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Investigating daily fatigue scores during two-week offshore day shifts

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1. Introduction

Fatigue has been identified to be among the most important health and safety risk factors in the offshore oil and gas industry (Parkes, 2015; Ross, 2009). Some of the major offshore and industry disasters have been linked to human error, and more specifically fatigue (U.S. Chemical Safety and Hazard Investigation Board, 2007; U.S. Chemical Safety and Hazard Investigation Board, 2016). In industrial settings the terms fatigue and sleepiness are often used interchangeably although conceptual differences exist. Fatigue has been associated with impaired task performance resulting from physical or psychological strain, whereas sleepiness has been associated with the neurobiological need to sleep, resulting from physiological wake and sleep drives (Sadeghniiat-Haghighi and Yazdi, 2015). Although the causes of fatigue and sleepiness may vary, the consequences are similar. Both fatigue and sleepiness may cause mental and physical performance impairments, which can increase the likelihood of health and safety incidents. In this article, we will use the term 'fatigue' to refer to both fatigue and sleepiness constructs.

The offshore work conditions (e.g. remote shift work, limited light exposure, long periods of consecutive work days and 12-h shifts) are likely to predispose offshore workers to higher degrees of fatigue and fatigue-related work injuries and accidents. Previous research showed that shift work, long daily work hours and working more than 50 h per week increases the risk of work injuries related to poor sleep quality (Arlinghaus et al., 2012; Folkard and Tucker, 2003; Uehli et al., 2014). In the offshore environment, poor sleep quality (Menezes et al., 2004; Parkes, 1994, 2016), short sleep periods (Menezes et al., 2004; Parkes, 2002, 2016), and high fatigue scores (Parkes, 1993; Riethmeister et al., 2016) have been identified.

Although a few studies on fatigue have been conducted in the offshore industry, not much is known on daily fatigue scores during offshore shifts. The majority of existing offshore studies has focused on the effect of shift work (night and swing shifts) on fatigue, circadian rhythm adjustments as well as health and safety outcomes (Barnes et al., 1998; Bjorvatn et al., 2006; Harris et al., 2010). Yet, only a few studies have also identified fatigue and sleep problems in offshore day shift workers (Menezes et al., 2004; Parkes, 2016). Ignoring offshore day shift workers from occupational health and safety studies is of concern, as offshore day shift workers represent the largest workforce in the oil and gas industry. In addition, most existing offshore fatigue and sleep studies have not used longitudinal, repeated measures designs and have for the most part been conducted using small sample sizes (Harris et al., 2010; Waage et al., 2012) employing primarily self-reported measures (Harris et al., 2010; Parkes, 2002, 2016; Waage et al., 2012).

An important factor in preventing fatigue is a consolidated period of sleep. A consolidated sleep phase is possible when people have the opportunity to sleep long enough at the optimal circadian phase (Dijk and Czeisler, 1994). The high prevalence of fatigue offshore may be caused by a multitude of factors related to the nature of offshore work affecting sleep and circadian rhythms. For example, combinations of long offshore work periods, 12-h work days, early start times and offshore workers evening behaviours and routines, can change the phase angles between sleep and circadian rhythms, resulting in circadian rhythm phase shifts even in day shift workers. These circadian rhythm phase shifts may negatively impact offshore workers sleep timing, duration and quality as well as daily recovery processes and fatigue in return.

A more thorough investigation of daily fatigue scores over two-week offshore day shifts is needed to better understand the course of fatigue over time spent offshore and the possible association with circadian rhythm markers. Moreover, detailed knowledge on daily fatigue scores over offshore day shift periods will help to improve the existing fatigue risk prediction models. Thus, the aims of this study were to examine daily fatigue scores and changes in circadian rhythm markers over the course of two-week offshore day shift periods.

2. Materials and method

2.1. Study population & design

A longitudinal observational study was conducted in N = 60

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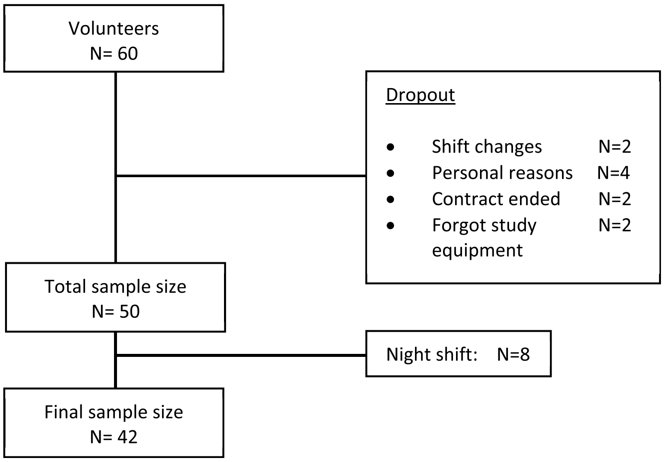

Fig. 1. Flowchart of study sample.

offshore day shift workers on four offshore platforms located in the Dutch Continental Shelf. This study is part of a larger investigation on sleep and fatigue parameters across full offshore day shift rotations, including both work and leave periods. The present study concerns the two-week offshore work period. The offshore work schedule consisted of two weeks of 12-h workdays. The day shifts lasted from 07:00–19:00 o'clock. During the study period, no overtime was officially requested nor recorded. Break times can vary between platforms. In this study, no data on break times was assessed. All offshore workers, contractors and permanent staff, working 14-day rotations on one of the four selected platforms, between February to June 2015, were invited to participate in the study. Offshore workers were excluded from the study if they performed any night shifts during the study period (Fig. 1). Study participation was voluntarily. Informed consent was obtained from all participants. Ethical approval for the study was granted from the Medical Ethics Committee of the University Medical Center Groningen, The Netherlands (reference number: M14.165646).

2.2. Procedure

The study was conducted between February and June 2015. Due to operational and logistic constraints, it was not possible for the investigators to be present on the offshore platforms for the conduction of the study. On each platform, a study supervisor was allocated to implement the study protocol. The implementation was mainly executed by the offshore medic or first aider. In addition, elaborate briefing sessions with the offshore platforms and the participating offshore workers were held to ensure correct conduction of the study tasks. Also, individualized study material (i.e. actigraphs) and procedures were sent to the offshore workers including detailed daily study timelines. One week before the start of the offshore shift period, all participating offshore workers received an electronic link, via e-mail, for a baseline questionnaire on demographic, work and health variables. In addition, offshore workers started to wear an actigraph (MotionWatch8®, Camntech) one week before the offshore work period commenced until one week after the offshore work period ended. This study concerns only the offshore work period.

Twice a day electronic questionnaires were used for the assessment of fatigue. Every morning before shift start and every evening post-shift, offshore workers received a personal electronic link, via e-mail, to the fatigue questionnaire. An online questionnaire portal was used to access, monitor and store fatigue recordings. Psychomotor vigilance task (PVT-B) testing took place in the accommodation block of the offshore platforms. Offshore workers were instructed to find a quiet room to complete the task. The online portal of the PVT-B app provider (Pulsar Informatics; Joggle Research®) was used to access, monitor and store PVT-B recordings in real-time. On days with saliva sampling, daily reminders were sent to the offshore platforms and offshore workers. Offshore workers were instructed to collect hourly saliva samples from 19:00 h until bedtime. Exposure to light, consumption of food and beverages other than water were forbidden during this period. All salivary samples were stored in the offshore freezers (−20 °C) until study sampling was completed. Upon study completion, all samples were sent to the laboratory of the University Medical Center Groningen, Groningen, The Netherlands for analyses.

2.3. Measurements

2.3.1. Fatigue

Reaction times and accurateness on simple reaction time tasks, objective proxies for fatigue, were measured before and after each shift with the 3-min IPad app version of the psychomotor vigilance tsk (PVT-B) (Pulsar Informatics; Joggle Research®) (Basner et al., 2011; Grant et al., 2016). Each platform was equipped with a maximum of four Ipads which were shared among offshore workers and were stored in the common room areas of the living quarters. The PVT-B has been successfully implemented in workplace settings to measure subcomponents of fatigue such as: alertness, sleepiness, and neurobehavioral performance (Basner et al., 2011; Lamond et al., 2005; Shattuck and Matsangas, 2015). Due to operational constraints, no PVT-B tests could be conducted on the offshore arrival day (day 1). The following PVT-B metrics were investigated: mean valid reaction times in milliseconds (reaction times > 100 ms), number of false starts (responses without a stimulus or reaction times < 100 ms), errors (pressing the wrong button or failing to release the button for 3s or longer), and lapses (reaction times ≥355 ms). The lapse threshold was adopted from suggested PVT-B scoring algorithms for 3-min versions (Basner et al., 2011).

Self-reported sleepiness, from now on referred to as subjective fatigue, was assessed pre- and post-shift (07:00 & 19:00 h) using the Karolinska Sleepiness Scale (KSS) (Akerstedt and Gillberg, 1990). The KSS consists of a nine-point Likert scale, rating sleepiness with (1) extremely alert, (2) very alert, (3) alert, (4) rather alert, (5) neither alert or sleepy, (6) some signs of sleepiness, (7) sleepy, but no effort to keep awake, (8) sleepy, some effort to keep awake (9) very sleepy, great effort to keep awake, fighting sleep (Akerstedt et al., 2014; Kaida et al., 2006). Higher KSS scores indicate higher subjective fatigue.

2.3.2. Circadian rhythm markers

Circadian rhythm markers were calculated based on salivary cortisol and melatonin levels in the evening. Saliva was collected using Salivettes® cotton rolls (Sarstedt) on three offshore days (day 2, 7 and 13) following the methodology of Harris and colleagues (Harris et al., 2010). Both, the pattern of evening cortisol concentration on the three investigated offshore days and the average cortisol concentration in the evening were used as a measure of circadian rhythmicity over the course of the two-week offshore day shifts. Dim light melatonin onset (DLMO) times were measured as phase markers of endogenous time. Cortisol and melatonin rhythms have been shown to be reliable circadian markers (Groeschl, 2008; Voultsios et al., 1997) and have been used in industrial settings to measure circadian disruption as a result of shift schedules and occupational exposures (Ferguson et al., 2012; Harris et al., 2010).

Saliva samples were analysed using liquid chromatography in combination with isotope dilution mass spectrometry, as described elsewhere (Booij et al., 2015; Bouwmans et al., 2015). The functional sensitivity was 200 pmol/L for cortisol and 3.0 pmol/L for melatonin. Salivary melatonin scores were used to obtain DLMO times. DLMO was defined as the moment at which the melatonin rhythm crossed the 11.01 pmol/L concentration by linearly interpolating the raw values around the 11.01 pmol/L concentration at the rising part of the curve, or that was within the first hour of extrapolation (Benloucif et al.,