Alertness Strategies in the Rail Industry: Managing the Challenges of 24-hour Operations

Components of Fatigue Management Plans:

Effects of Sleep Loss, Recovery & Refresh Rate on Performance

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Modern humans often consider sleep optional

"Sleep is an acquired habit. Cells don't sleep. Fish swim in the water all night. Even a horse doesn't sleep. A man doesn't need any sleep."

— Thomas Edison (Inventor who helped usher in the 24/7 society via the discovery of cheap bright artificial light)
Train operators are at risk for fatigue-related errors due to work-rest schedules and sleep disorders.
Repeated nights of restricted sleep results in cumulative cognitive impairments.


How much sleep is needed to recover from the neurobehavioral effects of sleep restriction?

The **Recovery** Question:

1. 11 day protocol with two randomized recovery periods after 5 nights of sleep restriction to 4h time in bed, N=180
   - 1980 lab days, 75% completed

The **Recycle** Question:

2. 16 day protocol with one randomized recovery night between 2 intervals of 5 nights sleep restriction to 4h time in bed, N=80
   - 1280 lab days, 75% completed

- Combined these studies will represent 3260 laboratory days of data on healthy subjects aged 22-45y
Study 1 – 11 day Protocol

Sleep Restriction Group
N=180, 1280 lab days
45% data analyzed
79 Subjects
30±6.6yrs; 47 males

Control Group
N=20, 220 lab days
90% data analyzed
18 Subjects
30±6.7yrs; 7 males
Study 1 – 11 day Protocol

Neurobehavioral tests every 2h during the day 8am-8pm

1. Vigilant attention – Psychomotor Vigilance Task Lapses (RTs # >500ms)
2. Subjective sleepiness – Karolinska Sleepiness Scale (KSS)
3. Ability to resist sleep – Maintenance of Wakefulness Test (MWT)
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Preliminary analysis to focus on the first recovery sleep dose night - R1
Total sleep time closely tracked time in bed

Total Sleep Time (TST) – Solid Bar
Time In Bed (TIB) – Striped Bar

Sleep Restriction (4h TIB per night)
Recovery (R1) TIB Sleep Doses

Baseline | SR1 | SR5 | 0 | 2 | 4 | 6 | 8 | 10 | Control Group (10h)
---|---|---|---|---|---|---|---|---|---
8.7 | 3.8 | 3.9 | 10 | 4 | 3.9 | 4 | 5.7 | 6 | 7.1 | 8 | 9.2 | 10 | 10
Amount of time in bed needed to recover from 5 nights of 4h sleep restriction?

<table>
<thead>
<tr>
<th></th>
<th>Intersection with control group</th>
<th>95% confidence interval</th>
<th>Best fit model</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Subjective Sleepiness</strong>– Karolinska Sleepiness Scale</td>
<td>10.4h</td>
<td>7.4h -13.4h</td>
<td>Linear</td>
</tr>
<tr>
<td><strong>Vigilant Attention</strong> – PVT Lapses</td>
<td>10.3h</td>
<td>7.8h -12.9h</td>
<td>Linear</td>
</tr>
<tr>
<td><strong>Ability to resist sleep</strong> – Maintenance of Wakefulness Test</td>
<td>16.1h</td>
<td>10.7h - 21.4h</td>
<td>Linear</td>
</tr>
</tbody>
</table>

It appears that 1 night of ≈ 10h time in bed is enough to be equivalent to the control group (at least for 1 day) but the confidence intervals are large.
Conclusions – Study 1

Preliminary conclusions

1. It appears to be possible to recover some neurobehavioral deficits induced by sleep debt (5 nights at 4h TIB) with a single night of 10h time in bed (more sleep more recovery)

2. But the confidence intervals are large and MWT recovery is beyond this value

3. Additionally, there are large individual differences in vulnerability to sleep restriction and in the ability to recover
A second experiment is being conducted to determine whether recovery sleep has benefit in the face of subsequent sleep debt - which addresses the question, what happens when we are exposed to further sleep restriction after a recovery opportunity?
**Study 2 – 16 day Protocol**

Neurobehavioral tests every 2h (daily avg. from 08:00 to 20:00)

Vigilant Attention - PVT Lapses

Sleep Restriction Group
N= 80
17 Subjects
30±6.6yrs; 9 males

Control Group
N=9
9 Subjects
30±6.7yrs; 5 males
Conclusions – Study 2

Preliminary data suggests that when recovery from sleep debt is incomplete, neurobehavioral vulnerability to further sleep restriction appears to be disproportionately increased.

More data is being collected
Implications for Fatigue Management

Finding 1: Restricting sleep to 4-7h per night results in near-linear cumulative increases in daytime fatigue deficits (i.e., lapses of attention, microsleeps, sleepiness) in most people (80-85%).

Implication: Chronic sleep restriction should be prevented or its effects on alertness must be countered with more frequent recovery sleep opportunities.

Finding 2: Nocturnal bedtime must be extended to approximately 10h or more to get what appears to be full recovery of daytime fatigue deficits due to 5 nights at 4h sleep restriction. However, recovery is not apparent in the subset of people (15-20%) most severely affected by sleep restriction.

Implication: Following sleep restriction, recovery sleep periods should be as long as possible, and more than one night may be required to ensure all people achieve full recovery.

Speculation: Acute recovery of functions following a night of prolonged sleep (after sleep restriction) may be deceptive. Data are currently being gathered on the extent to which “recovery” also reflects the ability to cope with subsequent sleep restriction (i.e., the “recycle” question).
Recommendations

1. Educate on the essential need for recovery (prolonged) sleep to minimize the cumulative effects of sleep restriction.

2. Allow two nights for recovery from work schedules that result in sleep restriction for 5 or more days.

3. Recognize that some individuals may be very vulnerable to the fatiguing effects of chronic sleep restriction, making it important to individualize (tailor) fatigue management to those who most need it.

4. Recognize that there is little (no?) systematic science on the extent to which apparent recovery of functions following sleep restriction can be used to conclude that people are not more vulnerable to subsequent sleep restriction (i.e., the recycle problem).

5. The recommendations above are based on all sleep periods occurring at night and work occurring in the daytime. If the opposite occurs, the cumulative effects of sleep restriction will be worse, and the potential to obtain prolonged recovery sleep will be reduced.
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