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Original Article

The Influence of Break Timing on the Sleep Quantity and Quality of Fly-in, Fly-out Shiftworkers

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Abstract: Although shift and break timing is known to affect the sleep of shiftworkers, this has not been demonstrated in Fly-in, Fly-out (FIFO) settings which, compared to residential based settings, may be favourable for sleep. This study investigated the sleep quantity and quality of shiftworkers working a FIFO operation comprising of shifts, and therefore breaks, across the 24-h day. The sleep of 24 males (50.43 ± 8.57 yr) was measured using actigraphy and sleep diaries. Morning breaks were associated with less sleep (09:00–12:00 h; 4.4 ± 1.3 h) and a poorer sleep quality (06:00–09:00 h; 3.1 ± 1.0, "average") compared to breaks beginning between 00:00 h and 03:00 h (6.8 ± 1.7 h; 2.2 ± 0.9, "good"). Sleep efficiency remained constant regardless of break timing (85.9 ± 5.0% to 89.9 ± 3.5%). Results indicate that even in operations such as FIFO where sleeping conditions are near-optimal and the break duration is held constant, the influence of the endogenous circadian pacemaker on sleep duration is evident.

Key words: Shiftwork, Total sleep time, Sleep efficiency, Subjective sleep quality, Break timing

Introduction

In Australia, approximately 16% of the working population, or 1.4 million people, report working shiftwork on a regular basis, with a large proportion of these individuals working within the mining sector[1)]. Shiftworkers experience sleep loss and sleep disturbances which may lead to high levels of sleepiness, fatigue, and performance impairments[2–7)]. Such impairments are associated with an increased risk of fatigue related incidents or accidents[8)]. The sleep loss faced by shiftworkers is often the result of reduced opportunity for adequate sleep due to 1) a short turnaround times between shifts[9–11)], 2) sleeping out of phase with society and the external environment[12, 13)] and 3) sleeping out of phase with the endogenous circadian rhythm of sleep and wake[13)]. In controlled laboratory studies it is possible to separate the influence of the circadian timing system on sleep from the aforementioned factors[14, 15)], however these studies may not always be directly translatable to field environments. The current study provided a unique opportunity to investigate the impact of shift timing on sleep, while controlling the turnaround between shifts (i.e., constant break duration), the sleeping environment, and social/family responsibilities within a field environment.

Controlled laboratory studies have widely demonstrated the influence of the endogenous circadian pacemaker on sleep consolidation and sleep structure[14, 15)]. Sleep during

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the early morning hours or near the minimum of the core body temperature rhythm (approximately 04:00–06:00 h) is easily initiated and highly consolidated[14, 15]. Conversely, sleep during the evening hours, or around the maximum of the core body temperature rhythm is more difficult to initiate and often more fragmented[14, 15]. In addition, sleep is usually longest when the sleep episode is initiated on the declining phase of the core body temperature rhythm, or during the evening/night. Sleep episodes initiated on the rising phase of the core body temperature rhythm, or during the morning/daytime, are associated with short sleep durations[16–18].

Although controlled laboratory studies have clearly demonstrated the impact of time of day on sleep quantity and quality, results from these studies may not always be directly translatable to field situations, due to differences in participant demographics, and environmental, social, domestic and leisure conditions between laboratory and field situations. Field-based studies such as those by Ingre *et al.*[9] and Roach *et al.*[19] have demonstrated the influence of shift timing on the sleep duration of shiftworkers. Shifts beginning shortly before noon (between 09:00 and 12:00 h) are associated with up to 8-h of sleep, compared to approximately 6 h of sleep for shifts beginning in the early morning (between 03:00 and 06:00 h)[9]. Similarly, rest breaks scheduled to begin in the evening (between 18:00 and 20:00 h, or after a daytime shift) are associated with up to 8 h of sleep, compared to a maximum of 6 h of sleep for rest breaks scheduled to begin in the early morning (between 06:00 and 08:00 h, or after a night shift)[19]. Therefore, shiftworkers attempting to sleep during the daytime following a night shift, and early in the evening prior to or between morning shifts are likely to have reduced sleep durations[9, 19–22].

Importantly, studies such as those by Ingre *et al.*[9] and Roach *et al.*[19] involved irregular shift schedules with varied shift and break durations between shifts. These variable shift schedules may be particularly disruptive, due to the constant state of circadian misalignment[10, 13, 23–25]. A further limitation is that sleep during these studies is influenced by time of day and sleep opportunity (i.e., shift/break duration). As such, it is difficult to separate the contribution of time of day from shift/break durations. Investigation of a schedule that has a consistent sleep opportunity (in the form of break duration), but shifts/breaks occurring at different times of the day, provides a unique opportunity to better understand the independent contribution of sleep timing within field settings.

Fly-in, Fly-out (FIFO) operations are particularly important in Australia, where the rapid expansion of the mining industry has increased a demand for skilled workers in extremely remote locations. FIFO operations often mean that skilled workers can be employed without needing to relocate to remote areas, with consequent benefits for both employers and employees. In FIFO operations, employees fly to the work site or a nearby location, which may be based either onshore (e.g., mines) or offshore (e.g., oil rigs). Employees work a block of shifts, living onsite (offshore) or in a camp/nearby town (onshore), and fly home for blocks of time off. Shifts are commonly regular or fixed, whereby the shift start times and break durations are the same for all shifts (e.g., 12-h shifts with two start times, one in morning and one in evening).

It has been suggested that FIFO operations may be conducive for sleep, even during the daytime[26–28] when sleep propensity is typically low[14–17], with previous work in offshore FIFO populations indicating that workers obtain more sleep than residential-based shiftworkers[29]. FIFO characteristics thought to aid sleep include an absence of social commitments (i.e., factors that compete with sleep), and conditions that promote sleep (i.e., dark/quiet bedrooms, reduced natural light exposure)[26–29]. Indeed, several studies have demonstrated that offshore FIFO workers obtained up to 7 h of sleep, even when the sleep opportunity occurred during the daytime[26–28].

Recent studies in onshore FIFO workers suggest the opposite; that break or shift timing may be more influential than the specific work arrangement in determining the amount of sleep that shiftworkers can obtain[30–32]. While these studies suggest that shift timing may be more influential on sleep duration, the range of shift start times examined were very narrow. Specifically day shifts started between 05:00 and 06:00 h and night shifts started between 17:00 and 18:00 h. Thus, the impact of an onshore FIFO operation with shift start times across a 24-h period on sleep duration is unknown.

The current study examined the sleep quantity and quality of train drivers working in a FIFO operation that comprised of fixed break durations yet variable shift start times, making it possible to investigate the influence of time-of-day on sleep in a FIFO field setting with a constant break duration.

Subjects and Methods

Participants

A total of 42 train drivers were recruited for the study, with 13 withdrawing prior to study completion. Out of the remaining 29 train drivers, five worked roster schedules that deviated from the majority and so were excluded for the purposes of the current study (e.g., frequent days off due to sick leave, differing numbers of work days and days off between and during roster cycles). A final total of 24 male train drivers gave written, informed consent to participate in the study. Answers to a general health questionnaire revealed that participants were aged 50.43 ± 8.57 yr (mean ± SD, range: 34–65 yr), with a self-reported BMI of 28.79 ± 2.95 kg/m^2(range: 24.45–35.79 kg/m^2), which is considered to be overweight33). Six participants reported that they regularly smoked cigarettes and the majority (21 participants) regularly consumed caffeinated beverages (average <3 drinks/day). About half (n=14) of the participants reported consuming alcoholic beverages on days off with an average of 8.6 ± 5.7 drinks per week (range: 2–21). All participants were experienced train drivers, with a self-reported average of 27.1 ± 8.5 yr (range: 14–40 yr) working shiftwork within the rail industry. Morningness/eveningness scores were not determined.

Prior to participation, informed consent was obtained from all participants. The current study approval from the University of South Australia Human Research Ethics Committee using guidelines established by the National Health and Medical Research Council of Australia. Participants did not receive any additional payment above their normal salary. Participants were informed that their participation was completely voluntary and that they could withdraw at any time without giving any reason. Participants were also informed that neither their results from the study, nor their involvement in the study would impact their employment status with the company in any way.

Materials

Sleep was assessed throughout the study using wrist activity monitoring devices (Actiwatch-64, Philips Respironics, Bend, Oregon, USA). The use of actigraphy in field settings has been shown to be comparable to polysomnography (PSG) with regards to sleep duration34). Participants were told that they could wear the activity monitor on either wrist but that they must wear it on the same wrist at all times except where contact with water was unavoidable (e.g., whilst showering or swimming) or in situations where the monitor was likely to get damaged (e.g., whilst performing heavy labour). Activity monitors contained a piezo-electric accelerometer with a sensitivity of 0.1g.The analogue sensor samples movement every 125 ms (i.e., at a frequency of 8 Hz) and the signal is filtered by a band-pass filter of 0.25–3.0 Hz. The activity counts are then expressed as 1-min epochs. Data from the activity monitor were extracted and an automated algorithm was generated using the Actiware-Sleep software version 3.4 (Mini Mitter Company, Inc., Bend, Oregon, USA).

Participants also provided detailed information about their sleep in a sleep diary. Prior to and following each sleep episode, including naps, participants recorded the location where they attempted to sleep (e.g., at provided accommodation site, at home, on the train, on a plane or other), the time that they attempted to start sleeping (i.e., “lights-off”), the time that they finished sleeping (i.e., “lights-on”) and their sleep quality rating. Subjective sleep quality was assessed using a 5-point Likert scale where 1 = “very good” and 5 = “very poor”. Participants were also free to record any additional comments regarding their sleep, for example, noise disturbance, difficulty falling asleep and nap episodes.

Sleep-wake patterns were assessed using information from activity monitors in conjunction with sleep and shift diaries. Algorithms derived from the Actiware-Sleep software were integrated into a Microsoft Excel workbook to generate an activity plot. The resultant activity plot was then used to cross-reference input from sleep and shift diaries with output from the activity algorithms. Where any inaccuracies were identified adjustments were made consistent with previously published reports32, 35). For example, if a participant had reported that they were sleeping but the activity monitor indicated that they were not sleeping (as indicated by high activity counts) then the sleep period was adjusted to reflect a more accurate representation of the sleep episode. Variables extracted from the sleep diaries and activity monitors included:

- *Total sleep time (TST):* the total amount of sleep obtained between sleep onset and sleep offset
- *sleep efficiency:* the TST as a percentage of time in bed (TIB) from sleep onset to sleep offset
- *subjective sleep quality:* subjective reports of sleep quality using a 5-point scale.

Participants provided detailed information about their actual shift start and end times in a shift diary.

Work setting

The roster used on site involved seven shifts beginning every hour between 01:00 and 12:00 h (hereafter referred to as “AM shifts”) followed by seven shifts beginning every hour between 13:00 and 00:00 h (hereafter referred to as “PM shifts”). All shifts were 12 h (i.e., 12 h breaks) in duration with a 24-h change-over period between AM shifts and PM shifts. Work cycles were followed by either seven or 14 d off. As such, a complete roster cycle lasted for either 21 or 28 d, depending on the number of days off.

For each roster cycle, participants were scheduled the same shift start time for all AM shifts and the same shift start time for all PM shifts. Upon returning to work for the subsequent roster cycle, drivers were scheduled a different shift start time (usually 1 h later than the previous roster cycle) for all AM shifts and all PM shifts. A graphical representation of this shift schedule is shown in Fig 1. The roster was designed such that over an extended period of time (i.e., multiple months to a year) all participants were scheduled to start shifts at all times of the day and night.

Participants flew to a township nearby the main rail depot from various parts of Australia and New Zealand (one participant). Throughout the two-week work cycle, participants were accommodated in company-owned facilities. Participants stayed in single-room apartments containing an ensuite and small kitchen area. All rooms were equipped with a bed and basic amenities (e.g., a television, fridge, kettle, telephone, and internet access). Rooms had block-out blinds to minimise/eliminate daytime light exposure and were relatively quiet, with a self-contained air-conditioning unit (i.e., participants could adjust room temperature to suit themselves). Although participants did not always stay in the same room each time they were onsite, all rooms were similar and therefore provided comparable sleeping conditions for all participants. Data was collected across the Australian summer months (sunrise and sunset approximately 05:00–19:00 with approximately 14 h natural sunlight, compared to approximately 11 h natural sunlight during the winter months).

All meals (main meals and snacks) and non-alcoholic drinks (e.g., water, juice and soft drinks) were provided onsite. Participants were required to drive to the main rail depot, approximately a 15-min drive, before and after each shift. Whilst drivers were required to make their own way to work, vehicles for transportation were provided.

Procedure

Data were collected from drivers for one roster cycle period involving seven AM shifts, seven PM shifts and seven days off. For drivers with 14 d off, data were collected for the first seven days off. During this period participants worked their normal scheduled roster. Data regarding participants' sleep-wake patterns were obtained using sleep diaries in conjunction with wrist activity monitors. Participants reported their actual hours of work in a shift diary.

Data analysis

To assess the effect of break timing on sleep quantity and quality, break onset times (i.e., shift end times) were grouped into 3-h bins starting at midnight (e.g., 00:00–03:00 h, 03:00–06:00 h). Naps were defined as sleep periods with a TIB ≤30 min (reported sleep times in sleep diary) and when a driver had specified that the sleep was a "nap" in their sleep diary. Although napping whilst on shift was not condoned by the company, two participants reported napping while on shift. Further, while seven participants reported having naps at some stage during the study, only two of these participants (the same two participants that reported napping while on shift) regularly napped (e.g., one nap between each shift) and so naps were excluded from the analyses.

Where any participant had multiple sleep periods between shifts or within a 24-h period on days off (with the exclusion of the predefined naps) the sleep periods were combined to give one value for TST and one value for sleep efficiency (sum TST/sum TIB*100). Nine participants (22 occurrences) split their sleep (had more than one sleep episode); all were associated with breaks beginning between 04:00 and 12:00 h. Multiple sleep episodes were combined to determine how much sleep drivers were obtaining between shifts and on days off. In the instances where sleeps were combined, the subjective sleep quality rating was averaged. A total of 293 sleep episodes were included in these analyses. Separate mixed model analyses were performed to assess the main effects of *break onset time* (independent variable) on TST, sleep efficiency and subjective sleep quality (dependent variables). Where a significant main effect was found, post-hoc pairwise comparisons (least significant difference) were performed.

To assess sleep quantity and quality between work cycles and days off, sleep episodes were labelled as either a "work day" or a "day off" irrespective of the time of day that the sleep episode occurred. A total of 428 sleep episodes (293 + 135 [sleep episodes between shifts + sleep episodes on days off]) were included in these analyses. Separate mixed model analyses were performed to assess the main effects of *work or rest* (independent variables) on TST, sleep efficiency and subjective sleep quality (dependent variables).

All analyses were performed using SPSS v.17 for Windows and all models specified participant ID as a random effect. Data are presented as mean ± SD unless specified otherwise and significance was assumed at $p \leq 0.05$. p values are reported to two decimal places except where $p < 0.001$.

Whilst there were a few instances where participants

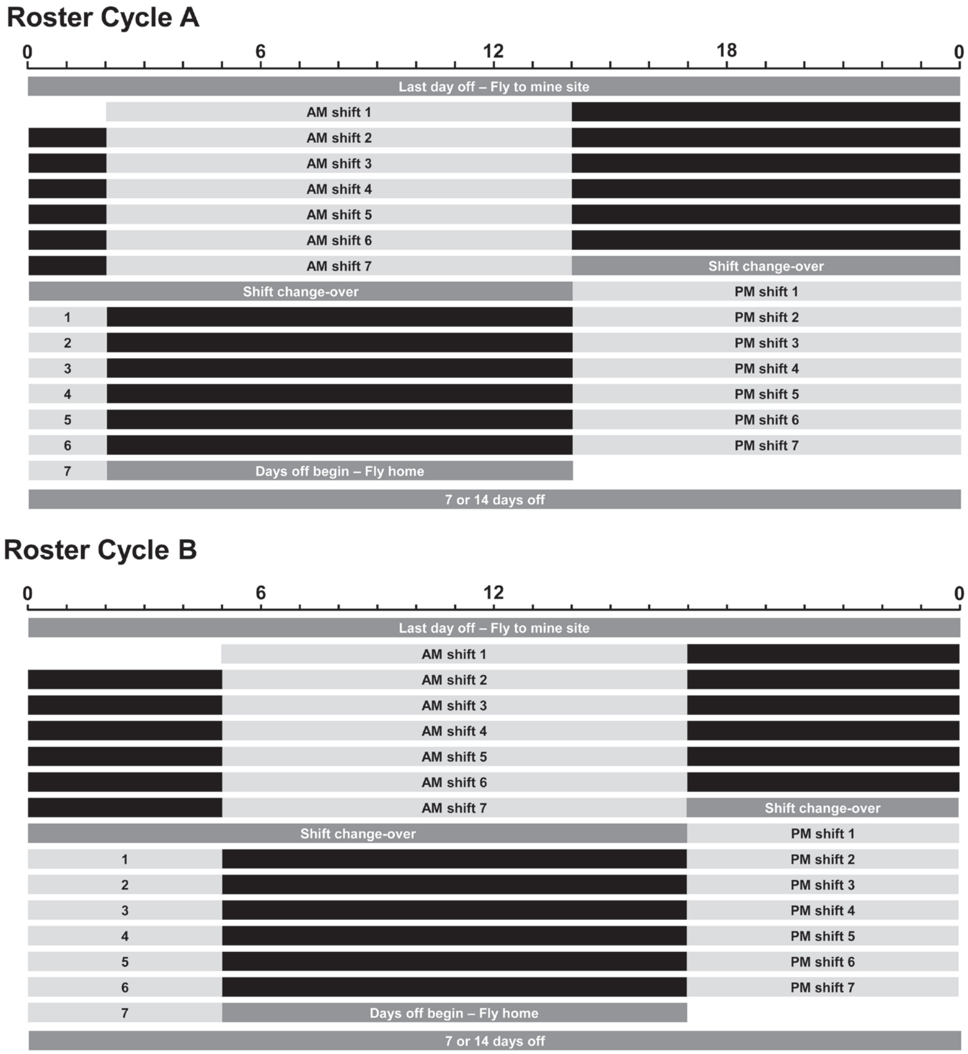

Fig. 1. Representation of the shift schedule for two participants over one roster cycle.
Light grey bars represent rostered shift periods. Black bars represent allowed rest opportunity between shifts. Dark grey bars represent non-work periods (i.e. days off and the shift change-over period between day shifts and night shifts). For the first participant (roster cycle A), the shifts were scheduled to begin at 02:00 h (AM shifts) and 14:00 h (PM shifts). For the second participant (roster cycle B), shifts were scheduled to begin at 05:00 h (AM shifts) and 17:00 h (PM shifts). Note that this is a representative schedule demonstrating the differing shift start times for each driver.

reported sleeping either on the train (n=2) or on a plane (n=9), most participants reported primarily sleeping either at the accommodation site or at home. Due to the criteria defining a nap episode, most of the sleep episodes that drivers reported having on either the train or a plane were excluded from data analyses.

Results

Shift times

We captured data from participants whose breaks began at all times of the day except 11:00 and 23:00 h (we were unable to obtain volunteers for this break onset time). Despite a wide range in the break onset times, the majority of the participants began their breaks between 06:00 and 09:00 h (approximately 23% of all the shifts examined), and 18:00 and 21:00 h (approximately 25% of shifts) (Fig. 2).

Sleep quantity and quality

Table 1 shows the average quantity and quality of sleep obtained by participants either between work periods

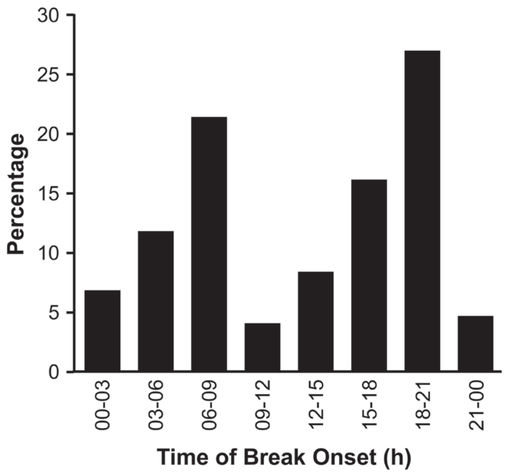

Fig. 2. Histogram representing the frequencies of break onset times worked by participants.

(work) or on days off (rest). Participants obtained significantly more sleep during their days off than they did between work periods (Table 1). There was little difference in sleep efficiency between work periods and days off (Table 1). However, participants reported that their sleep quality was better on days off than between work periods, reporting "good" sleep quality on days off compared to "average" between work periods (Table 1).

There was a main effect of *break onset time* on TST obtained ($F_{7,151}$=5.54, p<0.001). Breaks beginning between 09:00 and 12:00 h were associated with the shortest TST, averaging 4.4 h ± 1.3 h, whereas breaks beginning between 00:00 and 03:00 h were associated with the longest TST, averaging 6.8 h ± 1.7 h. In general, TST was shorter for morning and daytime breaks than for breaks beginning during the evening and night (Fig. 3).

Sleep efficiency was not influenced by break onset time (Fig. 3), with no main effect of *break onset time* on sleep efficiency ($F_{7,208}$=1.26, p=0.28). Sleep efficiencies ranged from between 85.9% ± 5.0% (for breaks beginning between 06:00 and 09:00 h) and 89.9% ± 3.5% (for breaks beginning between 00:00 and 03:00 h).

Finally, there was a main effect of *break onset time* on subjective sleep quality ($F_{7,209}$=3.21, p=0.003). Participants reported that their sleep quality was poorest (3.1 ± 1.0, "average") when breaks began between 06:00 and 09:00 h, which corresponded with the lowest sleep efficiency observed (Fig. 3). Similarly, participants reported that their sleep quality was the best (2.2 ± 0.9, "good") when breaks began between 00:00 and 03:00 h, which corresponded with the highest sleep efficiency observed (Fig. 3).

Table 1. Sleep variables for work periods and days off

	Work	Rest	DF	F	*p*
Total sleep time (h)	6.1 ± 1.5	6.6 ± 1.6	1,411	11.94	0.001
Sleep efficiency (%)	87.5 ± 5.2	88.1 ± 4.9	1,406	0.04	0.85
Subjective sleep quality (ratings)	2.8 ± 0.9	2.5 ± 0.9	1,432	6.4	0.01

Work = sleep obtained between shifts; rest = sleep obtained on days off. Values represent mean ± SD. Subjective sleep quality ratings were based on a 5-point Likert scale where 1 = "very good" and 5 = "very poor".

Discussion

The current study investigated the influence of break timing on the sleep quantity and quality of train drivers working an onshore FIFO operation. Although controlled laboratory studies have demonstrated the impact of time of day on sleep quantity and quality[14, 15], results from these studies may not always be directly translatable to field situations, primary due to differences in participant demographics, and environmental, social, domestic and leisure conditions between laboratory and field situations. Likewise, while previous studies[9, 19] have demonstrated an effect of shift and break timing on the sleep of shiftworkers, these studies involved irregular shift schedules with varied shift and break durations between shifts. In this way, the sleep of shiftworkers in these studies is influenced by both time of day and the sleep opportunity (i.e., shift/break duration). We were given the unique opportunity to investigate the influence of break timing on sleep duration while controlling the break duration, the sleeping environment, and the social/family responsibilities within a field environment.

The amount of sleep participants obtained between shifts and their subjective assessments of sleep quality were dependent on break onset time, whereas sleep efficiency remained high irrespective of the time of day that breaks occurred. Although it has been suggested that compared to residential based settings, FIFO work arrangements may be conducive for sleep[26–29], this does not appear to hold true for all settings (i.e., onshore settings). Current results support recent work[30–32] suggesting that even in FIFO operations where there is sufficient time for sleep between shifts and near-optimal sleeping conditions, the influence of the endogenous circadian pacemaker on sleep duration is evident.

Participants obtained an average of 6 h sleep, which may represent moderate sleep restriction[2, 6]. Participants may have also experienced circadian misalignment during

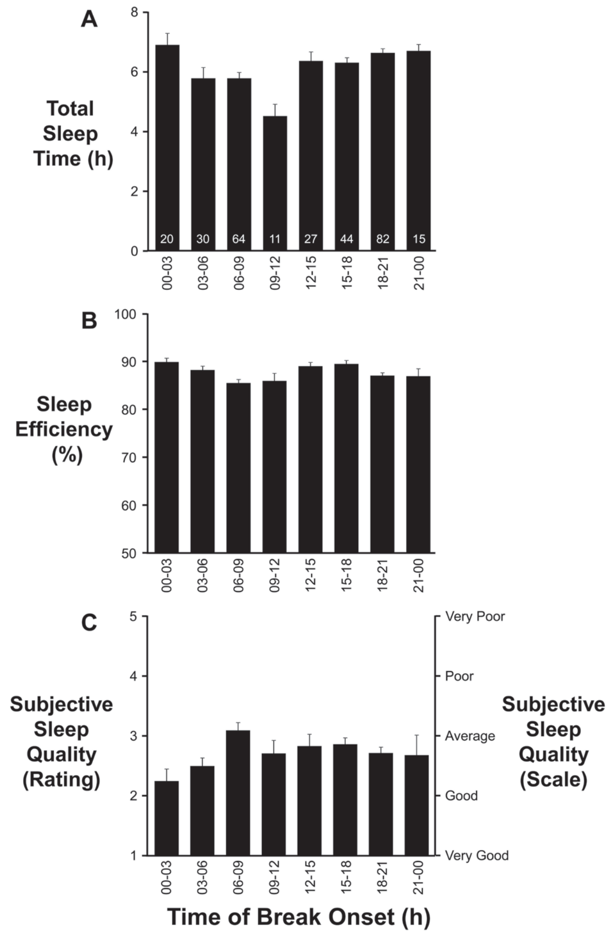

Fig. 3. Total sleep time, sleep efficiency and subjective sleep quality as a function of break onset time.
Total sleep time (top) is expressed in hours and sleep efficiency (middle) is expressed as a percentage of time spent asleep between sleep onset and sleep offset. Subjective sleep quality (bottom) is expressed as a rating of 1–5 with the scale shown on the right y axis. All variables are the mean ± SEM of individual sleep episodes. The number of samples for each break onset time is indicated in white text.

their shift schedules due to sleeping out of phase with their endogenous circadian timing system[12, 13]. The sleep restriction and circadian misalignment that participants may have been experienced could have negatively influenced their sleep[36, 37] and waking performance[6, 38].

Sleep duration was dependent on break timing, with night-time breaks associated with almost 7 h sleep, compared to breaks beginning in the early to mid-morning which were associated with as little as 4.5 h sleep. While a time of day effect on sleep duration is in concordance with previous field based studies[9, 19, 21], the overall amount of sleep obtained by participants in the current study was greater than these previous reports. Specifically, in the study by Roach *et al.*[19] shiftworkers obtained an average of 5.2 h sleep between shifts, 1 h less than current results. The longer sleep durations observed in the current study may indicate that the FIFO work arrangement (i.e., the reduction in competing factors for sleep) enabled shiftworkers to better utilise sleeping opportunities than those in residential situations. Although no residential-based group was involved in the current study recent work[32] demonstrates that onshore FIFO workers obtain similar sleep durations to their residential counterparts. Current results, along with these previous suggestions[32], indicate that the endogenous circadian timing system[14–18, 39] is likely to have a greater influence on sleep duration than the specific work arrangement.

Although it might be assumed that 12-h breaks allow sufficient time for sleep, particularly in FIFO settings where social and family responsibilities are reduced, previous studies suggest that with 12-h breaks it may be difficult for workers to obtain more than 6 h sleep[11, 19]. It is important to note that a 12-h break between shifts does not always allow for 12 h of rest time, or necessarily equate to a long sleep opportunity. Break periods between shifts usually also encompass the commute, activities such as eating, showering, exercising and contacting family/friends, and general "down-time" (e.g., watching TV, surfing the net)[40, 41]. As such, when designing rosters, activities outside work such as the commute and general downtime should be taken into consideration with regards to break duration.

TST increased on days off relative to work periods yet the amount of sleep obtained was less compared to previous reports[30–32]. This may reflect habitual sleep patterns in the current population. However, as we only recorded sleep during the first seven days off (some participants had a total of 14 d off), it is possible that participants may have obtained more sleep during their second week off. Unlike previous reports[30–32], most participants in the current study had long flights home from the work site (up to a full day of travelling) and many participants had time zone differences between the work site and their homes (where there was a time zone difference this was a minimum of 2.5 h). The attempt to recover from extended work periods with unusual shift start times, mild jet lag, and extended travelling times may have increased the length of time required by participants to return to their habitual sleeping patterns.

Irrespective of the time of day that breaks began, sleep efficiencies ranged between 86% and 90%. An average sleep efficiency of 88% is within the expected range for healthy adults (80–90%)[42] and is in concordance with previous reports[27, 28, 43]. Despite this, it was expected that break timing would influence sleep efficiency to some extent[14, 15, 39]. The absence of a time-of-day effect on sleep efficiency may simply be the difference between the requirements of laboratory-based protocols and field-based protocols. In laboratory protocols, participants are typically required to remain in bed, even if they are not sleeping (i.e., there is a set TIB). Alternatively, in most field situations, individuals are not required to remain in bed. As sleep efficiency is calculated as a percentage of TIB, depending on the TIB, sleep efficiency can vary.

The high sleep efficiencies in the current study may also indicate that drivers were experiencing some form of sleep restriction[44], potentially during work periods and days off. Recent research suggest that when sleep is restricted to the equivalent of 6 h per 24-h period, the circadian influence on sleep efficiency is reduced, such that sleep remains consolidated regardless of circadian timing[36, 37]. It is also possible that favourable sleeping environments (e.g., quiet, dark rooms both at home and while onsite) aided in sleep consolidation.

Participants reported poorer sleep quality for breaks beginning in the morning compared to breaks beginning during the night. Participants may have felt that sleep during the day was "lighter" or less restorative than sleep during the night. However, they may have also expected to sleep worse during the day than at night, either consciously or subconsciously rating their sleep quality accordingly. Recently, it has been demonstrated that subjective assessments of fatigue made in the absence of knowledge of time of day or sleep duration are influenced by circadian timing and sleep duration[45], suggesting that the subjective measures of sleep quality in the current study reflect the actual influence of circadian timing on subjective sleep quality measures rather than anticipated influences. Regardless, the influence of knowledge of time of day on subjective sleep quality ratings needs further investigation.

Participants also reported poorer sleep quality onsite compared to sleep whilst on days off. An improved sleep quality whilst on days off may just be the result of participants sleeping at home in their most comfortable environment. Alternatively, a better report of sleep quality on days off may be reflective of the longer sleep durations on days off compared to work periods.

Although results from the current study highlight the importance of shift timing on the sleep quantity and quality, there are some limitations that need to be considered. The current sample size was relatively small, with the majority of breaks beginning around 06:00 and 18:00. It is possible that results may reflect some inter-individual differences and so future work should encompass a greater variety in shift start times to gain a more comprehensive account of the impact of shift start times in such a unique setting.

Sleep in the current study was objectively assessed using actigraphy. Actigraphy is widely used in field settings, partly because it is non-invasive and is reasonably efficient. However, PSG is considered to be the "gold standard" for recording sleep and can allow for more detailed assessments of sleep efficiency and individual sleep stages to be measured. Although actigraphy has been shown to be a good indicator of sleep duration when compared to PSG, actigraphy is less accurate at measuring sleep efficiency, particularly daytime sleep and sleep in older populations[34, 46, 47]. Results from the current study regarding the sleep efficiency during daytime sleep episodes may be somewhat overestimated. Future studies could encompass some measures of PSG to gain a wider, and perhaps more accurate, insight into how shift timing affects the specific sleep structure in field settings.

While the current study was partly aimed at determining if a FIFO environment minimises the effect of break/shift timing on sleep duration, no residential-based group was involved. Future studies should include residential workers to compare to FIFO workers. However, based on previous work conducted by our group[32], it appears that there is little difference in the amount of sleep between residential-based workers and FIFO workers on the same schedule, at least within Australian environments. The influence of factors such as natural or bright light exposure and the endogenous circadian timing system[14, 15, 48, 49] are likely to outweigh any specific work or living arrangements when it comes to sleep duration. Therefore, it might be expected that even if a residentially based comparison group was included in the current study, sleep durations would have been similar between the FIFO workers and residential workers.

In contrast to onshore settings, there are several conditions in some offshore settings that may have positive effects on sleep. Factors such as 1) cooler temperatures in the northern hemisphere[50], 2) the amount (and timing) of natural light exposure[48, 51, 52] and 3) fewer competing factors for sleep[29, 52], should be taken into account when comparing current results to previous reports[26–28].

The current study confirms that shift timing is a critical factor in determining sleep duration and subjective perceptions of sleep in shiftworkers, even in FIFO settings where break duration is held constant, sleeping conditions are near-optimal and the social/family responsibilities are minimised. Sleep efficiency remained high at all times, implying that despite possible circadian misalignment, shiftworkers are still able to obtain relatively consolidated sleep episodes. Current results suggest that despite the unique FIFO conditions (e.g., long break duration, near-optimal sleeping conditions and minimised social/family responsibilities) the circadian timing on sleep remains evident. In conclusion, there is not a one-size-fits-all approach to managing the challenges of shiftwork. Differences in environments, facilities, shift schedules and even participant demographics, no matter how small, may alter the way in which a particular shift arrangement affects the sleep quantity and quality of workers[53]. Policies made based predominately on results from laboratory or offshore FIFO may not be applicable to all situations, as indicated by current results.

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