A comprehensive firefighter fatigue management program ‘Operation Stay Alert’

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Physiological determinants of fatigue

- Biological time of day (circadian rhythms)
- Number of hours awake
- Nightly sleep duration (chronic sleep debt)
- Sleep inertia (time to ‘get going’ after waking)
1 – Circadian time of day

Approximate time of day

Psychomotor performance reaction time (ms)

- Slowest 10%
- Mean
- Median
- Fastest 10%

Time since waking (h)

2 – Acute sleep deprivation

Cognitive throughput Deviation from mean (#)

3 – Chronic sleep deprivation

Psychomotor performance lapses (#)

- 4 h TIB
- No sleep
- 6 h TIB
- 8 h TIB

Study days

4 – Sleep inertia

Cognitive throughput Deviation from mean (#)

Time since waking (h)
<table>
<thead>
<tr>
<th>Psychomotor performance</th>
<th>Reaction Time (ms)</th>
<th>Time since waking (h)</th>
<th>Approximate time of day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td></td>
<td>16</td>
<td>08</td>
</tr>
<tr>
<td>Median</td>
<td></td>
<td>10</td>
<td>03</td>
</tr>
<tr>
<td>Slowest 10%</td>
<td></td>
<td>40</td>
<td>04</td>
</tr>
<tr>
<td>Fastest 10%</td>
<td></td>
<td>20</td>
<td>05</td>
</tr>
</tbody>
</table>

### Time course of single vehicle truck accidents

**1 – Circadian time of day**

- **Graph:**
  - X-axis: Time of Day
  - Y-axis: Percent
  - Data points show peaks in accidents at certain times of the day.

**2 – Acute sleep deprivation**

- **Graph:**
  - X-axis: Hours Driving
  - Y-axis: Relative Risk
  - Data show increased risk of accidents as hours driving increase.

### Cognitive throughput

<table>
<thead>
<tr>
<th>Deviation from mean (#)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
</tr>
</tbody>
</table>

### Time course of single vehicle truck accidents by hours driving

- **Graph:**
  - X-axis: Hours since 6:00 h wake time
  - Y-axis: Hourly accident coefficient

### Lapses of attention by MDs on two work schedules

- **Graph:**
  - X-axis: Week
  - Y-axis: Number of Lapses (RT >500msec)

- **Data:**
  - 30-hour shifts, 85 h/wk
  - 16-hour shifts, 65 h/wk

### Sleep inertia

- **Graph:**
  - X-axis: Hours since 6:00 h wake time
  - Y-axis: Hourly accident coefficient

- **Data:**
  - Fighters
  - All aircraft

### Pilot crashes by time since waking

- **Graph:**
  - X-axis: Week
  - Y-axis: Number of Lapses (RT >500msec)
After being **awake for 19 hours**, impairment on a simple reaction time test was comparable with impairment observed at a **blood alcohol concentration of 0.05%**.

After being **awake for 24 hours**, impairment on a simple reaction time test was comparable with impairment observed at a **blood alcohol concentration of roughly 0.10%**.

Harvard Work Hours, Health and Safety Group
Past research populations

Astronauts
Resident physicians
Police officers
Doctors working 24 h straight:

- make 36% more serious medical errors
- make 6 times more serious diagnostic errors
- get ‘needlestick’ injuries twice as often overnight
- report nearly 4 times more fatigue-related errors when working 1-4 24 h shifts/month
- report 300% more fatal adverse events

Risk of car crash on drive home from work

Physician work hours, sleep and patient safety

- Physicians driving home after 24 h shift have 2.3x the odds of a crash than after <24 h shift
- Each extended shift adds 16% increased risk

<table>
<thead>
<tr>
<th>Variable</th>
<th>Extended Work Shifts (≥24 hr)</th>
<th>Nonextended Work Shifts (&lt;24 hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crashes</td>
<td>58</td>
<td>73</td>
</tr>
<tr>
<td>No. of commutes</td>
<td>54,121</td>
<td>180,289</td>
</tr>
<tr>
<td>Rate (per 1000 commutes)</td>
<td>1.07</td>
<td>0.40</td>
</tr>
<tr>
<td>Odds ratio (95% CI)</td>
<td><strong>2.3 (1.6–3.3)</strong></td>
<td><strong>1.0</strong></td>
</tr>
</tbody>
</table>

Near-miss incidents

<table>
<thead>
<tr>
<th>Variable</th>
<th>Extended Work Shifts (≥24 hr)</th>
<th>Nonextended Work Shifts (&lt;24 hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. reported</td>
<td>1,971</td>
<td>1,156</td>
</tr>
<tr>
<td>No. of commutes</td>
<td>54,121</td>
<td>180,289</td>
</tr>
<tr>
<td>Rate (per 1000 commutes)</td>
<td>36.42</td>
<td>6.41</td>
</tr>
<tr>
<td>Odds ratio (95% CI)</td>
<td><strong>5.9 (5.4–6.3)</strong></td>
<td><strong>1.0</strong></td>
</tr>
</tbody>
</table>

*Barger et al., N Eng J Med 2005*
Physiological determinants of fatigue

• Biological time of day (circadian rhythms)
• Number of hours awake
• Nightly sleep duration (chronic sleep debt)
• Sleep inertia (time to ‘get going’ after waking)
• Clinical sleep disorders
Obstructive Sleep Apnea (OSA)

Temporarily stopping breathing during sleep
- Caused by narrowing of airway during sleep
- Reduces oxygen to the lungs

Symptoms
- Snoring plus ‘gasping’ or stopping breathing
- Excessive sleepiness during wake
- Large neck size
- Obesity
- High prevalence in overweight middle-aged men
- Higher risk of CV disease, hypertension, and stroke
- Higher rate of ‘fall asleep’ car crashes
- Most people are undiagnosed

http://www.sleephealth.com
Sleep duration and heart disease

- Risk of hypertension higher in those sleeping < 6h per night (adjusted OR 1.66 [gender, race, AHI,BMI]) and > 9 (OR 1.30) compared to those sleeping 7 to < 8 h per night (n=5,900)
  
  Gottlieb et al., 2006

- Risk of hypertension higher in those sleeping $\leq$ 5h per night (adjusted HR 2.10 in middle-aged subjects (n=4,800)
  
  Gangwisch et al., Hypertension 2006

- Longer sleep duration associated with reduced coronary artery calcification (adjusted OR 0.67 per hour) (n=500)
  
  King et al., JAMA 2008

- Short sleep duration (<7.5 hours) in hypertensive patients is predictive of with incident CVD (stroke or heart attack) (HR, 1.68) (n =1255)
  
  Eguchi et al., Arch Int Med 2008
24-hour circadian rhythms in motor vehicle crashes and heart attacks

Fatigue-related fatal crashes by time of day

Onset of myocardial infarction by time of day

Peak rate at 5am

Peak rate at 9am

Federal Motor Carrier Safety Administration 2000

Muller et al., New Engl J Med 1985
TABLE. Number and percentage of fatalities among career and volunteer firefighters, by cause/contributing cause — United States, 1994–2004

<table>
<thead>
<tr>
<th>Cause/Contributing cause</th>
<th>Career</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th>Volunteer</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.</td>
<td>(%)</td>
<td></td>
<td></td>
<td></td>
<td>No.</td>
<td>(%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heart attack*</td>
<td>142</td>
<td>(39)</td>
<td></td>
<td></td>
<td></td>
<td>306</td>
<td>(50)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stress/Overexertion</td>
<td>138</td>
<td>(97)</td>
<td></td>
<td></td>
<td></td>
<td>301</td>
<td>(98)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>4</td>
<td>(3 )</td>
<td></td>
<td></td>
<td></td>
<td>5</td>
<td>(2 )</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Motor vehicle–related trauma</td>
<td>44</td>
<td>(12)</td>
<td></td>
<td></td>
<td></td>
<td>160</td>
<td>(26)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vehicle collision/crash</td>
<td>30</td>
<td>(68)</td>
<td></td>
<td></td>
<td></td>
<td>116</td>
<td>(73)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Struck by vehicle</td>
<td>12</td>
<td>(27)</td>
<td></td>
<td></td>
<td></td>
<td>33</td>
<td>(20)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other vehicle-related (e.g., crushed by or fell from a vehicle)</td>
<td>2</td>
<td>(5 )</td>
<td></td>
<td></td>
<td></td>
<td>11</td>
<td>(7 )</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asphyxiation</td>
<td>74</td>
<td>(20)</td>
<td></td>
<td></td>
<td></td>
<td>45</td>
<td>(7 )</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Caught/Trapped</td>
<td>56</td>
<td>(76)</td>
<td></td>
<td></td>
<td></td>
<td>31</td>
<td>(69)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other (e.g., lost inside a structure or exposed to smoke)</td>
<td>18</td>
<td>(24)</td>
<td></td>
<td></td>
<td></td>
<td>14</td>
<td>(31)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All other†</td>
<td>108</td>
<td>(29)</td>
<td></td>
<td></td>
<td></td>
<td>99</td>
<td>(16)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Caught/Trapped</td>
<td>32</td>
<td>(30)</td>
<td></td>
<td></td>
<td></td>
<td>19</td>
<td>(19)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fall</td>
<td>8</td>
<td>(7 )</td>
<td></td>
<td></td>
<td></td>
<td>15</td>
<td>(15)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exposure (e.g., to smoke)</td>
<td>9</td>
<td>(8 )</td>
<td></td>
<td></td>
<td></td>
<td>14</td>
<td>(14)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stress/Overexertion</td>
<td>16</td>
<td>(15)</td>
<td></td>
<td></td>
<td></td>
<td>14</td>
<td>(14)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Structure collapse</td>
<td>8</td>
<td>(7 )</td>
<td></td>
<td></td>
<td></td>
<td>3</td>
<td>(3 )</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>35</td>
<td>(32)</td>
<td></td>
<td></td>
<td></td>
<td>34</td>
<td>(34)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>368</td>
<td>(32)</td>
<td></td>
<td></td>
<td></td>
<td>610</td>
<td>(34)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* For example, myocardial infarction or arrhythmia.
† Includes deaths caused by burns, cerebral vascular accidents, drownings, electrocution, heat exhaustion, and trauma.

61% of firefighter fatalities due to heart attack or motor vehicle crash

35% vehicles privately owned

<table>
<thead>
<tr>
<th>Factors affecting firefighter fatigue</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Biological Time of Day</strong> (circadian phase)</td>
</tr>
<tr>
<td><strong>Number of Hours Awake</strong></td>
</tr>
<tr>
<td><strong>Nightly Sleep Duration</strong></td>
</tr>
<tr>
<td><strong>Sleep Inertia</strong></td>
</tr>
<tr>
<td><strong>Clinical Sleep Disorders</strong></td>
</tr>
</tbody>
</table>
Our primary aim:

- Improve alertness, sleep, health and safety of Firefighters

How we plan to achieve this:

- Sleep Hygiene Education
- Caffeine Use Re-education
- Sleep Disorders Screening and Treatment
- Policy Intervention where appropriate
We will test the hypothesis that ‘Operation Stay Alert’ will:

• improve firefighters’ sleep, alertness and cognitive performance

• improve firefighters’ safety, as determined by:
  - decreased rates of motor vehicle crashes
  - decreased on-the-job accidents and injuries

• improve firefighters’ health, as determined by:
  - diagnosis and treatment of sleep disorders
  - improved general health indices
  - decreased number of ‘sick’ days

• improve firefighters’ performance
1. Sleep, health and safety education:
   – introductory video
   – education about effects of sleep loss on health, safety and performance
   – sleep hygiene
   – advice about strategic napping
   – booklets on sleep and sleep disorders provided
2. Caffeine re-education:

- basic caffeine facts and food/drink content
- training session on effects of caffeine
- firefighters provided with a plan for caffeine consumption based on shift
3. Identification and treatment of firefighters with sleep disorders
   • Obstructive Sleep Apnea
   • Insomnia
   • Restless Legs Syndrome
   • Narcolepsy
   • Severe and chronic Shift Work Disorder

Individuals with increased risk of having a sleep disorder referred to a sleep physician for diagnosis and treatment
4. Potential future policy developments to improve alertness at work:
   – consultation with fire department and union
   – goal is to improve safety, health, productivity
Outcomes

1. Survey:
   a. Sleep and work schedules, sleepiness
   b. General health, mood, and functioning
   c. Injuries and motor vehicle accidents
   d. Job experiences and satisfaction

2. Safety and job performance data from existing departmental databases

3. Sleep logs and actigraphy in a sample to objectively validate self-reported sleep and work hours

4. Clinical and sleep disorders outcomes

5. Annual physical outcomes where available (in collaboration with Dr Stefanos Kales, HSPH)
Protecting confidentiality

• De-identification of data
• Certificate of Confidentiality from CDC:
  • protects against involuntary disclosure of the identities of research subjects or the release of data for individual subjects participating in this study
• HIPAA Privacy Rule
Expert-led Program: Randomized Paired Design

Aug 2009

Group A: 16 stations ~650 firefighters

Quiz
Education
Re-Quiz
Survey
High risk of Sleep disorder
Low risk of Sleep disorder
Referred to Sleep Clinic
Repeat survey after 1 yr

Aug 2009

Group B: 16 stations ~650 firefighters

No contact

Aug 2010

Group B: 16 stations ~650 firefighters

Quiz
Education
Re-Quiz
Survey
High risk of Sleep disorder
Low risk of Sleep disorder
Referred to Sleep Clinic
Repeat survey after 1 yr
Expert-led Program: Randomized Paired Design

- Program conducted in 16/32 Stations
- ~1,280 officers in potential cohort (50% in Y1)
- Mandatory training/Voluntary survey participation with informed consent
- 52 presentations given to 599 firefighters over 2.5 weeks
- Paper surveys completed by 464 firefighters (77%)
- Study Advisory Committee
  (Fire Dept & Union Representatives, Research Team)
Outcomes – Firefighter Databases

- Demographic data (e.g., gender, age, service)
- Work hours and leave, sick leave, temp transfers
- Motor vehicle accidents
- Accidents and injuries
- Physical exam record
- Sleep clinic record

- Confirming sleep and work hours with daily logs and wrist actigraphy for 3 weeks
OPERATION STAY ALERT
Federal Emergency Management Agency
Harvard Work Hours, Health and Safety Group

Tier 1: Randomized clinical study design, standard expert-led education (e.g., Columbus)
Tier 2: Web-based education
Tier 3: Train the trainer
**Tier 4: Online survey only**

Flexible approach depending on local preferences:

- Education and survey presented via BWH research team, online or fire department trainers
- Survey available paper/pencil or online
- Existing departmental databases utilized (Tier 1 only)
- Existing annual physical data utilized (Tier 1 only)
- Sleep clinic data utilized (Tier 1 only)

- Interested Fire Departments can still participate
**Methods**

**Tier 1 – In person**

- Month 1:
  - Survey half Dept
  - Leave half Dept
  - Database measures last 12 mos
  - Data from last Physical Exam

- Month 12:
  - Year-end survey (online)
  - Initial survey (online)
  - Database measures last 12 mos
  - Data from last Physical Exam
  - Data from Sleep Clinics

- Month 24:
  - Year-end survey (online)
  - Database measures last 12 mos
  - Data from last Physical Exam
  - Data from Sleep Clinics

Focus groups included

**Tier 2 – Web-based**

- Month 1:
  - Survey whole Dept (pre-, post-exam)

- Month 12:
  - Survey whole Dept (End-year survey)

Focus groups included

**Tier 3 – Train the trainer**

- Month 1:
  - Survey whole Dept (pre, post-exam)

- Month 12:
  - Survey whole Dept (End-year survey)

Focus groups included
Harvard Work Hours, Health and Safety Group

Research Team

Division of Sleep Medicine
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