Whole-body Vibration related Ergonomic Study of U.S. Railroad Locomotives & Operators

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www.wholebodyvibration.org
Aim of study:

• Ergonomic factors in relation to whole-body vibration exposure in US locomotives
• Assess Cab and Seats currently in use
• Assess ergonomic factors and confounders possibly mitigating WBV exposure effects
Background:

- Low back disorder occupational risk factors
  - Bending, twisting, lifting,
  - **awkward posture & WBV**

- Rail bound vehicles:
  - Unique environment with exposure to multi-axis whole-body vibration and shocks (WBV):
    - lateral acceleration
    - frequent irregular shocks
    - events often unpredictable
Epidemiology of neck and lower back disorders:

- **Method:**
  - self-administered 200-item survey (cross-section)
    - Musculoskeletal diseases (back, neck, large joints)
    - Working conditions and ergonomic factors
    - Psycho-social stress (Karasak et al. Model)
  - US & Canada randomly selected group of active railroad engineers and a comparison group (civil engineers)
  - Response rate: 47% for railroad engineers (n=1195) and 41% for controls (n=323).

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Epidemiology of neck and lower back disorders:

- Serious LBP and neck/shoulder complaints among locomotive engineers was ~ double c/w control group

- Adjusted* OR for sciatic pain (a back condition with neurological complications) was 2.17 (95% CI 1.33-3.56) *Age, gender, race, smoking, non-occupational WBV exposure

- Attenuation of risk after controlling for psychosocial work factors, time sitting at work, and time at work being bothered by vibration
Method:

- Standardized cross-sectional questionnaire survey of North-American locomotive engineers (n=1195) and controls (n=323).
- Comparison with a non-exposed control group (sedentary office worker)
- 50+ locomotive cab and seat inspections
- Observation of tasks and body movements of locomotive operators during routine revenue service
## Results: Seat transfer function (SEAT)

<table>
<thead>
<tr>
<th></th>
<th>x</th>
<th>y</th>
<th>z</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>42</td>
<td>42</td>
<td>42</td>
</tr>
<tr>
<td>Mean</td>
<td>1.43</td>
<td>1.21</td>
<td>0.97</td>
</tr>
<tr>
<td>Min</td>
<td>1.00</td>
<td>1.03</td>
<td>0.61</td>
</tr>
<tr>
<td>Max</td>
<td>2.32</td>
<td>1.51</td>
<td>1.56</td>
</tr>
<tr>
<td>SD</td>
<td>0.32</td>
<td>0.11</td>
<td>0.17</td>
</tr>
<tr>
<td>Mode</td>
<td>1.20</td>
<td>1.25</td>
<td>0.92</td>
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</table>

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Traditional cab and seat design
(“AAR Control Stand”)

www.wholebodyvibration.org
New Generation “Wide body” locomotive cab and seating

- Communication radio
- Reverser
- Throttle
Field observations:
Posture during yard - switching
Conductor and fireman seat
SD40-2 cab

Traditional toad stool
Newer type floor and side mounted seat

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Model GE C41-8, 4135 hp, built in 1991 (UP 9077) - USSC Seat retrofitted (2001)
## Seat characteristics

(n=1419)

<table>
<thead>
<tr>
<th></th>
<th>Locomotive operator</th>
<th>Control</th>
<th>( \chi^2 )</th>
<th>p(( \chi^2 ))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arm rest</td>
<td>82.3</td>
<td>1011</td>
<td>89.1</td>
<td>313</td>
</tr>
<tr>
<td>Any back support</td>
<td>78.7</td>
<td>1043</td>
<td>90.3</td>
<td>310</td>
</tr>
<tr>
<td>Adjustable back support</td>
<td>30.5</td>
<td>1026</td>
<td>14.7</td>
<td>299</td>
</tr>
<tr>
<td>Air cushion system</td>
<td>11.1</td>
<td>1026</td>
<td>37.4</td>
<td>297</td>
</tr>
<tr>
<td>Round seat pad (toad stool)</td>
<td>20.0</td>
<td>985</td>
<td>23.1</td>
<td>303</td>
</tr>
<tr>
<td>Footrest available?</td>
<td>34.1</td>
<td>954</td>
<td>5.6</td>
<td>305</td>
</tr>
</tbody>
</table>
Evaluation of seat features and comfort rating (*** p < 0.001)

RR: n = 982 - 1050; Control: n = 174 - 307

<table>
<thead>
<tr>
<th>Feature</th>
<th>RR (***</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Comfort</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adjustment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Footrest</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ease of turning</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arm rest</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leg room</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Mean: 95% CI (1 = excellent, 4 = unacceptable)
# Wide-body locomotives working conditions and rating (n=1019)

<table>
<thead>
<tr>
<th></th>
<th>YES</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(%)</td>
</tr>
<tr>
<td><strong>Any particular problem with wide body locomotives?</strong></td>
<td>62.7</td>
</tr>
<tr>
<td>Cab lay out</td>
<td>49.1</td>
</tr>
<tr>
<td>Vibration</td>
<td>21.9</td>
</tr>
<tr>
<td>Air conditioning</td>
<td>11.1</td>
</tr>
<tr>
<td>Ventilation</td>
<td>6.4</td>
</tr>
</tbody>
</table>
Important vibration risk assessment factors:

- Vibration basic values
- Crest factor, MTVV, VDV etc.
- Resonance range (hertz) (PSD)?
- Exposure duration
- Seating Posture
- Adequate rest periods
- Consider all facts in overall analysis
Other discussion points

- Locomotive engineers are working often overtime and long hours (+60 h/week)
- Seats in use are often defective, loose and poorly adjustable
- Seat position and mounting contributes to ergonomic postural stress (back).
- A health survey indicates high MSD risk
Discussion

Study limitation:

- No exact time motion / postural measurements over work shift
- CUELA measuring system
- Logistical problems
- Equipment variation
- Participation
Steam engine seat...
“Union” Inductive Train Communication-Cab Signals
German Railroads developed an “idealized” dampened locomotive cab seat.

Fig. 5.1 Proposed standard seat for The German Federal Railways

1. Backrest incline adjustment
2. Seat cushion adjustment (angle & height)
3. Seat cushion adjustment
4. Seat depth adjustment
5. Fixed turn position
6. Body weight adjustment

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1969

Swiss standard locomotive seat.
Primary criteria was to dampen vertical vibration.

Fig. 5.2 Standard seat of the Swiss Federal Railways installed in the cab
Standard locomotive seat (FRG) since 1970/80
Suspension seat with head support
- passenger locomotive - FRG 2002
1. Improve seats – eliminate the “toad stool.”

2. Measure locomotive cab vibrations.

3. Dampen vibration.

The FEDERAL GOVERNMENT Studied Shock & Vibration in Locomotives in Order to Protect Rail Employees

HUMAN FACTORS SURVEY
OF LOCOMOTIVE CABS

30 JUNE 1972

PREPARED FOR
DEPARTMENT OF TRANSPORTATION
FEDERAL RAILROAD ADMINISTRATION
Washington, D.C.
Seated locomotive engineers are exposed to unique vibration and shock in all three direction.

Lateral vibration and unpredictable irregular shocks are of concern.

Current seats, including newer type seats appear inadequate to reduce vibration and provide sufficient postural support.

Combined ergonomic risk factors and WBV exposure

Preventive engineering and interventions utilizing current technology and medical knowledge appear prudent
Texas Railroad Research Yard 2004

European Union Driver Desk Concept (EUDD) 2004