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Original

The Comparison of Risk Factors Caused by Musculoskeletal Disorders in Female Assembly Workers utilizing MFA and NERPA Methods

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Abstract

Background: Occupational injuries and work-related disabilities are among the most factors contributing to the creation of musculoskeletal disorders (MSDs) in industry. Improper workstation and poor posture increase fatigue load and, eventually, the appearance of MSDs. In addition to reducing physical strength, MSDs mitigate accuracy, augment the accidents, and reduce job productivity. Hence, the purpose of this research was to assess the risk factors for MSDs in electrical devices assembly workers utilizing Muscle Fatigue Assessment (MFA) and Novel Ergonomic Pos-tural Assessment (NERPA). **Methods:** This study was one cross-sectional descriptive study in the year … and was conducted in one electrical device manufacturing workshop in Khuzestan province along with 84 female workers. 13 jobs and 32 postures were selected in this workshop. Nordic Questionnaire was used to determine the frequency of MSDs. Then, the risk levels were specified in the studied individuals with the use of MFA and NERPA. The obtained data were analyzed in SPSS software version 16. The statistical methods applied in this study were mean, standard deviation, frequency, frequency percentage, t-test of two independent samples, and correlation coefficient assessment. Furthermore, the significance level of statistical tests was considered to be $P<0.05$. **Results:** Findings obtained from MFA exhibited that the right wrist and waist were with 66.7%, neck and right shoulder were with 60% of workers and NERPA method results mentioned that the right wrist with 67.3% and the waist with 65.4% and neck with 61.3% and the right shoulder with 60.8% were at "very high" level of corrective actions priority, which these actions must be taken immediately. Also, statistical results indicated that there was a significant correlation between the results of Nordic, MFA, and NERPA questionnaires ($P<0.05$). **Conclusion:** Concerning the kind of activity and misuse of support, the highest percentage of risk was evident in the right wrist, waist, and neck. So, a proper design of workstation and implementation of managerial actions were proposed to minimize muscle fatigue. These two methods also had similarities. MFA method was preferred when it was required to assess all body parts. On the other hand, NERPA was applied to determine more details.

Keywords: Musculoskeletal Disorders (MSDs); MFA, NERPA; Nordic Questionnaire

Introduction

One of the most prevalent factors of occupational injuries in occupational jobs is MSDs of the upper limbs.[1] MSDs are associated with injuries or disorders of the muscles, tendons, joints, cartilage, and intervertebral discs.[2] Based on the published reports by the United States, 44% of the total reported occupational diseases

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were related to MSDS, while the reports associated with MSDs in Iran were limited.[3, 4] Based on the published report by the Iran ministry of health, 76% of people working in the work environment have improper posture, and it can be the cause of MSDs.[5] In the work environment, different risk factors are involved in creating these injuries which can be divided into the physical risk factors such as improper posture, lifting and carrying heavy loads, works with repetitive physical movements such as bending, stretching and twisting as well as organizational and individual factors .[6, 7] MSDs often involve the upper limbs and lead to disability in workers.[8] These disorders include muscular disorders, tendon, tendon sheath, peripheral nerves, joints, bones, ligaments, and blood vessels, caused by repetitive stress during the time or by immediate or acute trauma.[9] The feeling of pain and discomfort in various parts of the musculoskeletal system is the main reason for the workers' absences. The studies revealed that more than half of absenteeism in the work environment was due to the MSDs.[10, 11]

These disorders appear in every occupation and industry. When a situation in a profession is such that repeated activities exceed the worker's capacity and ability, these activities will result in a lesion. Traumas caused by repetitive movements of one organ benefit from accumulative features that are evolved over time and appear their effects in the long-term as injuries that involve the musculoskeletal system.[12, 13] Studies exhibited that there was a significant relationship between fatigue caused by work and MSDs, the appearance of fatigue impacted the accuracy of people's performance and reduced their tendency in performing tasks and daily activities.[14-16] In production lines of small parts assembly, the workers perform most of their tasks in a repetitive, accurate, and static way. In these occupations, the workers reduce the quality of products, motivation, and productivity due to muscle fatigue and psychological stress.[17, 18] Bernardes et al. (2012), in an interventional study, investigated the ergonomics of transport unit assembly workers. They redesigned the assembly line layout to assuage the waist pain of workers, and they removed some of the assembly tasks that contributed to the risk of mentioned injury.[19] Other researches exhibited that the assembly workers were working for a long time in undesirable static postures in the assembly industry according to the type of work process, its high elegance, and the sensitivity and accuracy of the operation. This matter contributed to muscle fatigue and injuries to areas of the neck, shoulders, arms, and waist.[20, 21]

Against most MSDs assessment methods, the MFA and NERPA methods were considered to assess only some parts of the body, all parts of the body, and on the other hand, required the cooperation of the workers to do the scoring. These methods in occupations with no specific biomechanical problems were taken into account as a proper predictor of problems, especially tasks that had high speed and low control of the worker on her work pattern (like the task of assembly workers).[22] Due to the prevalence of MSDs, it was necessary to examine accurately and select the appropriate method to assess these disorders. In this study, the priority level of corrective actions was determined for different areas of the body with the use of two assessment methods of muscle fatigue, MFA, and NERPA. Also, the Nordic Questionnaire was applied in this study to investigate the prevalence and record the symptoms of MSDs and its relationship with occupational factors. Generally, the prevalence of MSDs was more common in women than in men. For instance, in a study conducted in German in 2003, the prevalence of chronic waist pain in the 12 months prior to the study was 16% in men and 22% in women.[23] Although women were considered to be a large population of society and the decrease in their performance indirectly caused the decline in the performance of the forces involved in the production, there were few scientific studies carried out on the frequency of MSDs in Iran so far. So, the purpose of the present study was to determine the frequency of MSDs by means of MFA and NERPA in women working in an electrical devices assembly workshop.

Methods

This research was a cross-sectional descriptive study performed in the assembly of electrical devices of one of the manufacturing workshops in Khuzestan province. The participants of this study were 84 female workers with an average age of 25 to 60 years and a work experience of 7 to 29 years. Regarding the fact that the number of employees in the manufacturing workshop was low, all employees participated in this study voluntarily. Firstly, all the research conduction steps were explained to the employees in order to observe research ethics. Also, they were guaranteed that this information would be kept confidential. The participants could give up at any time

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with complete consent. In this study, 13 occupations were selected, and 32 postures assessed the risk factors contributing to the MSDs and determined the risk levels in the studied participants by means of MFA and NERPA methods through field observation of the type of activity, interviewing the people during work, preparing photos of people's postures and reviewing people's medical records and reasons for absenteeism. It is worth mentioning that those who had a history of acute musculoskeletal problems or an impressive accident were excluded from the study. Firstly, this study used Nordic Questionnaire, which was designed by Mokhtarnia et al. (2015) on the standard Nordic Questionnaire, and its validity and reliability were confirmed to determine the frequency of MSDs.[24, 25] This questionnaire was known as a self-report method, which was investigated utilizing four-choice and yes-no questions in the physical activity questionnaire.[26] In the following, the MFA and NERPA assessment methods were applied, and their results were compared with each other to assess the risk factors contributing to MSDs and determine the risk levels in the studied participants.

MFA method

The Muscular Fatigue Assessment (MFA) method is known as a functional work assessment technique enriched by Rodgers and Williams in 1987 to describe workers' discomfort. Since workers monitored their fatigue, it was a desirable way of determining the amount of fatigue accumulated.[22] The MFA evaluation steps are explained in figure 1.

This method evaluated all areas of the body, including the neck, shoulders, waist, arms/elbows, wrists/hands/fingers, feet (from thighs to legs) / knees, ankles/feet/fingers. This method determined the priority level of corrective actions as low, medium, and high and very high concerning three variables, such as the level of effort, duration of effort, and repetition of effort in each area of the body.[27] Eventually, the result of the three mentioned factors assessment would be a three-digit number that exhibited the priority level of changes or corrective actions.

NERPA Method

NERPA was one of the upper limb posture assessment methods, which was firstly represented by Sanchez et al. in 2013. This method was applied to be used in different manual tasks.[22]

NEPRA steps are described below:

The First Step: Recording the Status of Work Conduction

Work conduction status assessment initiated with direct observation of the tasks of the examined person during several work cycles. The assessment and recording of the score of each poster during the work cycle were carried out based on the NERPA method.

Second Step: Scoring System

The scoring system in the NERPA method conformed with 11 specific steps. Body organs were classified A and B. Group A includes the arms, forearms, wrists, and Group B consists of the neck, trunk, and legs. Each central part of the body was assessed based on the amount of displacement from its normal state to analyze work postures. Then, score A and score B, and ultimately the final score of NERPA was obtained based on table C and by observing the effect of force and repetition of motion. After calculating the final score, the priority level of the corrective action would be determined.[28] The achieved scores would be between 1 and 7 on four levels. Level 1: Final score 1 or 2 (acceptable), Level 2: Final score 3 or 4 (requires further study), Level 3: Final score 5 and 6 (creating ergonomic intervention in the near future) and Final Level 4: Score Final 7 (immediate ergonomic interventions). Regarding the fact that all the workers working in the workshop were women and were few in number, the whole population working in the workshop was sampled. Then, the achieved information was examined, and SPSS software version 16 was applied to analyze them statistically. Following the final obtained score in each method, the Pearson test was used to evaluate the correlation results of methods' scores. Also, a t-test was applied to compare risk assessment methods for MSDs and Nordic Questionnaire. Furthermore, the significance level of statistical tests was equal to $P>0.05$.

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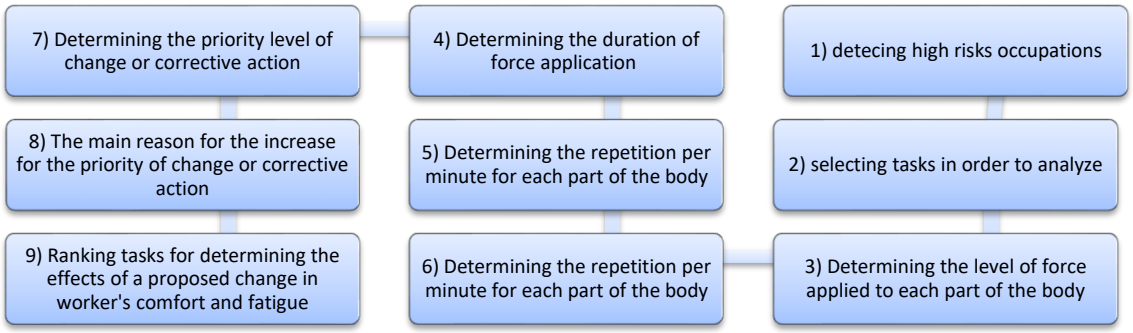

Figure1. MFA steps

Results

The female workers were working in the electrical devices manufacturing workshop with an average age of (7.31) 37.73 and a work experience of (5.86) 15.83 years. All the participants in this study were supposed to perform their tasks in a sitting posture. Concerning MFA and NERPA methods and evaluation worksheets and the type of workers' activities in sitting posture, none of the effort level characteristics related to the ankle and foot were evaluated in this checklist. According to workers' comments in the Nordic Questionnaire, 76% of them had MSDs, at least in one of their organs. The prevalence of MSDs in the past 12 months in different areas of the body reported by the Nordic Questionnaire was illustrated in Figure 2.

Since table 1 showed the results of MFA, the right wrist and waist in 56 (66.67%) of workers were at the "very high" level of corrective action priority that should be corrected quickly. Then, it can be mentioned that neck and right shoulder in 50 (59.52%) of workers in the "very high" level of corrective action priority, in which inappropriate ergonomic conditions should be measured as soon as possible. Findings declared that highest percentage of risk was associated with the right wrist of 56 workers (66/67%), waist of 56 workers (66.67%), the right shoulder of 50 workers (59.52%), neck of 50 workers (59.52%), left-right of 44 workers (52.38%), the right arm of 39 workers (46.42%), left arm of 33 workers (39.28%) and left wrist of 28 workers (33.33%), respectively.

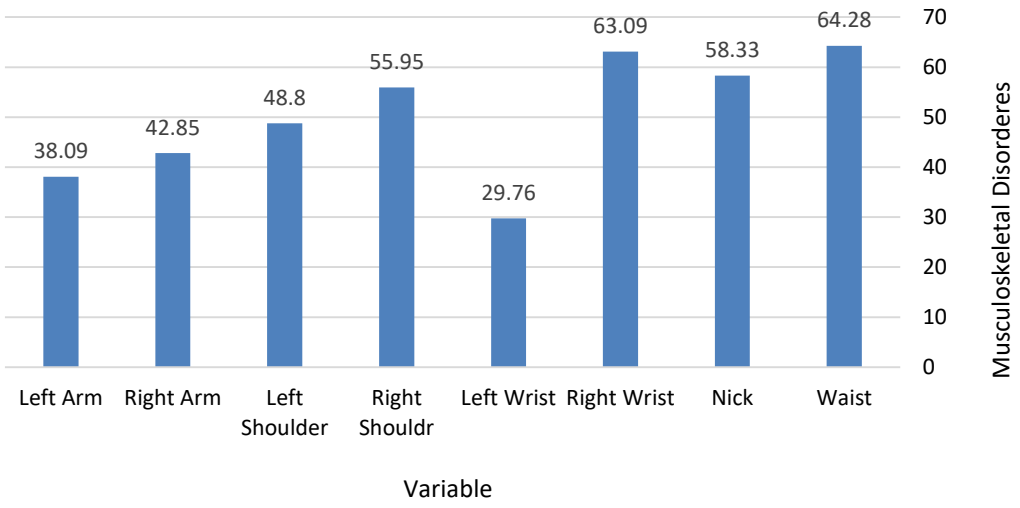

Figure2. Prevalence of the MSDs in assembly workers by Nordic Questionnaire

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Table1. Risk or corrective action priority in different areas with the use of the MFA method

Risk level or corrective action priority	Risk percentage in different areas							
	neck	Right shoulder	Left shoulder	waist	Left-arm	Right arm	Right wrist	Left wrist
Low	13.09	-	19.04	-	13.09	13.09	5.95	39.28
Medium	26.19	33.3	26.19	19.04	39.28	20.23	-	26.19
High	-	5.95	-	13.09	5.95	20.23	26.19	-
Very high	59.52	59.52	52.38	66.7	39.28	46.42	66.67	33.33

Table2. Risk or corrective action priority in different areas with the use of the NERPA method

Risk level or corrective action priority	Risk percentage in different areas							
	neck	Right shoulder	Left shoulder	waist	Left-arm	Right arm	Right wrist	Left wrist
Low	9.52	3.57	21.42	2.38	13.09	11.90	4.76	38.09
Medium	25	28.57	25	19.04	38.09	21.42	2.38	23.8
High	2.38	4.76	1.19	13.09	5.95	17.85	25	1.19
Very high	60.71	60.71	54.76	65.47	41.66	45.24	66.67	35.71

Table3. Correlation of MFA, NERPA methods and Nordic Questionnaires with one another

	Nordic	MFA	NERPA
Nordic	-	P=0.009 r=0.8	P=0.04 r=0.98
MFA	P=0.009 r=0.8	-	P=0.0098 r=0.75
NERPA	P=0.04 r=0.98	P=0.0098 r=0.75	-

As the results of NERPA was also illustrated in table 2, the right wrist of 56 workers (66.67%) and waist of 55 workers (65.47%) were at the "very high" level of corrective action priority, and corrective actions must be measured immediately. In the following, 61.3% of the neck and 60.8% of the right shoulder should be placed at the "very high" level of corrective action priority, in which inappropriate ergonomic conditions should be tackled as soon as possible. As the results cleared, a high percentage of workers in all different organs enjoyed the highest level of risk, which they were respected with the neck of 51 workers (60.71%), the right shoulder of 51 workers (60.71%), left shoulder of 46 workers (54.76%), waist of 55 workers (65.47%), left arm of 35 workers (41.66%), the right arm of 39 workers (46.42%), the right wrist of 56 workers (66.67%) and left wrist of 30 workers (35.71%), respectively.

Therefore, it can be mentioned that the areas of the waist, right wrist, neck, and right shoulder in the assembly job have a higher risk than other body parts for MSDs. Moreover, the results achieved by the Pearson correlation coefficient test declared an acceptable correlation between the results obtained from both methods (r=0.08, *P*-value<0.05). Furthermore, a significant and direct relationship could be observed between MFA and NERPA risk levels. This study figured out that 63 of studied the workers (75%) suffered from pain and fatigue while performing work. The correlation of MFA, NERPA methods, and Nordic Questionnaires with one another is cleared in Table 3.

Discussion

This study was conducted to compare the risk factors contributing to the MSDs of assembly workers with the use of MFA and NERPA methods in an electrical devices company. As cleared by results, a high percentage of workers had the highest level of risk in all different body organs. The results illustrated that a high prevalence of MSDs was observed among assembly workers due to undesirable ergonomic conditions of the work environment as well as incorrect body posture during work. The results of the other studies exhibited that the MFA method, as a tool for assessing ergonomic risk factor, was capable of evaluating repetitive tasks with repetitions fewer than 15 times per minute. This method was useful for evaluating all the muscles involved during the task conduction.[29, 30] The results of the present study declared that waist and right wrist with 66.67% had the highest level of risk, and this was because most workers were right-handed and did not have proper support in the chair, and they performed their activities with the right hand. On the other hand, since the least activities were performed on the left side, the left wrist had the lowest risk level, with 33.33%. Rodgers's study, which investigated the muscle fatigue in workers who

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transported 11-kilogram packages and installed them on the back seat of a vehicle with the use of MFA method, indicated that the areas of shoulder, waist, and hands incurred maximum fatigue due to the relatively heavy load and the lack of a suitable spot to place the side.[31] A study conducted by Chang et al. (2015) exhibited that 78.5% of workers, who had to twist their trunk while working, had low waist pain.[32] The results of examining the ergonomic status of assembly workers in the study of Dehghan et al. (2013) declared that SDMs symptoms were highly prevalent among assembly workers of electronic circuits. The highest prevalence was reported in the neck, waist, shoulders, and arms, respectively.[21]

Moreover, in the study carried out by Motamedzadeh et al. (2016) muscle fatigue in workers in an assembly industry was assessed with the MFA method, in which the neck, waist, legs, and knees organs were at a very high level in 6.67%, 20%, and 13.33% of workers, respectively.[30] As mentioned in the review method, the activity of the participants in this study was in a sitting posture, and the upper limbs were more involved. In the present study, the highest injuries were reported in the waist area at a very high-risk level. In the study by Jabari et al. (2017), which muscle fatigue and risk factors determination of tailors were examined with the use of the MFA method, it was found that the highest prevalence of MSDs in the area of the waist was 57%.[33] The most involved organs in tailors were upper limbs and confirmed the results of the present study. The results of the present study declared that 60% of workers suffer from MSDs in the neck area. This matter stressed that workers were forced to bend their necks due to low general and local lighting during performing tasks. Gheibi et al. (2015) discovered that workers who operated in a workshop with a recommended overall light intensity were more likely to suffer from MSDs in the area of the neck with 97.4% than those workers performing with a light intensity less than recommended light.[34]

By calculating the Pierson correlation coefficient between the results of Nordic, MFA, and NERPA study, it was revealed that the correlation between the findings of the Nordic Questionnaire and MFA was statistically significant. These findings were in line with the results of Motamedzadeh et al. And Jabbari et al. [30, 33] Furthermore, the results of the correlation coefficient between Nordic and NERPA Questionnaires declared a significant relationship between them, which was consistent with the results of the study conducted by Habibi et al.[35] Also, the relationship between MFA and NERPA methods was significant and had a correlation coefficient (P<0/001). According to the results of a study performed by Habibi et al. (2017) entitled "Assessing the risk of SMDs in an industrial company using NERPA and QEC methods and comparing their results," the matching rate of findings of Nordic Questionnaire with the determined priority level by QEC was higher than that of NERPA. Still, the Nordic Questionnaire had a significant relationship with the mentioned methods.[35] Concerning the correlation between Nordic Questionnaires and MFA and NERPA methods, this correlation between Nordic and NERPA method was higher in this study. In another study carried out by Zokaei et al. (2014) entitled "Assessment of MSDs risk using MFA method and the survey of correlation between its results and results of RULA method", it was concluded that MFA method had a higher validity when all body organs were more involved. Also, this method studied much smaller body organs.[36] The results of Zokaei's study confirmed the reason for the higher correlation between MFA and Nordic in comparison to the NERPA method. In a study that surveyed the ergonomic status of operational unit workers using NERPA, REBA, and RULA methods, there was no significant relationship between risk levels of NERPA and REBA methods (P<0/05).

Meanwhile, the risk levels of NERPA and RULA were statistically significant. Moreover, the highest risk was for the waist area, which was in line with the results of the present study.[37] Although QEC, MFA, and REBA methods were among the methods of risk assessment for the whole body, Previous studies illustrated that the NERPA method, which was a method of assessing the risk of the upper limbs, was able to be associated with risk assessment methods of the whole body, as it was seen in the study by Habibi, but it was refuted in the study by Zokaei.[35, 36] This contradiction could be deduced that the type of occupations surveyed in different studies and the examination of the body organs involved in the activities were able to affect the results of this study and the mentioned studies. In previous studies examining the anthropometric body dimensions between Iranian men and women, it was cleared that there was a significant difference between their dimensions [38-41]. In the present study, the only MSDs in women workers were surveyed. This single-gender investigation could also affect the results of the study. So, the designed dimensions of equipment and

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workstations in the industry were typically provided for men's activities and might leave a greater impact on women's MSDs.

Conclusion

The assessments in this study indicated that there was a high matching level between the findings of the Nordic Questionnaire and the determined priority level by MFA and NERPA. It is worth mentioning that, concerning the findings, NERPA and MFA methods investigated the various factors of the prevalence of symptoms of MSDs such as body postures, the force required to perform muscle activity, workstations, etc. Therefore the use of NERPA and MFA methods was appropriate with respect to the working conditions with the aim of investigating the prevalence of symptoms of MSDs. As mentioned above and based on the type of activity and the aim of the assessment, it can be declared that the MFA method assessed more involved body organs in the activity. On the other hand, the NERPA method evaluated a much smaller body involved in the activity organs more accurately. When the lower limbs were used, the MFA method would be more preferable to the NERPA method.

The diagnosis and automatic prediction of MSDs have broad applications in human factor engineering, to predict and prevent the occurrence of musculoskeletal injuries during various activities. The results of the Nordic Questionnaire and the posture assessment of women assembly workers using MFA and NERPA methods declared that there was a high risk of MSDs in workers' different body parts, so the corrective action or intervention in this unit would be required. Regarding the fact that the prevalence of MSDs in the area of wrist and waist had the highest percentage in this study, it was recommended to use a suitable chair and desk-based on the anthropometric structure to improve work posture. Also, by modifying the general and local lighting status of the work environment and using high magnification eye lenses, this study was able to prevent undesirable postures during work and the occurrence of MSDs, especially in the neck and shoulder areas. Moreover, training the proper method of work performance that led to changes in behavior was of a particular performance, and ultimately, the use of management measures could be conducive to improve the work cycle and rest. This study had some limitations, and one of them was the low number of participants. So, it was recommended to use the methods of 3DSSPP, ErgoMan, and Santos in future studies to evaluate the ergonomic status of the work environment. These techniques presented more information about the body posture, accessibility, and vision of the individual.

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