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The investigation of work-related musculoskeletal disorders and working posture of ships' staff using Nordic questionnaire and RULA method

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Abstract

Background: Work-related musculoskeletal disorders (WMSDs) impose a heavy burden on individuals, organizations, and governments.

Aim: The purpose of this study was to provide information about WMSDs and working posture. This information can be helpful in designing preventive programs.

Materials and Methods: The present study is a descriptive-analytical study. 207 subjects participated in this study. For WMSDs investigation and postural assessment during work, Nordic Questionnaire and Rapid Upper Limb Assessment (RULA) method were used, respectively. Gathered data from research variables measurement analyzed using Chi-square test and descriptive statistics. A p value of equal or less than 0.05 took into account to be statistically significant.

Results: The most prevalent work–related musculoskeletal disorder was found in lower back region, the percentage for large, medium and small ships staff was 58%, 61.7% and 45.1%, respectively. A significant relationship was found between WMSDs in neck (*P*=0.001), hands and wrists (*P*=0.02), back (*P*=0.04) and knees (*P*=0.001) and used ship by staff. A higher proportion of level four corrective action, was found in small ship staff.

Conclusion: WMSDs are prevalent among staff of all ships. WMSDs are more prevalent in lower back. Also, immediate change in posture and investigation is more necessary in small ship staff.

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1. Introduction

Work-related musculoskeletal disorders (WMSDs) are one of the primary causes of disability and occupational injuries in both developed and developing countries [1, 2, 3, 4]. These disorders pose a huge burden on many organizations, including industries, insurance companies, and health services [5]. WMSDs place a significant burden on individuals, organizations, and governments worldwide [6]. Iran is no exception to this burden. According to compensation statistics provided by the Social Security Organization, in 2012, over 52,059 documents were issued for compensation related to skeletal and joint disorders, amounting to 116,330,901,800 Rials. Additionally, compensation statistics for conditions like herniated discs and muscle spasms, which are not separately reported by this center, could also be added to the occupational injury statistics making the total quite substantial [7]. Reports also indicate that the prevalence of musculoskeletal disorders in the lower back and knees among Iranian workers is higher than in other countries [8].

Musculoskeletal disorders encompass a wide range of inflammatory and degenerative conditions affecting muscles, tendons, ligaments, joints, peripheral nerves, and blood vessels [9]. These disorders are associated with physical, psychological, and organizational work-related factors [9]. Sahrmann (2010: 5-7) identified sustained postures and repetitive movements as inducers that lead to small injuries through adaptation in neuromusculoskeletal tissues, ultimately resulting in significant damage and dysfunction in the affected area. According to the model proposed by Sahrmann, known as kinesiopathology, disorders in the body's musculoskeletal system begin with incorrect postures and repetitive movements and end in pathology [10].

Protecting the workforce's health and improving the work environment to maintain employee well-being is of great importance [11]. Epidemiological studies can provide valuable information about musculoskeletal disorders and form the basis for preventive programs. In Iran, musculoskeletal disorders in various work environments and occupations have been studied [12, 13, 14, 15]. Yousefi et al. (2017) conducted a meta-analysis on the prevalence of WMSDs in agriculture, industry, health, and administrative services, finding the highest rates of disorders in the knee and lower back regions [12]. Among municipal greenspace workers, the highest prevalence was reported in the knee (59%) and lower back (52%) [13]. In the carpet weaving industry, the highest prevalence was in the shoulder (47%) and lower back (45%) [14].

Several epidemiological studies have examined musculoskeletal disorders in maritime and port environments [15-25]. Ullman et al. (2024) in a systematic review study investigated the prevalence of chronic musculoskeletal pains amongst high-speed boat operators. The combination of results discovered a pooled prevalence of chronic musculoskeletal pain of 74% [15].

In a recent longitudinal study Mullinax et al. (2023) reported an ascending trend in the prevalence of back pain among United State of America Navy and Marine personnel going from 9.99% in 2009 to 12.09% in 2015 [16].

In another study, Fraser et al. (2023) showed that most of the neuromusculoskeletal disorders in Navy and Marine personnel occur in Low back and ankle-foot regions [17].

In a systematic review study, Chang et

al. (2022) showed that noncombat-related musculoskeletal disorders are common in the Navy with total prevalence extending from 12.69% to 48.81% [18].

de Alwis et al. (2021) investigated the prevalence of musculoskeletal pain among high-performance marine craft occupants and showed that the prevalence of musculoskeletal pain was 72% among which lower back pain was the most prevalent (46%) followed by neck pain (29%) [19].

Moreover, Hurpin et al. (2022) reported that more than 70% of French military high-speed boat pilots suffered from chronic pains, especially in lower back and neck regions [20].

In a study by Zighaimat et al. (2011), the highest pain and discomfort reported over the past 12 months among motorboat workers were in the lower back (61%) and knees (60%). More than 20% of musculoskeletal disorders in the lower back and knees led to physician-recommended rest [21].

A study of port workers in Iran revealed that over 60% of employees experienced at least one musculoskeletal pain in a body part over the past year [22]. Among Norwegian Navy personnel, the highest prevalence of musculoskeletal disorders was reported in the lower back (15%) and shoulders (12%). The study found that musculoskeletal disorders were more prevalent in non-military personnel compared to military personnel [23]. Musculoskeletal injuries due to overuse were more common than acute injuries among U.S. Navy personnel [24]. Research on special boat operators showed that anatomical regions such as the lower back (33%), knees (21%), and shoulders (14%) sustained more injuries compared to other body parts [25].

To evaluate musculoskeletal disorders, ergonomists have proposed several tools. Observational methods for assessing posture include the Ovako Working Posture Assessment System (OWAS) and the Rapid Upper Limb Assessment (RULA) [26]. Analysis of dental practitioners' postures using the RULA method has shown that all of dentist postures fall into corrective action levels two and three [27].

Results of evaluating the postures of assembly line workers using RULA indicated that 3.3% of workers had final scores of 1 and 2, warranting level one corrective actions, while 96.7% had final scores of 3 or 4, requiring level two corrective actions [28].

In recent decades, the prevention and control of musculoskeletal injuries have gained special importance, with OSHA (Occupational Safety and Health Administration) stating that ergonomics aims to prevent these disorders. The World Health Organization has designated the 2000s as the decade for the prevention of musculoskeletal disorders [29]. Whether OSHA has achieved its goal of preventing musculoskeletal disorders requires validation through epidemiological studies. To the best of my knowledge this study is the first study that investigates the working posture of ships' staff using RULA method. Given that individuals involved in maritime activities are exposed to various harmful factors, such as physical and ergonomic factors, and have a high risk of WMSDs, this study aims to determine the prevalence of WMSDs and assess work postures among these individuals.

2. Materials and Methods

2.1. Participation

The present study is a descriptive-analytical study. The statistical population comprised of 400 individuals involved in maritime

activities at ports in the north and south of the country. The sample size for this research was estimated using the PASS 15 software. By entering the necessary information as detailed below, the appropriate sample size for data analysis based on the chi-square test was determined (Table 1).

In the PASS program, the Chi-Square Effect Size Estimator was used to calculate and apply the W value. The power, effect size and significance level considered to be 0.95, 0.28 and 0.05 respectively. The sample size based on the chi-square test was determined to be 197 individuals (Table 1). In this study, 210 samples were considered, and 207 samples were used for statistical analysis. The inclusion criterion was that all participants must have at least one year of experience in maritime activities. The exclusion criteria were having a history of surgery and accident, having a history of traumatic injury outside of working environment, and having a history of neuromusculoskeletal diseases.

Table 1. Sample size estimation using PASS software

Df= 2	**Alpha=0.05**	**Power= 0.95**
W (effect size)= 0.28034 *	Estimated of N= 197	

2.2. Instrument

To assess WMSDs, the Nordic Questionnaire was used. This standardized questionnaire was designed by Kuorinka et al. in 1987. It evaluates anatomical areas including the neck, shoulders, elbows, hands and wrists, upper back, lower back, thighs, knees, ankles, and feet for problems and discomfort experienced over the past 12 months. The validity and reliability of the Nordic Questionnaire have been reported as adequate in previous research. Kuorinka et al. reported that the number of inconsistent responses varied from 0 to 23% in two separate studies. Regarding the validity of the questionnaire compared to clinical history, the number of inconsistent responses ranged from 0 to 20% [30]. In the present study, a Cronbach's alpha of 0.56 was obtained, indicating a moderate level of reliability.

The RULA method was used to assess posture during work. In RULA, postures are sampled during work, and the worst postures are recorded. The worst postures were identified based on observation and sampling. Both the dominant and non-dominant limbs were analyzed in this study. The intraratter and interrater reliability of the RULA method has been reported as moderate to good [31]. The interrater reliability for the RULA posture assessment method has been reported as excellent [32] and is considered a valid method for postural evaluation in work environments [33].

The RULA method involves three stages: recording the postural status during work, scoring the postures, and determining the overall score and list of actions. In the first stage, the work posture is observed directly over several work cycles. In the second stage, scoring is based on the angle of movement, muscle force, and load on the body. This stage results in a final score for the different postures. In the third stage, action levels are determined based on the final score [34]. The RULA posture evaluation score was determined using the ERGointelligence-UEA software.

2.3. Procedure

Before the completion of questionnaire and assessment of working posture, the

participants completed the consent form. All subjects were declared that their information will be private, and they could exit the study whensoever they desired. The demographic characteristics of the participants were obtained through an information collection form. Then, Nordic Questionnaires were filled in by participants. Finally, the worst working posture of participants were assessed using RULA method. In this study high-speed vessels considered as small vessels, cargo carriers and passenger carriers counted as large vessels and vessels with a size between these two categories considered as medium vessels.

2.4. Statistic

The obtained data were analyzed with SPSS version 16 at a significance level of 0.05 using frequency, mean, standard deviation, and chi-square test.

3. Results

The statistical sample of this study consisted of 207 individuals involved in maritime activities, who were selected through a convenient sampling method. The mean and standard deviation of the participants' age, height, weight, body mass index, and work experience are presented (Table 2). According to the study results, 82.1% of the participants were married, while 17.9% were single. The body mass index of the employees was normal in 64.3% of cases and abnormal in 35.7% of cases.

In the assessment of WMSDs across different types of vessels, the following results were obtained: For employees on large vessels, the highest prevalence of musculoskeletal disorders was observed in the lower back (58%), knees (55.1%), and neck (37.7%). On medium vessels, the highest frequencies were related to the lower back (61.7%), knees (36.2%), and neck (36.2%). On small vessels, nearly half of the individuals experienced musculoskeletal disorders in the lower back (45.1%), and nearly a quarter experienced disorders in the knees (24.2%; Figure 1).

Regarding corrective actions for different types of vessels, significant results were found: the percentage of corrective action at level 4 for large, medium, and small vessels, and for the right and left sides of the body, from right to left, were as follows: 43.8%, 70%, 94.1%, 43.8%, 80%, 94.1%. As shown, the corrective actions at level 4 for the right and left sides of the body on small vessels were higher compared to other vessels (Table 3).

Table 2. Demographic characteristics of the participants

Variable	M±SD
Age (years)	29.24±4.83
Height (cm)	174.15 ± 5.64
Weight (kg)	73.29 ± 10.31
BMI (kg/m^2)	24.14 ± 3.02
Work experience (years)	9 ± 4.96

Table 3. Corrective action levels in staffs of different ships

Corrective action level/ Type of ship	Large		Medium		Small	
	Right side	Left side	Right side	Left side	Right side	Left side
1	0%	0%	6.70%	3.30%	0%	0%
2	18.80%	18.80%	10%	10%	0%	5.90%
3	37.50%	37.50%	13.30%	6.70%	5.90%	0%
4	43.80%	43.80%	70%	80%	94.10%	94.10%

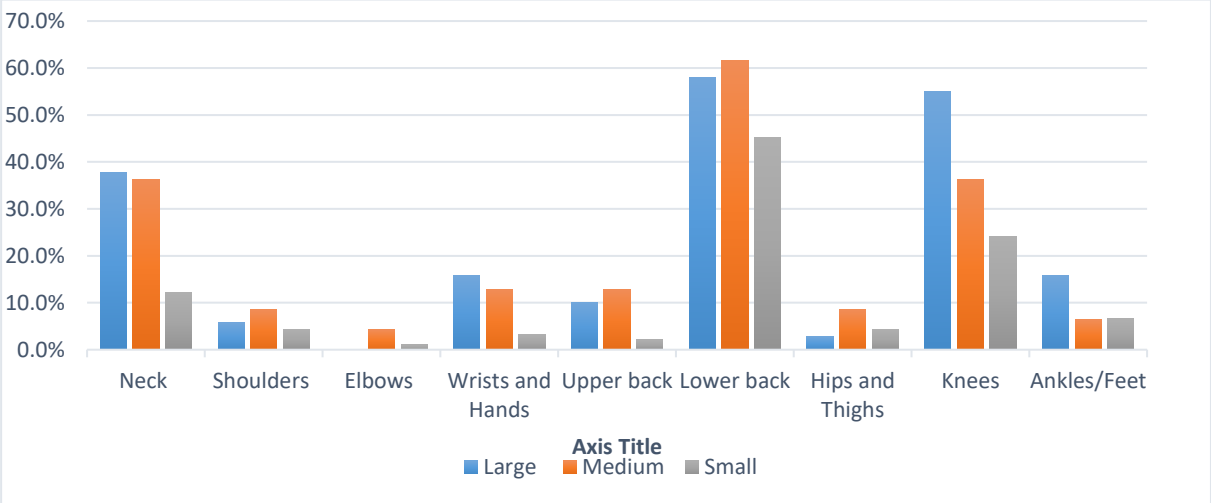

Figure 1. Prevalence of musculoskeletal disorders based on location in ship staffs

Based on chi-square test, a significant relationship was found between the prevalence of musculoskeletal disorders in the neck (x^2=16.538, *P*=0.001, phi= 0.283), hands and wrists (x^2=7.861, *P*=0.02, phi= 0.195), back (x^2=6.444, *P*=0.04, phi= 0.176), and knees (x^2=16.064, *P*=0.001, phi= 0.279) with the type of vessel used by the employees. Musculoskeletal disorders in the neck, hands and wrists, back, and knees were more prevalent among employees on large and medium vessels. No significant relationship was found between the prevalence of musculoskeletal disorders in other body areas and the type of vessel.

4. Discussion

The results of the present study indicate that WMSDs are more prevalent in the lower back and knees across all types of vessels—large, medium, and small. These results are coherent with the results of previous studies [17, 19, 20]. Also, these findings are consistent with studies by Zighaimat et al. (2011) [21], Khandan et al. (2017) [22], Morken et al. (2007) [23], and Ensign et al. (2000) [25]. Zighaimat et al. (2011) reported that the highest pain and discomfort among motorboat employees were in the lower back (61.1%) and knees (60.4%) [21]. Additionally, the present study aligns with Khandan et al. (2017), who reported the highest prevalence of WMSDs in the lower back [22]. The present study's finding of the highest prevalence in the lower back also corresponds with Morken et al.'s results [18]. Morken et al. (2007) reported a direct relationship between physical activity and a reduction in WMSDs [23]. Furthermore, the results of the present study are consistent with Ensign et al. (2000), who investigated the prevalence of WMSDs in operators of specialized boats [25].

The high prevalence of WMSDs in the lower back and knees among individuals engaged in maritime activities can be explained by the Sahrmann's kinesiopathological model [10]. According to this model, sustained postures and repetitive movements lead to pathology in the lower back and knees. Prolonged standing and sitting, especially in incorrect postures, put stress on the tissues in the lower back and knees, leading to elastic and plastic changes in these tissues. Additionally, repetitive movements such as climbing stairs, lifting and carrying heavy loads, and bending can contribute to the

development of musculoskeletal disorders in these areas.

As mentioned, musculoskeletal disorders in the lower back and knees have been among the most common issues across all types of vessels. Exercise and physical conditioning are recommended to reduce WMSDs and to improve muscle performance and strength [35, 36, 37]. Even stretching exercises can be beneficial in preventing WMSDs [38]. Additionally, it appears that using movement techniques to distribute and absorb forces can be useful in reducing musculoskeletal disorders in these areas. Implementing ergonomic interventions can also help in preventing WMSDs [39]. Appropriate design of vessels has this potential to decrease WMSDs in people that are involved in maritime activities.

More than one-third of participants in this study had abnormal BMI. It has been reported that high BMI is responsible for 36.6 million cases of low back pain [40]. Vertebral bodies and intervertebral discs of the lumbar spine will be compressed as a result of rise in BMI that leads to low back pain [41]. Moreover, elevated load borne by joints, can lead to musculoskeletal disorders in weight-bearing joints such as knee [42].

Based on the study results, the corrective actions at level 4 for the right and left sides of the body are higher on small vessels compared to other types of vessels, with the lowest level of 4 corrective actions observed on large vessels. Corrective actions among employees engaged in maritime activities are significantly higher than those for employees involved in dental and assembly tasks [27, 28].

Choobineh et al. (2012) reported that all postures of dentists fall within corrective action levels 2 and 3, whereas, according to the present study, over 90% of postures for individuals involved in maritime activities on small vessels are at corrective action level 4. Additionally, on medium and large vessels, corrective action levels 4 are also present in over 40% of cases [27].

Compared to the postural conditions during work for individuals engaged in assembly activities, the postural conditions for employees involved in maritime activities are worse, with corrective action levels being significantly higher. Specifically, corrective action levels for assembly workers are reported to be at levels 1 and 2 [28].

In comparison, the corrective action levels for bakers are better than those for maritime activity workers. Corrective action levels for bakers are at level 4 in only 33% of cases, whereas corrective action levels for employees engaged in maritime activities on small vessels are reported at level 4 in over 90% of cases. Additionally, corrective action levels for employees on medium and large vessels are higher than those reported for bakers. According to the RULA method, small vessels have the highest need for changes, suggesting that ergonomic adjustments and modifications related to body posture should be prioritized.

The study results indicate a significant relationship between the prevalence of musculoskeletal disorders in the neck, hands and wrists, back, and knees with the type of vessel used by employees involved in maritime activities. Musculoskeletal disorders in these areas were more prevalent among employees on large and medium vessels.

Factors that may contribute to the increased prevalence of musculoskeletal disorders in the neck, hands and wrists, back, and knees among employees on large and medium vessels include: improper body

posture during work [43, 44], prolonged static work and vibration [45, 46], lack of postural variety, inadequate design of the vessels leading to incorrect body positions, lack of exercise [47], poor workplace ergonomics (e.g., seating) [48], insufficient rest space for employees on large and medium vessels, and failure to consider the physical dimensions of employees in the design of vessels and their equipment. Psychological factors may also play a role as they can affect individuals' postures [49, 50].

5. Conclusions

The results of this study suggest that musculoskeletal disorders are more prevalent among employees on large and medium vessels compared to those on small vessels. Future studies should assess and report long-term effects of WMSDs on people that are involved in maritime activities. Also, in future studies, the researchers should investigative the efficacy of various preventive interventions such as ergonomic ones, in order to decrease the prevalence and intensity of WMSDs in these people. There is also a greater need for corrective actions related to body posture for employees on small vessels. Specific interventions such as redesigning ship layouts, ergonomics awareness trainings and posture training programs have this potential to improve working posture in people that are involved in maritime activities

Conflict of interest

The authors declared no conflicts of interest.

Authors' contributions

The author contributed to the original idea, study design.

Ethical considerations

The author has completely considered ethical issues, including informed consent, plagiarism, data fabrication, misconduct, and/or falsification, double publication and/or redundancy, submission, etc.

All participants have signed informed consent prior to enrolment in the study. This research was conducted ethically in accordance with the World Medical Association Declaration of Helsinki.

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