

## ELECTRONIC PAPER

# The amount of sleep obtained by locomotive engineers: effects of break duration and time of break onset

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**Aims:** To determine the effects of break duration and time of break onset on the amount of sleep that locomotive engineers obtain between consecutive work periods.

**Methods:** A total of 253 locomotive engineers (249 male, 4 female, mean age 39.7 years) participated. Data were collected at 14 rail depots, where participants drove electric or diesel locomotives; worked with another engineer or drove alone; carried passengers, freight, or coal; and operated in rural or urban areas. Participants completed sleep diaries and work diaries for a two week period while working their normal roster patterns.

**Results:** For breaks that began at similar times of day, total sleep time (TST) increased with break duration. For breaks of similar duration, TST was greater for those that occurred during the night-time than for those that occurred during the daytime. An average of 3.1–7.9 hours sleep was obtained in 12 hour breaks (minimum break requirement in the Australian rail industry), depending on when the break began.

**Conclusions:** The duration and timing of breaks are both important factors in determining the amount of sleep that locomotive engineers obtain between consecutive work periods. Consequently, minimum length break requirements that do not include a time of day component may not provide locomotive engineers with the opportunity to obtain a sufficient amount of sleep prior to resuming work.

The function of sleep is not fully understood, but it is generally accepted that it serves to recover from previous wakefulness and/or to prepare for functioning in the subsequent wake period.<sup>1–2</sup> While the physiological mechanisms by which sleep restores alertness and cognitive performance are not known, studies in which sleep has been restricted and/or fragmented indicate that the duration and quality of sleep determine its restorative value (for review, see Wesensten and colleagues<sup>3</sup>). The relation between sleep duration and recuperation may not be linear,<sup>4</sup> but performance and alertness during wakefulness are generally enhanced as sleep duration increases.<sup>5–6</sup>

Shiftworkers typically obtain less sleep and sleep of poorer quality than day workers, such that sleep disruption is considered one of the major negative aspects of shiftwork.<sup>7–10</sup> Working at night is particularly disruptive because it forces sleep to be taken during the daytime—that is, outside the optimal phase of the circadian sleep cycle. Consequently, daytime sleep tends to be shorter and of lower quality than sleep initiated during the night-time.<sup>11–12</sup> Other difficulties associated with obtaining daytime sleep include environmental disruptions such as light, heat, and noise,<sup>13–14</sup> and the desire and/or expectation to participate in family, social, and/or community activities.<sup>15–18</sup>

The duration and timing of breaks between successive work periods have both been identified as potentially important determinants of the amount of sleep that shiftworkers obtain. Specifically, Kurumatani and colleagues<sup>19</sup> found a high and significant positive correlation between break duration and total sleep time (TST), whereby TST fell as the time off between work periods reduced. Kurumatani *et al* also suggested that breaks between work periods that occur during the daytime result in less TST than breaks at night-time. This general effect has been confirmed by studies showing that shiftworkers who work at night and sleep during the day obtain significantly less sleep (40–180 minutes) than those who work during the day and sleep at night.<sup>20–21</sup> While the effects of the duration and timing of

breaks between consecutive work periods on the amount of sleep obtained by shiftworkers have been considered previously, the interaction of these factors has not been comprehensively examined.

The current study was designed to determine the sleep and work patterns of shiftworkers in a real work setting. The aim of the study was to examine the effects of break duration and time of break onset on the amount of sleep obtained between consecutive work periods. It was hypothesised that the amount of sleep obtained in breaks between work periods would vary depending on both their length and timing. Specifically, it was expected that TST would increase as break duration increased, and that more sleep would be obtained in breaks that occurred during the night-time than in breaks that occurred during the daytime.

## METHODS

### Participants

A total of 253 locomotive engineers (249 male, 4 female) gave written, informed consent to participate in the study as volunteers. All participants were employees of a member organisation of the Australian Rail Industry Fatigue Management Consortium (WestRail, Vline, National Rail, Australian National, State Rail, Queensland Rail, or FreightCorp). Participants worked at one of 14 rail depots in five Australian states. Participants had a mean (SD) age of 39.7 (6.8) years and had been doing shiftwork for an average of 19.8 (7.7) years. Participants did not receive any additional payment for participating in the study above their usual salary. The study was approved by the University of South Australia Human Research Ethics Committee using guidelines established by the National Health and Medical Research Council of Australia.

### Work setting

The 14 rail depots chosen were representative of the varied work settings in the Australian rail industry and thus encompassed a wide range of working conditions and roster

### Main messages

- The duration and timing of breaks are both important factors in determining the amount of sleep that locomotive engineers (and shiftworkers in general) obtain between consecutive work periods.
- Minimum length break requirements that do not include a time of day component may not provide locomotive engineers (and shiftworkers in general) with the opportunity to obtain a sufficient amount of sleep prior to resuming work.

schedules. Participants drove electric or diesel locomotives; worked with another engineer or a conductor or drove alone; carried passengers, freight, or coal; operated in rural or urban areas; and obtained rest at home or in barracks. In general, participants' rosters could be categorised as irregular. Work periods had a mean duration of 8.4 (1.9) hours; 34.2% were shorter than 8 hours, 50.5% were 8–10 hours in duration, and 15.3% were longer than 10 hours (fig 1A). Furthermore, 43.9% of work periods began between 04:00 and 12:00, 34.0% began between 12:00 and 20:00, and 22.1% began between 20:00 and 04:00 (fig 1B). Depending on the depot, participants had between 12 hours and two weeks notice of their work schedule, which could be altered with as little as 2–4 hours notice. None of the depots had bidding systems such that participants with higher seniority could choose their preferred hours of work.

### Procedure

Data were collected at each rail depot in a succession of 14 studies conducted over a two year period. Data regarding participants' sleep/wake patterns, work schedules, neurobehavioural performance, self rated alertness, and urinary 6-sulphatoxymelatonin excretion rates were collected at each depot for a period of 14 days. During that time, participants worked their normal roster patterns. (The performance, alertness, and melatonin data will be reported elsewhere.)

For each day of the study, participants recorded their sleep/wake schedules (sleep onset time and wake up time) in a sleep diary. Participants also recorded their *actual* hours of work, as distinct from their *rostered* work schedule, in a work diary.

### Measures and data analysis

The dependent variable in all analyses was total sleep time (TST). TST was defined as the total amount of sleep (including main sleep periods and naps) obtained between successive work periods.

For breaks between work periods of 12–24 hours duration, the linear relation between the duration of a break and TST was determined by Pearson product-moment correlation. In addition, the effect of time of break onset on TST was determined using factorial analysis of variance (ANOVA).

The amounts of sleep obtained in breaks of 12, 16, and 24 hours duration were binned in two hour intervals depending on the time of day that the breaks began. These break durations were chosen because they represent the minimum break duration in the Australian rail industry (12 hours), the normal break duration between eight hour shifts of the same type (16 hours), and a relatively long break between successive work periods (24 hours). The effect of break duration on TST was determined using factorial ANOVA and post hoc analyses were conducted with Fisher's protected least significant difference (PLSD). For

### Policy implications

- Prescriptive duty hours regulations that incorporate minimum length break requirements may not necessarily protect employees from being exposed to an unacceptable level of fatigue risk. To minimise this fatigue risk, duty hours regulations should be modified to take account of the effect of time of day on the propensity to sleep.

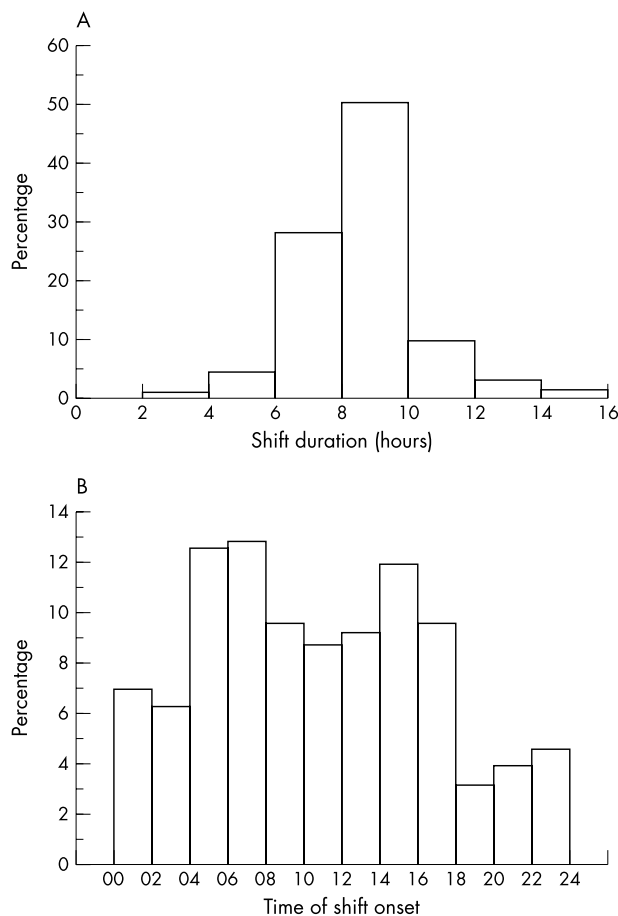
each break duration, the effects of time of break onset were analysed using separate factorial ANOVA.

### RESULTS

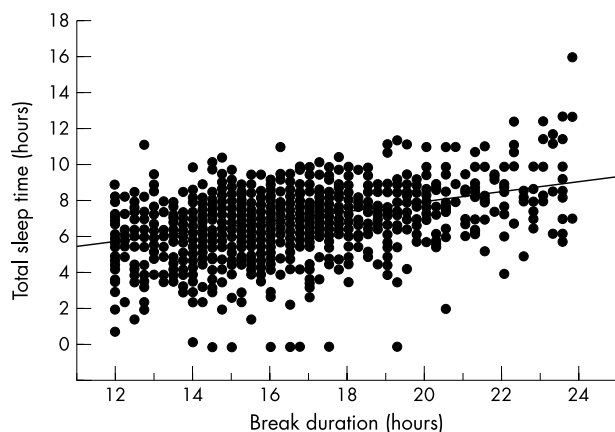
For all breaks of 12–24 hours duration, the length of the break and the total amount of sleep obtained in the break (that is, TST) are plotted in fig 2. There was a significant positive correlation between break duration and TST ( $r_{1152} = 0.39$ ,  $p < 0.0001$ ).

The effect of time of break onset on TST for breaks of 12–24 hours duration is represented in fig 3. Factorial ANOVA indicated that there was a significant effect of time of break onset on TST ( $F_{11,1140} = 9.49$ ,  $p < 0.0001$ ). Indeed, the figure shows a progressive rise in TST for breaks that began between 04:00–06:00 and 18:00–20:00, and a progressive fall in TST for breaks that began between 18:00–20:00 and 04:00–06:00.

The effects of time of break onset on TST for breaks of 12, 16, and 24 hours duration are represented in fig 4. An



**Figure 1** Histograms representing the frequency of work periods depending on (A) their duration, and (B) the time of day that they began.



**Figure 2** Scatterplot of break duration and total sleep time for breaks of 12–24 hours duration (with simple linear regression line of best fit,  $r=0.39$ ).

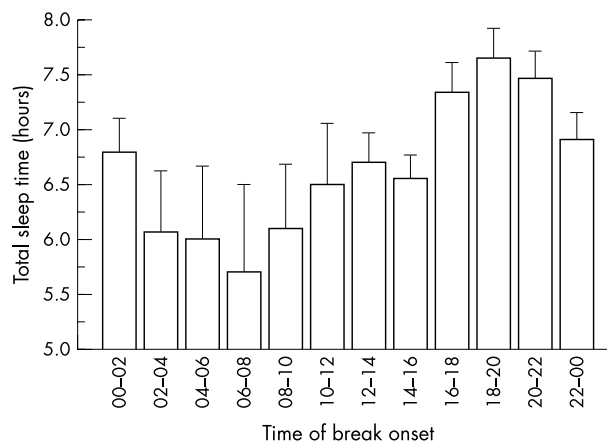
average of 5.2 (2.32) hours sleep was obtained in 12 hour breaks, ranging from a minimum of 3.1 hours for breaks that began at 08:00–10:00, to a maximum of 7.9 hours for breaks that began at 20:00–22:00. In comparison, an average of 6.5 (1.61) hours sleep was obtained in 16 hour breaks, ranging from a minimum of 4.8 hours for breaks that began at 04:00–06:00, to a maximum of 7.7 hours for breaks that began at 18:00–20:00. Finally, an average of 8.9 (2.29) hours sleep was obtained in 24 hour breaks, ranging from a minimum of 6.8 hours for breaks that began at 14:00–16:00, to a maximum of 12.3 hours for breaks that began at 06:00–08:00. Factorial ANOVA indicated that there was a significant effect of break duration on TST ( $F_{2,465} = 53.29$ ,  $p < 0.0001$ ). Post hoc analyses showed that TST significantly increased as break duration increased (both  $p < 0.0001$ ). Factorial ANOVA also indicated that there was a significant effect of time of break onset on TST for 12 hour breaks ( $F_{11,102} = 5.24$ ,  $p < 0.0001$ ), 16 hour breaks ( $F_{11,365} = 11.03$ ,  $p < 0.0001$ ), and 24 hour breaks ( $F_{10,38} = 2.12$ ,  $p < 0.05$ ).

## DISCUSSION

### Amount of sleep obtained in breaks between successive work periods

Shiftworkers are in a constant struggle to obtain a sufficient amount of sleep between successive work periods, particularly between consecutive night shifts and between consecutive shifts with quick changeovers. Typically, the duration of the break between successive work periods is considered the major determinant of the amount of sleep obtained.<sup>19</sup> In the current study though, the analyses indicated that the amount of sleep obtained between successive work periods was significantly affected not only by the duration of a break, but also by the time of day that a break occurred. Generally, total sleep time (TST) increased as break duration increased (fig 2), and TST was greater for breaks that occurred during the night-time than for breaks that occurred during the daytime (fig 3).

To examine the interaction between break duration and time of break onset on the amount of sleep obtained between successive work periods, consideration was given to the amount of sleep obtained in 12, 16, and 24 hour breaks that began at different times across the day (fig 4). Generally, the patterns of sleep accumulation for 12 and 16 hour breaks were similar: in both cases, more sleep was obtained in breaks that occurred during the night-time than in breaks that occurred during the daytime. However, the pattern of sleep accumulation for 24 hour breaks was markedly

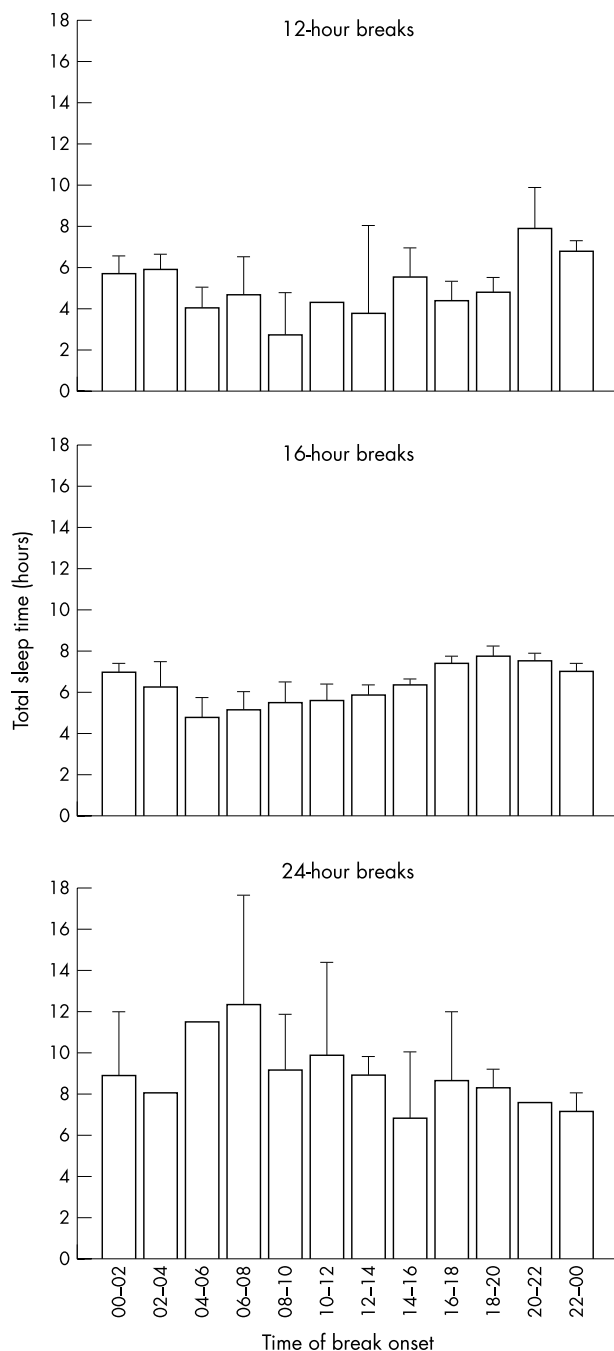


**Figure 3** Mean total sleep time (95% confidence intervals) as a function of time of break onset for breaks of 12–24 hours duration.

different. Contrary to expectations, TST was considerably greater for 24 hour breaks that began between 04:00–06:00 and 10:00–12:00 than for 24 hour breaks that began at other times of day, including even the night-time. An explanation for this curious finding came from inspection of individual sleep and work diaries for participants who finished one shift in the morning after working through the night, and started another shift at the same time the following morning (that is, changed over from night shift to day shift). In many of these instances, participants obtained a large amount of sleep between successive work periods because they were able to fit two substantial sleep periods into the 24 hour break. The first of these sleeps would have been to recover from the completed work period, and the second sleep would have been to prepare for the impending work period. This highlights a major complaint heard often in the course of collecting the current data. While a 24 hour break is typically considered a day off by employers, it is usually spent recovering from one work period and preparing for the next, and therefore is not considered a day off by employees.

Kurumatani and colleagues<sup>19</sup> investigated the relation between the duration of breaks and the amount of sleep obtained between consecutive work periods, and found that sleep duration fell as break duration reduced. Specifically, Kurumatani *et al* concluded that at least seven hours of sleep was typically obtained in breaks of at least 16 hours duration. On average however, participants in the current study obtained a minimum of 4.8 hours sleep and a maximum 7.7 hours sleep in 16 hour breaks. Participants only averaged at least seven hours of sleep for 16 hour breaks that began between 16:00–18:00 and 22:00–00:00. Thus, the current results indicate that break duration alone cannot be relied on to estimate TST, as the amount of sleep obtained during breaks of similar duration varied considerably depending on the time of day that the breaks began.

It is likely that the amount of sleep obtained between successive work periods is influenced not only by break duration and time of break onset, but also by prior time awake, sleep history in the preceding days, and work schedule in the coming days. For example, even if the duration and timing of breaks are similar, one may expect more sleep to be obtained in breaks that are (1) preceded by a long period of sustained wakefulness, (2) preceded by a number of days of sleep restriction/disruption, or (3) followed by a demanding work schedule. However, the current study was concerned specifically with the effects of break duration and time of break onset on TST. Even though the dataset obtained was relatively large, there was not a sufficient amount of data to allow consideration of the numerous



**Figure 4** Mean total sleep time (95% confidence intervals) as a function of time of break onset for breaks of 12 hours (top panel), 16 hours (middle panel), and 24 hours (bottom panel) duration. (In cases where a cell contained only one observation, there are no confidence intervals.)

possible combinations of prior time awake, sleep history, and work schedule. Consequently, the effects of break duration and time of break onset on TST were considered with the other three factors free to vary.

### Minimum break requirements

In many industries in which employees are required to do shiftwork (for example, road, rail, and air transport), hours of work regulations specify maximum duty limits (for a day, a week, or a month) and minimum break requirements between consecutive work periods. One aim of such duty limits is to protect shiftworkers from being exposed to an

unacceptable level of fatigue risk. For example, an intent of minimum length break regulations is to ensure that employees have an adequate opportunity to recover (that is, sleep) prior to resuming work. A major weakness of these prescriptive regulations though is that they rarely take account of the effects of time of day on (a) the recovery value of break periods or (b) the fatigue associated with work periods. Despite their importance, duty hours regulations are often based on factors other than scientific research, such as the balance of power in the relevant industrial relations arena. This can be problematic because particularly demanding work conditions may be negotiated if fatigue is treated as an industrial relations issue, rather than as an occupational health and safety issue. Specifically, if fatigue is seen to be soluble in over-award payments, the safety and wellbeing of employees may be compromised in return for financial compensation.

In many industries, including the Australian rail industry, the minimum allowable break duration between consecutive work periods is around 12 hours. The current data were used to consider whether or not a 12 hour break necessarily provides employees with sufficient time off to adequately recover between consecutive work periods. A working definition of adequate recovery was established based on TST. Several studies have considered the amount of sleep that is required to function normally in the subsequent wake period,<sup>6 22-25</sup> but none have conclusively determined a minimum sleep requirement. For the purpose of constructing an example, five hours TST was taken as an estimate of the amount of sleep needed to adequately recover between consecutive work periods. However, it is acknowledged that an individual's minimum sleep requirement may actually be greater (or less) than the five hours chosen here.

Depending on when the break began, an average of between 3.1 and 7.9 hours of sleep was obtained during 12 hour breaks (fig 4). At least five hours of sleep was obtained during 12 hour breaks that began between 20:00–22:00 and 02:00–04:00 and during breaks that began at 14:00–16:00. These results suggest that 12-hour breaks that began at any other time of day did not provide participants with a sufficient opportunity to recover (that is, sleep) prior to resuming work. Furthermore, if it is assumed that six hours of sleep (rather than five hours) is needed to recover between consecutive work periods, then there were even less points across the 24 hour day at which 12 hour breaks were adequate. Specifically, at least six hours of sleep was obtained only during 12 hour breaks that began between 20:00–22:00 and 22:00–00:00.

These findings indicate that duty hours regulations that include rest limits based on minimum length break requirements may be too simplistic. To increase the likelihood that employees will obtain a sufficient amount of sleep between consecutive work periods, rest limits should be modified to take account of time of day effects. Briefly, the minimum rest limit for breaks that occur during the daytime should be greater than the minimum limit for breaks that occur during the night-time. This very recommendation was recently made for the whole of the Australian transport industry, including locomotive engineers, by a federal parliamentary inquiry into fatigue in transportation.<sup>26</sup>

### Conclusions

The results of the current study indicate that both the duration and timing of breaks between successive work periods are important factors in determining the amount of sleep that locomotive engineers obtain. The timing of breaks is of great importance because sleep initiated during the daytime is typically shorter than sleep initiated during the night-time. Consequently, prescriptive duty hours regulations



that incorporate minimum length break requirements may not necessarily protect employees from being exposed to an unacceptable level of fatigue risk. To minimise this fatigue risk, duty hours regulations should be modified to take account of the effect of time of day on the propensity to sleep.

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