How Well Do Train Driver’s Sleep in Relay Vans?

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Abstract: Relay working operations typically require two crews of train drivers to work a rotating 8-h schedule for two or more days. While one crew is driving, the other has the opportunity to sleep onboard the train. The current study investigated the impact of relay work on drivers sleep quantity and quality. Fourteen drivers wore wrist activity monitors and completed sleep/wake diaries for 3 d prior to and during short (<48 h) relay trips. Drivers obtained an average of 7.8 h sleep per night while at home, and an average of 4 h sleep per opportunity during the relay trip. Sleep obtained in the relay van was associated with longer sleep onset latencies, lower efficiency and poorer subjective quality than sleep at home. During the relay trip, drivers obtained significantly more sleep during opportunities that occurred in the evening, than those that occurred early morning or during the day. These findings suggest that while drivers are able to obtain sleep during short relay operations, it is of poorer quality than sleep obtained at home. Further, the timing of the sleep opportunities during the relay trip impacts on the quantity and quality of sleep obtained.

Key words: Relay vans, Train drivers’, Sleep duration, Sleep quality, Timing

Introduction

It is becoming increasingly evident that train drivers frequently experience disturbed sleep and sleep that is of reduced duration1–3). In particular, it has been reported that when train drivers are not sleeping at home between consecutive shifts, sleep quantity and quality may be degraded3, 4) . For drivers who spend most of their sleep periods on a moving train rather than in a hotel or in barracks, as is the case during relay working operations, it is probable that obtaining adequate restorative sleep is even more difficult.

Relay working involves crewing a train to permit continual work/rest, rest/work operation between a specified departure and destination location, without driver relief. Thus, relay work requires multiple crews (usually two pairs of drivers) and on-train accommodation. While one crew is driving, the other has the opportunity to rest in a specially modified relay (or crew) van that is usually comprised of a kitchen, a sitting/eating area, washroom facilities and individual sleeping quarters that contain a bed and storage space. This area typically includes at least one reverse-cycle air condition for climate control. Relay operations are normally undertaken in remote and isolated areas, and generally involve trips that are greater than 30 h in duration.

In many Australian states, relay working has been introduced to facilitate the delivery of goods around-the-clock and year-round. While relay operations are often considered cost-effective and practical, there is widespread concern that relay work has a detrimental impact on the drivers sleep and performance. Specifically, Australian rail regulatory bodies have expressed concern about the quantity and quality of sleep obtained by drivers in the relay vans. In most cases, the rest periods usually occur while the train is moving, and often during the daylight hours. Thus, the sleeping conditions for relay workers may be comparable to those of long-haul truck drivers who attempt to reduce their fatigue levels by utilising tractors equipped with sleeper berth units.

While efforts are usually made to block out light in the sleeping quarters, often little is done to significantly reduce the noise and movement associated with train travel. This
has caused concern, as environmental disturbances can significantly impact on sleep⁵–⁷). Certainly, recent work by the Federal Motor Carrier Safety Administration on the use of sleeper berths in the United States trucking industry suggests that sleep obtained on the road is of poorer quality and depth than sleep obtained at home⁸). Specifically, their findings suggest that while the vehicle was in motion, the noise and vibration significantly degraded the driver’s sleep.

It is also likely that the sleep obtained during relay trips is affected by the shift schedules themselves. As relay operations typically include night and early morning work, sleep opportunities may occur, at least in part, during the day, when the body is usually active⁹, 10). As research indicates that the quantity and quality of sleep obtained by train drivers during the daytime hours is significantly reduced compared to that obtained at night¹⁰, this could be problematic. The fact that the time off between each shift (and thus the opportunity for sleep) is relatively short may also negatively impact on the quantity and quality of sleep obtained during relay work.

Relatively few studies have investigated the impact of train drivers working conditions on their sleep. To date, no studies have looked at the quantity and quality of sleep obtained by train drivers during relay work. This study aimed to assess whether train drivers were able to obtain quality sleep in relay vans during a short (<48 h) relay trip.

**Materials and Methods**

**Participants**

Fourteen male drivers (mean ± stdev age = 46.6 ± 4.9 yr) from an Australian rail company that worked an Adelaide-Melbourne relay trip volunteered to participate in the study. It was clearly explained that participation in the project was entirely voluntary and that they were free to withdraw at any stage. Those drivers interested in participating were asked to complete a consent form and a short General Health Questionnaire to screen for medical and sleep disorders. Information from the questionnaire indicated that participants did not have a major sleep disorder, such as insomnia or sleep apnea. On average, the drivers had been involved with shiftwork for 26.9 (± 5.0) yr. One third of the drivers were smokers, while 94% reported that they regularly consumed beverages containing caffeine (average daily consumption of 250 ml caffeinated beverages = 5.4 ± 3.5). All of the drivers in the current study reported that they exercised regularly and had an average body mass index of 28.41 (± 2.13), which is considered slightly overweight but not obese.

The Adelaide-Melbourne relay took approx 40 h to complete and required two train crews (each consisting of two drivers) to work alternating eight-hour shifts. To prepare the train for the trip, the first crew booked on at 1730 h (Day 1) and worked a 2.5 h shift. They were relieved by the second crew, who booked-on at 1930 h and began driving approximately 30 min later. This allowed the second crew to organize their personal equipment in the relay van and read any paperwork relevant to the trip. Subsequent shift change-overs were scheduled to occur at 0400 h (Day 2), 1200 h (Day 2), 2000 h (Day 2) and 0400 h (Day 3). While one crew was driving, the other had the opportunity to rest in a relay van. In total, drivers had either two or three eight-hour sleep opportunities (see Fig. 1).

For each driver, sleep/wake data was collected for three days prior to and the duration of two relay trips (once when they were scheduled to start at 1730 h and once for the 1930 h start). A total of 27 data sets were collected, as one driver was on annual leave during his second trip.
Materials

To objectively assess sleep/wake behaviour, drivers were required to continuously wear a wrist activity monitor (Gaehwiler Electronic, Hombrechtikon, Switzerland). Each activity monitor contained a piezo-electric accelerometer with a sensitivity of 0.1 g. The analogue sensor sampled movement every 125 ms and the information was stored in 1-min intervals for analysis. Drivers were instructed to only remove the activity monitor whilst taking a shower (or in any other situation where the device was likely to be damaged).

Drivers also provided detailed information about their sleep and work patterns. For each sleep periods, including naps, drivers recorded the time that they went to bed (to attempt sleep), the time they initiated sleep, the final wake time, the number and length of awakenings they felt they experienced during the sleep period, and how well they slept (1=very well to 5=very poorly). In addition, drivers rated their level of alertness immediately before and after each sleep period using the 7-point Stanford Sleepiness Scale (1=alert and wide awake to 7=almost in reverie), and provided an estimate of the total amount of sleep they felt they had obtained. Drivers also completed a work diary, which required them to provide information about the start and end time of shifts. To increase recall accuracy, drivers were instructed to record the information as soon as practicable after waking/finishing their shift.

Statistical Analysis

The Actiware-sleep software (Cambridge Neurotechnology Ltd), in conjunction with the data from the sleep diaries (i.e. lights out and wake-up time), was used to determine the following variables for each sleep period:

- Total sleep time (TST): the sum of ‘sleep’ epochs within the time from sleep start to sleep end.
- Sleep onset latency: the time from lights out to the start of the first twenty-minute period that contained at least nineteen minutes with no activity.
- Sleep efficiency: total sleep time as a percentage of time in bed.

In addition, data from the sleep/work diaries provided subjective ratings of sleep quality and sleepiness prior to and after each sleep period. Values are reported as mean ± standard deviation.

Statistical analysis was performed with SPSS (version 11.0.2, SPSS Inc, USA). Separate mixed-model ANOVA were used to assess systematic differences between sleep obtained at home and sleep obtained in the relay vans. Specifically, analysis focused on each of the objective and subjective variables described above. This statistical technique was employed to properly account for systematic inter-individual variation, as our data set involved repeated measurements from each subject (i.e. early and late roster). Where relevant, planned comparisons were also performed. In addition, separate mixed-model ANOVA were used to assess whether sleep quantity and quality varied as a function of the timing of sleep opportunities during the relay trip.

Results

Sleep in relay vans and at home

Table 1 shows the quantity and quality of sleep obtained by drivers in the relay vans and at home prior to the relay trips. At home prior to the trip, drivers obtained an average of 7.8 (± 1.8) h sleep per night. During the relay trip, drivers obtained an average of 4.0 (± 1.1) h sleep during each of the 8-h sleep opportunities. Further calculations indicated that on average, drivers obtained 5.8 ± 1.3 h of sleep per “twenty-four hour period” during the trip.

In general, sleep obtained in the relay vans was of poorer quality than sleep obtained at home. Drivers took significantly longer to initiate sleep and their sleep was significantly less efficient during the relay trips. In line with this, drivers reported that the quality of their sleep in the relay van was poorer than sleep obtained at home. Specifically, drivers rated 68% of home-based sleep periods as good or very good, 20% as average, and only 12% as poor or very poor. In contrast, they felt that only 31% of sleep periods obtained in the relay vans were good or very good, while 48% were average, and the remaining 21% were poor or very poor. Despite lower ratings of quality, they felt they had experienced a similar number of awakenings during relay van and home-based sleep periods.

On average, drivers reported feeling significantly less alert prior to each home-based sleep period than they were prior to sleep periods during the relay trip. In line with this, drivers reported that the quality of their sleep in the relay van was poorer than sleep obtained at home. Specifically, drivers rated 68% of home-based sleep periods as good or very good, 20% as average, and only 12% as poor or very poor. In contrast, they felt that only 31% of sleep periods obtained in the relay vans were good or very good, while 48% were average, and the remaining 21% were poor or very poor. Despite lower ratings of quality, they felt they had experienced a similar number of awakenings during relay van and home-based sleep periods.

The timing of sleep opportunities during the relay trip

Table 2 displays the quantity and quality of sleep obtained in relay vans during sleep opportunities that commenced in the early morning (0400 h, n=27), during the day (1200 h, n=14) and in the evening (2000 h, n=27).

The timing of the sleep opportunities during the relay trip impacted on the quantity and quality of sleep obtained. Specifically, drivers obtained significantly more sleep during
opportunities that occurred in the evening, than those that occurred early morning or during the day. Sleep periods that occurred during the day were associated with significantly shorter sleep onset latencies and significantly higher efficiency than those that occurred early morning. Although drivers tended to report more awakenings during evening sleep periods, and fewer awakenings during daytime sleep periods, this was not statistically significant (p=0.072).

Overall, drivers reported feeling significantly less alert prior to sleep periods that occurred early morning than they did prior to evening sleep periods. In contrast, subjective ratings of alertness following the sleep periods did not vary as a function of timing.

**Discussion**

For relay operations to be a safe option for transporting both passengers and goods, drivers need to obtain adequate restorative sleep between work periods. Sleep disturbances are a common complaint of shiftworkers [1-3, 12, 13]. For example, sleep following night work and prior to early morning work is typically shorter, and of poorer quality than night sleep [14-16]. As a result, performance and alertness are often reduced, and risk of accident is increased. In addition to involving an irregular shift schedule, relay work is associated with several other factors that may compound this. Specifically, the majority of their sleep opportunities occur on a moving train, which is usually quite noisy.

The current study sought to determine the quantity and quality of sleep obtained by train drivers during short (<48 h) relay operations. Given the design of the relay schedule (i.e. alternating between 8-h driving and 8-h resting), a direct comparison of the duration of sleep periods obtained in the relay van with those obtained at home is not realistic. Not surprisingly, drivers obtained less sleep per period for those spent in the relay van. In large part, this is likely due to the fact that (1) prior wake was reduced, and (2) drivers sleep opportunities in the relay van were restricted.

### Table 1. Mixed model analyses results comparing sleep obtained at home and sleep obtained in relay vans

<table>
<thead>
<tr>
<th></th>
<th>Relay Van</th>
<th>Home</th>
<th>DF</th>
<th>F</th>
<th>P</th>
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<tbody>
<tr>
<td><strong>Objective measures</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Sleep Time (h)</td>
<td>4.0 ± 1.1</td>
<td>7.8 ± 1.8</td>
<td>1,102</td>
<td>274.1</td>
<td>0.0001</td>
</tr>
<tr>
<td>Sleep onset latency (min)</td>
<td>27.5 ± 37.2</td>
<td>11.1 ± 15.3</td>
<td>1,72</td>
<td>11.7</td>
<td>0.0010</td>
</tr>
<tr>
<td>Sleep efficiency (%)</td>
<td>80.8 ± 14.8</td>
<td>92.7 ± 5.3</td>
<td>1,72</td>
<td>47.7</td>
<td>0.0001</td>
</tr>
<tr>
<td><strong>Subjective measures</strong></td>
<td></td>
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<td></td>
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<tr>
<td>Sleep quality</td>
<td>2.9 ± 0.9</td>
<td>2.2 ± 1.1</td>
<td>1.95</td>
<td>22.5</td>
<td>0.0001</td>
</tr>
<tr>
<td># Awakenings</td>
<td>1.7 ± 1.7</td>
<td>1.8 ± 1.6</td>
<td>1.88</td>
<td>0.6</td>
<td>ns</td>
</tr>
<tr>
<td>Alertness prior to sleep</td>
<td>3.3 ± 1.0</td>
<td>4.0 ± 1.6</td>
<td>1.76</td>
<td>7.7</td>
<td>0.0070</td>
</tr>
<tr>
<td>Alertness after to sleep</td>
<td>2.7 ± 0.9</td>
<td>2.2 ± 1.2</td>
<td>1.78</td>
<td>24.4</td>
<td>0.0001</td>
</tr>
</tbody>
</table>

Values represent mean ± standard deviation.

### Table 2. Mixed model analyses results comparing morning (0400 h), daytime (1200 h) and evening (2000 h) sleep opportunities during the relay trips

<table>
<thead>
<tr>
<th></th>
<th>Morning</th>
<th>Day</th>
<th>Evening</th>
<th>DF</th>
<th>F</th>
<th>P</th>
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<tbody>
<tr>
<td><strong>Objective measures</strong></td>
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<tr>
<td>Total Sleep Time (h)</td>
<td>3.6 ± 1.0</td>
<td>3.6 ± 1.1</td>
<td>4.6 ± 1.1</td>
<td>2,30</td>
<td>11.2</td>
<td>0.0001</td>
</tr>
<tr>
<td>Sleep onset latency (min)</td>
<td>37.7 ± 45.7</td>
<td>6.3 ± 6.2</td>
<td>28.4 ± 33.4</td>
<td>2,19</td>
<td>7.9</td>
<td>0.003</td>
</tr>
<tr>
<td>Sleep efficiency (%)</td>
<td>77.8 ± 15.6</td>
<td>89.4 ± 8.2</td>
<td>79.3 ± 15.4</td>
<td>2,30</td>
<td>3.6</td>
<td>0.0410</td>
</tr>
<tr>
<td><strong>Subjective measures</strong></td>
<td></td>
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<tr>
<td>Sleep quality</td>
<td>2.7 ± 1.0</td>
<td>2.7 ± 0.8</td>
<td>3.1 ± 0.9</td>
<td>2,18</td>
<td>4.7</td>
<td>0.022</td>
</tr>
<tr>
<td># Awakenings</td>
<td>1.6 ± 1.6</td>
<td>1.2 ± 1.4</td>
<td>2.2 ± 1.9</td>
<td>2,19</td>
<td>3.0</td>
<td>ns</td>
</tr>
<tr>
<td>Pre-sleep Alertness</td>
<td>3.8 ± 1.0</td>
<td>3.1 ± 0.8</td>
<td>3.0 ± 0.8</td>
<td>2,21</td>
<td>6.0</td>
<td>0.009</td>
</tr>
<tr>
<td>Post-sleep Alertness</td>
<td>2.7 ± 1.0</td>
<td>2.8 ± 1.0</td>
<td>2.6 ± 0.7</td>
<td>2,32</td>
<td>0.1</td>
<td>ns</td>
</tr>
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</table>

Values represent mean ± standard deviation.
Generally, individuals who work regular hours or have time off from work are awake for approximately 16 h prior to each sleep period. Due to this extended period of time awake, the need for sleep before each period is usually high. In contrast, drivers in the current study had the opportunity to sleep every 8-h, thereby substantially reducing prior wake time. As a result, it is probable that drivers did not need as much sleep per opportunity during the relay trip as compared to during the sleep periods at home prior to the trip. Certainly, this is supported by the fact that drivers typically reported feeling more alert prior to sleep opportunities that occurred in the relay vans than prior to those that occurred at home.

The rotating schedule associated with the relay trips also meant that the opportunity for sleep during each period was restricted to less than 8-h. In addition to sleeping, drivers also had to allow time to eat, shower and unwind etc during the 8-h rest opportunities. It should be noted that the experimental protocol in itself further reduced each of the sleep opportunities slightly and consequently, may have impacted on sleep duration. Specifically, drivers were required to get up at least half an hour prior to the commencement of their shift to complete the performance test and their sleep/work diaries. For some drivers, this meant terminating their sleep earlier than they may have liked. Thus, because the requirements of the study slightly reduced sleep opportunity, it may have underestimated the amount of sleep usually obtained.

Importantly, the findings of the current study show that drivers were able to obtain sleep in the relay vans. On average, drivers obtained 4 h of sleep during each opportunity in the relay van (each driver had either 1 or 2 sleep period(s) per day during the trip). Notably, unlike normal circumstances when people generally have a single sleep during each twenty-four hour period, for drivers working relay sleep opportunities occur more frequently. Taking into account the fact that the trip did not encompass two full days and that the sleep opportunities were of limited length, the amount of sleep that drivers obtained per “twenty-four hour period” was estimated based on the total amount of sleep obtained during the trip and the number of hours spent at work. These calculations indicated that on average, drivers obtained approximately six hours of sleep per “twenty-four hour period” during the relay trip.

Recent research by Belenky and colleagues suggests that behavioural deficits may become evident after two nights when sleep opportunity is restricted to 3 h, or after three nights when sleep opportunity is restricted to 5 h. As drivers typically had at least one 4-h sleep each day, this suggests that drivers were obtaining sufficient sleep to function safely during the relay operations studied here. For relay trips longer than 2 d however, where the opportunity to accumulate a significant sleep debt is greater, this may not be the case.

For relay workers, the absence of competing social factors is likely to be a factor that promotes sleep during non-duty periods. Research clearly indicates that social and domestic factors often greatly influence how much sleep shift-workers obtain. Specifically, sleep may often be curtailed to spend time with friends, family or to complete domestic activities. During relay operations, drivers are on a train for the majority (if not all) of the period, away from family and friends. Certainly, the relay drivers in this study appeared to make reasonable use of their rest periods, spending spent two thirds of their rest periods actually sleeping.

It is apparent from the findings that relay work impacts on the drivers sleep quality. Specifically, drivers took twice as long to initiate sleep while in the relay vans. Notably however, their sleep onset latency was still within what is typically considered normal range in clinical settings (i.e. >30 min). Similarly, efficiency was lower than at home, and indicated that drivers were awake for an average of 19% of the time that they were in bed. As sleep efficiency is determined as the percentage of time spent in bed actually asleep, it is dependent on both the time it takes to fall asleep and the amount of time spent awake during the sleep period. Given the relatively long sleep onset latencies observed for the drivers in relay vans, it is apparent that sleep efficiency was reduced due to the time it took drivers to initiate sleep, rather than due to time awake following sleep onset. Indeed, this suggestion is supported by the fact that the number of arousals reported by drivers for each sleep period did not vary between home and relay van sleeps. As with sleep onset latency, while sleep efficiency was reduced, it was not in a range that would be considered clinically significant (i.e. <80%).

In the current study, the sleep that the drivers obtained in the relay vans was rated as poorer than night-time sleep obtained at home. While drivers rated two-thirds of the sleep periods obtained at home as good or very good, this was the case for only one third of the sleep periods obtained in the relay vans. Conversely, relative to those obtained at home, twice as many sleeps obtained in relay vans were rated as poor or very poor. It is also apparent that sleep obtained in the relay vans was less restorative. Despite feeling less alertness prior to sleep at home, drivers also reported feeling more alert following home sleeps than following sleep obtained in the relay van. It is probable that this was directly related to sleep length.

It is likely that a combination of factors associated with
the relay operations lead to longer sleep onset latencies and feelings of poorer sleep. In line with previous studies of shiftworkers, the timing of the sleep opportunities impacted on sleep quantity and quality. Not surprisingly, sleep opportunities that occurred during the evening/night (i.e. 2000 h–0400 h) were associated with longer sleep duration than sleep opportunities that occurred in part, or in total, during the day (i.e. 0400 h–1200 h and 1200 h–2000 h). Interestingly however, the quality of these sleep periods were rated as poorer. Despite lower ratings of quality, the evening/night sleep opportunities were not associated with longer sleep latencies than were the early morning sleep periods. The evening/night sleeps were however, associated with slightly more awakenings than the other sleep periods (although not statistically significant). This finding is in line with previous research indicating subjective sleep quality is strongly related to sleep continuity.

Interestingly, daytime sleep periods were associated with significantly shorter sleep onset latencies than those occurring early morning. This was despite the fact that drivers felt less alert prior to the early morning sleep, which occurred after the drivers had worked a night-shift. A possible reason for drivers finding it easier to initiate sleep during the day was the fact that the train was not moving as much during this sleep period. Rather, it was generally stopped in Melbourne for unloading and reloading. As this meant that several factors that often negatively affect sleep (such as noise and movement) were reduced, the shift schedule somewhat counteracted the fact that it is usually most difficult to obtain restorative sleep during the day. This finding emphasises the need for flexibility within relay rosters regarding the timing of sleep opportunities.

Notably, this also raises the issue that train movement may have affected the activity monitor recordings and concerns about the accuracy of actigraphy in general. Reports from studies conducted in the laboratory, in space, and onboard aircraft have suggested that while actigraphy is useful for determining sleep duration, detection of sleep onset and short awakenings (i.e. quiescent wakefulness) using actigraphy is less accurate. Thus, as sleep efficiency decreases (and conversely, the amount of wake time within in the sleep period increases), the accuracy of actigraphy also decreases. Ideally, polysomnography (PSG) would have been used in the current study to assess sleep quality and quantity. However, as PSG is rather invasive and time-consuming it was considered impractical.

To date, no studies have compared wrist actigraphic and PSG measures of sleep onboard trains. Importantly however, a recent study comparing PSG and actigraphy during sleep periods in hotels and in bunks onboard aircraft (whilst flying) demonstrated that the actigraph performed in a similar manner regardless of where the sleep occurred. Moreover, the researchers found no evidence that (1) the actigraph recording was contaminated by aircraft movement, or that (2) actigraphy over or underestimated PSG values in a systematic manner. Furthermore, subjective reports indicate that drivers in the current study experienced fewer awakenings during the daytime sleep period, and thus had a more consolidated sleep. This supports the suggestion that this sleep was actually more efficient, due to a stationary train, as opposed to the suggestion that train movement itself directly affected the activity monitor recordings.

Overall, this study suggests that while drivers are able to sleep onboard trains during relay operations, the quality of their sleep is not as good as sleep obtained at home. Notably, further research is needed to validate the use of actigraphy on trains, and thereby confirm the findings presented here. In particular, future studies should consider using PSG to provide a more definitive assessment of the quality and quantity of sleep obtained in relay vans, and in turn, the restorative value of sleep during relay operations.

References