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Prioritization of the causal factors of fatigue in seafarers and measurement of fatigue with the application of the Lactate Test

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ABSTRACT

Despite the developed technology and numerous rules introduced for the purpose of reducing the effects of human error on marine accidents, human error remains as the greatest cause of the accidents. A great majority of the accidents occur due to human error caused by fatigue. Human fatigue is difficult to measure and even more difficult to state as a cause to an accident. Therefore, conducting studies on the causes of fatigue and fatigue levels of seafarers is important in terms of emphasizing on the effect of fatigue in marine accidents.

In our study, the factors that cause fatigue on seafarers were examined analytically and their quantitative priorities were determined through the use of the Analytic Hierarchy Process (AHP) method. In addition, Lactate Test as an objective method to measure fatigue was used to indicate the fatigue levels of seafarers. Lactate data, commonly accepted as the most significant indicator of physiological parameters, were collected from seafarers at different times and in actual marine conditions. Obtained data were analyzed in SPSS software and Exploratory Data Analysis (EDA) was applied. Examining AHP results shows that sleep has a substantial role on the occurrence of fatigue in seafarers. According to the results of Lactate Test, it was determined that seafarers are generally highly fatigued and the fatigue levels increase particularly during port calls. In conclusion, the purpose of this study is to determine the fatigue levels of seafarers and to set forth the quantitative prioritization of the factors causing fatigue.

1. Introduction

Several publications (Bal and Arslan, 2011; Barnett, 2005; Chauvin, 2011; Chauvin et al., 2013; Darbra and Casal, 2004; Hetherington et al., 2006; Schröder-Hinrichs et al., 2011; Nielsen and Panayides, 2005; Piniella, 2007; Schröder-Hinrichs, 2010) have drawn attention to the role and importance of human factor and organizational factors in maritime safety. In comparison with other modes of transportation, International Maritime Organization (IMO) focused on the human factors rather late. Particularly in aviation, data on human factors are being systematically collected ever since the 1970s.

Yet, until the capsizing of the Herald of Free Enterprise in 1987 with the loss of 193 lives (Department of Transport, 1987) the maritime industry had not paid due attention to human and organizational factors in marine accidents. The following to this catastrophe led to the adoption of the International Safety Management (ISM) Code (IMO, 1993). The ISM code was added in 1994 as chapter IX of International Convention for the Safety of Life at Sea (SOLAS), "Management of the Safe Operation of Ships". The scope of the ISM code focuses on to establish a safety culture for the maritime industry and thereby to reduce the accidents caused by human error.

Maritime industry has a history of accidents. International Maritime Organization (IMO) recognizes human error as one of the primary causes of marine accidents (IMO, 1999). Although modern ships are equipped with high end navigation technologies, data collected from International Union of Marine Insurance (IUMI) indicate that the number of marine accidents is in the rise and they are mostly caused by the people on board (Nilsson et al., 2009).

Fatigue is considered to be an important cause of human error fatigue (Akhtar and Utne, 2014; Dorrian et al., 2011; Gould and Koefoed, 2007; Lützhöft et al., 2007; Xhelilaj and Lapa, 2010). Although it is not proved yet, studies indicate a strong relation between fatigue and risk of accidents (Jensen et al., 2004; Rothblum et al., 2002; Xhelilaj and Lapa, 2010). The lowering of the alertness level caused by fatigue increases the risk of accidents (HSE, 2006; Smith, 2001). Fatigue due to inadequate sleep is often used to explain the relationship between extended work shifts and work stress as well as impaired alertness, reduced safety and diminished health and well-being (Härmä, 2006).

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The term of fatigue is used in several different meanings and it has no single accepted definition (Desmond and Hancock, 2001; Noy et al., 2011; Williamson et al., 2011). Williamson et al. (2011) defined fatigue as 'a biological drive for recuperative rest'. According to IMO's conceptualisation of fatigue as 'a reduction in physical and/or mental capacity as the result of physical, mental, or emotional exertion which may impair nearly all physical abilities including: strength, speed, reaction time, coordination, decision making or balance' (IMO, 2001).

The maritime industry is subjected to a number of international regulations and initiatives aims to mitigate the risk of fatigue through limiting the hours of work and rest of seafarer. IMO has adopted a number of resolutions related fatigue factors and guideline on fatigue mitigation and management since the early 1990s. The International Labour Organization (ILO) Convention concerning 'Seafarers' Hours of Work and the Manning of Ships' entered into force in 2002.

Fatigue is a complex phenomenon (Akhtar and Utne, 2014; Allen et al., 2008; IMO, 2001) and examining solely individual causes or series of factors would not provide a holistic picture (Smith et al., 2006). Therefore, while examining marine accidents also the interactions between several factors need to be taken into consideration (Zhao et al., 2011). It is difficult to measure human fatigue and it is even more difficult to set forth fatigue as the definite cause of a given accident. Due to this reason, accident investigation reports are usually reluctant in assigning significant importance to human fatigue (Akhtar and Utne, 2014).

For the above reasons, it is important to address causes of fatigue and devise methods to detect and quantify the fatigue of seafarers. The factors that cause fatigue in seafarers were categorized in psychological and physical terms, and the strengths and weaknesses with opportunities and threats of fatigue on seafarers were examined with the use of SWOT analysis (Bal and Arslan, 2011). This study aims to identify the factors causing fatigue analytically and determine their quantitative priorities through the use of AHP method. In addition, Lactate Test as an objective measurement method of fatigue was used to determine the fatigue levels of seafarers. Lactate data, commonly accepted as the most significant indicator of physiological parameters, were collected from seafarers at different times and in actual marine conditions. Obtained data were analyzed in SPSS software and the effects of the difference in work load during sailing and port calls on seafarers' fatigue levels were performed through the use of EDA method.

2. Fatigue in seafarers

There are several fatigue risk factors peculiar to the marine environment such as the length of voyages, quality of sleep, environmental factors, working hours, nature of shift and frequency of calling ports/turnaround times. In order to understand fatigue at sea, negative risk factors should not be considered individually but all together (Smith et al., 2006). The factors causing fatigue are grouped under four main categories in our study. These are factors peculiar to seafarers, administrative factors, ship specific factors and environmental factors.

2.1. Factors peculiar to seafarers (F1)

2.1.1. Sleep condition (F1.1)

For a good performance seafarers need a deep and uninterrupted sleep during rest hours (IMO, 2001). Average sleep duration of healthy adults is generally accepted to be about 7 h (Ohayon et al., 2004). Short sleep duration/deprivation of sleep is common among shift workers or people working at nighttime and as a result it is likely that they are exposed to higher risk of increased fatigue then daytime workers or unemployed people (Ohayon and Roth, 2001, 2002). Researches show that sleeping less than 5 h within the 24 h before work, or less than 12 h within the 48 h before starting to work may cause risks of fatigue and impaired performance (Dawson and McCulloch, 2005). This is a common case among shift workers (Dorrian and Dawson, 2005; Dorrian et al., 2008; Mitler et al., 1997).

It is not always possible for seafarers to have uninterrupted and long sleep durations to support performance and remove fatigue. Due the fact that the navigation officer had only 5 or 6 h of sleep in the 24 before the infamous Exxon Valdez accident in 1989, it is considered that fatigue may have been a contributing factor to this environmentally catastrophic grounding (National Transportation Safety Board [NTSB], 1990). In 2006, a total of 88 vessels grounded in Norway, in 8 of which the navigation officers fell asleep on duty (Gould and Koefoed, 2007).

2.1.2. Biological clock (F1.2)

Irregular working hours and frequently working at nighttime that cause changes in the cycle of being asleep/awake affect both the alertness and ability to sleep (Caldwell et al., 2008). In consequence, the workers' circadian rhythm, one of the most important factors in fatigue, is impaired (Schutte, 2009). Increasing fatigue levels in turn pave the way for risks related with human error (Hobbs et al., 2011).

The probability of falling asleep and subjective ratings of sleepiness indicate a pronounced circadian rhythm with maximum values happening at about 06:00 under normal conditions during night sleep (Åkerstedt, 1995; Lavie, 1986; Zulley, 1990).

In marine working environment, jet lag caused by constant travelling or the deprivation of personal communication due to the impairment of synchronization (Comperatore and Krueger, 1990).

2.1.3. Stress (F1.3)

Occupational stress is the term used to define the stress originating from the working environment (Cartwright et al., 1996). Occupational stress differs from other kinds of stresses in life in certain aspects (Cartwright et al., 1996). For instance it is possible that poor job/position design, poor job support and heavy work load to contribute to occupational stress. Occupational stress usually results in physical exhaustion, emotional release, absenteeism, low productivity and low performance (Cushway et al., 1996).

It is known that cognitive skills such as situational awareness are susceptible against conditions related with the job, such as fatigue and stress (Endsley, 1999; Sexton et al., 2000; Tucker et al., 2010). Increase in stress level in individuals may cause reduced working memory capacity and decreased attention (Hancock and Szalma, 2008; Hockey, 1986). Due to its excessive load on individuals' cognitive resources, stress can result in weakness of concentration/attention and this in turn may cause a decrease in the field of attention of individuals (Sneddon et al., 2013).

Environmental effects (such as noise and vibration), weather conditions, personal problems, long working hours, interruption of recreational times are some of the factors that cause stress on seafarers.

2.1.4. Work load (F1.4)

Working in shifts disrupts the cycle of being asleep/awake cycle (Ferguson et al., 2008; Tepas and Mahan, 1989), causing to fatigue and decrease in performance (Åkerstedt, 1991; Folkard and Monk, 1979). Studies show that shift times is important in determining sleep duration. The duration of sleep may shorten after a night shift and workers may have difficulty in having adequate sleep before morning shift (Åkerstedt, 1995; Dorrian et al., 2008; Frese, 1984).