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AAP-3940; No. of Pages 6
ARTICLE IN PRESS
Accident Analysis and Prevention xxx (2015) xxx–xxx
Contents lists available at ScienceDirect
Accident Analysis and Prevention
journal homepage: www.elsevier.com/locate/aap

Are two halves better than one whole? A comparison of the amount and quality of sleep obtained by healthy adult males living on split and consolidated sleep–wake schedules

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ARTICLE INFO

Article history:
Received 26 June 2015
Received in revised form 6 October 2015
Accepted 13 October 2015
Available online xxx

Keywords:
Shiftwork
Work–rest
Sleep loss
Forced desynchrony
Monophasic
Polyphasic

ABSTRACT

The aim of this study was to compare the quantity/quality of sleep obtained by people living on split and consolidated sleep–wake schedules. The study had a between-groups design, with 13 participants in a consolidated condition (all males, mean age of 22.5 yr) and 16 participants in a split condition (all males, mean age of 22.6 yr). Both conditions employed forced desynchrony protocols with the activity:rest ratio set at 2:1, but the consolidated condition had one sleep–wake cycle every 28 h (9.33 + 18.67), while the split condition had one sleep–wake cycle every 14 h (4.67 + 9.33). Sleep was assessed using polysomnography. Participants in the split and consolidated conditions obtained 4.0 h of sleep per 14 h and 7.6 h of sleep per 28 h, respectively. Some differences between the groups indicated that sleep quality was lower in the split condition than the consolidated condition: the split sleeps had longer sleep onset latency (9.7 vs. 4.3 min), more arousals (7.4 vs. 5.7 per hour in bed), and a greater percentage of stage 1 sleep (4.1% vs. 3.1%), than the consolidated sleeps. Other differences between the groups indicated that sleep quality was higher in the split condition than the consolidated condition: the split sleeps had a lower percentage of wake after sleep onset sleep (11.7% vs. 17.6%), and a greater percentage of slow wave sleep (30.2% vs. 23.8%), than the consolidated sleeps. These results indicate that the split schedule was not particularly harmful, and may have actually been beneficial, to sleep. Split work–rest schedules can be socially disruptive, but their use may be warranted in work settings where shiftworkers are separated from their normal family/social lives (e.g., fly-in fly-out mining) or where the need for family/social time is secondary to the task (e.g., emergency response to natural disasters).

1. Introduction

The frequency of shiftwork in developed nations has grown substantially over the last few decades, as many industries have responded to technological innovations, increased customer demands, changed community expectations, and the emergence of global competition, by expanding their operations to cover 24 h-a-day, 7 days-a-week. Sleep loss is one of the major problems associated with shiftwork (Åkerstedt, 2003), and the timing and duration of rest breaks between work periods are two of the major determinants of the amount of sleep that is obtained by shiftworkers (Roach et al., 2003).

Historically, shiftwork has been arranged using two types of work–rest schedules. The more common type, i.e., consolidated schedules, contain one work period and one rest period each day. The less common type, i.e., split schedules, contain at least two work periods and two rest periods each day. Consolidated schedules are favoured over split schedules in most shiftwork industries because it is considered less disruptive to employees' family and social lives to have one work period in a day rather than two (Bohle et al., 2004), and the lay perception is that one longer sleep is more restorative than two shorter sleeps, even if the total amounts of time in bed are similar (Stampi, 1992). Nevertheless, there are several lines of converging evidence to indicate that splitting work into two periods and having two shorter sleeps each day may have some benefits (Jackson et al., 2014). First, field studies indicate that shiftworkers on split schedules obtain a similar

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http://dx.doi.org/10.1016/j.aap.2015.10.012
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amount of sleep to shiftworkers on consolidated schedules (e.g., compare Darwent et al., 2008, with Åkerstedt, 2003). Second, it has been estimated that around half the recovery in neurobehavioural function associated with an 8-h night sleep occurs in the first 2 h (Jewett et al., 1999). This is a controversial concept given that sleep loss of 2–3 h/day over 1–2 weeks causes cumulative impairment in neurobehavioural function (Belenky et al., 2003; Van Dongen et al., 2003), but it raises the possibility that the total recovery provided by two shorter sleeps may be greater than the recovery provided by one longer sleep. Third, when 'anchor' night sleeps and daytime naps of various lengths are paired, neurobehavioural function depends on the total amount of sleep obtained, rather than the extent to which sleep occurs during the anchor sleep or the nap (Minors and Waterhouse, 1983; Mollicone et al., 2008).

Anchor sleep studies, like those mentioned above, represent the most comprehensive systematic comparisons of split and consolidated schedules that have been conducted to date. However, a limitation of these studies is that their protocols are based on main sleeps that only occur at night and naps that only occur during the day. Consequently, the ecological validity and generalisability of these studies are restricted because many shiftwork schedules do not allow the main sleep to be taken at night-time. In the current study, this limitation was avoided by examining the efficacy of split schedules using a protocol that ensured that sleep and wake episodes occurred at all times of day. The aim of this study was to examine the efficacy of split work–rest schedules by comparing the amount/quality of sleep obtained by participants adhering to a split sleep–wake protocol with those adhering to a consolidated sleep–wake protocol.

2. Materials and methods

2.1. Participants

A total of 29 males volunteered, and gave written informed consent, to participate in the study, which was approved by the human research ethics committees at the University of South Australia and Central Queensland University. The participants were assigned to either a consolidated sleep–wake condition or a split sleep–wake condition (see details below). The 13 participants in the consolidated condition had a mean (±SD) age of 22.5 (±2.2) yr and a mean body mass index of 22.2 (±2.1) kg/m^2, and the 16 participants in the split condition had a mean age of 22.6 (±2.9) yr and a mean body mass index of 22.0 (±1.9) kg/m^2. Participants were instructed to maintain a self-selected sleep–wake schedule with consistent bedtimes and ~8 h of sleep each night for the week prior to study admission, and adherence was verified using wrist-worn activity monitors (Philips Respironics, Bend, Oregon, USA) in conjunction with self-report sleep diaries.

2.2. Design

The study had a between-groups design with two conditions: (i) consolidated sleep–wake schedule and (ii) split sleep–wake schedule (see Fig. 1). Both conditions employed a forced desynchrony protocol such that sleep occurred across all circadian phases. In both conditions, the activity:rest ratio was set at 2:1, equivalent to 16 h of wake and 8 h in bed per 24 h. The critical difference between the two conditions was that the consolidated condition had one sleep episode (9.33 h) and one wake episode (18.67 h) every 28 h, while the split condition had one sleep episode (4.67 h) and one wake episode (9.33 h) every 14 h.

2.3. Materials

During all sleep episodes, data related to sleep were collected using standard polysomnography (PSG), with a 5-channel montage composed of two electroencephalograms (C4–M1 and C3–M2), two electrooculograms (left outer canthus and right outer canthus), and an electromyogram. PSG data were recorded directly to a data acquisition, storage, and analysis system (Compumedics E-Series/Grael, Melbourne, Victoria, Australia), and then all sleep episodes were visually scored in 30-s epochs by a trained technician in accordance with recommended criteria (Iber et al., 2007). Throughout the study, core body temperature (CBT) was continuously sampled at 1-min intervals with a rectal thermistor (Cincinnati Sub-Zero Products, Cincinnati, Ohio, USA) connected to a data logger (Minimitter, Bend, Oregon, USA), and physical activity was continuously recorded in 1-min epochs using a wrist-worn activity monitor (Philips Respironics, Bend, Oregon, USA). Each participant's CBT data were cleaned of artefacts, demasked for the effects of sleep and physical activity, and fitted with a cosine equation with a fundamental period (360° ≈ 24 h) and a single harmonic, to generate circadian phase estimates for each minute of the protocol (for details, see Darwent et al., 2010). These phase estimates were used in analyses of test battery data (see below) that have been reported elsewhere (Kosmadopoulos et al., 2014; Zhou et al., this issue), but they were not required for the analyses reported in this manuscript.

2.4. Procedure

During scheduled sleep episodes, participants lay in bed from lights off to lights on, with the exception of bathroom breaks. During scheduled wake episodes, participants completed a ~1-h test battery every 2.5 h, with the first battery beginning 1.5 h after the scheduled end of a sleep episode. The battery included the Karolinska Sleepiness Scale, Profile of Mood States, Psychomotor Vigilance Task, Postural Sway Test, and York Driving Simulator. Data from the test battery are not reported here, but they have been reported elsewhere for the consolidated sleep–wake condition (Darwent et al., 2010; Matthews et al., 2012a, 2012b; Sargent et al., 2010; Zhou et al., 2010, 2011, 2012) and the split sleep–wake condition (Kosmadopoulos et al., 2014; Zhou et al., this issue). The majority of the participants' free time between test batteries was spent in their own private living rooms – reading, writing, drawing, watching DVDs, or listening to music. Participants were not permitted to sleep at any time during wake episodes, and technicians monitored compliance either in person or via closed circuit cameras.

2.5. Laboratory environment

The consolidated and split sleep–wake conditions were conducted in two different time-isolation sleep laboratories at the University of South Australia and Central Queensland University, respectively. To eliminate time cues, the laboratories were windowless, sound-attenuated, temperature-controlled (with a target range of 21–23 °C), and free of timekeeping devices. The laboratories were configured such that they could accommodate 3–4 participants at a time, each with their own bedroom, living room, and bathroom facilities. During wake episodes, the ambient light level was <15 lx at the angle of gaze at a height of 183 cm from the floor. During sleep episodes, the lights were extinguished.

2.6. Measures

Most sleep data can be expressed as total amounts or as percentages of time in bed. In the current study, sleep episodes in the split condition were half the length of sleep episodes in the consolidated condition, so inferential statistical analyses were conducted primarily with percentage-based, rather than amount-based, measures:

Please cite this article in press as: Roach, G.D., et al., Are two halves better than one whole? A comparison of the amount and quality of sleep obtained by healthy adult males living on split and consolidated sleep–wake schedules. Accid. Anal. Prev. (2015), http://dx.doi.org/10.1016/j.aap.2015.10.012