 2004 and continues
  - Question Text: "On average, how many hours of sleep do you get in a 24-hour period?"
**Statistical Analysis**

- Analytic SAS Survey procedures
  - Adjusting for complex sampling design: weighting, stratification, and clustering
- Weighted annualized work-related injury rates estimated across a priori defined categories of daily sleep
  - Stratified by BMI categories: healthy weight (BMI <24.99)*, overweight (BMI 25-29.99), and obese (BMI ≥30)
  - Includes underweight (~1% of data)
- Weighted logistic regression modeling used to estimate adjusted injury risk across categories of daily sleep hours and BMI
  - Controlling for age, gender, education, race/ethnicity, working hours, industry, occupation, and type of pay

**Study Sample and Response Rate: National Health Interview Survey (2004-2010)**

<table>
<thead>
<tr>
<th>Year</th>
<th>Households</th>
<th>Persons</th>
<th>Workers</th>
<th>Interviewed for Usual Sleep Hours and BMI</th>
<th>Overall Response Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004</td>
<td>36,279</td>
<td>94,692</td>
<td>40,095</td>
<td>17,304</td>
<td>72.5</td>
</tr>
<tr>
<td>2005</td>
<td>38,339</td>
<td>98,649</td>
<td>43,274</td>
<td>17,450</td>
<td>69.0</td>
</tr>
<tr>
<td>2006</td>
<td>29,204</td>
<td>75,716</td>
<td>33,265</td>
<td>13,484</td>
<td>70.8</td>
</tr>
<tr>
<td>2007</td>
<td>29,360</td>
<td>75,716</td>
<td>33,056</td>
<td>13,871</td>
<td>70.8</td>
</tr>
<tr>
<td>2008</td>
<td>33,856</td>
<td>88,446</td>
<td>36,651</td>
<td>14,692</td>
<td>65.4</td>
</tr>
<tr>
<td>2009</td>
<td>33,856</td>
<td>88,446</td>
<td>36,651</td>
<td>14,692</td>
<td>65.4</td>
</tr>
<tr>
<td>Total</td>
<td>230,533</td>
<td>597,247</td>
<td>257,101</td>
<td>101,891</td>
<td>67.0</td>
</tr>
</tbody>
</table>

1. Persons, age 18-74 years who reported “working at paid job” in the previous week.
2. Sample Adults, age 18-74 who reported both average sleep hours in a 24-hour period and height and weight to calculate BMI.
3. Abstracted from NHIS documentation for each respective year.


<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Number of Workers Interviewed</th>
<th>Weighted Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gender</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>51,584</td>
<td>51.71</td>
</tr>
<tr>
<td>Female</td>
<td>50,307</td>
<td>48.29</td>
</tr>
<tr>
<td><strong>Age (Years)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18-29</td>
<td>22,892</td>
<td>23.80</td>
</tr>
<tr>
<td>30-54</td>
<td>61,271</td>
<td>62.45</td>
</tr>
<tr>
<td>55+</td>
<td>17,728</td>
<td>17.75</td>
</tr>
<tr>
<td><strong>Mean ± S.E.M.</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>41.06 ± 0.08</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Work-Related Injury</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Injured</td>
<td>723</td>
<td>6.75</td>
</tr>
<tr>
<td>Not Injured</td>
<td>101,190</td>
<td>93.25</td>
</tr>
<tr>
<td><strong>Weekly Work Hours</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-15 h</td>
<td>17,549</td>
<td>17.74</td>
</tr>
<tr>
<td>16-29 h</td>
<td>52,896</td>
<td>52.28</td>
</tr>
<tr>
<td>30+ h</td>
<td>16,453</td>
<td>17.73</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>114,998</td>
<td>100.00</td>
</tr>
</tbody>
</table>

*Most frequent injuries were overexertion (24.4%), fall (22.8%), and cut/pierced (15.5%). 1989 subjects missing weekly work hours.
Interviewed Workers NHIS (2004 – 2010), BMI and Sleep Duration Prevalence (weighted %)

Usual Sleep Duration

*Healthy weight includes those who were underweight or BMI <18.5 (∼1% of data).

Body Mass Index (BMI)

Estimated Annualized Work-related Injury Incidence (/100 workers) by Usual Sleep Duration and BMI

Includes individuals reporting employment at a job or business and reported usual sleep hours.

*Includes underweight (~1% of data)

Survey Logistic Regression, Adjusted Odd-Ratio Estimates - Injury Risk by Sleep and BMI

Adjusted for weekly work hours, age, gender, education, ethnicity, industry, occupation, and type of pay.

Note: No significant interaction between usual daily sleep duration and BMI (Wald-Chi Square = 2.08; p = 0.72)
Slide 19

Study Strengths

• Pooling 7 years of NHIS injury data
  – Significantly increased statistical power
  – Reduced standard error of estimate
• Strong external validity
  – Response rate 67% among sampled adults
• Overcomes many shortcomings of other national based systems
  – Increased recall accuracy (severity defined as seeking medical treatment)

Slide 20

Study Limitations

• 3 month recall of injuries may under-estimate rate of injury (unlikely to be differential across BMI or sleep categories)
• Components of BMI (height, weight) are self-reported → potential information bias (unlikely to be differential across categories of sleep or injury)
• Usual sleep patterns may not be representative of sleep time or sleep quality at the time of injury
  – Daily variability may make it difficult to integrate into “usual” and may also be differential across sleep length
• Cross-sectional design → should be confirmed within a large cohort study, where a causal relationship can be established

Slide 21

Summary

• These results from a large representative sample of US workers suggest:
  – a significant increase in work-related injury risk for reduced daily sleep duration (<7 h), regardless of body mass
  – a significant increase in work-related injury risk for obese (BMI 30+) workers, regardless of daily sleep duration (co-morbidities, more hazardous work, healthy worker effect?)
Conclusions

The independent additive risk of these factors on work-related injury is potentially modifiable:

- Given the high prevalence of workers reporting,
  - high BMI (36.0% overweight and 25.6% obese)
  - low sleep durations (23.1% <7 h, 7.7% <6 h)

Work-related safety and health prevention programs should consider approaches to reducing fatigue and encourage healthy weight.

Publication

Generating knowledge to help people live safer, more secure lives

www.libertymutualgroup.com/researchinstitute