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The effects of different navy watchkeeping systems on crew performance, sleepiness, and fatigue – a review

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In most naval operations, round-the-clock watchkeeping is required to allow vessels to operate 24 hours a day. Watchkeeping can be carried out by a variety of different watchkeeping systems, some of which may exacerbate crew fatigue, particularly during prolonged operations. This review aims to analyse the impact of different watchkeeping systems on crew performance, sleepiness, and fatigue.

Introduction

Human factors in naval operations

A substantial proportion of maritime accidents can be attributed to human errors. According to analysis by Rothblum et al. (2002), approximately 80% of accidents and near-misses involve human error. Human factors that can contribute to errors and accidents include, for example, lack of technical knowledge, fatigue, poor judgment, and risk-taking.

Fatigue is recognised as a critical risk factor affecting the safety of naval operations. Various estimates suggest that fatigue is either the primary cause or a contributing factor in approximately a quarter of all maritime accidents (Raby & McCallum, 1997; MAIB, 2004). A study investigating the factors associated with 93 marine accidents found that a fatigued crew increases the risk of an accident by 23 per cent compared to a well-rested crew (Akthar & Utne, 2014). Furthermore, fatigue has routinely been cited as the "number one" concern among seafarers regarding their safety (Rothblum et al., 2002).

Factors contributing to fatigue

Naval operations present numerous challenges to crew performance. Crew members are often required to work extended hours and may not obtain sufficient rest. Even when an adequate amount of rest can be provided, sleep may be fragmented or occur predominantly during daylight hours, thereby diminishing the restorative benefits of sleep. In addition, work tasks are often monotonous and require sustained attention, which has been shown to reduce alertness and performance, especially in already fatigued individuals (Williamson et al., 2011). The challenging living conditions aboard naval vessels, characterised by constant motion and background noise within accommodation areas, can further contribute to additional stress for the crew (Repo, 2004).

Chronic partial sleep restriction

Chronic restriction of sleep to less than 7–8 hours per night over extended periods leads to significant impairments in cognitive functioning for the majority of adults (see review: Banks & Dinges, 2007). In a study by Dinges et al. (1997), participants were restricted to approximately five hours of sleep per night for one week, resulting in increased subjective fatigue and decreased mood and vigilance. Recovery of cognitive functioning to baseline levels required two consecutive nights of eight hours of sleep. Subsequently, Van Dongen et al. (2003) directly compared the effects of acute and chronic sleep deprivation, finding that limiting sleep to six hours a night for 14 days impaired cognitive performance to a degree comparable to being awake for 48 hours.

Consequently, even when crew members receive a seemingly adequate amount of rest, their performance may be compromised if sleep consistently falls below optimal levels. Notably, in cases of chronic partial sleep restriction, subjective perceptions of sleepiness do not necessarily correlate with deficits in performance (Van Dongen et al., 2003; Banks et al., 2010). As a result, crews may not be able to accurately assess their functional capacity when experiencing sleep deprivation.

Polyphasic sleep

While total sleep duration is important, it is not the only factor affecting recovery. One considerable challenge in naval operations is the fragmentation of sleep. A study conducted by the Finnish Defence Research Agency (Simola, 2014) monitored the performance and fatigue of a ship's crew during a week-long exercise, revealing that the exercise was stressful and demanding, even though the total amount of sleep was sufficient. The restorative effect of rest was judged to be insufficient, as sleep was fragmented into several parts instead of one longer sleep period.

A review by Weaver et al. (2021) regarding the impact of polyphasic sleep patterns concluded that segmented sleep is detrimental to both health and performance compared to a long, consolidated sleep episode, particularly when total sleep time is reduced. One rationale for advocating longer sleep episodes relates to sleep stages and to the quality of sleep obtained. Brief sleep episodes may yield insufficient amounts of rapid eye movement (REM) sleep, which is crucial for cognitive and emotional restoration (Šušmáková, 2004; Mukai & Yamanaka, 2023).

The International Maritime Organization (IMO) mandates that crews on civilian vessels receive at least six hours of uninterrupted rest daily (IMO, 2017). However, military organisations are not bound by these regulations. While most armed forces implement their own internal regulations regarding crew management, flexibility and operational requirements often take precedence over crew welfare. As a result, military watchkeeping schedules may allow for shorter periods of uninterrupted rest.

Circadian influences

A further challenge associated with round-the-clock operations is the misalignment of watch times with the body's internal circadian rhythm. Shifts are frequently at night, when alertness is at its lowest. At the same time, rest periods may be scheduled in the daytime, making it more challenging to obtain sleep. Additionally, operational requirements necessitate maintaining low lighting levels at night to enhance the visual acuity of lookouts monitoring the dark sea, which can further increase sleepiness (Vinagre-Ríos et al., 2021).

Consequently, time of day has been linked to accident risk in several studies (Folkard, 1997; MAIB, 2004; Vinagre-Ríos et al., 2021). A comprehensive analysis of 1,163 maritime accidents (Vinagre-Ríos et al., 2021) indicated that the risk of accidents is significantly elevated during night shifts, peaking between 0000–0400 hours, with an increased risk also observed from 0400–0800 hours. Furthermore, accidents occurring during night shifts tend to be more severe than those during the day. This phenomenon may be partially explained by findings that demonstrate a more pronounced decline in alertness from the beginning to the end of night shifts compared to day shifts (Härmä et al., 2008; van Leeuwen et al., 2013; van Leeuwen et al., 2016; Horizon, 2012).

Methods

This review was conducted as a rapid review, in which information was gathered using the keywords "watch schedule," "watchkeeping," and "solo watchkeeping," along with the additional terms "navy," "marines," and "maritime." Data retrieval was conducted across multiple databases, including Scopus, EBSCO, PubMed, ScienceDirect, and ProQuest Military Collection, as well as from the reference lists of key articles identified in the search.

Watchkeeping systems

Watchkeeping can be carried out by a variety of different watchkeeping systems, which require a different number of watch sections and differ in terms of the length of watches and rest periods. They also differ in terms of whether they employ a fixed schedule or a rotating schedule, where the timing of shifts varies with each day. Table 1 provides an overview of the different watch-keeping systems in use and Tables 2 and 3 illustrate in more detail the daily schedules of two watch-keeping systems.

Watchkeeping system	Description
4:4	A watch system of working and resting in four-hour cycles. Used only within military organizations.
6:6	Six hours of watchkeeping is followed by six hours of rest
4:8	A three-section system where four hours of watchkeeping is followed by eight hours of rest.
5:10	Five hours of watchkeeping followed by ten hours of rest.
8:8	Eight hours of watchkeeping, eight hours of rest.
8:4:4:8	Eight and four-hour work and rest periods alternate.
7:5:5:7	Seven and five-hour work and rest periods alternate.

Table 1. Different watchkeeping systems.

Number of Watch Sections

The number of watchkeeping teams determines which watchkeeping systems vessels are able to implement. Most naval ships operate with either two or three watch sections. Watch standing systems with several watch sections are preferable to two-section systems due to a more favourable work-to-rest ratio. For instance, studies have consistently shown three-group systems to be preferable to two-group systems in terms of crew performance and fatigue.

A systematic review by Short et al. (2015) compared the three-section 4:8 system with the two-section 6:6 and 8:8 systems, finding that personnel in the 4:8 system obtain, on average, one hour more sleep and experience lower levels of fatigue than those in the 6:6 or 8:8 systems. A study by Paul & Love (2021) assessing six different watchkeeping schedules identified the three-section 8:16 and 4:8 schedules as most favourable in terms of fatigue and performance. Additionally, simulation studies have indicated that the 6:6 model is more fatiguing compared to the 4:8 system (Project Horizon, 2012; van Leeuwen et al., 2013).

However, the main drawback of three-section watchkeeping systems is their requirement for a larger crew. According to Akhtar & Utne (2014), a three-section 4:8 system should not be implemented if there are insufficient personnel available, as an undermanned system can lead to greater crew fatigue than a properly used two-section system.

		Group 1		Group 2	
Time		Day 1	Day 2	Day 1	Day 2
00-06	6 h	Work	Work	Rest	Rest
06-12	6 h	Rest	Rest	Work	Work
12-18	6 h	Work	Work	Rest	Rest
18-00	6 h	Rest	Rest	Work	Work

Table 2. A fixed two-section 6:6 watch-keeping system. (Paul & Love, 2021).

Time	02-07	07-12	12-17	17-22	22-02
Day 1	Group 1	Group 2	Group 3	Group 1	Group 2
Day 2	Group 3	Group 1	Group 2	Group 3	Group 1
Day 3	Group 2	Group 3	Group 1	Group 2	Group 3

Table 3. A rotating three-section 5:10 watch system. (Shattuck & Matsangas, 2015).

Daily Rotation of Shifts

Empirical evidence suggests that fixed schedules are preferable compared to rotating schedules in terms of crew fatigue and performance. Arulanandam & Tsing (2009) found that crews on a fixed schedule reported more sleep and less fatigue than in a rotating system, with the night shift being less exhausting. Myllylä et al. (2022) compared a rotating 4:4 schedule with a fixed 4:4/6:6 system, concluding that the fixed schedule resulted in less fatigue, sleepiness, and psychological stress among crew members. Paul & Love (2021) also found that rotating systems negatively impacted crew performance.

Brown et al. (2015) compared the traditional three-section rotating 5:10 system of the U.S. Navy with a fixed four-section 3:9 system. Although both groups obtained an equal amount of sleep, the 3:9 system was associated with better sleep quality, reduced daytime sleepiness, better mood, and better vigilance.

Timing of rest and length of uninterrupted rest

The length of continuous rest and the timing of rest significantly impact crew functioning. A review by Short et al. (2015) indicates that shift systems with a smaller portion of the shift in the circadian nadir are beneficial in terms of performance and sleepiness. Guzetti et al. (2024) employed an experimental design to compare the effects of sleep timing on cognitive functions—such as working memory, learning, visual search, and visuomotor tasks—across four different watch systems, all allowing for equal rest time:

a) 8:8:4:4 (sleep 0930–1600)
b) 6:6 (sleep 0830–1230 and 2130–0000)
c) 4:8 (sleep 1800–0030)
d) 4:8 (sleep 0130–0800)

The best performance in cognitive tasks was observed in group D, which had uninterrupted rest entirely at night. Conversely, group B showed the poorest performance, as sleep was divided into two segments, with the second period occurring during the day. Group D also had the most sleep (383 min, the average for the other groups 350 min) and the highest sleep efficiency.

Paul & Love (2021) compared six different watchkeeping systems:

a) a two-section 6:6 system
b) a rotating three section system (3h shifts at night, 4h shifts during the day)
c) a two-section 7:5:5:7
d) a two-section 8:4:4:8
e) a three-section 4:8
f) a three-section 8:16

In both the 6:6 and 7:5:5:7 systems, the watch change took place at 0000 hours, while in the d, e and f systems the change took place at 0400 hours, enabling the night shift to be distributed between two teams. Paul & Love found the three-section 8:16 system to be the most effective for managing fatigue, with the 4:8 system also maintaining a relatively high level of performance. Among the two-section systems, 8:4:4:8 was found to be the preferred system, with the rotating three-section system and the 6:6 system being the most detrimental to performance. In other words, the three best systems all incorporated a fixed schedule, prolonged periods of uninterrupted rest, and shared night shift responsibilities among multiple groups.

Studies have consistently shown that watch schedules allowing for longer uninterrupted rest periods are preferable, even if this results in longer watch durations. For instance, Van Leeuwen et al. (2016) found that the 8:8 system led to less sleepiness, improved sleep quality, and greater total sleep compared to the 6:6 system. Kongsvik et al. (2011) compared a 6:6 system with an 8:4:4:8 system, concluding that the latter resulted in more sleep and greater efficiency of rest time. Röttger et al. (2023) compared the 6:6 and 7:5:5:7 systems over a week, finding that psychomotor vigilance declined in the 6:6 system, but remained stable in the 7:5:5:7 system. Additionally, the 6:6 system was associated with a higher proportion of crew members reporting significant fatigue or sleepiness. Notably, differences between the watch systems began to emerge after the sixth day. The results were likely also influenced by the timing of shift changes: the 7:5:5:7 system had its night shift change at 03:00, while the 6:6 system changed at 0000, allowing for a more equitable distribution of night shift responsibilities.

Discussion

In conclusion, watchkeeping systems can have a considerable effect on crew performance and fatigue. According to current literature, the most favourable watchkeeping systems are those that incorporate more than two watch sections, enabling crew members to spend fewer than 12 hours on watch each day. Additional factors that enhance recovery and performance include the implementation of a fixed daily schedule, the provision of an adequately long, uninterrupted rest period, and ensuring that at least a portion of this rest occurs during night-time.

While the current review suggests that three-section systems should be preferred over two-section systems, practical challenges—such as space limitations on vessels, manning shortages, and cost considerations—often prevent their implementation. Thus, regarding crew fatigue and performance, the choice of watchkeeping system is likely particularly critical for vessels operating with a two-section watch system. By implementing a fixed schedule and ensuring a long, uninterrupted rest period, many of the risks associated with two-section systems can be mitigated.

Although extended, uninterrupted rest periods are generally beneficial for crew performance, some operational conditions may require adjustments. In certain contexts, such as operating in the Finnish archipelago, it has been suggested that watchkeeping durations exceeding six hours may be inadvisable (Myllylä et al., 2022). In the case of two-section systems, this would imply that the duration of uninterrupted rest would be limited to only six hours. However, this six-hour rest period is likely unsustainable over prolonged operations, as it may not provide adequate recovery for the crew.

It is important to recognise that during naval exercises watchkeeping constitutes only a portion of the crew's responsibilities. Crew members are also engaged in other tasks, such as ship maintenance and training. Consequently, off-watch periods cannot be fully allocated to sleep. As a result, the overall working hours of the crew can be extensive, highlighting the critical importance of ensuring sufficient recovery time when crew members are not on watch. Without sufficient recovery time, even a well-designed watchkeeping system may fail to mitigate fatigue.

For Further Information

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