Applied Ergonomics 54 (2016) 72–82

Contents lists available at ScienceDirect

Applied Ergonomics

journal homepage: www.elsevier.com/locate/apergo

The effect of split sleep schedules (6h-on/6h-off) on neurobehavioural performance, sleep and sleepiness

Michelle A. Short [a, b, c, *], Stephanie Centofanti [a], Cassie Hilditch [a], Siobhan Banks [a], Kurt Lushington [a], Jillian Dorrian [a]

[a] Centre for Sleep Research, University of South Australia, Adelaide, Australia
[b] Bushfire Cooperative Research Centre, East Melbourne, Australia
[c] School of Psychology, Flinders University, Bedford Park, Australia

ARTICLE INFO

Article history:
Received 27 October 2014
Received in revised form
20 October 2015
Accepted 9 December 2015
Available online

Keywords:
Split sleep
Shiftwork
Sustained operations
Continuous operations
Attention
Performance

ABSTRACT

Shorter, more frequent rosters, such as 6h-on/6h-off split shifts, may offer promise to sleep, subjective sleepiness and performance by limiting shift length and by offering opportunities for all workers to obtain some sleep across the biological night. However, there exists a paucity of studies that have examined these shifts using objective measures of sleep and performance. The present study examined neurobehavioural performance, sleepiness and sleep during 6h-on/6h-off split sleep schedules. Sixteen healthy adults (6 males, 26.13y ± 4.46) participated in a 9-day laboratory study that included two baseline nights (BL, 10h time in bed (TIB), 2200h-0800h), 4 days on one of two types of 6h-on/6h-off split sleep schedules with 5h TIB during each 'off' period (6h early: TIB 0300h-0800h and 1500h-20000h, or 6-h late: TIB 0900h-1400h and 2100h-0200h), and two recovery nights (10h TIB per night, 2200h-0800h). Participants received 10h TIB per 24h in total across both shift schedules. A neurobehavioural test bout was completed every 2 h during wake, which included the Psychomotor Vigilance Task (PVT) and the Karolinska Sleepiness Scale (KSS). Linear mixed effects models were used to assess the effect of day (BL, shift days 1–4), schedule (6h early, 6h late) and trial (numbers 1–6) on PVT lapses (operationalised as the number of reaction times >500 ms), PVT total lapse time, PVT fastest 10% of reaction times and KSS. Analyses were also conducted examining the effect of day and schedule on sleep variables. Overall, PVT lapses and total lapse time did not differ significantly between baseline and shift days, however, peak response speeds were significantly slower on the first shift day when compared to baseline, but only for those in the 6h-late condition. Circadian variations were apparent in performance outcomes, with individuals in the 6h-late condition demonstrated significantly more and longer lapses and slower peak reaction times at the end of their night shift (0730h) than at any other time during their shifts. In the 6h-early condition, only response speed significantly differed across trials, with slower response speeds occurring at trial 1 (0930h) than in trials 3 (1330h) or 4 (2130h). While subjective sleepiness was higher on shift days than at baseline, sleepiness did not accumulate across days. Total sleep was reduced across split sleep schedules compared to baseline. Overall, these results show that while there was not a cumulative cost to performance across days of splitting sleep, participants obtained less sleep and reported lowered alertness on shift days. Tests near the circadian nadir showed higher sleepiness and increased performance deficits. While this schedule did not produce cumulative impairment, the performance deficits witnessed during the biological night are still of operational concern for industry and workers alike.

1. Introduction

Shift work is problematic because it frequently entails both prolonged wakefulness and circadian misalignment (Folkard et al., 2005). Resultantly, shift work is associated with impaired alertness and heightened risk of fatigue, workplace accidents, performance

* Corresponding author. Centre for Sleep Research, University of South Australia, GPO Box 2471, Adelaide, SA, 5001, Australia.
E-mail address: michelle.short@unisa.edu.au (M.A. Short).

http://dx.doi.org/10.1016/j.apergo.2015.12.004

deficits, insufficient and low quality sleep, and poor health (Dembe et al., 2006; Dinges, 1995; Driscoll et al., 2007; Pilcher et al., 2000; Rajaratnam and Arendt, 2001; Tilley et al., 1982). To manage the need for 24-h work coverage, many industries have implemented 12-h or 8-h shift work rosters (Barnes et al., 1998; Bjorvatn et al., 2006; Driscoll et al., 2007; Parkes, 2012). The most common ones include 12-h day and night shift rosters, where 2 panels of employees work 12-h shifts (day, night) with 12-h breaks, and 8-h rosters where 3 panels of employees work 8-h shifts (early, late, night) with 16-h breaks. These schedules frequently combine risk from both circadian misalignment and extended wakefulness for those workers who work the evening and night shifts: two of the largest risk factors predictive of workplace accidents and injuries (Folkard et al., 2005). As an alternative, some industries have implemented shorter, more frequent shifts (such as 6h-on/6h-off, 4h-on/8h-off and 8h-on/8h-off) to address the dual risk of homeostatic and circadian factors (Arendt et al., 2006; Colquhoun et al., 1968; Condon et al., 1984; Darwent et al., 2008; Harma et al., 2008; van Leeuwen et al., 2013). In these rosters, the build-up of homeostatic sleep drive may be reduced by limiting continuous work time with shorter shifts, which also allow more frequent sleep opportunities. Therefore, while circadian factors still operate, they are not coupled with heightened homeostatic sleep pressure and associated impairment (Mollicone et al., 2010). Additionally, these shorter and more frequent shifts typically allow at least some opportunity for sleep across the biological night for all workers.

Split sleep work schedules such as the ones described above, have been most frequently implemented in maritime operations, for example 6h-on/6h-off (involving two crews of workers) or 4h-on/8h-off (involving three crews) watch-keeping schedules (Eriksen et al., 2006; Hansen and Holmen, 2011; Harma et al., 2008; Howarth et al., 1999; Lutzhoft et al., 2010; Rutenfranz et al., 1988; Sanquist et al., 1997). Research into these split sleep rosters has found that those with a lower ratio of work to sleep, and schedules that begin and end at the same clock time every 24 h are associated with better sleep, performance and daytime functioning (Short et al., 2015). This would therefore indicate that the 6h-on/6h-off schedules, with a 1:1 work: rest ratio and starting at the same fixed times each day may be associated with less impairment than 8h-on/8h-off schedules, which have moving shift times each 24h period (Darwent et al., 2008). Further, not all work environments can accommodate the three teams of workers required to maintain a 1:2 work: sleep ratio, such as would be required by 4h-on/8h-off schedules. The 6h-on/6h-off schedules may therefore have particular operational promise. However, previous research in this area is limited to a relatively small number of studies in specific industry populations (Colquhoun et al., 1987; Condon et al., 1988; Darwent et al., 2008; Eriksen et al., 2006; Jay et al., 2006). Most research has involved field studies, which are high in ecological validity, but are vulnerable to potential confounds such as differences in the individual characteristics of workers within that industry, light exposure, and unrestricted use of caffeine, medications and drugs (Howarth et al., 1999; Lamond et al., 2005).

One study surveyed 577 shipping workers, 377 of whom worked a 6h-on/6h-off schedule and 182 of whom worked a 12h-on/12h-off schedule (Hansen and Holmen, 2011). While individuals working the 6h-on/6h-off schedule reported more sleep disturbances, the groups did not report different work capability or safety. In a study of bridge officers, those on a 6h-on/6h-off schedule (N = 45) reported less sleep, a higher prevalence of excessive sleepiness, and greater frequency of nodding off while on duty than those on a 4h-on/8h-off schedule (N = 68) (Harma et al., 2008). Lutzhoft and colleagues (Lutzhoft et al., 2010) also compared watch keepers working a 6h-on/6h-off schedule (n = 15) with those working a 4h-on/8h-off schedule (N = 15). Similar to Harma's group, Lutzhoft and colleagues found greater sleepiness at night for workers on the 6h-on/6h-off schedule. However, there was no significant difference in *overall* sleepiness between the two schedules, nor were there any significant differences in actigraphically-defined total sleep time, sleep efficiency, reaction time or blink duration. One confounding factor discussed by the authors is that actual shift length was routinely longer than what was rostered, particularly for individuals working the 6h-on/6h-off shifts. As such, the ratio of work to rest was likely much higher than 1:1 and the opportunity to obtain sleep was truncated. These maritime studies included predominantly male samples, and relied largely on subjective reports of sleep and performance. In addition, as these studies were conducted in the workplace, it may be difficult to collect baseline measures, where individuals were not at work, and not affected by previous shifts. Further, the effect of the schedules on sleep architecture was not measured. Laboratory simulation studies provide a research environment where these imperatives (as well as control of potential confounds) are more achievable.

In their laboratory simulation, Eriksen and colleagues (Eriksen et al., 2006) investigated a 6h-on/6h-off schedule with 12 male merchant marines and navy navigators. The simulation lasted for 66 h, in which the first 30 h was spent working one of the two possible 6h-on/6h-off schedules (0000h-0600h and 1200h-1800h, or 0600h-1200h and 1800h-2400h), then a 3h-on/3h-off "dog watch" occurred to rotate individuals across to the other schedule, followed by 30 h of the second, inverse 6h-on/6h-off schedule. Participants rated their subjective sleepiness every 30 min on the Karolinska Sleepiness scale (KSS) and completed a sleep diary after every break period in which they attempted to sleep. Subjective sleepiness and reported sleep duration were similar for both watch rotations. Across individual watches, subjective sleepiness was higher on the night watch (2400h-0600h) than either the day (1200h-1800h) or the evening (1800h-2400h) watches, and increased from beginning to end of each watch (1200h-1800h, 1800h-2400h & 2400h-0600h), except for the morning watch (0600h-1200h). Sleep duration was longer on the morning (0600h-1200h) than the day (1200h-1800h) off-duty periods and longer on the night (0000h-0600h) than both the day (1200h-1800h) and evening (1800h-2400h) off-duty watches. This study provides more fine-grained information on subjective sleepiness across a 6h-on/6h-off split sleep schedule, by comparing the two watch systems and comparing each watch and off-duty period with those occurring at different times, all of which are strengths of this study. Study limitations included a lack of objective measurement of sleep and performance, no baseline comparisons, and caffeine was limited but not excluded (participants were able to consume up to 2 cups of coffee per 24 h).

The present study has dual aims. Firstly, it aims to compare individuals' performance, sleepiness and objective sleep during one of two complementary 6h-on/6h-off rosters with their performance during a daytime baseline, equivalent to a 12h dayshift. The second aims is to compare objective sleep per 5h sleep opportunity during the simulated 6h-on/6h-off shift schedules. This extends upon the previous work in this field by employing a laboratory-based study to examine two 6h-on/6h-off split sleep schedules in a controlled laboratory environment. This study utilises polysomnographic measurement of sleep (the gold-standard), and includes both male and female participants.

2. Materials and methods

2.1. Participants

Participants were 16 healthy adults (6 male, aged 26.13years ± 4.46). Eight participants were randomised to each 6h