# Ergonomic Assessment on Roll-on-roll-off Ship Workers

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## Abstract

Roll-on-roll-off (RoRo) ships are one of the most successful marine vessels operating today because of the flexibility, ability to integrate with other transport systems, and speed of operation. Studies have shown that seafarers suffer from Musculoskeletal Disorders (MSDs) caused by prolonged shifts with improper body postures and that working in the short sea sector such as RoRo operations has been found to cause more fatigue due to more port calls which increases the workload. The purpose of this paper is to conduct an ergonomic assessment on the tasks performed by RoRo ship workers during the docking, undocking, and lashing process as well as identify the factors that contribute to high ergonomic risk levels and recommend necessary ergonomic interventions to prevent workers from acquiring MSDs. The researchers used various ergonomic assessment tools such as the REBA, CMDQ, and NIOSH to measure the risk levels and applied statistical analysis tools such as regression, correlation, and ANOVA to identify the factors that have a significant effect on the CMDQ scores. The researchers were able to calculate high-risk levels on the different postures associated with the tasks performed by the workers and identified that age and company were the variables that significantly affected the CMDQ scores. Necessary ergonomic interventions were recommended to lower the risk levels and prevent the roll-on-roll-off ship workers from potentially acquiring Musculoskeletal Disorders.

## Keywords

Mooring, Line throwing, Lashing, Ergonomic Intervention

## 1. Introduction

### 1.1 Background

The International Maritime Organization (IMO) described the roll-on-roll-off ship as one of the most successful marine vessels operating today because of the flexibility, ability to integrate with other transport systems, and speed of operation. Raunek (2019) defined a roll-on-roll-off (RoRo) ship as a passenger ship with ro-ro cargo spaces or special category spaces. Vehicles enter and exit the ship by built-in ramps. According to the website Statista, approximately 10% of the ships worldwide are considered as RoRo ships which are around 4,812 ships as of January 2019. In the same year, the Philippine Ports Authority recorded 7,779,361 RoRo traffic nationwide which is approximately a 12% increase from the previous year. According to an article by Thomas (2020), working on ships may have its perks however, it is also known to be one of the most hazardous occupations due to the nature of the onboard work. The common illnesses that can commonly occur when working on marine vessels are Musculoskeletal Disorder (MSD). Smedegaard (2020) categorized RoRo workers to be working on short sea sectors. Short sea sectors or shipping is defined as the movement of cargo and passengers by sea over short distances. According to Jepsen et al (2015), working in the short sea sector causes more fatigue due to more port calls which increases the workload. Middlesworth defines musculoskeletal disorder as injuries and disorders that affect the human body's movement or musculoskeletal system which consists of the muscles, tendons, ligaments, nerves, discs, blood vessels, etc. Middlesworth explained that MSD is the effect when a worker is exposed to risk factors leading to fatigue which over time will develop a musculoskeletal imbalance. Some risk factors included high task repetitions, forceful exertions, sustained awkward postures, poor work practices, etc. A study by Magnavita et al (2011) also confirmed that long exposures to some environmental factors in the workplace could also contribute to MSDs. Temperature, noise, and light are the three most common complaints with regards to environmental factors. This led the researchers to conduct an ergonomic risk assessment on the different tasks performed by workers in a roll-on-roll-off ship specifically in the

docking, undocking, and lashing procedures. The study identified, analyzed and created measurable improvements to the work environment in order to minimize the effects of the different ergonomic risk factors that contribute to the ergonomic risk levels of the workers when performing various tasks inside the roll-on-roll-off ship.

### 1.2 Gap of Missing Information

Present studies recognized that there are risks for workers working in the maritime industry. However, it is important to note that different types of ships require different tasks for crew to perform as well as the environmental conditions affecting the performance. Ergonomic risk assessment for roll-on-roll-off ship workers on different types of roll-on-roll-off ships in the Philippines has not been studied before. Therefore, in this study, researchers conducted an ergonomic risk assessment for roll-on-roll-off ship workers on a RoPax type of roll-on-roll-off ship to determine the potential effects caused by the different risk factors in the tasks performed by the crew. RoPax is a type of roll-on-roll-off ship that is built for freight transport with passenger accommodation. The researchers assessed and apply the necessary ergonomic interventions to minimize the potential risks to the workers.

### 1.3 Objectives

The first objective in this study was to evaluate the ergonomic risk levels of the tasks performed by roll-on-roll-off ship workers and its potential effects. The second objective was to identify the ergonomic risk factors that contributed to the risk levels of the workers. Finally, the researchers aimed to apply the necessary ergonomic interventions in order to attain the acceptable level of risks for MSD's among the RoRo ship workers.

### 1.4 Significance of Study

Identifying the potential risks helped researchers create an effective design to minimize the ergonomic risks involved with the daily tasks done by the workers. Minimizing the ergonomic risks reduced the risk of workers from acquiring MSD's or other related injuries which may have affected the operations of the company. Keeping a healthy workforce is important to ensure that tasks are performed efficiently since workers are more engaged and focused on the responsibilities given. Having an efficient and effective workforce reduced the risk of operational delays and interruptions as well as improved the quality of service provided to the customers resulting in an increased level of satisfaction from the customers which is vital for the company's success. The marine transportation industry relies heavily on manpower to perform various tasks to be able to operate on a large scale. As an archipelago country, the contributions of RoRo ships have been significant not only on the logistical aspect but also boosting tourism to islands only accessible by seawhich is why the researchers aims to assess the working tasks of RoRo ship workers and potentially remove identified risk factors to prevent MSD's among workers.

## 2. Literature Review

### 2.1 Cornell Musculoskeletal Discomfort Questionnaire

For self-reports, the objective is to collect data on workplace exposure on both physical and physiological factors which can be gathered through web-based questionnaires. Colim et al (2020) mentioned that the most commonly used is the Nordic Musculoskeletal Questionnaire (NMQ) and the Cornell Musculoskeletal Discomfort Questionnaires (CMDQ). Observational methods usually require direct observations that aim to assess exposure factors such as posture, load handling, movement frequency, duration, recovery, vibration, and others. Observational methods are also known to be inexpensive and practical to use for a wide range of workplaces. Some validated observational tools which can be used to assess RoRo ship workers are the Rapid Upper Limb Assessment (RULA), NIOSH Lifting Equation, Rapid Entire Body Assessment (REBA).

### 2.2 Rapid Entrire Body Assessment

A study by Madani and Dababneh (2016) aims to deliver a summary of one of the ergonomic assessment tools; Rapid Entire Body Assessment (REBA) in regard to its development, applications, validity, and limitations. Industrial jobs, health care jobs, construction firms, supermarket industry, food industry, computer-based jobs, firefighters, and emergency medical technicians are some professional settings, which research showed REBA's convenience for postural assessment of jobs.

### 2.3 Ergonomic Interventions

One study conducted by Loisel et al. (1997) discovered that full ergonomic assessments followed by the necessary ergonomic interventions resulted in a reduction in worker absenteeism due to work-related MSD. The researchers will observe key aspects to conducting EI which are postural modifications, equipment adjustments, as well as providing ergonomic education to ensure the effectiveness of the interventions implemented and reduce the risks to workers working on roll-on-roll-off ships.

## 3. Methods

The researchers conducted an ergonomic assessment on the different tasks performed by the roll-on-roll-off ship workers involved in the docking and undocking procedure. The assessment aimed to identify the risk level pose by the different tasks of the workers that could potentially result in MSDs. The researchers utilized various ergonomic assessment tools to determine the risk levels of the tasks followed by statistical analysis tools to the significant ergonomic risk factors and finally applying the necessary ergonomic interventions to lower the risk-levels of the different tasks and prevent workers from acquiring MSDs

### 3.1 Conceptual Framework

The conceptual framework as shown below illustrated the researchers' approach in conducting the ergonomic assessment to achieve the impact which was to develop effective measures to prevent musculoskeletal disorders among workers. The process started by observing the work tasks performed by the workers on the ship. A risk analysis was conducted which aimed to determine the ergonomic risk levels on the workers by utilizing the various ergonomic assessment tools identified by the researchers based on the observed work tasks. Having measured the ergonomic risk levels, the figure then shows the various ergonomic risk factors which can be grouped into different categories of physical workload such as repetition, forceful & sustained exertions, awkward postures, and environmental factors. The researchers were able to identify the different risk factors that significantly contributed to the increased risk levels of MSDs to the worker's tasks. The necessary risk controls such as ergonomic interventions were done once the researchers were able to properly identify the risk factors significantly affecting the risk levels measured on the tasks of the workers. By choosing the correct type of ergonomic interventions, the researchers were able to develop the appropriate measures needed to prevent RoRo ship workers from potentially acquiring musculoskeletal disorders.

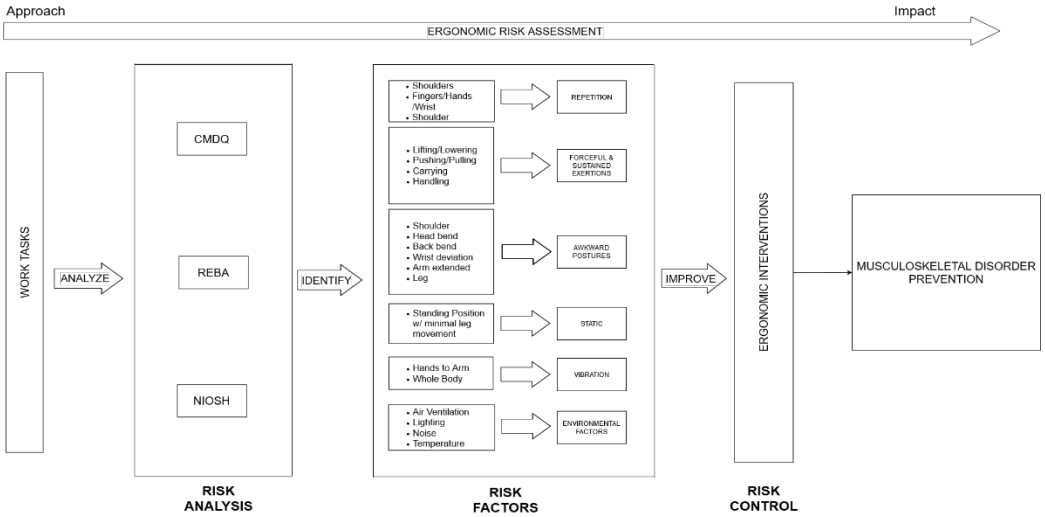


Figure 1. Conceptual Framework

### 3.2 Analytical Tools

#### 3.2.1 CMDQ

The Cornell musculoskeletal discomfort questionnaire (CMDQ) has been used to evaluate discomfort experienced by workers in various working groups. The CMDQ is a 54-item questionnaire that includes a body chart

and requires the subject to answer questions regarding musculoskeletal ache, pain or discomfort in over 20 parts of the body in the past week. By determining the Cronbach's alpha coefficient, each part of the questionnaire has been proven reliable to detect the presence of pain and discomfort, degree of pain and discomfort, and pain effect on working power therefore can be used as a part of ergonomic research and health surveillance programs to prevent musculoskeletal disorders. The purpose of this tool is to collect suitable information for statistical analysis regarding the pain and discomfort experienced by the RoRo ship workers across different parts of the body and help complement other ergonomic assessment tools which were used to evaluate the risk level of the different tasks that could potentially result to MSDs

### 3.2.2 REBA

Rapid Entire Body Assessment (REBA) offers a quick and simple measure to evaluate different work postures for the risk of work-related musculoskeletal disorders. The body is divided into sections and assessed independently, based on body posture, forceful exertion, type of movement, repetition, and coupling. REBA (See Appendix B) is more acceptable in ergonomic assessment of dynamic and unpredictable postures, compared to RULA which shows better results in ergonomic assessment in static postures. Since the tasks in docking and undocking of Roro ships is dynamic, the researchers will utilize the REBA.

### 3.2.3 NIOSH

The tool was developed to assess the risks in manual material handling which is commonly associated with lifting and lowering tasks. The objective of the NIOSH lifting equation is to determine the Recommended Weight Limit (RWL) which is the maximum weight a healthy worker can lift in a common 8-hour shift. The Lifting Index (LI) is also calculated which indicates the physical stress associated with the lifting task. Common tasks that require material handling in a RoRo ship setting is during docking and undocking procedures and fastening of vehicles to the ship. This task would require workers to lift various equipment such as ropes, blocks, etc. The NIOSH lifting equation will be used to determine the RWL of workers as well the physical stress experience associated with the lifting and lowering tasks performed by the workers.

### 3.2.4 Ergonomic Interventions

The researchers conducted the necessary ergonomic interventions to create preventive measures to reduce the RoRo ship workers risk for acquiring musculoskeletal disorders. Ergonomic interventions (EI) have helped ergonomists numerous times to rectify the different factors that negatively affect workers' physical health as well as efficiency. Ergonomic interventions have been found to have promising results as it comes in many forms to address different issues such as awkward postures, improper lifting techniques, and high stress development in the workplace. The reason behind the effectiveness of EI is its capability to detect less visible factors that may contribute to MSD's. Several studies have indicated that ergonomic assessments and workstation modifications have a significant effect on reducing symptoms for MSD's.

## 3.3 Statistical Analysis Tools

### 3.3.1 Regression Analysis

Regression analysis is the oldest and most widely used multivariate technique. This statistical tool is used to determine the relationship between a set of independent and dependent variables by producing a regression equation where the coefficients denote the relationship between the variables. Regression analysis can also be used to make predictions and help identify the risk factors that influence the outcome.
The regression equation is as follows:

$$y = \beta 0 + \beta 1x1 + \beta 2x2 + \cdots + \beta kxk + \varepsilon$$

Where y is the predicted or expected value of the dependent variable, x1through xk are k distinct independent or predictor variables, β0 is the value of y when all of the independent variables (x1 through xk) are equal to zero, β1 through βk are the estimated regression coefficients, ε is the random error. Regression Analysis was used to determine the relationship between the identified ergonomic risk factors to the risk levels measured by the researchers.

### 3.3.2 Correlation

Correlation is used to test relationships between variables to determine how things are related. Correlation has the capability to provide results which can help researchers make future predictions about future behavior if the relationship between the variables is properly determined. The researchers used correlation to verify the relationship between the dependent and independent variables providing researchers and identify which among the independent variables would show a strong correlation with the CMDQ scores.

### 3.3.3 Anova

Analysis of Variance (ANOVA) is an analysis tool in statistics that is used to test differences between means. F statistic or F ratio is the result of the ANOVA which allows the analysis of numerous groups of data to identify the variability among samples and within samples. One-way analysis of variance determines if there are significant differences between means of two or more groups. One-way ANOVA will be used to understand whether risk factors differed based on worker's age.

## 4. Data Collection

In the first phase of the study, the researchers measured the ergonomic risk level posed by the different tasks performed by the roll-on-roll-off ship workers through observation and evidenced by photographs during the docking and undocking process in Batangas Port. A survey was conducted by the researchers using the Turkish versions of the Cornell Musculoskeletal Discomfort Questionnaire to identify the discomfort score of each worker and its specific body part which has been considered as an effective valuable data collection tool. The survey was distributed among RoRo workers using online platforms. In addition, the researchers also recorded the temperature and sound level in the research locale to determine whether environmental factors also posed a certain level of risk to the workers

In the second phase of the study, the researchers identified the ergonomic risk factors that contributed to the high-risk levels measured using the different ergonomic assessment tools in the previous phase. For the results of the CMDQ, the researchers utilized three different statistical analysis tools such the regression analysis, correlation analysis, and analysis of variance (ANOVA). The regression analysis was used to determine which independent variables had a significant effect on the CMDQ scores gathered by the researchers. Using the one-way ANOVA test, the researchers identified whether there was a significant difference in the CMDQ scores between the different age groups as well as the respective company of the RoRo worker.

## 5. Results and Discussions

### 5.1 CMDQ Results

The following data were gathered based on the results of the survey conducted by the researchers using the Cornell Musculoskeletal Discomfort Questionnaire (CMDQ) where 372 roll-on-roll-off workers participated in online platforms prepared by the researchers and the company. Table 52 shows the frequency of discomfort felt by workers in each specific body part. The frequency of discomfort was based on how many times a worker experienced some level of discomfort on a specific body part even if the pain is minimal.

Table 1. Frequency of Discomfort

| Body Part | Frequency | Cumulative Frequency % |
|---|---|---|
| Lower Back | 221 | 59% |
| Hip/Buttocks | 176 | 47% |
| Upper Back | 169 | 45% |
| Lower Leg (Right) | 131 | 35% |
| Upper Arm (Left) | 129 | 35% |
| Lower Leg (Left) | 127 | 34% |
| Knee (Right) | 126 | 34% |
| Upper Arm (Right) | 123 | 33% |
| Knee (Left) | 121 | 33% |
| Shoulder (Left) | 103 | 28% |
| Thigh (Right) | 99 | 27% |
| Shoulder (Right) | 97 | 26% |
| Thigh (Left) | 93 | 25% |
| Neck | 79 | 21% |
| Foot (Right) | 58 | 16% |
| Forearm (Left) | 53 | 14% |
| Foot (Left) | 53 | 14% |
| Forearm (Right) | 52 | 14% |
| Wrist (Left) | 50 | 13% |
| Wrist (Right) | 45 | 12% |

As shown in Table 1, more than half of the respondents or around 59% complained about lower back discomfort which was followed by the hips/buttocks with 47% complaints, upper back with 45%, and so on. The right wrist had the least frequency with only 12% of the total workers feeling discomfort in the said area

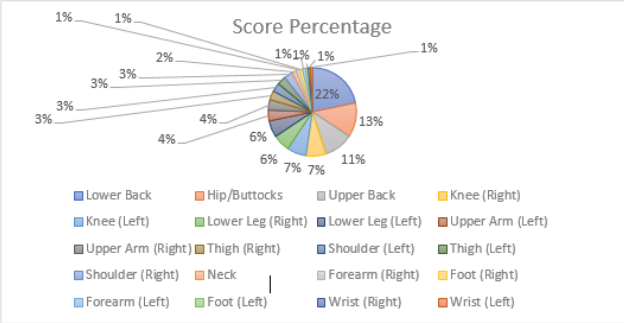


Figure 2. Score Percentage

Out of the total CMDQ Score of 18,219 computed, 22% of the score came from the lower back area, followed by the hip/buttocks with 13%, upper back with 11% while the forearm, foot, and wrist had the lowest score percentage with 1% each. The results from Table 52 and Figure 45 indicate that majority of the workers feel some level of discomfort in the lower back, hip/buttock, and upper back area.

The researchers considered different possible factors that could have affected the CMDQ scores gathered from the respondents which were age, weight, height, body mass index (BMI), company, and working hours. However, since the working hours of the respondents were the same, the said variable was not included in the analysis. Out of the 372 respondents, 160 of the respondents worked at Company A, 111 at Company B, and 101 worked at Company C. The youngest respondent was 26 years old while the oldest was 56 years old. The average height, weight, and BMI of the workers were 169 cm, 57 kg, and 20.26, respectively. Using multiple linear regression, the researchers were able to identify which variable had a significant effect on the CMDQ scores.

## 5.2 Regression Analysis

```
Analysis of Variance

Source              DF   Adj SS  Adj MS  F-Value  P-Value
Regression           3   494263  164754    96.89    0.000
  Age (Required)     1   483865  483865   284.56    0.000
  Company            2    15284    7642     4.49    0.012
Error              368   625756    1700
Total              371  1120019


Model Summary

      S    R-sq  R-sq(adj)  R-sq(pred)
41.2362  44.13%     43.67%      42.69%

Regression Equation

Company
Company 1  CMDQ Score = -110.31 + 4.238 Age (Required)

Company 2  CMDQ Score = -95.41 + 4.238 Age (Required)

Company 3  CMDQ Score = -107.4 + 4.238 Age (Required)
```

Figure 3. Multiple Regression Analysis

As shown in the regression analysis, only the age and the company of the worker had a significant effect on the CMDQ scores recorded based on the p-value of 0.000 and 0.012 respectively which was less than 0.05 while other variables such as the weight, height, and BMI did not have a significant effect on the dependent variable. The r-squared value of 44.13% which indicates the percentage of the variance in our dependent variable that the independent variable explains collectively. The r-squared value is also expected to be lower than 50% since the study predicts human responses which are generally harder to predict. The regression equation shows that for every unit increase in age, the CMDQ score increases by 4.238 regardless of the company.

### 5.3 Correlation Analysis

| | CMDQ Score | Age (Required) | Weight (kg) | Height (cm) |
|---|---|---|---|---|
| Age (Required) | 0.654<br>0.000 | | | |
| Weight (kg) | 0.012<br>0.813 | -0.048<br>0.354 | | |
| Height (cm) | 0.004<br>0.931 | 0.001<br>0.978 | -0.016<br>0.752 | |
| BMI (Required) | 0.002<br>0.962 | -0.048<br>0.353 | 0.859<br>0.000 | -0.521<br>0.000 |

Figure 4. Correlation Analysis

Furthermore, the researchers conducted a correlation analysis as shown in Figure 4. The results of the correlation show that among the independent variables, only age displayed a strong positive correlation with the CMDQ Score calculating a value of 0.654. The weight, height, BMI had a Pearson correlation value of 0.012, 0.004, and 0.002 respectively with the CMDQ score showing a low correlation. Weight and BMI had a low negative correlation with age with both having a value of -0.048 while height had a 0.001 correlation with age. The height of the workers also had a low negative correlation with the weight with a value of -0.016 while BMI on the other hand showed a strong correlation with the weight having a Pearson correlation value of 0.859 indicating that as weight increases, the BMI also increases. On the contrary, BMI had a negative correlation with height having a value of -0.521 which indicates that as the height increases, the BMI of the worker decreases.

The result further supports the observation in the regression analysis where age was the only independent variable that had a significant effect on the dependent variable aside from the categorical variable.

The researchers also categorized the CMDQ scores into 7 different groups such as group A, B, C, D, E, F, and G based on the age of the respondents respectively from 20-25, 26-30, 31-35, 36-40, 41-45, 46-50, and 51-56 years old. Using the ANOVA test, the researchers were able to determine whether there is any statistically significant difference between the different age groups.

### 5.4 Analyis of Variance (CMDQ Score vs Age group)

**One-way ANOVA: CMDQ Score versus Age Group**

| | |
|---|---|
| Null hypothesis | All means are equal |
| Alternative hypothesis | At least one mean is different |
| Significance level | α = 0.05 |

Equal variances were assumed for the analysis.

Factor Information

| Factor | Levels | Values |
|---|---|---|
| Age Group | 7 | A, B, C, D, E, F, G |

Analysis of Variance

| Source | DF | Adj SS | Adj MS | F-Value | P-Value |
|---|---|---|---|---|---|
| Age Group | 6 | 542735 | 90456 | 57.19 | 0.000 |
| Error | 365 | 577284 | 1582 | | |
| Total | 371 | 1120019 | | | |

Figure 5. Analysis of Variance (CMDQ vs Age)

As shown in ANOVA results in Figure 48, the p-value was 0.000 which directs the rejection of the null hypothesis that all means are equal and accept the alternative hypothesis that at least one mean is different among the groups.

### 5.5 Tukey Pairwise Comparisons

To determine which specific groups are significantly different, the researchers also conducted a Tukey's test to properly differentiate the means among the groups.

**Tukey Pairwise Comparisons**

Grouping Information Using the Tukey Method and 95% Confidence

| Age Group | N | Mean | Grouping |
|---|---|---|---|
| G | 17 | 166.6 | A |
| F | 46 | 103.24 | B |
| E | 61 | 63.95 | C |
| D | 73 | 41.64 | D |
| C | 71 | 33.27 | D E |
| B | 56 | 15.51 | E F |
| A | 48 | 9.70 | F |

Means that do not share a letter are significantly different.

Figure 6. Tukey Pairwise Comparisons

The results displayed in Figure 6 show that age groups G, F, and E have a significantly different CMDQ score from that of the other age groups which means that workers belonging to age groups G (51-56), F(46-50), and E (41-45) experience more pain when performing tasks compared with the other age groups. Age group C (31-35) experience a similar level of pain with age group D (36-40) and B (26-30) while age group B also share a similar level of pain with age group A (20-25). It can also be observed based on the means of the groups that as the age increases, the mean of the CMDQ scores also increases which also provides evidence that age is a factor in the results of the survey.

## 5.6 Analysis of Variance (CMDQ Score vs Company)

The researchers also conducted an ANOVA test comparing the CMDQ Scores with the company where the workers worked for. Three companies were indicated in the survey results respectively labeled as Company A, B, & C.

**One-way ANOVA: CMDQ Score versus Company**

| | |
|---|---|
| Null hypothesis | All means are equal |
| Alternative hypothesis | At least one mean is different |
| Significance level | α = 0.05 |

Equal variances were assumed for the analysis.

Factor Information

| Factor | Levels | Values |
|---|---|---|
| Company | 3 | Company A, Company B, Company C |

Analysis of Variance

| Source | DF | Adj SS | Adj MS | F-Value | P-Value |
|---|---|---|---|---|---|
| Company | 2 | 10398 | 5199 | 1.73 | 0.179 |
| Error | 369 | 1109621 | 3007 | | |
| Total | 371 | 1120019 | | | |

Figure 7. Analysis of Variance (CMDQ vs Company)

The analysis of variance shown in Figure 7 calculated a p-value of 0.179 which is greater than 0.5 and in contrast with the previous ANOVA test, directs the acceptance of the null hypothesis which states that all means are equal. The acceptance of the null hypothesis indicates that there is no significant difference between the means of CMDQ Scores between the musculoskeletal discomfort experienced by the workers working in different companies.

## 5.7 Summary of Results from REBA

Table 2. Summary of Results from REBA

| Tool Used | Procedure Assessed | | Risk Level | High Risk Position(s) | Ergonomic Risk Factor(s) | Potential Musculoskeletal Disorder(s) (MSD) |
|---|---|---|---|---|---|---|
| REBA | MOORING | Line Adjustment | High | • Trunk<br>• Legs<br>• Upper Arms | ▪ Bending<br>▪ Static Posture | o Muscle/Tendon Strain<br>o Tendonitis<br>o Chronic Back Pain |
| | | Line Wrapping | High | • Trunk<br>• Legs<br>• Upper Arms | ▪ Bending<br>▪ Static Posture | o Muscle/Tendon Strain<br>o Chronic Back Pain<br>o Carpal Tunnel Syndrome |
| | | Line Inspection | High | • Trunk<br>• Legs<br>• Upper Arms | ▪ Bending<br>▪ Static Posture | o Muscle/Tendon Strain<br>o Tendonitis<br>o Chronic Back Pain |
| | LINE THROWING | Line Preparation | Very High | • Trunk<br>• Legs<br>• Upper Arms | ▪ Bending<br>▪ Static Posture | o Muscle/Tendon Strain<br>o Tendonitis<br>o Chronic Back Pain |
| | | Line Twirl | Medium | • Shoulder | ▪ High Repetition | o Rotator Cuff Strain<br>o Carpal Tunnel Syndrome |
| | | Line Throw | Very High | • Trunk<br>• Legs<br>• Upper Arms | ▪ Awkward Posture | o Muscle/Tendon Strain<br>o Tendonitis<br>o Chronic Back Pain |
| | | Follow Through | High | • Trunk<br>• Legs<br>• Upper Arms | ▪ Awkward Posture | o Muscle/Tendon Strain<br>o Tendonitis<br>o Chronic Back Pain |
| | LASHING | Lashing | High | • Trunk<br>• Legs<br>• Upper Arms | ▪ Bending<br>▪ Static Posture | o Muscle/Tendon Strain<br>o Tendonitis<br>o Chronic Back Pain |

The results in Table 2 shows the summary of all the results gathered from the Rapid Entire Body Assessment, it can be observed that all postures associated with the different procedures performed by the workers in the RoRo ship indicate at least a high-risk level for acquiring musculoskeletal disorders. In the mooring procedure, all postures have the same high-risk position which are the trunk, legs, and upper arms due to bending and static postures which may potentially result in different musculoskeletal disorders such as muscle strain, tendonitis, chronic back pain, and carpal tunnel syndrome for the line wrapping posture. For the line throwing procedure, both the line preparation and the line throw posture indicate a very high-risk level for MSDs due to the bending, static & awkward posture of the trunk, legs, and upper arms. The follow-through posture also has the same high-risk positions due to awkward posture but only indicates a high risk for MSDs. The line twirl however had the lowest risk level among all posture at medium risk where only the shoulder is at risk due to high repetition of the rotating motion which could potentially result in MSDs such as rotator cuff strain and carpal tunnel syndrome. Lastly, the lashing procedure indicated a high-risk level for MSDs due to bending and static posture of the trunk, legs, and upper arms.

In addition, Table 3 also shows the summarized results from the other assessment tools such as CMDQ, NIOSH, and Environmental Factors. For the CMDQ, using regression analysis, the researchers were able to identify that only the age and company had a significant effect on the CMDQ scores gathered from the workers. The regression equation directs that for every single unit increase in age, the CMDQ score of the worker also increases by 4.238. In the NIOSH Lifting Equation, the researchers were able to calculate the risk index of the workers lifting task as well as the recommended weight limit which were all within the safe levels. Lastly, the researchers also recorded the temperature and sound level in the working area for 14 days and determined that both variables were also within safe limits and pose no threat to the RoRo workers.

Table 3. Summary of CMDQ, NIOSH, and Environmental Assessment Results

| Tool Used | Variable Assessed | Risk Level | Ergonomic Risk Factor(s) | Potential Musculoskeletal Disorder(s) (MSD) |
|---|---|---|---|---|
| **CMDQ** | CMDQ Pain Score | *NA* | ▪ Age<br>▪ Company | As age increases, the CMDQ Pain Score increases by 4.238 regardless of the company |
| **NIOSH Lifting Equation** | Lifting Risk Index | Low | ▪ Vertical Distance<br>▪ Horizontal Distance<br>▪ Average Weight<br>▪ Angle of Asymmetry<br>▪ Lifts/Minute<br>▪ Working Hours | No potential risk due to Low Risk Level |
| | Recommended Weight Limit | Low | | No potential risk due to Low Risk Level |
| **Environmental Factors** | Temperature | Low | ▪ Temperature | No potential risk due to Low Risk Level |
| | Sound Level | Low | ▪ Sound Level | No potential risk due to Low Risk Level |

## 5.8 Ergonomic Interventions

As observed from the results above, the majority of the procedures were classified to be high risk based on the postures displayed by the workers. It was also observed that all the procedures above were performed manually which increases the number of postures needed to complete one procedure. Therefore, based on the results from the risk assessment conducted, the researchers came up with ergonomic interventions recommending the utilization of automated equipment as well as some posture adjustments to reduce and lower the risk level of the remaining working tasks of the workers and prevent musculoskeletal disorders. The ergonomic interventions recommended by the researchers apply to all RoPax types of RoRo vessels which all the three companies in this study operate.

## 5.9 Mooring

For the mooring process, the researchers recommend the use of mooring winches as the best way of greatly improving the risk levels. Mooring winches secure the shipboard end of mooring lines, provides for adjustment of the mooring line length, and compensates for changes in draft and tide. Acquiring the said machines will eliminate the workers' need to physically adjust and wrap the lines and only require minimal effort to inspect the line after the whole process.

Figure 8. Mooring Winches

## 5.10 Line Throwing

The researchers recommend the company to utilize a line throwing apparatus. A line throwing apparatus is used to throw weighted ropes known as lines over long distances. It displays a variety of launching methods that can be used for numerous maritime operations.

Figure 9. Line Throwing Apparatus

A line throwing apparatus usually has a range between 230 to 250 meters and can be used in all situations where a line is required to be passed accurately and quickly between ship-to-ship, ship-to-shore, shore-to-ship, and even rescue services. Using a line throwing apparatus for the line throwing procedure would greatly reduce the ergonomic risk level the procedure poses to the workers since it would not require high-risk body postures as well as eliminate some of the postures observed in the current process.

### 5.11 Vehicle Lashing

As of today, there is no equipment available that would automate the lashing of vehicles inside a roll-on-roll-off vessel. Instead, the researchers were able to observe an alternative posture for the lashing procedure that would improve the posture and reduce the ergonomic risk level imposed on the workers during the lashing procedure.

Figure 10. Improved Lashing Posture

### 5.12 Summary of Improved Results

Table 4 shows the comparison between the current and the improved measurements based on the ergonomic interventions recommended by the researchers. The table highlights how each high-risk posture from Table 2 has significantly improved by eliminating the ergonomic factors and even eliminating the entire posture itself which results in a significantly lower risk level for the workers and preventing them from acquiring MSDs. Using automated mooring winches for the mooring procedure, the angles measured for the line adjustment were significantly decreased thus eliminating the bending posture and resulting in a negligible risk level while the line wrapping, and line inspection postures were eliminated reducing the task of the workers. Similarly, by utilizing a line throwing apparatus for the line throwing procedures, the angles for the line preparation were also decreased along with the eliminated bending which resulted in a low-risk level. The twisted side bending trunk and raised shoulder for the line throw posture were also eliminated in the improved REBA along with the decreased angle measurements which also resulted in a low-risk level while both the line twirl and follow though posture was eliminated. Lastly, the bending postures for the trunk and legs were also eliminated while angles were also reduced which resulted in a low-risk level.

The researchers also conducted a NIOSH assessment on the new lifting task associated with the new line throwing apparatus which yielded a risk index within safe levels together with the recommended weight limit as well.

The ergonomic interventions recommended by the researchers did not only lower the risks involved with the tasks of the RoRo workers but also eliminated entire postures which reduced the overall tasks needed to be performed by workers.

| | | | Current | | Improved | | *Remarks* |
|---|---|---|---|---|---|---|---|
| | **Procedure** | **High Risk Position** | **Measurements** | **Risk Level** | **Measurements** | **Risk Level** | |
| MOORING | Line Adjustment | Trunk | 20°-60°; Twisted or Side bending | High Risk | 0° | Negligible Risk | ✓ Bending Removed<br>✓ Angle Reduced |
| | | Legs | Bending; > 60° | | 30°-60° | | |
| | | Upper Arms | > 90° | | 20°-45° | | |
| | Line Wrapping | Trunk | > 60°; Side bending | High Risk | Posture Eliminated | None | ✓ Posture Eliminated |
| | | Legs | Bending; > 60° | | | | |
| | | Upper Arms | 45°- 90° | | | | |
| | Line Inspection | Trunk | > 60°; Twisted or Side bending | High Risk | Posture Eliminated | None | ✓ Posture Eliminated |
| | | Legs | Bending; > 60° | | | | |
| | | Upper Arms | 45°- 90° | | | | |
| LINE THROWING | Line Preparation | Trunk | > 60°; Side Bending | Very High Risk | 0° | Low Risk | ✓ Bending Removed<br>✓ Angle Reduced |
| | | Legs | Bending; > 60° | | 30-60 | | |
| | | Upper Arms | > 90° | | 45-90° | | |
| | Line Twirl | Shoulder | > 90°; Shoulder raised | Medium Risk | Posture Eliminated | None | ✓ Posture Eliminated |
| | Line Throw | Trunk | 0 - 20°; Twisted & Side Bending | Very High Risk | 0°-20° | Low Risk | ✓ Bending Removed<br>✓ Shoulder Lowered<br>✓ Angle Reduced |
| | | Legs | Bending; > 60° | | 30°-60° | | |
| | | Upper Arms | > 90°; Shoulder raised | | 20°-45° | | |
| | Follow Through | Trunk | 0 - 20°; Twisted & Side Bending | High Risk | Posture Eliminated | None | ✓ Posture Eliminated |
| | | Legs | Bending; 30°-60 | | | | |
| | | Upper Arms | 45° - 90°; Shoulder raised | | | | |
| LASHING | Lashing | Trunk | > 60°; Side Bending | Very High Risk | 0° | Low Risk | ✓ Bending Removed<br>✓ Angle Reduced |
| | | Legs | Bending; > 60° | | 30°-60° | | |
| | | Upper Arms | > 90° | | 45°-90° | | |
| NIOSH | NIOSH Lifting Equation | Risk Index | N/A | | 0.33 & 0.28 | Low Risk | ✓ New Lifting Task Safe |
| | | Weight Limit | | | 29.11 lbs. & 34.52 lbs. | | |

Table 4. Summary of Improved Results

## 6. Conclusion

Using different analysis tools, the researchers were able to determine the risk levels associated with the different tasks performed by the workers on the ship. The researchers were also able to identify which factors significantly contributed to the risk level using various statistical analysis tools. Lastly, ergonomic interventions were made to lower the risk level of the different tasks performed by the workers and preventing them from acquiring musculoskeletal disorders.

The RoRo vessels observed in this study were categorized as RoPax type which usually carry both vehicles and passengers and is the most common type of RoRo vessel in the Philippines. However, different types of RoRo vessels may potentially require different procedures associated with various postures as well as lifting tasks that may differ from each type of vessel. Therefore, for further studies, the researchers recommend to conduct ergonomic assessments on the tasks performed by workers working on the different types of roll-on-roll-off vessels such as Pure Car Carriers (PCC) which purely carry cars, Container Vessel and RoRo (ConRo) Ships, which carry both container vans and vehicles, and General Cargo and RoRo (GenRo) Ships which also carry specific loads and vehicles. In addition, the researchers also recommend considering RoRo ships operating in different environmental settings as it can also increase the potential risks on the workers especially when working in extremely hot or cold temperatures and high sound levels.

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