Accident Analysis and Prevention xxx (2015) xxx–xxx

Contents lists available at ScienceDirect

Accident Analysis and Prevention

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

Do split sleep/wake schedules reduce or increase sleepiness for continuous operations?

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ARTICLE INFO

Article history:
Received 26 June 2015
Received in revised form 20 October 2015
Accepted 23 October 2015
Available online xxx

Keywords:
Subjective sleepiness
Split sleep
Forced desynchrony
Shiftwork

ABSTRACT

This study compared the impact of split and consolidated sleep/wake schedules on subjective sleepiness during the biological day and biological night. This was achieved using a between-group design involving two forced desynchrony protocols: consolidated sleep/wake and split sleep/wake. Both protocols included 7 × 28-h days with 9.33 h in bed and 18.67 h of wake each day. While the consolidated sleep/wake protocol had 1 × 9.33-h sleep opportunity and 1 × 18.67-h wake period each day, the split sleep/wake protocol had 2 × 4.67-h sleep opportunities and 2 × 9.33-h wake periods each day. For both protocols, subjective sleepiness was measured using the Karolinska Sleepiness Scale every 2.5 h during wake. A total of 29 healthy adult males participated, with 13 in the consolidated sleep/wake group (mean age = 22.5 yrs) and 16 in the split sleep/wake group (mean age = 22.6 yrs).

On average, subjective sleepiness during wake periods of the split condition was significantly higher than that during the first half of wake periods of the consolidated condition, but was similar to the level during the second half. These findings were observed for wake periods that occurred during both the biological day and biological night. Previous data have shown that cognitive impairment at night is lower for split schedules than consolidated schedules, but the current data indicate that feelings of sleepiness are greater for split schedules than consolidated schedules for at least half of the time awake. Thus, it should be explained to people operating split sleep/wake schedules that although they may perform well, they are likely to feel sleepy.

1. Introduction

1.1. Background & previous studies

Severe sleepiness is a common complaint among shift workers. This is primarily due to working and sleeping at irregular hours, designated by work–rest schedules (Akerstedt, 1995, 2003; Rajaratnam et al., 2013). Typically, shift workers have so called 'consolidated' schedules, which contain a single work period and a single rest period each day – e.g., 12 h on/12 h off (Rosa and Bonnet, 1993; Tucker et al., 1996; Baulk et al., 2009) and 8 h on/16 h off (Rosa and Bonnet, 1993; Tucker et al., 1996). As alternatives, split schedules also exist, where compared to consolidated schedules the daily work and rest periods occur twice as often and half the duration – e.g., 6 h on/6 h off (Harma et al., 2002; Eriksen et al., 2006) and 4 h on/8 h off (Condon et al., 1988; Harma et al., 2002). Given that shift work cannot be eliminated, it is important to determine which schedule type yields a lower level of sleepiness at work.

From a theoretical perspective, each schedule type has its own advantage. Assuming that rest periods are primarily used for sleep, the more frequent rest periods of split schedules imply that workers on such schedules do not stay awake for as long as do workers on consolidated schedules before the next sleep opportunity. It is well known that sleepiness accumulates with an increasing level of wakefulness (Dijk et al., 1992; Dijk and Czeisler, 1995). Split schedules may then yield a lower level of sleepiness at work than consolidated schedules. On the other hand, the shorter rest periods of split schedules would mean shorter recovery opportunities for sleepiness before the next work period. It is well known that the recovery of sleepiness is sleep dose dependent (Jewett et al., 1999; Belenky et al., 2003; Van Dongen et al., 2003), such that shorter sleeps would not provide as much recovery as longer sleeps. With longer rest periods, consolidated schedules may then yield a lower

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http://dx.doi.org/10.1016/j.aap.2015.10.027
0001-4575/

level of sleepiness at work than split schedules. Thus, it seems difficult to select a better schedule type theoretically. Nor does empirical evidence provide an adequate basis to make a selection.

Field studies have examined sleepiness during consolidated schedules such as 12 h on/12 h off (Rosa and Bonnet, 1993; Tucker et al., 1996; Baulk et al., 2009) and 8 h on/16 h off (Rosa and Bonnet, 1993; Tucker et al., 1996), as well as split schedules such as 4 h on/8 h off (Condon et al., 1988; Harma et al., 2002), 6 h on/6 h off (Harma et al., 2002; Eriksen et al., 2006) and 8 h on/8 h off (Darwent et al., 2008; Jay et al., 2008). However, these studies intend to describe sleepiness during a given schedule type, rather than comparing sleepiness between schedule types. In laboratory settings, only two published studies to date have directly compared split and consolidated schedules on subjective sleepiness. A study by Mollicone and colleagues (2008) compared a consolidated schedule with a daily sleep opportunity of 8.2 h at night with an array of split schedules that contained a night-time sleep, 4.2–6.2 h in duration, and an afternoon nap, 0.4–2.4 h in duration. Schedule type explained too little variance in subjective sleepiness to be considered to have an impact. Thus, split and consolidated schedules seem to yield a similar level of sleepiness. However, in this study sleepiness was mainly assessed during the biological day, such that the difference between the two schedule types during night-time wake periods is undetermined. This is an important point for consideration, given that sleepiness is particularly elevated during the biological night (Dijk et al., 1992; Dijk and Czeisler, 1995).

Different from Mollicone et al., Jackson and colleagues (2014) observed that, having two 5-h sleep opportunities, from 0300 h to 0800 h and from 1500 h to 2000 h, yielded a lower level of sleepiness than having a single 10-h opportunity, but only when this single sleep opportunity occurred during the biological day. In this study, sleepiness was assessed during the biological day in the split condition (i.e., 2 × 5-h sleep), but it was assessed during the biological night in the consolidated condition (i.e., 10-h sleep). Thus, the result is largely explained by time of day variation in sleepiness, as opposed to schedule type. Once again, in this study differences between the two schedule types during night-time wake periods remain undetermined.

1.2. Current study

Given the abovementioned difficulty in theoretical prediction and the gap in empirical evidence, the current study systematically compared a split sleep/wake schedule with a consolidated schedule on subjective sleepiness during night-time wake periods and during day-time wake periods.

2. Materials & methods

2.1. Ethics

The study was approved by the Human Research Ethics Committees at the University of South Australia and Central Queensland University. Prior to taking part, participants were informed about the general nature of the study and gave written consent. Upon completion, all participants received financial compensation.

2.2. Participants

A total of 29 males participated. They were recruited through flyers around the general community in Adelaide, Australia. Participants' health status was assessed using a general health questionnaire. Based on their responses, participants did not have any medical conditions, psychiatric disorders, or sleep disorders; none of them were taking any prescribed medication or had a high consumption of alcohol or caffeine at the time of the study. These participants were not shift workers and had not undertaken transmeridian travel in the last three months. One week prior to the experiment, participants were instructed to go to bed between 22:00 h and 00:00 h and to have a ~8-h bed period each night, which was verified using activity monitors (Kosmadopoulos et al., 2014b; Actical, Philips Respironics, Bend, Oregon, USA) in conjunction with self-report sleep diaries.

2.3. Design & procedures

The study employed two forced desynchrony (FD) protocols with a consolidated sleep/wake schedule and a split schedule. Out of the 29 participants recruited, 13 were in the consolidated schedule (mean age 22.5 ± 2.2 yrs, mean body mass index 22.2 ± 2.1 kg/m^2), and 16 were in the split schedule (mean age 22.6 ± 2.9 yrs, mean body mass index 22.0 ± 1.9 kg/m^2). The consolidated protocol was carried out between years 2008 and 2009 at the Centre for Sleep Research, University of South Australia. The split protocol was carried out in the year 2013 at the sleep laboratory of Appleton Institute, Central Queensland University.

The sleep/wake schedules of the two protocols are summarised in Fig. 1. Both protocols began with two training days, during which subjective sleepiness and other neurobehavioural tasks were introduced and practiced. The training phase was followed by a baseline day, where subjective sleepiness was assessed five times at 2-h intervals. The following forced desynchrony phase comprised 7 × 28-h days. The wake to rest ratio of each day was set at 2:1, such that a total of 18.67 h was allocated to wakefulness and a total of 9.33 h to sleep, which is essentially equivalent to 8 h in bed per 24 h. Sleep and wakefulness alternated in 9.33 h/18.67 h cycles in the consolidated schedule, but in 4.67 h/9.33 h cycles in the split schedule. Thus, for each 28-h day participants in the consolidated schedule had a single 18.67-h wake period and a single 9.33-h sleep period, whereas participants in the split schedule had two 9.33-h wake periods and two 4.67-h sleep periods (Fig. 1A).

For both protocols, subjective sleepiness along with a set of other neurobehavioural tasks were assessed every 2.5 h starting from 1.5 h into scheduled wakefulness. In total, there were seven test sessions per day in the consolidated schedule but six in the split schedule (due to an extra set-up requirement for sleep recording). The two protocols were configured such that all seven sessions spread over a continuous 18.67-h wake period for the consolidated schedule, whereas for the split schedule the six sessions spread across to two 9.33-h wake periods, with three sessions in each period (Fig. 1A). For the ease of comparing the two protocols, test session 7 of the consolidated schedule was excluded from analyses.

All test sessions were conducted individually in each participant's living room. Between sessions, only non-strenuous activities such as watching pre-recorded TV programmes and reading books were permitted. No naps were allowed during wake periods. To ensure compliance, participants were closely monitored by researchers either in person or via a closed circuit television system. Prior to each scheduled sleep period, a polysomnography montage was applied to each participant for sleep monitoring. The polysomnography data are reported in another paper (Roach et al., 2015). To recap briefly, participants in the consolidated schedule obtained an average of 7.6 h of sleep per 9.33 h in bed, which did not significantly differ from the 8.0 h obtained by their counterparts in the split schedule. There was no significant difference between the two protocols for the average amount of REM sleep, although participants in the split schedule obtained slightly more slow wave sleep (~2.8 h/9.33 h in bed) than their counterparts in the consolidated schedule (~2.2 h/9.33 h in bed).