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Sleep and performance in simulated Navy watch schedules

Elena Skornyakov[a,*], Nita L. Shattuck[b], Michael A. Winser[a], Panagiotis Matsangas[b], Amy R. Sparrow[a], Matthew E. Layton[a], Rylie J. Gabehart[a], Hans P.A. Van Dongen[a]

[a] Sleep and Performance Research Center and Elson S. Floyd College of Medicine, Washington State University, PO Box 1495, Spokane, WA 99210-1495, USA
[b] Naval Postgraduate School, 1411 Cunningham Road, Monterey, CA 93943, USA

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ABSTRACT

To operate Navy ships 24 h per day, watchstanding is needed around the clock, with watch periods reflecting a variety of rotating or fixed shift schedules. The 5/15 watch schedule cycles through watch periods with 5 h on, 15 h off watch, such that watches occur 4 h earlier on the clock each day – that is, the watches rotate backward. The timing of sleep varies over 4-day cycles, and sleep is split on some days to accommodate nighttime watchstanding. The 3/9 watch schedule cycles through watch periods with 3 h on, 9 h off watch, allowing for consistent sleep timing over days. In some sections of the 3/9 watch schedule, sleep may need to be split to accommodate nighttime watchstanding. In both the 5/15 and 3/9 watch schedules, four watch sections alternate to cover the 24 h of the day. Here we compared sleep duration, psychomotor vigilance and subjective sleepiness in simulated sections of the 5/15 and 3/9 watch schedules. Fifteen healthy male subjects spent 6 consecutive days (5 nights) in the laboratory. Sleep opportunities were restricted to an average of 6.5 h daily. Actigraphically estimated sleep duration was 5.6 h per watch day on average, with no significant difference between watch sections. Sleep duration was not reduced when sleep opportunities were split. Psychomotor vigilance degraded over watch days, and tended to be more variable in the 5/15 than in the 3/9 watch sections. These laboratory-based findings suggest that Navy watch schedules are associated with cumulative sleep loss and a build-up of fatigue across days. The fixed watch periods of the 3/9 watch schedule appear to yield more stable performance than the backward rotating watch periods of the 5/15 watch schedule. Optimal performance may require longer and more consistent daily opportunities for sleep than are typically obtained in Navy operations.

1. Introduction

Navy surface operations involve watchstanding 24 h per day to be able to operate around the clock. Watchstanding duties include a variety of tasks essential to the operation of the ship. To operate around the clock, these duties are distributed among different crews, which work alternating schedules called watch sections. Usually, there are three or four such watch sections in order to cover all hours of the day.

In most traditional watch schedules, the alternation of watch sections is not aligned with the 24 h cycle of day and night. Various commonly used watch schedules rotate backward, causing desynchronization of circadian rhythms (Sallinen and Kecklund, 2010). Furthermore, in addition to watchstanding duties, Naval personnel are assigned many other tasks. As a consequence, sleep opportunities on board tend to be restricted (Shattuck and Matsangas, 2015a, 2015b).

The combination of around-the-clock operations with insufficient sleep has the potential to induce significant levels of fatigue (Åkerstedt, 2007) due to the effects of two key biological processes of sleep/wake regulation (Van Dongen and Dinges, 2005). The circadian process, which keeps track of time of day, produces a drive for wakefulness during the day, but withdraws this drive during the night and early morning, thereby promoting fatigue. The homeostatic process, which keeps track of sleep and wakefulness, produces an elevated drive for sleep in the face of sleep loss, which also promotes fatigue.

In this pilot study, we considered sleep and fatigue in two specific Naval watch schedules: the traditional 5/15 watch schedule and the more recently introduced 3/9 watch schedule. The 5/15 watch schedule rotates through periods with 5 h on watch followed by 15 h off watch, creating a 20 h watch day. Through the inclusion

* Corresponding author.
E-mail addresses: elenaskorn@gmail.com (E. Skornyakov), nlshattu@nps.edu (N.L. Shattuck), mike.winser@wsu.edu (M.A. Winser), pmatsang@nps.edu (P. Matsangas), amy.sparrow@wsu.edu (A.R. Sparrow), layton@wsu.edu (M.E. Layton), rylie.gabehart@wsu.edu (R.J. Gabehart), hvd@wsu.edu (H.P.A. Van Dongen).

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of a 4 h watch every fourth day, this schedule repeats a backward rotating watch pattern in 4-day cycles. In contrast, the 3/9 watch schedule involves periods with 3 h on watch followed by 9 h off watch, which through two iterations creates a fixed 24 h watch day. Both the 5/15 and the 3/9 schedules are four-section watch schedules, meaning that four different crews alternate to fill the watches of the day.

Using a laboratory simulation of a typical Navy environment, we investigated the effects of circadian misalignment and restricted sleep opportunity on amounts of sleep obtained and levels of fatigue experienced in Navy watch schedules. Controlled laboratory conditions allowed for precise measurements by standardizing or eliminating potential confounds in the measurement of sleep and performance, such as weather conditions, variable workload, and hostile encounters. We compared sleep duration, psychomotor vigilance and subjective sleepiness in individuals working simulated watch sections of the 5/15 and 3/9 schedules, keeping total watch duration and total sleep opportunity equal across schedules.

2. Methods

2.1. Subjects

Fifteen healthy male volunteers (ages 18–29 y) completed a six-day, five-night laboratory study. Subjects were physically and psychologically healthy as assessed by history, questionnaires, and physical examination. They were free of traces of drugs and alcohol as assessed by blood and urine chemistry and history. They reported to be good sleepers, habitually sleeping between 6 and 10 h daily with regular bedtimes and typical wake times between 06:00 and 09:00.

Subjects were instructed to maintain regular sleep-wake schedules during the seven days preceding the study. Compliance was verified with wrist actigraphy, sleep logs, and a time-stamped voice recorder on which subjects reported their bedtimes and rising times. During the seven days before the study, subjects were to avoid napping, caffeine or alcohol consumption, and drugs including tobacco. Compliance was verified with urine and breathalyzer tests.

The study was approved by the Institutional Review Board (IRB) of Washington State University. All subjects gave written, informed consent, and were financially compensated for their time.

2.2. Experimental design

The study took place in the controlled laboratory environment of the Sleep and Performance Research Center at Washington State University Spokane. Subjects were in the laboratory continuously for six days (five nights). The first day was an adaptation day, during which subjects practiced laboratory performance tests. The next four days involved simulated watchstanding schedules, described below. These days are referred to as *watch days 1–4* throughout the rest of this paper (see Fig. 1). The last day in the laboratory included an 11.5 h sleep opportunity for recovery before subjects went home.

Subjects were assigned to one of four watch sections, as shown in Fig. 1:

5/15-A: a 5/15 watch section, backward rotating, with 6.5 h sleep opportunities beginning at 00:30 on watch day 1, 22:30 on

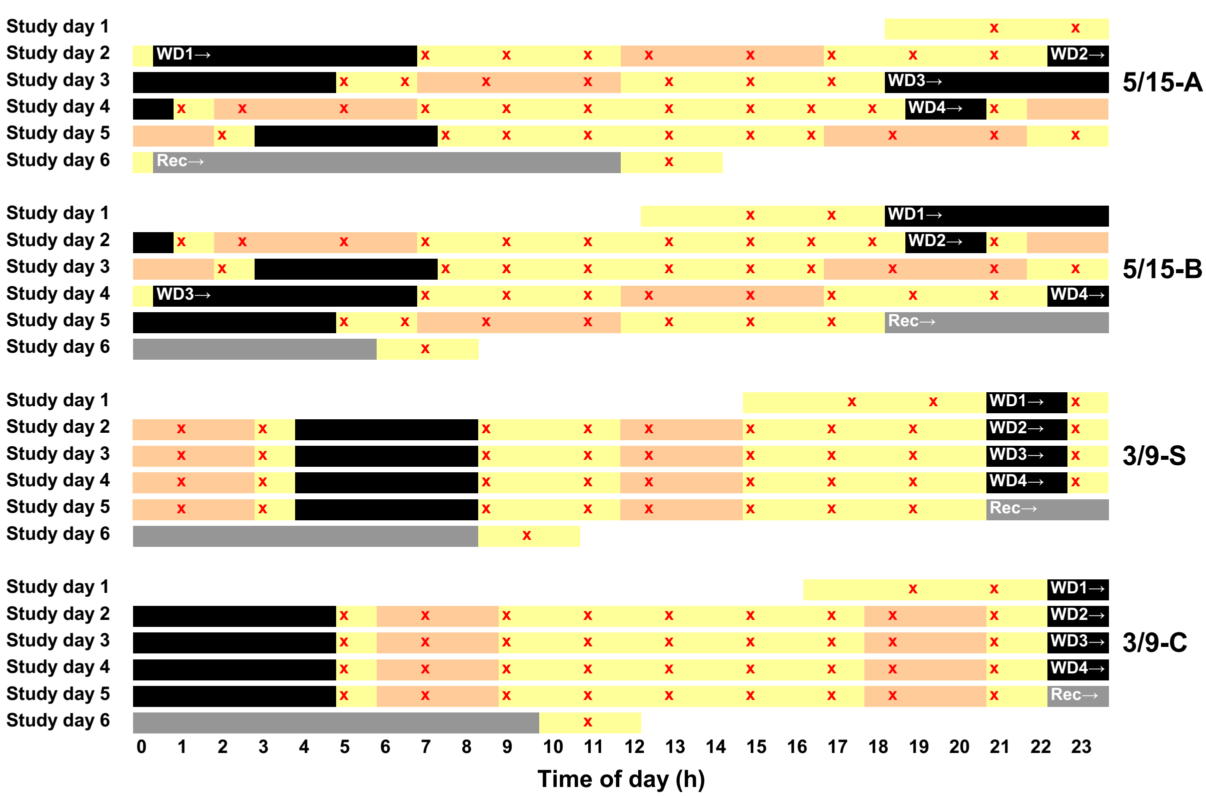

Fig. 1. Schematic of the study design showing each of the four watch sections simulated in the laboratory. Within each watch section, days progress from top to bottom and time of day progresses from left to right. All watch sections began with an adaptation day, included four watch days, and concluded with a recovery day. The beginning of each watch day is indicated with a white marker with an arrow; WD1→ indicates the beginning of watch day 1, etc. The beginning of the recovery day is indicated with Rec→. Black bars represent scheduled sleep opportunities (time in bed), and gray bars indicate scheduled recovery sleep. Orange bars represent scheduled watchstanding periods. Yellow bars represent all other periods of wakefulness. The red cross marks indicate the times when psychomotor vigilance and subjective sleepiness were measured (approximately every 2 h during scheduled wakefulness).