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DEVELOPING ERGONOMIC PRACTICES ON BOARD SHIPS: A PILOT STUDY BASED ON A MULTIPLE REGRESSION APPROACH

Dario Medić*
Faculty of Maritime Studies - University of Split, Split, Croatia
Tomislav Bubalo
TJB Business Consulting d.o.o., Zagreb, Croatia
Nikola Krstinić
Faculty of Maritime Studies – University of Split, Split, Croatia
Igor Jelaska
Faculty of Kinesiology – University of Split, Croatia

* Corresponding author: *dmedic@pfst.hr (Dario Medić)*

ABSTRACT

The aim of this study is to quantify the impact of selected factors on seafarers' satisfaction with ergonomics in the work environment. A sample of N=45 experienced seafarers were asked to complete a validated and reliable questionnaire to assess their perception of their working conditions, the application of ergonomic principles, the presence of health issues related to ergonomics, and the need for further education on this topic. A linear multiple regression analysis showed that none of the factors examined here had a statistically significant impact on seafarers' satisfaction with ergonomics ($p > 0.05$). The perception of ergonomic conditions had the highest non-significant positive effect ($b = 0.34$, $b^* = 0.35$, $t = 1.76$, $p = 0.09$). This study analyses the most recent stage of integration of ergonomic practices among seafarers and highlights the importance of enhancing education and raising awareness among seafarers regarding the application of ergonomic principles. The results contribute to a better understanding of ergonomic challenges in the maritime industry, and offer initial insights that may support future improvements to the working conditions on board ships.

Keywords: seafarers, ergonomic practices, employee satisfaction, working conditions, ship safety

INTRODUCTION

As an interdisciplinary field, ergonomics is gaining in importance among researchers of working conditions, particularly in sectors with high physical and mental demands, such as the maritime industry [1]. Seafarers operate under demanding conditions that include long shifts, work within confined and restricted spaces, and exposure to vibrations, noise, and extreme weather conditions. These factors not only affect their physical health, but also impact their mental well-being, work efficiency, and long-term safety [2]. Previous research has shown that the proper application of ergonomic principles can significantly improve working conditions, reduce fatigue and injuries, and increase productivity [3][4][5]. However, in practice, significant obstacles hinder the implementation of ergonomic solutions, particularly on ships, where the organisational structure, space constraints, and available resources often limit the ability to adapt the work environment to optimal ergonomic standards [6].

Traditional approaches to maritime ergonomics are based on international guidelines and standards, such as ISO 11226:2000, which define criteria for evaluating static working postures, acceptable levels of force exertion, repetitive tasks, and limits for biomechanical strain [2]. ISO 6385:2016 provides general ergonomic principles for the design of work systems, and emphasises human-centred approaches that take into consideration workload management and environmental conditions [7]. In addition to ISO standards, the guidelines and codes issued by the International Maritime Organization (IMO), American Bureau of Shipping (ABS), and other classification societies also emphasise ergonomic factors related to ship design, bridge layout, and crew safety. Examples include the IMO MSC/Circ.982 Guidelines on Ergonomic Criteria for Bridge Equipment and Layout [8], the ABS Guidance Notes on Ergonomic Design of Navigation Bridges [9], and ISO 8468:2007 Ship's Bridge Layout and Associated Equipment—Requirements and Guidelines [10]. Although these standards are widely accepted, their implementation depends on the perception and commitment of employers, as well as their willingness to invest in improving working conditions [11]the hull with superstructure and the internal ship spaces, as well as the functional arrangement of different ship's equipment. Shipbuilding architecture includes the design of ship's hull and the interior shipbuilding architecture. According to the provisions of the International Convention for the Safety of Life at Sea (SOLAS. The perceptions of employers, together with seafarers' awareness and knowledge of ergonomics, represent a key factor shaping the actual impact of ergonomic measures on employee satisfaction [12].

Despite the growing awareness of the importance of ergonomics, research suggests that its implementation often fails to deliver the expected results, due to organisational barriers, lack of enforcement, and inconsistent approaches to training [2]. Studies of the maritime sector indicate that although ergonomic measures are regarded as beneficial, their practical application is frequently prevented by regulatory obstacles, employer resistance, and operational constraints [13]. Seafarers may have access to basic ergonomic guidelines, but without effective training or employer support, the application of ergonomic principles remains limited [14].

Furthermore, research suggests that seafarers often do not directly associate their health problems with poor ergonomics, but instead perceive them as an inevitable part of the job [15]. This highlights the need for further education and a better understanding of the relationship between ergonomic factors and job satisfaction.

Ergonomic conditions on board are usually analysed based on various factors, typically including perceptions of the employer's commitment to ergonomics, the frequency of application of ergonomic principles, the presence of health problems associated with working conditions, and the need for additional education [12][15]. Previous research indicates that satisfaction with ergonomics is not necessarily a result of the mere presence of ergonomic measures, but depends on the employees' subjective perception of their effectiveness [16]and indicates the importance of further research into risk factors and preventive interventions at sea. This chapter gives an overview of the key issues relating to seafarer fatigue. A literature study was conducted aimed at collecting publications that address risk factors for fatigue, short-term and long-term consequences for health and safety, and options for fatigue mitigation at sea. Due to the limited number of publications that deal with seafarers, experiences from other populations sharing the same exposures (e.g. shift work. It is therefore essential to identify the factors that most significantly influence seafarers' satisfaction with ergonomic conditions in order to guide future improvements in this area.

To clearly assess the impact of these factors, this study involved multiple regression analysis, an advanced statistical method that enables the precise identification of key predictors of employee satisfaction. Multiple regression allows for the simultaneous examination of the relationships between multiple independent variables and a dependent variable, providing detailed insights into which aspects of ergonomics have the greatest influence on seafarers' perception of their working environment [17].

For the purposes of this study, key aspects of ergonomics relevant to the maritime environment were considered. The questionnaire used in the study was previously validated through pilot testing (N=10), as described in a separate validation study presented at the IMSC 2025 conference [18]. The primary objective of this pilot study is to test the applicability of the proposed methodology for examining the factors that may influence seafarers' satisfaction with ergonomic conditions on board ships. The aim is to explore preliminary patterns and to assess the potential of this approach in terms of informing future large-scale studies and improvements to ergonomic standards in the maritime industry.

Ultimately, this study emphasises the importance of a systematic approach to ergonomics, and particularly of raising awareness among seafarers and strengthening employers' commitment to ergonomic improvements. Continuous monitoring of health outcomes may be beneficial in terms of identifying the long-term effects of working conditions. This approach could not only generate greater employee satisfaction and improved productivity but also contribute to the long-term safety and sustainability of the maritime industry.

RESEARCH METHODOLOGY

SAMPLE OF PARTICIPANTS

In this research, N=45 seafarers were asked to complete an online questionnaire. All participants were active deck officers employed on commercial cargo vessels, with at least one year of sea service. To provide insight into the varying levels of professional experience, respondents were stratified into three groups: Group 1: less than five years (n=10); Group 2: five to 10 years (n=15); and Group 3: more than 10 years (n=20). The study was conducted in accordance with the highest ethical standards, in order to protect participants and their data. Special attention was paid to ensuring respondent anonymity and the confidentiality of the collected information [19]. Before participating, respondents received a clear explanation of the purpose and objectives of the research, with assurance that their data would be used exclusively for scientific purposes. The study strictly followed the guidelines outlined in the Helsinki Declaration, thus ensuring transparency in the research process and the protection of participants' rights. Each respondent had the right to withdraw from the study at any time, without any consequences [20].

QUESTIONNAIRE

A customised questionnaire was developed for this study that covered ergonomics issues in the maritime work environment. The questionnaire consisted of 10 items, which were formulated based on previous research and the available scientific literature [21]which are the predominant factors in maritime accidents, and the various attempts that have been made to reduce human errors by identifying the existing challenges. Advanced techniques for human and organizational factor modelling, including human error identification in accident investigation, human error probability quantification in risk analysis, and human and organizational factor analysis for emergency situations, are comprehensively analysed and discussed. The most widely used modelling technique for human error identification is the Human Factors Analysis and Classification System (HFACS[22]considering the influential factors of dynamic cognitive human behavior and complex interactions among core risk factors. The HFACS-MA structure consists of five levels of human factors based on the International Maritime Organization (IMO. Nine questions were structured on a five-point Likert scale, ranging from one ("strongly disagree") to five ("strongly agree"), while the final question was open-ended to allow respondents to share personal experiences or suggestions relevant for future research. The questions covered the following topics: satisfaction with ergonomic conditions, perceptions of employer's commitment to ergonomics, the impact of ergonomic practices on health and work efficiency, and the need for additional training in ergonomics. It included the following items: familiarity with ergonomic principles and practices onboard (Q1), frequency of application of ergonomic principles at work (Q2), proper ergonomic standards and awareness ensured by employer (Q3), health problems caused by poor ergonomics (Q4), awareness of the proper setup of an ergonomic workstation (Q5), the need for additional ergonomic training to improve efficiency and safety (Q6), the impact of poor ergonomics on work efficiency (Q7), frequency of fatigue or exhaustion after work (Q8), and overall satisfaction with ergonomics on board (Q9) [18].

The reliability and validity of the questionnaire were assessed in a previous study [18]. The questionnaire was found to have high internal consistency and test-retest reliability, thus confirming its suitability for measuring perceptions of ergonomics among seafarers. The test-retest reliability analysis, conducted on a subsample of $n=10$ respondents over a 15-day interval, showed acceptable internal consistency (ranging from $r=0.68$ to $r=0.98$, $p<0.05$), indicating stability in the responses over time. The highest reliability was observed for Q3 ($r=0.98$, $p<0.01$), which highlighted strong consistency in perceptions regarding employers' commitment to ergonomics. Similarly, high reliability scores were recorded for awareness and application of ergonomic principles (Q1: $=0.90$, $p<0.01$; Q5: $r=0.91$, $p<0.01$).

The values of the coefficient of determination (r^2) ranged from 0.27 to 0.96, confirming that a substantial proportion of the variance was explained by repeated measurements. A factor analysis using Varimax rotation identified two primary factors that together explained 57% of the total variance. The first factor, knowledge and application of ergonomic principles (33%), included variables related to the awareness and practical implementation of ergonomic measures, indicating that familiarity with ergonomic principles is closely linked to their application. The second factor, health problems and efficiency (24%), encompassed variables associated with ergonomic deficiencies, health concerns, and perceived work efficiency, highlighting the impact of poor ergonomics on seafarers' well-being and performance [18]. These findings confirm that ergonomic knowledge and health-related challenges represent distinct but critical dimensions of the maritime work environment, emphasising the need for effective training and stronger engagement from employers in ergonomic improvements. These findings provide preliminary support for the questionnaire's structure and relevance in regard to assessing ergonomic conditions on board, and may serve as a foundation for further methodological refinement in future studies.

STATISTICAL ANALYSIS

The collected data were analysed using Statistica 14 software, and a multiple regression analysis was conducted to ensure a comprehensive understanding of respondents' response patterns in relation to their satisfaction with ergonomics on board ships [23]. In the multiple regression analysis, β coefficients and b coefficients were calculated together with their standard errors. A model was developed using the coefficients of multiple correlation, multiple determination and F value [24]. Descriptive statistics were used to evaluate the fundamental parameters, including the mean, median, mode, response frequencies, minimum and maximum values, and standard deviation (Table 1). Measures of distribution asymmetry (skewness) and kurtosis were calculated to assess the normality of the data.

DATA COLLECTION

The study was conducted using online surveys, to enable a broader outreach to respondents [25][26]. Data were collected between January and April 2024. To ensure a higher response rate and improve data reliability, respondents were invited to participate voluntarily, and clear instructions were provided regarding the purpose and confidentiality of the study. The survey was designed to be mobile-friendly, allowing seafarers to complete it at their convenience using smartphones, tablets, or laptops while at sea or during shore leave. Reminders were sent regularly to reduce non-response bias. The questionnaire was designed to be concise (10–15 minutes) to minimise disruption to daily routines. Response validation was applied to prevent incomplete entries and ensure the consistency of the collected data.

MATERIALS AND METHODS

DESCRIPTIVE STATISTICAL ANALYSIS

To provide a comprehensive overview of seafarers' perceptions of ergonomics, descriptive statistical analyses were conducted, including mean, median, mode, and frequency distributions (Table 1). The sample consisted of seafarers with varying levels of experience: 22% (n=10) had less than five years of work experience, 33% (n=15) had between five and 10 years, while the majority, 45% (n=20), had more than 10 years of service at sea. This distribution provides valuable insight into how long-term exposure to shipboard working conditions influences perceptions of ergonomics. The prevalence of highly experienced seafarers enables a deeper understanding of how ergonomic conditions change over time and the challenges associated with their implementation.

The mean values indicated a generally positive perception of ergonomics, particularly in regard to knowledge of ergonomic principles (Q1, M=3.89, SD=0.98) and awareness of proper ergonomic workplace setup (Q5, M=3.62, SD=0.98). However, responses related to health problems caused by poor ergonomics (Q4, M=2.31, SD=1.22) had lower scores, suggesting that seafarers may not fully associate health issues with inadequate ergonomic conditions.

Tab. 1. Results for descriptive statistics

Variables	Mean ± Std. Dev.	Median	Min-Max	Skewness	Kurtosis
Q1	3.89±0.98	4.00	1.00–5.00	−0.82	0.51
Q2	3.67±0.88	4.00	1.00–5.00	−0.54	0.77
Q3	3.20±1.08	3.00	1.00–5.00	0.26	−0.80
Q4	2.31±1.22	2.00	1.00–5.00	0.46	−1.12
Q5	3.62±0.98	4.00	1.00–5.00	−0.66	0.67
Q6	3.89±1.07	4.00	1.00–5.00	−0.70	−0.22
Q7	3.69±1.06	4.00	1.00–5.00	−0.64	0.15
Q8	3.38±1.09	4.00	1.00–5.00	−0.60	−0.32
Q9	3.38±1.05	4.00	1.00–5.00	−0.71	−0.04

The median values reinforce these findings, with most responses clustering around higher agreement levels (median=4) for statements supporting ergonomic awareness and training needs (Q5, Q6, Q8). The median value for Q4 (median=2) suggests low agreement that poor ergonomics significantly affects health.

Similarly, a mode analysis revealed that the most frequently selected response was 4, indicating strong agreement with statements related to knowledge and application of ergonomics. However, the mode value of 1 for Q4 (health-related variables) suggests that many seafarers do not perceive ergonomic deficiencies as a significant cause of their health issues.

A response frequency analysis highlighted the need for enhanced training and awareness programs, as a considerable number of respondents (n=16) expressed interest in additional ergonomic training (Q6, mode=5). In addition, the minimum and maximum values (ranging from 1 to 5) reflected a wide range of opinions, particularly regarding employer commitment to ergonomics (Q3, M=3.20, SD=1.08), indicating a diverse variety of experiences based on factors such as work environment and years of service at sea.

The distribution of responses was assessed using skewness and kurtosis measures. Most variables exhibited a slight negative skew, indicating a tendency toward higher agreement levels; the exception was Q3 (employer commitment to ergonomics, skewness=0.26), which showed a slightly positive skew. The kurtosis was generally close to normal, with minor deviations from the expected range.

CORRELATION ANALYSIS AND MULTICOLLINEARITY CHECK

To ensure the appropriateness of a multiple regression analysis, a correlation analysis was conducted to assess the potential for multicollinearity among the independent variables (Q1–Q8). Pearson correlation coefficients were calculated, and the results are presented in Table 2. Most correlations were low to moderate, with the highest being r=0.6848 (between Q1 and Q5). No correlation exceeded the commonly accepted threshold of r=0.80, indicating that multicollinearity is not present in this dataset.

Tab.. 2. Pearson correlation matrix for variables Q1–Q8

Variables	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8
Q1								
Q2	0.6669 p<0.01							
Q3	0.4505 p=0.002	0.5752 p<0.01						
Q4	0.0674 p=0.660	0.0353 p=0.818	−0.1 p=0.513					
Q5	0.6848 p<0.01	0.5081 p<0.01	0.4798 p<0.01	0.1379 p=0.366				
Q6	0.2257 p=0.136	0.2012 p=0.185	0.0787 p=0.607	0.3572 p=0.016	0.175 p=0.250			
Q7	0.3147 p=0.035	0.2759 p=0.067	0.2341 p=0.122	0.269 p=0.074	0.3635 p=0.014	0.5085 p<0.01		
Q8	−0.0024 p=0.988	0.0158 p=0.918	−0.0655 p=0.669	0.3866 p=0.009	0.0512 p=0.738	0.3862 p=0.009	0.3775 p=0.011	

MULTIPLE REGRESSION ANALYSIS

A multiple regression analysis was conducted to examine the key factors influencing seafarers' satisfaction with ergonomics on board ships. This approach enabled the identification of the most significant predictors and their respective contributions to overall ergonomic satisfaction. Analysing the relationships between independent variables and the dependent variable enabled us to quantify the extent to which factors such as ergonomic awareness, employer commitment, and perceived health impacts shape seafarers' evaluations of workplace ergonomics.

A multiple regression model was used to predict satisfaction with ergonomics (Y) based on eight independent variables. The general multiple regression equation used in this study was as follows [27]:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 \ldots + \beta_n X_n + \varepsilon \qquad (1)$$

where:

- Y represents satisfaction with ergonomics (Q9), the dependent variable,
- $X_1, X_2, \ldots, X_n$ are the independent variables examined in the study, as follows
  - X_1 - knowledge of ergonomic principles (Q1),
  - X_2 - application of ergonomic principles (Q2),
  - X_3 - employer commitment to ergonomics (Q3),
  - X_4 - health problems caused by poor ergonomics (Q4),
  - X_5 - awareness of ergonomic principles (Q5),
  - X_6 - need for additional ergonomic training (Q6),
  - X_7 - impact of poor ergonomics on work efficiency (Q7),
  - X_8 - feeling of fatigue due to ergonomic conditions (Q8).
- β_0 is the intercept, representing the expected satisfaction level when all predictors are zero,
- $\beta_1, \beta_2, \ldots, \beta_n$ are the regression coefficients, indicating the effect of each predictor variable on satisfaction with ergonomics,
- ε is the error term, which captures the unexplained variance in satisfaction.

The proposed model of seafarers' satisfaction with ergonomics is based on conditional regression analysis, using a linear programming technique, which can be represented as follows [25]:

$$Y^* = \sum_{i=1}^{n} b_i\, X_i^*; \sum_{i=1}^{n} b_i = 1 \qquad (2)$$

where b_i is the weight value of criterion i, and Y^* and X_i^* are functions of values. To achieve a more accurate understanding of the ergonomic judgments of seafarers' satisfaction, these values must be normalised over the interval [0,100]. The variables used in the model and their corresponding descriptions are listed in Table 3 [25].

Tab. 3. List of variables and descriptions

Variable	Description
Y	Seafarers' overall satisfaction
a	Number of global satisfaction levels
y^m	m-*th* global satisfaction level (m=1,2, …, a)
n	Number of criteria
X_i	Seafarers' satisfaction according to the i-*th* criterion
a_i	Number of satisfaction levels for the i-*th* criterion
x_i^k	*k-th* satisfaction level of the i-*th* criterion k=1,2, …, a_i)
Y*	Value function of *Y*
y^{*m}	Value of the y^m satisfaction level
X_i^*	Value function of X_i

The function values Y^* and X_i^* must be normalised to the interval represented by the constraint principles. Their formulation can be written as [28]:

$$\begin{gathered} y^* = 0, y^{*q} = 100 \\ x_i *= 0, x_i^{*a^i} = 100;\ i = 1,2,\ldots,n \end{gathered} \qquad (3)$$

The goal of the model is to achieve maximum consistency and relevance between Y^* and Y, which represents its main achievement. This relationship can be expressed using only two terms in the linear regression equation, as shown in the following form [29]:

$$Y^* = \sum_{i=1}^{n} b_i\, X_i^* - \sigma^+ + \sigma^-; \sum_{i=1}^{n} b_i = 1 \qquad (4)$$

where $\boldsymbol{\sigma}^+ + \boldsymbol{\sigma}^-$ are the two errors of overestimation and underestimation, respectively. In order to understand the seafarers' overall satisfaction, it is necessary to evaluate these two terms with their associated variables separately for each seafarer, as well as for each ergonomic criterion separately (Fig. 1).

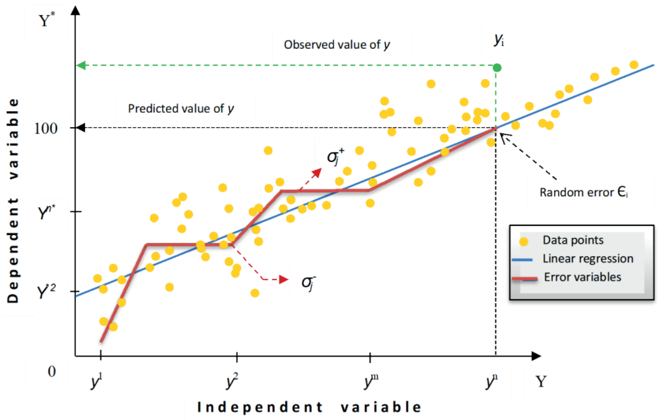

Fig. 1. Error variables for the j-th seafarer

To reduce the complexity of the formulation, the transformation variables z and w were introduced. The regression function values Y^* and Xi^* then took the following form:

$$\begin{cases} zm = y*m+1 - y*m \; for \; m = 1,2,\ldots,\text{ʆ} - 1 \\ w_i k = b_i x_i * k+1 - b_i x_i * k \; for \; k = 1,2,\ldots,\text{ʆ}i - 1 \; and \; i = 1,2,\ldots,n \end{cases} \quad \textbf{(5)}$$

The transformation variables are the initial settings of the nonlinear problem (Eq. 4). In this formulation and with the new settings, both variables are formulated as a linear multiple regression problem. Consequently, the transformation variables are defined in the following linear form[28]:

$$\begin{cases} Y^{*m} = \sum_{t=1}^{m-1} z_t \; for \; m = 2,3,\ldots,\text{ʆ} \\ b_i x_i{}^{*k} = \sum_{t=1}^{k-1} w_{it} \; for \; k = 2,3,\ldots,\text{ʆ}i \; and \; i = 1,2,\ldots,n \end{cases} \quad \textbf{(6)}$$

By applying Eq. 6 and assuming that seafarer j has expressed overall satisfaction y^{tj} and partial satisfaction x^{tij} using the ordinal scales Y and X_i, the ordinal regression (Eq.4) can be reformulated as:

$$\sum_{m=1}^{tj-1} z_m = \sum_{k=1}^{tij-1} w_{ik} - \sigma + + \sigma -, \forall_j \quad \textbf{(7)}$$

Accordingly, the final formulation of the linear optimisation problem within this model is as follows:

$$[min]F = \sum_{j=1}^{M} (\sigma_j^+ + \sigma_j^-) \quad \textbf{(8)}$$

The model calculates a_i–1 variables w for each criterion i, along with a–1 variables z representing the overall satisfaction. In cases where the values of a_i are identical across all criteria, the model requires a minimum of $(a_i–1)$ $n+a$–1 seafarers' evaluations. In line with the study's objective, the regression model was applied to examine the influence of selected predictors on ergonomic satisfaction among seafarers. For each evaluated criterion, it was possible to obtain relative weights to reflect its perceived importance. The resulting values were normalised to the interval [0, 100] and corresponded to the actual satisfaction levels recorded on both the global Y and partial X_i scales [28].

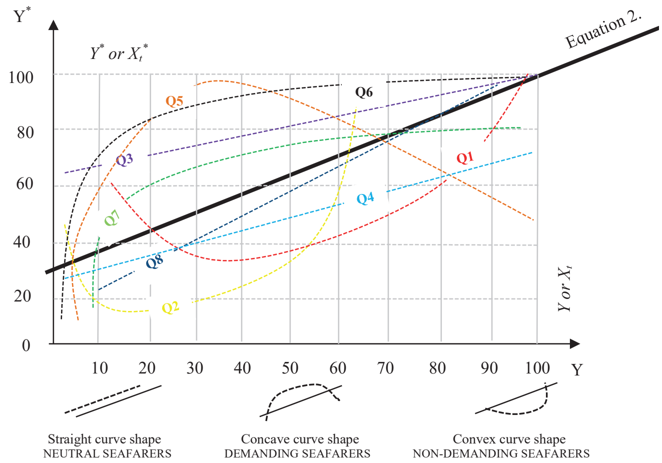

Fig. 2. Overall results for seafarers' satisfaction with different levels of demand

RESULTS

The linear value function for seafarers who rated ergonomics as neutral (neither satisfied nor dissatisfied) has a flat shape that is clearly defined if the seafarers are more satisfied, and less pronounced if the seafarers are less satisfied. The linear value function for seafarers who are extremely satisfied with the ergonomics on board has a convex shape, while for seafarers who are extremely dissatisfied it takes on a concave shape. To determine the values for the linear function, it is important to determine the ratio of the weight of the criterion to the importance of the ergonomics criterion (Fig. 2).

Tab. 4. Results of a multiple regression analysis

N=45	b*	Std. Err. for β	b	Std. Err. for b	t(36)	p-value
Intercept			2.82	0.93	3.03	<0.01
Q1	−0.03	0.24	−0.03	0.26	−0.12	0.91
Q2	−0.19	0.22	−0.23	0.27	−0.84	0.40
Q3	0.35	0.20	0.34	0.19	1.76	0.09
Q4	−0.12	0.17	−0.10	0.15	−0.68	0.50
Q5	0.15	0.22	0.16	0.24	0.69	0.49
Q6	0.11	0.19	0.11	0.18	0.61	0.55
Q7	0.01	0.19	0.01	0.19	0.08	0.94
Q8	−0.13	0.18	−0.13	0.17	−0.75	0.46

The regression coefficients (β) were estimated using the ordinary least squares (OLS) method, in which the sum of squared residuals is minimised to produce the best linear unbiased estimates. The statistical significance of each predictor was assessed using the t-test, while the overall model fit was evaluated using the coefficient of determination ($R2$) and the F-test. Table 4 presents the results of the multiple regression analysis, showing the standardised ($b*$) and unstandardised (B) coefficients, their standard errors, t-values, and significance levels for each predictor variable.

A moderate correlation was found between the independent variables and the dependent variable. The dependent variable Q9 (satisfaction with ergonomics) had a correlation coefficient (r) of 0.41, while the coefficient of determination (r^2) was 0.17. This indicates that the model explains only a small portion of the variability in the dependent variable. Although this correlation is moderate, an F-test ($F(8,36)=0.92$, $p<0.51$) showed that the model is not statistically significant, meaning that the independent variables cannot sufficiently explain the variability in satisfaction with ergonomics. These results confirm the limited explanatory power of the model, a finding that is consistent with the exploratory nature of this pilot study.

The intercept of the model, representing the average level of satisfaction with ergonomics among respondents, was 2.82 (std. err=0.93; $t(36)=3.03$; $p<0.01$). This suggests that seafarers generally report a moderate satisfaction level regarding onboard ergonomics, although there is considerable variation between individuals. The statistical significance of the intercept confirms that some level of satisfaction exists within the sample, despite the relatively low explanatory power of the model.

Each variable in the regression model had a different impact on the dependent variable (Fig. 3). No significant effect was found for knowledge of ergonomic principles (Q1) and their application (Q2). This finding indicates that merely being aware of ergonomic measures is insufficient to improve satisfaction, unless this is accompanied by supportive workplace conditions and management engagement, a finding that is in line with previous studies suggesting that systemic changes and organisational support are crucial for the effective implementation of ergonomics.

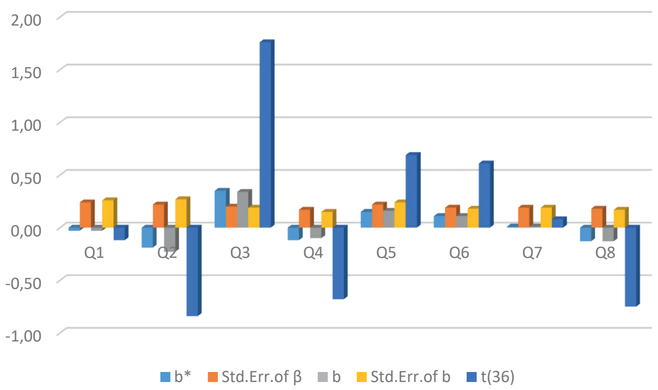

Fig. 3. Impact of Q-variables on the dependent variable

Employer commitment (Q3) emerged as the strongest predictor, with the most positive effect on satisfaction ($b^*=0.35$; $b=0.34$; $p=0.09$). Although this finding is on the threshold of statistical significance, it highlights the critical role of organisational support in achieving higher ergonomic satisfaction. Seafarers who perceived active employer engagement reported higher satisfaction, highlighting the importance of management-driven initiatives, as previously established in related studies of high-risk industries.

Significant impacts on satisfaction were not found for other variables such as health problems (Q4), awareness of workstation ergonomics (Q5), the need for additional training (Q6), the impact of ergonomics on efficiency (Q7), and fatigue due to ergonomic conditions (Q8). These results suggest that although seafarers recognise ergonomic issues, these factors alone do not significantly influence their satisfaction.

INTERPRETATION OF MULTIPLE REGRESSION ANALYSIS RESULTS

This multiple regression analysis provided a detailed insight into the relationship between satisfaction with ergonomics on board ships and selected independent variables. The results indicated that employer commitment to ergonomics (Q3) was the only variable that had a slight positive association with satisfaction ($p=0.09$). Although not statistically significant, this may suggest an aspect that could be further examined in future research, particularly regarding how perceptions of employer engagement affect ergonomic satisfaction. This observation is consistent with previous research that has examined links between perceived employer engagement and employee satisfaction and productivity (Fig. 4).

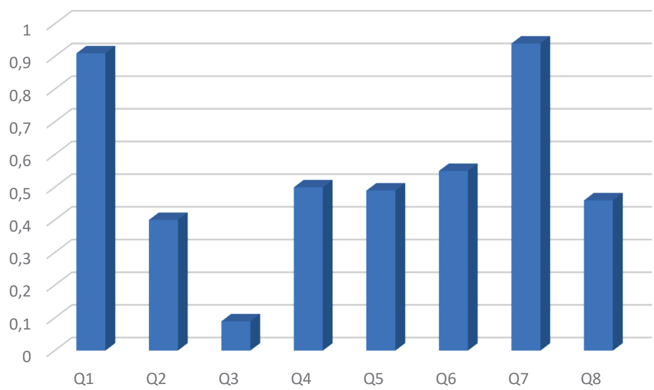

Fig. 4. p-value of predictors related to ergonomic satisfaction

In contrast, variables such as awareness of ergonomic principles (Q5) and the need for additional education (Q6) did not have a statistically significant effect on satisfaction with ergonomics. Although these findings are not statistically confirmed, they may indicate that an awareness of ergonomic rules alone is insufficient for improving satisfaction, and that the practical application of these principles in daily work is crucial. For instance, although seafarers may be familiar with the proper setup of their work environment (Q5), a lack of appropriate equipment or employer support may hinder its implementation.

The lack of significant results related to health issues (Q4) and work efficiency perceptions (Q7) may indicate a tendency towards normalising discomfort and health issues by seafarers, possibly due to their long-term adaptation to demanding maritime environments. Previous research within maritime and other high-risk occupational contexts has pointed to similar patterns, and authors have noted that workers commonly perceive occupational discomfort and health challenges as inherent to their profession rather than preventable ergonomic deficiencies.

Lastly, the variable representing fatigue after work tasks (Q8) also showed no significant predictive value for ergonomic satisfaction. This lack of statistical significance may indicate that seafarers attribute their fatigue primarily to their occupational conditions, such as extended working hours, shift irregularities, and physically demanding tasks, rather than directly linking fatigue to ergonomic inadequacies.

DISCUSSION

These findings are aligned with those of research in other high-risk industries, where employees often normalise physical discomfort and fail to recognise the long-term consequences of poor ergonomics [30]. Similar patterns have been observed in aviation and manufacturing, where compliance with ergonomic standards is largely dependent on employer-driven initiatives rather than individual awareness of ergonomic principles [15]. This suggests that even when seafarers are familiar with ergonomics (Q1) or apply certain ergonomic practices (Q2), a lack of employer-driven intervention reduces the likelihood of sustained improvement in working conditions.

Our analysis further reinforces the critical role of employer commitment (Q3), which emerged as the most impactful variable influencing seafarers' ergonomic satisfaction. This result reinforces the notion that seafarers' perceptions of workplace ergonomics are influenced more strongly by management engagement than by their own knowledge or experiences with ergonomic measures. This finding is consistent with those of studies in other high-risk industries, where employees tend to view safety and ergonomic improvements as the responsibility of management rather than individual initiatives [13]. In industries where regulatory systems are well-established and ergonomic training is delivered in a systematic way, employee satisfaction with workplace conditions is significantly higher [13][16] and indicates the importance of further research into risk factors and preventive interventions at sea. This chapter gives an overview of the key issues relating to seafarer fatigue. A literature study was conducted aimed at collecting publications that address risk factors for fatigue, short-term and long-term consequences for health and safety, and options for fatigue mitigation at sea. Due to the limited number of publications that deal with seafarers, experiences from other populations sharing the same exposures (e.g. shift work, suggesting that compliance with ergonomic standards is most effective when supported by systematic policies rather than relying solely on individual awareness or training.

In contrast, health-related concerns (Q4) and the perceived impact of poor ergonomics on work efficiency (Q7) were not found to be significant predictors of satisfaction. This result could indicate that seafarers tend to attribute physical discomfort and fatigue to the nature of their job rather than to ergonomic deficiencies. This aligns with broader trends in high-risk professions, where long-term exposure to physically demanding tasks leads to cognitive adaptation mechanisms, making workers less likely to link discomfort to modifiable workplace conditions.

Fatigue (Q8) did not significantly influence satisfaction with ergonomics, which may reflect its complex role in seafaring work environments. Further research is needed to clarify this relationship. The nature of seafaring is such that factors including irregular sleep patterns, extended work shifts, and high physical demands are likely to influence fatigue independently of ergonomic conditions. This may help explain why improvements in ergonomics do not necessarily lead to higher satisfaction in this domain.

Since the regression model explains only a limited portion of the variance (17%), future studies should first aim to test the model on a larger and more representative sample. Organisational culture, leadership engagement, ship design constraints, and the autonomy of seafarers in regard to modifying their workspaces could play a more significant role in shaping perceptions of ergonomic effectiveness. An expansion of this research to include qualitative insights from seafarers could provide a more comprehensive understanding of how they perceive and interact with ergonomic measures at sea.

During the course of this study, several challenges arose, including limited access to seafarers and constraints on reaching a larger and more diverse sample. These limitations affected the overall generalisability of the results and the strength of the conclusions; nevertheless, the findings offer valuable insights into ergonomic satisfaction among seafarers, and can serve as a foundation for future research.

PRACTICAL IMPLICATIONS

Although statistical significance was not found for any predictors, the observed patterns suggest that the perception of ergonomic conditions may play a role in seafarers' satisfaction, whereas the other analysed factors did not have a significant impact. Although it was expected that the perceived application of ergonomic principles and health problems related to working conditions would be stronger predictors, the data suggest that employees primarily value employer commitment to ergonomics.

These observations highlight possible practical considerations in the maritime industry, particularly regarding workplace improvements and raising awareness of ergonomics. One potential implication is the importance of a more active role of employers in ergonomic initiatives. Employees' perceptions of management engagement could influence their satisfaction with ergonomic conditions, and it is therefore recommended that organisations not only support the use of ergonomics verbally but also demonstrate real commitment through investment and concrete measures. Improvement in education and training programs is equally important, as our results suggest that many seafarers may not fully understand the link between ergonomic conditions and their health. Targeted, specific training programs could enhance employees' understanding of the long-term benefits of applying ergonomic principles and encourage proactive behaviour.

Monitoring and evaluating health outcomes should form an essential part of workplace management strategies on board. Although ergonomics-related health problems were not found to be statistically significant predictors of satisfaction, long-term monitoring could reveal additional causal relationships between working conditions and the well-being of employees.

These results suggest that seafarers may not directly associate their health issues and fatigue with ergonomic conditions but instead perceive them as an unavoidable aspect of the job. Similar findings have been reported in other high-risk industries, where employees often normalise discomfort and fail to recognise the long-term consequences of poor ergonomics [30]. Studies suggest that overcoming these challenges requires organisational commitment to ergonomics, regular risk assessments, and the engagement of employees in safety practices [13].

Although direct studies on the ergonomic satisfaction of seafarers are limited, research in aviation and manufacturing industries has found similar trends; for instance, compliance with ergonomic standards is strongly linked to employer engagement in safety measures rather than to individual awareness of ergonomic principles [15]. In industries with enforced regulatory frameworks and structured ergonomic training programs, employee satisfaction with working conditions is significantly higher [13][16]and indicates the importance of further research into risk factors and preventive interventions at sea. This chapter gives an overview of the key issues relating to seafarer fatigue. A literature study was conducted aimed at collecting publications that address risk factors for fatigue, short-term and long-term consequences for health and safety, and options for fatigue mitigation at sea. Due to the limited number of publications that deal with seafarers, experiences from other populations sharing the same exposures (e.g. shift work. Similar patterns have been observed in research in the area of maritime safety, where strong management commitment to a safety culture is correlated with improved compliance and crew well-being [12]. These parallels indicate that enhanced regulatory enforcement and targeted training interventions could improve seafarers' experiences and ensure better ergonomic integration in shipboard environments.

Improving ergonomic satisfaction among seafarers requires a multi-level approach. Employers should incorporate structured ergonomic training programs into onboard safety briefings, provide mandatory workplace assessments for high-risk tasks, and implement feedback mechanisms via which crew members can report ergonomic concerns. Regulatory bodies should ensure that ergonomic guidelines are incorporated into ship safety audits to track compliance with best practices.

LIMITATIONS OF THE STUDY

This study has several limitations that should be acknowledged. The sample size was relatively small (N=45), thus restricting the statistical power and generalisability of the findings. The distribution of respondents was not fully balanced in terms of work experience, and the test–retest reliability was explored with only 10 participants. Although none of the predictors achieved statistical significance, one result (Q3, p=0.09) was close to the conventional threshold, suggesting a potential association that warrants further investigation. The regression model explained only 17% of the variance in satisfaction, indicating that additional unmeasured factors may also be relevant. Future research should include a larger and more diverse sample, and should consider broader contextual variables to improve the robustness and applicability of the findings.

RECOMMENDATIONS FOR FUTURE RESEARCH

Future research should focus on expanding the sample and incorporating more diverse groups of seafarers to ensure greater representativeness of the results. A longitudinal approach could provide deeper insights into the impact of ergonomic interventions on satisfaction and health outcomes over time. Qualitative methods, such as interviews or focus groups, could help in gaining a better understanding of seafarers' attitudes and perceptions of ergonomics. Furthermore, analyses of cultural factors, vessel types, and organisational policies could provide additional insights into the factors influencing satisfaction with ergonomics.

CONCLUSION

This study has provided valuable insight into seafarers' perceptions of ergonomic conditions on board ships, and has examined the factors that influence their satisfaction with ergonomics. Through a multiple regression analysis, the key role of employer commitment to ergonomics (Q3) was highlighted as a mild but important predictor of satisfaction. Although this result was not statistically significant at the conventional level (p=0.09), it suggests that seafarers who perceive their employer as attentive to ergonomic issues tend to be more satisfied with their working conditions. These findings are aligned with those of previous research indicating that organisational culture and management support play a crucial role in shaping employees' perceptions of workplace ergonomics: when employees feel that their employer is committed to their well-being, it can positively impact their satisfaction and motivation.

None of the analysed predictors (Q1–Q8) had a statistically significant effect on satisfaction with ergonomics, although slight differences in the strength of association were observed. These results suggest that seafarers may not directly associate their health issues and fatigue with ergonomic conditions, but may instead perceive them as an inevitable part of the job. For instance, back pain or fatigue may be regarded as a normal consequence of demanding work on board, rather than a result of poor ergonomics. This highlights the need for additional education and awareness-raising initiatives to change perceptions and encourage the application of ergonomic principles in daily tasks.

In view of related findings in high-risk industries and the broader ergonomic literature, we suggest that shipping companies should consider a three-tiered approach to improving ergonomic conditions: (1) implementing real-time ergonomic monitoring systems to identify high-risk work areas; (2) mandating periodic ergonomic training sessions tailored to specific maritime tasks; and (3) offering financial incentives to crews who participate in safety and ergonomic compliance programs. These measures are aligned with best practices in high-risk industries such as aviation, where structured ergonomic interventions have significantly reduced musculoskeletal disorders among pilots and cabin crew. The organisation of regular ergonomics training programs could help seafarers better understand the importance of properly applying ergonomic principles, particularly in real working conditions. In addition, the introduction of a system for monitoring ergonomics-related health issues could help in identifying key risks and implementing preventive measures, such as regular medical check-ups and anonymous surveys on health concerns.

Ergonomics plays a critical role in improving working conditions, productivity, and safety in the maritime industry. This study confirms that seafarers' satisfaction with ergonomics is primarily influenced by employer commitment rather than individual knowledge or training. Although awareness of ergonomic principles is essential, its impact remains limited unless it is supported by management-driven interventions and systemic workplace improvements. These findings highlight the importance of structured ergonomic policies, continuous education, and proactive risk management in creating a safer and more comfortable working environment at sea.

Through the integration of real-time ergonomic monitoring, targeted training programs, and management-led engagement strategies, shipping companies can significantly improve ergonomic conditions on board, enhance the well-being of the crew, and foster a culture of safety and efficiency in maritime operations. Future research should build on these findings to develop evidence-based strategies for enhancing ergonomic standards and ensuring improvements in seafarers' working conditions.

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