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# Integrating Monitoring and Stress Management for Multidimensional Ship Safety Regulation and Seafarers' Well-Being Improvement

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*ABSTRACT*

The article deals with the problems of monitoring stress level in merchant seafarers using modern methods based on cortisol level measurement. The authors analyze the relationship between increased stress level and safety of navigation, highlighting cortisol as an important biomarker of stress. Data from studies conducted aboard two ships where the increase in cortisol levels in captains and their mates over a six-week period of employment was analyzed are presented. The results showed a significant increase in cortisol levels, indicating high stresses on the crew and potential risks to the safety of shipping. The paper proposes technological solutions for stress monitoring based on wearable biosensor devices that can be integrated into the crew management system for timely adjustment of working conditions and risk reduction. Special attention is paid to the interdisciplinary approach to stress management including psychophysiological, environmental and social factors.

## 1. Introduction.

One of the key problems of modern human resource management in the maritime industry is monitoring stress in navigating officers. Seafarers, especially captains and their mates, often work under conditions of increased stress, which can negatively affect their performance and safety of navigation. Stress is an important factor that affects concentration, reaction speed and the ability to make good decisions in critical situations especially in maritime environments

One effective method of monitoring stress is to measure the level of cortisol, a hormone that is produced by the adrenal glands in response to stress. This article addresses the problem of using the analysis of cortisol levels as a tool for continuous stress monitoring in boaters. The monitoring of this biomarker may allow prompt adjustment of working conditions, minimizing stress and, consequently, reducing the likelihood of accidents on ships.

Monitoring stress levels in workers, especially seafarers, is becoming increasingly important to ensure safety on ships. One of the key biomarkers of stress is cortisol, which is widely used in current research. Iqbal et al (2023) emphasize the importance of using biosensors to monitor cortisol in real time. Their work is particularly valuable in that it looks at current technology that can be adapted for the maritime industry where seafarers work under constant stress.

In addition, Cleveland Clinic (2023) provides basic information on testing cortisol levels, which are already widely used in medical practice to detect stressful conditions. These methods can serve as the basis for the development of stress monitoring systems for mariners, as evidenced by Driver et al. (2022), who proposed innovative approaches to population-level gluco-

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corticoid monitoring. Although their methodology is based on wastewater analysis, the principles of mass monitoring can be adapted for collective monitoring systems on ships.

A study by Walvekar et al. (2015) found a strong correlation between cortisol levels and stress in police officers, which may be useful for parallels with maritime crews who are also under intense physical and emotional pressure. This is supported by the findings of Oldenburg et al. (2009) who studied stressors in crews of merchant and passenger ships. They found that isolation from family, long shifts and physical strain play a significant role in increasing the stress levels of seafarers.

Interesting findings are also made by Fort et al (2009) who studied the relationship between stress and substance use among French seafarers. This study emphasizes the need to monitor the psychophysiological state of crews to prevent negative consequences. Similar attention to psychophysiological aspects is also given by Jeżewska et al (2006), which examined subjective self-assessment of stress levels among naval officers and cadets.

At the same time, Ok et al. (2023) proposed technologies of wearable and implantable devices for cortisol monitoring that offer new possibilities for marine applications. Technologies of this nature can provide continuous real-time monitoring of crew stress levels.

Comparing these studies with the work of Yuen et al. (2018), high stress levels and dissatisfaction with working conditions directly reduce seafarers' performance. This is supported by studies by Baygi et al. (2022) who investigated the impact of stress on seafarers' mental health and life satisfaction. The studies emphasize the need for systematic monitoring of stress and development of recommendations to improve working conditions on ships.

In their study, Russo et al (2020) examined the stress reactions of seafarers under extreme conditions. They suggested strategies to reduce stress, including changes in work organization and provision of psychological support. These findings may be useful for developing effective stress management techniques on ships. Melnyk et al (2022) examined the role of maritime situational awareness as a key factor in ensuring safe navigation. Their findings echo the research of Kusov et al. (2023) who proposed biosensor devices for clinically relevant cortisol monitoring, emphasizing the need for similar technologies in the maritime industry to reduce stress and improve safety.

The work of Farisyi et al. (2024) also adds to this theme by analyzing the impact of stress on productivity and safety in the Indonesian shipping industry. They emphasize the need for stress monitoring systems to improve management decisions in the maritime industry. The study by Wahyuni et al (2022) showed that the implementation of minimum service standards affects the operational performance of ships and stressors can reduce the quality of seafarers' performance. Their findings are important for creating more balanced work schedules and maintaining high levels of crew satisfaction. Thus, the work of Nikitakos et al. (2019) and Ertürk et al. (2021) adds to the research by suggesting systematic approaches to managing conflict and improving working conditions on ships. This indicates the importance of stress control in preventing conflicts and improving overall performance on board. In articles Melnyk et al., 2023 presented a method for assessing the quality of risk management on board ships using expert judgment to improve the safety of operations and discussed how to identify inconsistencies in a company's safety management system and their impact on error reduction. Sharma (2024) explores the integration of human, technological and innovative factors in safety management, especially considering advanced technologies such as autonomous ships (MASS). Ricciardelli (2024) presents an ethnographic study of the training of seafarers as first responders, emphasizing their safety and survival training for emergency preparedness.

In summary, most studies emphasize the importance of using technology to monitor stress among seafarers, which can contribute to improving maritime safety and working conditions. In particular, biosensor devices for cortisol measurement can play a key role in improving the operational management of the psychophysiological state of the crew.

The main objective of this study is to develop an effective approach to stress monitoring in seafarers using cortisol measurement techniques. To achieve this goal, the paper will review existing stress monitoring methods and their applicability in the maritime industry, analyze current biosensor technologies and their potential for use on ships, examine the relationship between working conditions, stress levels and shipping safety and finally develop recommendations for the implementation of stress monitoring systems to reduce accidents and improve crew performance. This will provide a deeper understanding of the impact of stress on maritime operations and provide specific solutions to improve safety and productivity in the industry.

## 2. Materials and Methods.

The analysis of ship accidents over the past ten years has shown a decrease in ship losses. However, in recent years, this figure has stagnated at around 55 vessels per year and we do not see a downward trend in this number. This indicates that the combined efforts of IMO, flag states, classification societies, shipowners and port authorities have had some effect in reducing the number of shipwrecks. The fluctuations in the number of cases around 55 per year indicate that there are some reasons that prevent further reduction of this number. Among these reasons, the main one, according to the authors, is the human factor, in particular the stress factor.

Stress is an important element that affects the ability of seafarers to make the right decisions in critical situations. One of the most important issues regarding stress is to determine the actual level of stress in a person. At the moment, there is no 100% reliable tool for determining the level of stress, and in many cases written tests or analysis of behavioral factors (movement, speech, eye expression, etc.) are used, which do not always give accurate results.

The relationship between stress levels and the amount of cortisol in a person has long been known among healthcare professionals. Cortisol is a hormone produced in the adrenal glands that plays a key role in protecting the body from stress. It regulates blood pressure and participates in the metabolism of proteins, fats, and carbohydrates. Therefore, monitoring cortisol levels allows you to determine the degree of stress and take timely measures to reduce it.

However, there are a number of other factors, such as health, age, and food on board that can affect cortisol levels making it difficult to accurately assess stress. This creates a need to develop more reliable methods for stress monitoring based on biosensor technologies that will reduce risks and improve safety of navigation.

### *2.1. Review of Existing Stress Monitoring Methods.*

#### *2.1.1. Traditional Methods.*

Traditional stress monitoring methods include the use of psychological tests and questionnaires to identify workers' subjective feelings of stress. These methods are often used to self-assess and analyze an individual's behavior based on their responses to questions about their well-being, mood, and perceptions of work stress. For example, instruments such as Perceived Stress Scale (PSS) questionnaires or tests to identify psychophysiological symptoms of stress are used in a wide range of occupations, including the maritime industry. However, these methods have limitations because they are based on subjective data, which can lead to inaccuracies and overestimation or underestimation of actual stress levels.

More objective approaches include measuring physiological parameters such as heart rate (HR), blood pressure and heart rate variability. These metrics, while providing more accurate data, require specialized devices and are not always applicable for long-term monitoring, especially in long shipboard voyages.

#### *2.1.2. Biosensors for Cortisol Monitoring.*

One of the most promising methods of stress monitoring is the measurement of cortisol levels, a hormone produced by the adrenal glands in response to stressful situations. Cortisol is considered to be the most accurate biomarker of stress because its levels increase with physical or emotional stress. Cortisol levels are most commonly measured through urine or saliva analysis, which allows us to track the daily fluctuations of this hormone.

The current description of the method used in the marine industry involves collecting urine to measure cortisol. This method, while effective, requires laboratory conditions for analysis, making it difficult to use in real time. However, in recent years, biosensor technologies have been actively developed that allow in situ measurement of cortisol levels with minimal intervention. For example, studies by Iqbal et al. (2023) and Ok et al. (2023) show that wearable devices and implantable sensors can monitor cortisol levels continuously, providing real-time data. Such devices can be integrated into the ship management system to monitor crew condition and automatically adjust working conditions.

#### *2.1.3. Comparison of Industry Solutions.*

Other industries, such as aviation and medicine, are already actively using stress monitoring to ensure worker safety and improve productivity. In aviation, for example, systems are used to monitor pilots' physiological parameters in real time to prevent potential errors due to stress or fatigue. Such systems are based on data on HR, blood oxygen levels and brain activity. These technologies make it possible to respond quickly to changes in the health of pilots, which may be a useful example for the maritime industry, where working conditions also require constant attention to the psycho-physiological state of the crew.

In medicine, stress monitoring systems are used to track the condition of patients in critical situations. Technologies such as wearable devices for measuring cortisol levels have already been shown to be effective in clinical settings and their application could be extended to the maritime industry. Studies by Driver et al (2022) and Cleveland Clinic (2023) demonstrate that biosensor technologies and cortisol analysis techniques can be successfully applied to monitoring at both the individual worker and whole team level.

Thus, a comparison of industry solutions shows that the use of biosensors to monitor stress levels can significantly improve mariner safety and performance by providing more accurate data for management decisions.

### *2.2. Technological Solutions for Stress Monitoring in Ship Officers.*

#### *2.2.1. Modern Wearable Devices for Cortisol Monitoring.*

Modern advances in biosensor technology are opening up new possibilities for real-time monitoring of stress levels in ship officers. One of the most effective methods for assessing stress is to measure the level of cortisol, a hormone that is produced in response to stressful situations. Traditional methods of measuring cortisol include urine or blood tests, but these require a laboratory setting and cannot be used for continuous monitoring. However, new technologies address this shortcoming by introducing wearable devices to monitor cortisol levels.

Wearable biosensors are devices that attach to a person's body and measure cortisol concentrations through sweat or saliva. Studies such as Iqbal et al. (2023) have shown that these devices can monitor cortisol levels in real time, providing data on the psychophysiological state of an individual. This is particularly important in the maritime industry, where stress in seafarers can vary significantly depending on working conditions, weather factors and other external stressors.

Biosensors can integrate with the ship's onboard control systems, allowing captains and shipowners to obtain operational data on the condition of the crew. For example, if a ship's cortisol levels exceed an acceptable limit, the system can automatically adjust work schedules or suggest measures to reduce stress, such as increased breaks or task changes.

An important advantage of wearable devices is their ability to conduct continuous monitoring without the need for active user involvement. This allows the crew to focus on their professional duties while the system automatically monitors and analyzes stress data. Such devices are already being used in other industries such as medicine and sports to monitor the condition of athletes and patients. In this regard, studies by Ok et al (2023) emphasize that wearable and implantable cortisol monitoring devices could form the basis for a comprehensive stress management system on ships. This will not only reduce accident rates through timely detection of stress conditions, but also improve the overall performance of the crew by improving their working conditions and enhancing psychological resilience.

In addition, the integration of wearable devices with mobile applications or computer systems enables real-time data tracking at various levels. Shipowners and crew managers can analyze historical data, identify stress patterns, and develop strategies to manage stress, which not only contributes to safer shipping but also improves seafarers' working conditions.

Thus, the introduction of advanced wearable cortisol monitoring devices represents an important technological solution for stress management on board ships, helping to reduce risks and improve the safety of maritime operations.

The importance of monitoring cortisol levels is noted when discussing the need to replace ship officers when stress levels are high. For example, after analyzing cortisol levels over a period of time, conclusions are drawn about the need for replacement personnel to reduce stress and improve safety in shipping.

Monitoring cortisol levels can help in regulating working conditions and reducing the risk of accidents. It is noted that this has a direct impact on the safety of seafarers and shipping in general, as it helps to adjust work schedules in time, implement changes in work schedules depending on weather conditions and other factors.

## 3. Results and Discussion.

### *3.1. The Impact of Stress on the Safety of Shipping.*

The authors of this publication have been monitoring cortisol levels in dredging shuttle navigating officers in the waters of the port of Chornomorsk, Ukraine for several months. The choice of the object for observation was based on a clear understanding that it is the navigators of this group who receive a very high stress load due to the performance of a large number of independent moorings in different weather conditions per day. According to the working conditions, among the eight crew members of the shuttle, only the captain and his duty officer are exposed to constant high stress loads. Thus, during the observation period, up to 25 approaches and departures of the shuttle to the dredger were noted within a very limited approach area due to the presence of many anchor ropes on which the dredger is standing. This was performed at different times of the day, in different visibility conditions. Often, during maneuvering, the navigators had to compensate for the negative impact of wind and current, which caused additional stress on them. It is quite clear that working in such conditions caused a constant increase in stress. For example, among merchant marine captains, there are many who, during their tenure as a captain, have never made a single independent mooring without the assistance of a pilot and tugs.

The cortisol is also called the stress hormone in many scientific publications. When the human body senses a threat, whether physical or psychological, the brain sends a signal to the adrenal glands, which respond by producing cortisol.

This hormone plays a key role in improving attention, stimulating blood circulation, and promoting glucose synthesis. These processes contribute to the release of additional energy so that the body can cope with stress more effectively. This approach to determining stress load was used in the study. With the support of the management of one of the shipowning companies, the authors took the following measures to obtain the most accurate observation results:

- before starting work under the contract, all seafarers had their daily cortisol levels analyzed. Among the available methods of performing the analysis, the authors chose to determine the level of cortisol through urine analysis. The authors were guided in their choice of research method by the fact that, firstly, about 10% of free cortisol is found in urine, and secondly, that this analysis is quite simple and does not require the presence of a medical professional;
- after making sure that the initial level of cortisol was not affected by any disease or problem, further monitoring of the level of stress was performed from the initial value;
- additionally, according to the agreement, the first shuttle's crew committed to following author's recommendations on the quality of food and beverages, while the second shuttle had no such restrictions;
- the samples were collected weekly in the morning, afternoon and evening. Laboratory results on the average amount of cortisol of each of the navigators were obtained in a few days.

A few explanations are necessary to understand the progress of this observation. We noticed that cortisol levels are not constant for different age groups of workers at different times of the day. For example, for men of the older age group (over 51 years), morning values will be in the range of 1.49-7.39 ng/ml, at noon - 0.95-6.8 ng/ml, in the evening - 0.22-2.54 ng/ml. For men aged 31 to 51 years, these figures will be as follows: in the morning - 0.94-15.1 ng/ml, at noon - 0.4-6.4 ng/ml, and in the evening - < 1.81 ng/ml. Also, the average daily cortisol level in these age groups will be different: for the older age group - 0.51-4.2 ng/ml, and for the middle age group - 0.18-4.3 ng/ml. Table 1 shows the results of the initial average cortisol analysis per day for the shalanders.

Table 1: Cortisol levels of ship officers before starting Work.

| | Suttle "A" | | Shuttle"B" | |
|---|---|---|---|---|
| | Captain | Duty Officer | Captain | Duty Oficer |
| Units of measurement (ng/ml) | 2.7 | 1.4 | 2.3 | 1.8 |

Source: Authors.

For example, both ship captains were practically the same age - about 60 years old, and their mates were in the age group of 31 to 51 years old. All crew members had no chronic diseases, medical problems, or unresolved family issues. Thus, no possible influences that could have distorted the results were anticipated before the study began. The navigators on the A shuttle were monitored for their meal with their consent. They followed a proper diet, refrained from drinking coffee, sweets, etc. that could affect cortisol levels. And for the navigators on the B shuttle, there were no restrictions on food or drink. At the end of the first week of work, the navigators took tests, the results of which are shown in Table 2.

Table 2: Cortisol levels of ship officers after the first week of work.

| | Shuttle "A" | | Shuttle "B" | |
|---|---|---|---|---|
| | Captain | Duty Officer | Captain | Duty Officer |
| Units of measurement (ng/ml) | 2.9 | 1.9 | 2.7 | 2.5 |

Source: Authors.

Analyzing the results, we noticed some nuances, namely:

- The increase in cortisol levels was more significant in duty officers. This is quite understandable, as the captains' work experience did not cause any personal concerns about ship safety. This fully confirms that a trained person is ready for any changes in the development of the situation during maneuvering, even negative ones, which does not cause a significant increase in stress. A lack of experience and training causes a significant increase in stress;
- The weather conditions during work were normal for winter time (wind condition - 3-4 points, sea condition - 2-3 points).

The results of the cortisol level tests for the second week of the seafarers' work are presented in Table 3.

Table 3: Cortisol levels of ship officers after the second week of work.

| | Shuttle "A" | | Shuttle "B" | |
|---|---|---|---|---|
| | Captain | Duty Officer | Captain | Duty Officer |
| Units of measurement (ng/ml) | 3.5 | 3.4 | 3.8 | 3.7 |

Source: Authors.

During this week, there was a deterioration in weather conditions (winds increased to 4-5 points and sea conditions to 3-4 points). Consequently, the level of cortisol in the newly qualified seafarers increased. Table 4 shows the results of cortisol levels in navigators for the third week of work.

Table 4: Cortisol levels of ship officers after the third week of work.

| | Shuttle "A" | | Shuttle "B" | |
|---|---|---|---|---|
| | Captain | Duty Officer | Captain | Duty Officer |
| Units of measurement (ng/ml) | 4.2 | 4.5 | 4.7 | 4.9 |

Source: Authors.

The weather conditions did not change during this week. Data for the fourth week of work of the shipowners are shown in Table 5.

Table 5: Cortisol levels of ship officers after the fourth week of work.

| | Shuttle "A" | | Shuttle "B" | |
|---|---|---|---|---|
| | Captain | Duty Officer | Captain | Duty Officer |
| Units of measurement (ng/ml) | 3.9 | 4.5 | 4.5 | 4.8 |

Source: Authors.

During this week, due to stormy weather conditions, the shuttles spent more time at the berths. There was no increase in cortisol levels, and in some vessels the level even decreased. This fact is very interesting. Firstly, it confirms the relationship between fatigue and stress, and secondly, it proves that it is possible to reduce stress by providing the necessary rest. The data for the fifth week of work are presented in Table 6.

Table 6: Cortisol levels of ship officers after the fifth week of work.

| | Shuttle "A" | | Shuttle "B" | |
|---|---|---|---|---|
| | Captain | Duty Officer | Captain | Duty Officer |
| Units of measurement (ng/ml) | 4.4 | 5.1 | 5.0 | 5.6 |

Source: Authors.

After obtaining the results of cortisol levels for the fifth week of work, the authors drew the shipowner's attention to the need to prepare a timely change of seafarers for rest due to the high level of stress. The possible consequences for the overall safety of navigation due to the high level of stress load were presented to the shipowner. At the end of the sixth week of work, the results of the cortisol level were presented in Table 7.

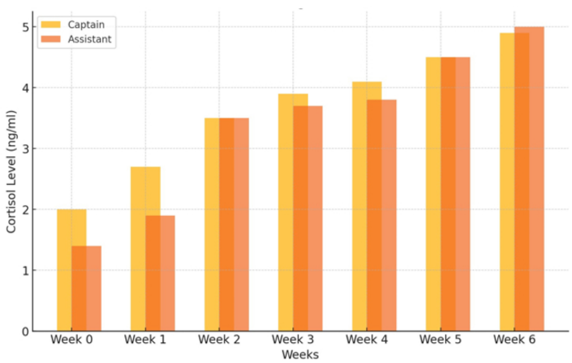
Table 7: Cortisol levels of ship officers after the sixth week of work.

| | Shuttle "A" | | Shuttle "B" | |
|---|---|---|---|---|
| | Captain | Duty Officer | Captain | Duty Officer |
| Units of measurement (ng/ml) | 4.8 | 5.9 | 6.6 | 6.9 |

Source: Authors.

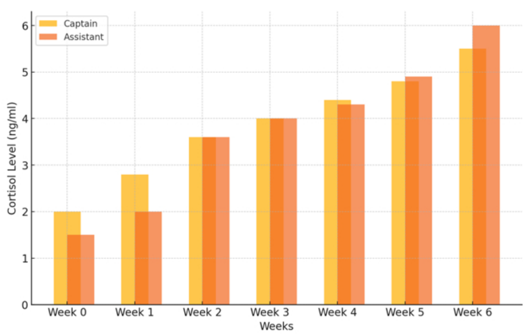
Based on these results, the authors persuaded the shipowner that continuing the navigators' work under such high levels of stress could pose significant safety risks. As a result, the shipowner agreed with the authors' assessment and proceeded to replace the navigators on the shuttle vessels. Furthermore, following the authors' recommendations, the contract duration was adjusted to 1.5 months during the winter season and 2 months during the summer. The cortisol level trends in shipmasters over the six-week period are illustrated in Figures 1 and 2.

Figure 1: Increase in cortisol levels in the navigators of the shuttle A [based on obtained results].




Source: Authors.

Figure 2: Increase in cortisol levels in the shuttle B crew [based on obtained results].




Source: Authors.

The study of cortisol levels in seafarers indicates the importance of taking into account the psychophysiological aspects of maritime labor. The monitoring of cortisol levels was accompanied by careful control over the psychophysiological state of the seafarers. The supervision was carried out by monitoring the behavior of navigators (body movements, eyes, communication), their blood pressure, pulse, etc. It was found that experience and working conditions have a significant impact on the stress level of seafarers. Particular attention should be paid to the safety and health of seafarers, taking into account not only the physical but also the mental aspects of their well-being. The study provides grounds for the introduction of systems for monitoring the psychophysiological state of seafarers, in particular, the use of modern technologies to control the level of cortisol and improve the organization of work in the marine environment.

### *3.2. Influence of Psychophysiological Factors on Stress Level.*

Psychophysiological factors play a key role in shaping the stress level of seafarers. One of the most significant factors is the mode of labor and rest. Work at sea is often accompanied by long shifts, lack of adequate sleep and physical activity, which in turn leads to increased stress levels. Studies show that lack of regular rest contributes to fatigue accumulation, decreased cognitive function and increased cortisol levels. Maintaining a balanced work and rest schedule is one of the most important factors in managing stress on board ship.

The meal on board also has a significant impact on stress levels. Poor or inadequate nutrition can lead to reduced physical and mental performance. Consumption of food poor in vitamins and micronutrients can negatively affect cognitive function and cause feelings of fatigue and anxiety, which in turn increases stress.

Physical activity, on the other hand, can help lower cortisol levels. Regular physical exercise can help improve mental well-being, promote the production of endorphins, and reduce stress levels. Shipowners can integrate physical activity programs into seafarers' daily schedules to improve their psychophysiological well-being.

### *3.3. Environmental and Social Aspects of Stress Management.*

In addition to psychophysiological factors, environmental and social conditions also influence seafarers' stress levels. Environmental conditions such as weather, climate change and noise pollution can significantly increase stress levels. For example, working in unfavorable weather conditions or in noisy ports leads to increased physical and mental stress in the crew. Environmental influences can have long-term effects on seafarers' well-being if measures are not taken to manage these factors.

The social aspects play an equally important role in stress management. Being away from family and friends for long periods of time creates a sense of isolation and loneliness, which increases stress. In addition, lack of social support on board can aggravate the psychological state of seafarers. Seafarers often find it difficult to adapt to shipboard life, leading to depression and other mental disorders.

To manage stress on board ship, it is important to create a favorable social environment: maintaining ties with family through regular communications, providing opportunities for socialization and psychological support on board. Shipowners can develop programs to improve social conditions to help seafarers better adapt to shipboard life and reduce stress levels.

## Conclusions.

Stress monitoring is a key element in ensuring safety of navigation. Analysis of cortisol level in navigating officers allows promptly assessing their psychophysiological state and taking preventive measures to reduce stress load. The results of studies conducted on board ships showed a significant increase in cortisol levels in captains and their mates during a six-week period. This indicates high stress loads, which can lead to decreased concentration and increased risks of accidents. The use of advanced biosensor technology to monitor cortisol levels allows for continuous real-time stress monitoring. Integration of wearable devices into the crew management system facilitates timely adjustment of work schedules and working conditions, which helps to reduce stress levels and improve navigation safety.

A multidisciplinary approach to stress management, incorporating psychophysiological, environmental and social factors, plays an important role in maintaining crew well-being. Incorporating these factors into the design of stress reduction programs can significantly improve performance and reduce accident risks. The introduction of stress monitoring technologies and their integration into shipboard management systems is a promising area for improving the safety and efficiency of maritime operations. Regular monitoring of the crew psychophysiological state allows improving working conditions and minimizing the impact of stress on the work of ship's crew.

**References.**


Iqbal, T., Elahi, A., Wijns, W., & Shahzad, A. (2023). Cortisol detection methods for stress monitoring in connected health. *Health Sciences Review*. https://doi.org/10.1016/j.hsr.2023.10-0079.

Cleveland Clinic. (2023). Cortisol test. Retrieved from https://my.clevelandclinic.org/health/diagnostics/22417-cortisol-test/.

Driver, E. M., Gushgari, A. J., Steele, J. C., Bowes, D. A., & Halden, R. (2022). Assessing population-level stress through glucocorticoid hormone monitoring in wastewater. *Science of The Total Environment*, 155961. https://doi.org/10.1016/j.scitotenv.2022.155961.

Walvekar, S. S., Ambekar, J. G., & Devaranavadagi, B. B. (2015). Study on serum cortisol and perceived stress scale in the police constables. *Journal of Clinical and Diagnostic Research*, 9(2), 10–14. https://doi.org/10.7860/JCDR/2015/1201-5.5576.

Iqbal, T., Elahi, A., Wijns, W., & Shahzad, A. (2023). Cortisol detection methods for stress monitoring in connected health. *Health Sciences Review*. https://doi.org/10.1016/j.hsr.2023.10-0079.

Ok, J., Park, S., Jung, Y. H., & Kim, T. I. (2023). Wearable and implantable cortisol-sensing electronics for stress monitoring. *Advanced Materials*. https://doi.org/10.1002/adma.20221-1595.

Kusov, P. A., Kotelevtsev, Y. V., & Drachev, V. P. (2023). Cortisol monitoring devices toward implementation for clinically relevant biosensing in vivo. *Molecules*, 28(52353). https:-//doi.org/10.3390/molecules28052353.

Melnyk, O., Bychkovsky, Y., & Voloshyn, A. (2022). Maritime situational awareness as a key measure for safe ship operation. *Scientific Journal of Silesian University of Technology. Series "Transport"*, 114, 8. https://doi.org/10.20858/sjsutst.20-22.114.8.

Kuznichenko, S. (2015). Technogenic terrorism in Ukraine: Genesis, typology, characteristics, offers to national concept of counter action. *Journal of Security and Sustainability Issues*, 5(1), 21–34. https://doi.org/10.9770/jssi.2015.5.1(2).

Zeitlin, L. (1995). Organizational downsizing and stress-related illness. *International Journal of Stress Management*, 2, 207–219. https://doi.org/10.1007/BF01681850.

Oldenburg, M., Jensen, H. J., Latza, U., & Baur, X. (2009). Seafaring stressors aboard merchant and passenger ships. *International Journal of Public Health*, 54, 96–105. https://doi.org/-10.1007/s00038-009-7067-z.

Jeżewska, M., Leszczyńska, I., & Jaremin, B. (2006). Work-related stress at sea self-estimation by maritime students and officers. *International Maritime Health*, 57, 66–75.

Fort, E., Massardier-Pilonchery, A., & Bergeret, A. (2009). Psychoactive substances consumption in French fishermen and merchant seamen. *International Archives of Occupational and Environmental Health*, 83, 497–509. https://doi.org/10.1007/s0-0420-009-0473-y.

Dodge, D., & Beck, B. (2016). Historical state of knowledge of the health risks of asbestos posed to seamen on merchant ships. *Inhalation Toxicology*, 28, 1–21. https://doi.org/10-.1080/08958378.2016.1244228.

Carter, T., & Roberts, S. (2017). Infectious disease mortality in British merchant seamen and Lascars since 1900: From causes to controls. *International Journal of Maritime History*, 29, 788–815. https://doi.org/10.1177/0843871417726746.

Lodde, B., Jegaden, D., Lucas, D., Feraud, M., Eusen, Y., & Dewitte, J. (2008). Stress in seamen and non-seamen employed by the same company. *International Maritime Health*, 59, 53–60.

Farisyi, S., Ricardianto, P., Purnaningratri, I., Setyawati, A., Negara, G., Weda, I., et al. (2024). Seafarer work stress and performance: Empirical evidence of shipping safety of Indonesia national shipping companies. *Uncertain Supply Chain Management*, 12, 1297–1306. https://doi.org/10.5267/j.uscm.2023-.11.007.

Wahyuni, T., Ricardianto, P., Harits, A., Thamrin, M., Liana, E., Anggara, D., et al. (2022). The implementation of minimum service standards on ship operational performance: Empirical evidence from Indonesia. *Uncertain Supply Chain Management*, 10, 1297–1304. https://doi.org/10.5267/j.uscm.2022.7.-010.

Yuen, K. F., Loh, H. S., Zhou, Q., & Wong, Y. (2018). Determinants of job satisfaction and performance of seafarers. *Transportation Research Part A: Policy and Practice*, 110, 1–12. https://doi.org/10.1016/j.tra.2018.02.006.

Nikitakos, N., Papachristos, D., & Dagkinis, I. (2019). The effects of the naval profession on the seafarers' mental health. In XXIII International Conference on "Material Handling, Constructions and Logistics" (pp. 1–5). Bar, Montenegro.

Ertürk, E., & Sağlam, B. (2021). Conflict-related incidents on board ships: An online news content analysis. *Transactions on Maritime Science*, 10. https://doi.org/10.7225/toms.v10.n0-1.018.

Baygi, F., Smith, A., Khonsari, N. M., Mohammadi-Nasrabadi, F., Mahmoodi, Z., Mahdavi, A., & Qorbani, M. (2022). Seafarers' mental health status and life satisfaction: Structural equation model. *Frontiers in Public Health*, 10, 969231. https:-//doi.org/10.3389/fpubh.2022.969231.

Fotteler, M., Bygvraa, D., & Jensen, O. (2020). The impact of the Maritime Labor Convention on seafarers' working and living conditions: An analysis of port state control statistics. *BMC Public Health*, 20. https://doi.org/10.1186/s12889-020-09682-6.

Ji, A., Liu, Y., Sun, Y., & Liu, C. (2020). Impact of work–family conflict, job stress and job satisfaction on seafarer performance. *International Journal of Environmental Research* *and Public Health*, 17, 2191. https://doi.org/10.3390/ijerph17-072191.

Oldenburg, M., & Jensen, H. J. (2019). Needs and possibilities for ship's crews at high seas to communicate with their home. *International Journal of Occupational Medicine and Environmental Health*, 32. https://doi.org/10.13075/ijomeh.1896-.01436.

Russo, A., Mandić, N., Sliskovic, M., & Mulic, R. (2020). Drop-out - Inadequate response of seafarers to stress. *Psychiatria Danubina*, 32, 53–57.

McVeigh, J., Maclachlan, M., Vallières, F., Hyland, P., Stilz, R., Cox, H., et al. (2019). Identifying predictors of stress and job satisfaction in a sample of merchant seafarers using structural equation modeling. *Frontiers in Psychology*, 10. https://-doi.org/10.3389/fpsyg.2019.00070.

Nor, F., Marsila, S., Mhd Ruslan, S., Mokhtar, K., Salleh, N. H. M., & Jeevan, J. (2019). Health and safety: Fatigue among seafarers in Malaysia. *Procedia Manufacturing*, 12, 79–88.

Sarinas, B. G., & Casaáare, A. F. (2022). Contributing factors and strategies applied onboard ship: Basis for development of booklet to enhance seafarers' mental health. *TransNav, the International Journal on Marine Navigation and Safety of Sea Transportation*, 16, 751–758. https://doi.org/10.12716/1001.1-6.04.17

Ricardianto, P., Prastiama, R., Thamrin, M., Agusinta, L., Abdurachman, E., & Perwitasari, E. (2021). The ship's crew performance of Indonesian national shipping companies. *International Journal of Research in Commerce and Management Studies*, 3, 52–66. https://doi.org/10.38193/IJRCMS.2021.3304.

Georgieva, D. (2019). Increase of the crew's well-being and reduction of stress. In *The 5th International Scientific Conference SEA-CONF 2019* (pp. 1-5). Constanta, Romania. https://-doi.org/10.21279/1454-864X-19-I1-011.

Peplińska, A., Jeżewska, M., Leszczyńska, I., & Połomski, P. (2013). Stress and the level of perceived anxiety among mariners: The mediating role of marital satisfaction. *International Maritime Health*, 64, 221–225. https://doi.org/10.5603/-IMH.2013.0008.

Melnyk, O., Onyshchenko, S., Onishchenko, O., Lohinov, O., Ocheretna, V., & Dovidenko, Y. (2022). Basic aspects ensuring shipping safety. *Scientific Journal of Silesian University of Technology. Series Transport*, 117, 139–149. https://doi.org/-10.20858/sjsutst.2022.117.10.

Melnyk, O., Onyshchenko, S. (2022). Ensuring safety of navigation in the aspect of reducing environmental impact. In *Lecture Notes in Networks and Systems*, 463, 95–103. https://-doi.org/10.1007/978-3-031-03877-8_9.

Onyshchenko, S., Bychkovsky, Y., Melnyk, O., Onishchenko, O., Jurkovič, M., Rubskyi, V., & Liashenko, K. (2024). A model for assessing shipping safety within project-orientated risk management based on human element. *Scientific Journal of Silesian University of Technology. Series Transport*, 123, 319–334. https://doi.org/10.20858/sjsutst.2024.123.16.

Popova, Y. (2020). Economic or financial substantiation for smart city solutions: A literature study. *Economic Annals-XXI*, 183(5-6), 125–133. https://doi.org/10.21003/EA.V183-12.

Mukhamediev, R., Amirgaliyev, Y., Kuchin, Y., Aubakirov, M., Terekhov, A., Merembayev, T., Yelis, M., Zaitseva, E., Levashenko, V., Popova, Y., & Symagulov, A. (2023). Operational mapping of salinization areas in agricultural fields using machine learning models based on low-altitude multispectral images. *Drones*, 7(6), 357. https://doi.org/10.3390/drones7060357.

Melnyk, O., Bychkovsky, Y., Onishchenko, O., Onyshchenko, S., & Volianska, Y. (2023). Development of the method of shipboard operations risk assessment quality evaluation based on experts' review. *In Studies in Systems, Decision and Control*, 481, 695–710. https://doi.org/10.1007/978-3-031-35088-7_40.

Melnyk, O., Onishchenko, O., Onyshchenko, S., Bondar, A., & Borovyk, S. (2024). Principles of identifying non - conformities in the safety management system of a shipping company while assessing its effectiveness in minimizing errors. *Journal of Maritime Research*, 21(2), 33–39.

Sharma, D. R. (2024). Integration of human, technology, organization, and innovation elements in safety management to meet challenges of advanced maritime technology including MASS. *Journal of Maritime Research*, 21(2), 110–117.

Ricciardelli, R. (2024). Seafarers as first responders: An ethnographic study of safety and survival training. *Journal of Maritime Research*, 21(1), 298–308.