RESEARCH ARTICLE

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Effectiveness of Three Ergonomic Risk Assessment Tools, Namely NERPA, RULA, and REBA, for Screening Musculoskeletal Disorders

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Background & Aims of the Study: Work-related musculoskeletal disorders (WRMSDs) are among the most common types of occupational diseases and damages, especially in repair and maintenance occupations. There are various methods for the prediction of the risk factors affecting the prevalence of WRMSDs. This study aimed to determine the effectiveness of three ergonomic risk assessment tools, namely the Novel Ergonomic Postural Assessment (NERPA), Rapid Upper Limb Assessment (RULA), and Rapid Entire Body Assessment (REBA), for screening the musculoskeletal disorders in the employees of repair and maintenance occupation in a power plant equipment industry in Alborz province, Iran, in 2017.

Materials and Methods: This cross-sectional study was carried out on all employees in the repair and maintenance department of a power plant equipment industry, including 295 subjects in six occupational groups. The General Nordic Questionnaire was used to determine the levels of musculoskeletal disorders. The REBA, RULA, and NERPA methods were employed in order to predict the risk of developing musculoskeletal disorders. Finally, the data related to the real values of musculoskeletal disorders and risk values predicted by the three mentioned methods were analyzed through Spearman's rank correlation coefficient and kappa agreement coefficient at the significance level of 0.05 using SPSS software (version 25).

Results: Mean age of the participants was reported as 37.52±3.61 years. Correlation values between the levels of musculoskeletal disorders and risk levels predicted in the RULA, NERPA, and REBA were observed to be 0.764, 0.723, and 0.689, respectively ($P<0.05$). Correlation coefficient values of the risk levels predicted in the RULA method with NERPA and REBA were 0.767 and 0.620, respectively ($P<0.05$).

Conclusion: Based on comparing the correlation level of prevalence rates of musculoskeletal disorders with predicted risk levels in the three studied methods, the results indicated that the best method for predicting the risk of musculoskeletal disorders in different examined tasks was the RULA method. However, none of the methods had adequate comprehensiveness for the assessment of all four risk levels.

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Background

Work-related musculoskeletal disorders (WRMSDs) are among the most common types of occupational diseases and damages. Moreover, WRMSDs are the main reasons for debilitation and damage to workers, loss of working time, increased costs and economic losses, as well as diminished productivity (1, 2). Musculoskeletal disorders involve the disorders of muscles, tendons, tendon sheaths, peripheral nerves, joints, bones, ligaments, and blood vessels. The aforementioned disorders are due to repeated exposure to stress over time or immediate or acute trauma. The symptoms include discomfort, pain, fatigue, stiffness, swelling, limited range of motion, muscle strains, paresthesia, and tingling sensations (3-5).

According to the investigation performed and documents presented by the World Health Organization in 2013 among occupational diseases, WRMSDs stands following respire-atory diseases in the second rank (6). Based on the reports, 40% of the work-related compensation costs in the world are related to WRMSDs (7). In Iran, musculoskeletal disorders are also the main cause of debilitation and related costs. According to available statistics, about 48% of work-related diseases consist of cumulative damages developed in response to physical or mechanical factors, which are themselves considered musculoskeletal conditions (8).

Among the occupations in which the prevalence of ergonomic disorders is very high are the professions associated with repair and maintenance in factories and industries. The individuals employed in repair and maintenance departments perform various tasks, including transporting loads, adjusting devices, replacing pieces, welding, milling, and periodic machine inspecting. When doing their tasks, these workers are affected by different and undesirable physical situations (9).

Previous studies conducted on one or a number of tasks by individuals employed in the repair and maintenance departments reported the presence of these disorders (10, 11). For instance, it was observed that the majority of physical problems in welding and milling among the frequent duties in repair and maintenance occupations include back pain, pain in the shoulders and knees, vibration white finger, carpal tunnel syndrome, and diminished muscular power (12).

Another study demonstrated that the prevalence of musculoskeletal disorders is high among repairmen employed in different industries, mostly affecting back and neck regions (4). Results of a study carried out in 2016 demonstrated that the prevalence rate of musculoskeletal disorders among the individuals employed in the repair and maintenance department is 21.8%, and it is among the occupations predisposing the person to develop WRMSDs (13).

To prevent these disorders, the effective risk factors in each occupation and task must be assessed in the first step predicting whether these occupations have the potentials to develop musculoskeletal disorders or not. Then, control measures can be performed on musculoskeletal disorders. Today, various methods have been devised to predict and assess the risk factors affecting the incidence of musculoskeletal disorders. Each method considers various factors, including the different states of body deviation from natural posture, repeated movements, force exertion, duration, as well as other environmental and individual factors. These methods are generally categorized as self-report, observational, and direct measurements (14, 15).

Among the most common methods are observational methods, as they are simple, flexible, and inexpensive for implementation. Among observational methods, the Rapid Entire Body Assessment (REBA) (focusing on whole-body assessment), Rapid Upper Limb Assessment (RULA), and Novel Ergonomic

Postural Assessment (NERPA) (focusing on the assessment of the upper limb) methods can be mentioned. The aforementioned techniques are among the widely used methods in the ergonomic assessment. In this regard, a small number of applied studies were conducted for investigating the predictive power of musculoskeletal disorders by these methods to identify the best method in different occupations (16).

Aims of the study

Predicting the risk of musculoskeletal disorders for preventing WRMSDs is very important. In addition, up to now, no study has been performed to identify the best method for predicting the risk of musculoskeletal disorders in repair and maintenance occupations. Therefore, the present study aimed to investigate the effectiveness of three ergonomic risk assessment tools, namely the NERPA, RULA, and REBA, for screening the musculoskeletal disorders in the employees of repair and maintenance occupation in a power plant equipment industry.

Materials & Methods

The present cross-sectional study was performed on 320 male subjects employed in the repair and maintenance department of a power plant industry in Alborz, Iran, working in six different duty groups, including general repairs (including the tasks of replacing pieces, milling, welding, transferring and locating machines, lubricating, and electricity repairs), adjusting machines, periodic servicing of machines, periodic checking and inspecting of machines, cleaning and washing machines plus devices, and lathing in 2017. Table 1 tabulates the summary of the features related to the examined tasks. The inclusion criteria were at least one year of work experience in the repair and maintenance department, and the exclusion criteria were defined as a lack of enough consent to participate in the study.

Study design

Eventually, based on the inclusion and exclusion criteria, a total of 295 individuals remained in the present study. Then, the stages of study implementation were explained to the subjects, and they announced their consent to participate in this study. Next, the General

Table 1) Duties and tasks under study

Duty		Task
General repairs	Replacing pieces	Turning off the device, opening the defective parts, replacing parts, and restarting
	Welding	Preparing welding machine and parts, performing welding operations, and cleaning
	Transferring and locating machines	Connecting the equipment to the overhead crane, moving the equipment to the designated location, precise positioning of the device, and opening the device from the crane
	Electricity repairs	Disconnecting power supply, determining causes of failure, performing repair, restarting, and final reviewing
Adjusting machines		Turning off equipment, initial inspecting, checking parts, adjusting, and restarting equipment
Periodic servicing of machines		Turning off equipment, initial inspecting, checking parts, replacing or repairing defective parts, final inspecting, and restarting equipment
Periodic checking and inspecting of machines		Initial inspecting, filling the relevant checklists, reviewing causes of defects
Cleaning and washing machines and devices		Turning off equipment, opening or sealing sensitive parts, disconnecting power, washing and cleaning, as well as restarting
Lathing		Preparing parts and lathe, lathing, and delivering parts

Nordic Questionnaire was used in order to determine the prevalence of developing musculoskeletal disorders among the subjects over the past year. First part of this questionnaire contained items associated with demographic information; however, the subsequent sections included the items about the musculoskeletal disorders of individuals in the neck region, upper back region, lower back region, shoulder region, thigh region, and knee, respectively, through Yes/No questions.

The above-mentioned questionnaire is a standard and well-known questionnaire for the determination of musculoskeletal disorders, whose reliability and validity have already been confirmed (17). Afterward, based on the prevalence of musculoskeletal disorders in different limbs of the subjects, these disorders were categorized in four levels, including low (prevalence rate: 0-25%), moderate (prevalence rate: 25-50%), high (prevalence rate: 50-75%), and very high (prevalence rate: 75-100%).

To calculate the prevalence of musculoskeletal disorders in the entire body, the prevalence of these disorders in different parts of the body was averaged and then categorized according to the above-mentioned classification. Levels of Nordic musculoskeletal disorders assessed by the Nordic General Questionnaire are considered the golden standard. In the next stage, the working cycles of the individuals were carefully observed. Then, the films and images were taken from the improper postures of these subjects, and their essential occupational information was noted in this study. After that, the films and images related to the worst and most frequent posture of the subjects were chosen for further investigations.

Eventually, the REBA, RULA, and NERPA were individually used in order to investigate the risk of developing musculoskeletal disorders in the improper posture selected for each person. In addition, there is a summary of these three methods in this study. Moreover, Table 2 tabulates the information associated with the comparison of the angles in the three methods. Furthermore, the comparison of force, type of activity, and risk levels in the three methods is presented in Table 3.

Musculoskeletal risk assessment methods

Rapid Upper Limb Assessment

This method was firstly presented by McAtamney and Corlett for the assessment of activities with a focus on the upper limbs. Bodily posture, exerted force, and static muscular activity of an individual are evaluated through this technique. Side of the body with a worse situation is evaluated in this method. In addition to the posture, the relevant force and movements are also considered in this technique. The final score range is considered within 1-7, and the scores 1-2, 3-4, 5-6, and 7 represent low, moderate, high, and very high risk levels, respectively (18). Reliability and validity of this method were confirmed in a previous study (15).

Rapid Entire Body Assessment

This method was developed based on the RULA and firstly presented by McAtamney and Hignett. Initially, the posture or activity is chosen for evaluation. Then, the posture of different limbs is coded using the design diagrams, and the score of the limb posture is combined with force exertion and type of activity. Finally, the total scores of risk incidence related to musculoskeletal disorders, priority level of corrective measures, and necessity of implementing ergonomic interventional programs are specified in this method. In this technique, the scores of 1-3, 4-7, 8-10, and 11-15 represent low, moderate, high, and very high risk levels, respectively (19). Reliability and validity of this method were confirmed in a previous study (20).

Table 2) Comparison between the angles and risk levels in Rapid Upper Limb Assessment, Rapid Entire Body Assessment, and Novel Ergonomic Postural Assessment

Parameter	Direction of change	Risk level	Angles in different methods		
			NERPA	RULA	REBA
Arm	Flexion and extension	Low	-20 to 20	-20 to 20	-20 to 20
		Moderate	>-20, 20 to 60	>-20, 20 to 45	>-20, 20 to 45
		High	>60	>45, >90	>45, >90
	Abduction and adduction	Low	0 to 20	0	0
		Moderate	20 to 60	0	0
		High	>60	0	0
Forearm	Flexion and extension	Low	60 to 100	60 to 100	60 to 100
		High	<60, >100	<60, >100	<60, >100
	Abduction and adduction	Low	<15	0	-
		High	>15	>0	-
Wrist	Flexion and extension	Low	0 to 15	0	0 to 15
		Moderate	15 to 45	0 to 15	-
		High	>45	>15	>15
	Radial and ulnar deviations	Low	<10	0	0
		High	>10	>0	>0
	Rotation to sides	Low	<70	0	0
		High	>70	>0	>0
Trunk	Flexion and extension	Low	0 to 20	0 to 20	0 to 20
		Moderate	20 to 40	20 to 60	20 to 60
		High	0< , >40	0< , >60	0< , >60
	Bending to sides	Low	<10	0	0
		High	>10	>0	>0
	Rotation to sides	Low	<10	0	0
		High	>10	>0	>0
Neck	Flexion and extension	Low	0 to 10	0 to 10	0 to 20
		Moderate	10 to 20	10 to 20	-
		High	>20, <-5	>20, <0	>20, <0
	Bending to sides	Low	<10	0	0
		High	>10	>0	>0
	Rotation to sides	Low	<10	0	0
		High	>10	>0	>0
Legs	Balance	Low	Balanced	Balanced	Balanced
		High	Unbalanced	Unbalanced	Unbalanced
	Flexion	Low	-	-	<30
		Moderate	-	-	30 to 60
		High	-	-	>60

NERPA: Novel Ergonomic Postural Assessment
RULA: Rapid Upper Limb Assessment
REBA: Rapid Entire Body Assessment

Novel Ergonomic Postural Assessment

This method was also developed based on the RULA and is one of the techniques for assessing the posture of upper limbs firstly developed by Sanchez et al. in 2013. The NERPA is among the newest methods presented in the domain of assessing bodily postures. This technique also uses scores for expressing physical states and conditions. Eventually, this method presents scores in the four levels of corrective measures. The final score range in this technique, as in the RULA method, is within 1-7; scores of 1-2, 3-4, 5-6, and 7 represent low, moderate, high, and very high risk levels, respectively (21). Reliability and validity of this method were also confirmed in a previous study (22).

Data analysis

Finally, to compare the predictive power of developing musculoskeletal disorders using the three above-mentioned methods, all the collected data were inserted into SPSS software (version 25). The collected data were

Table 3) Comparison between force, type of activity, and risk levels in Rapid Upper Limb Assessment, Rapid Entire Body Assessment, and Novel Ergonomic Postural Assessment

Parameter	Risk level	Parameter classification		
		NERPA	RULA	REBA
Force	Low	<2	<2	<5
	Moderate	2-10	2-10	5-10
	High	>10	>10	>10
Type of activity	Low	Nonstatic and nonrepeated	Nonstatic and nonrepeated	Nonstatic and nonrepeated
	High	Static and repeated	Static and repeated	Static and repeated

NERPA: Novel Ergonomic Postural Assessment
RULA: Rapid Upper Limb Assessment
REBA: Rapid Entire Body Assessment

then analyzed by Spearman's rank correlation coefficient and kappa agreement coefficient at the significance level of 0.05. The Kolmogorov-Smirnov and Shapiro-Wilk tests were utilized for investigating the normality/ abnormality of data distribution.

Results

Mean age of the participants was reported as 37.52±3.61 years. In terms of occupational tasks, 49.1%, 13.9%, 20%, 10.2%, 4.4%, and 2.4% of the subjects were in charge of general repairs, adjusting machines, periodic servicing of machines, periodic checking and inspecting of machines, washing and cleaning machines and devices, as well as lathing. Table 4 tabulates the prevalence of musculoskeletal disorders in different limbs of the participants regarding occupational tasks. According to the results, the prevalence rates of the aforementioned musculoskeletal disorders in the neck, shoulders, elbow, hand/wrist, back, waist, knee, leg/ankle, and hip/thigh were 56.3%, 64.1%, 43.7%, 32.5%, 44.4%, 52.5%, 39.3%, 38%, and 34.6%, respectively. The results obtained from the analysis of the prevalence rates of musculoskeletal disorders showed that 26%, 40%, 21%, and 13% of musculoskeletal disorders were at low, moderate, high, and very high levels, respectively.

Furthermore, the results obtained from assessing the ergonomic risk of occupational tasks indicated that in the REBA method, 20.8%, 41.2%, 20.6%, and 17.4% of predicted risk levels were at low, moderate, high, and very high risk levels, respectively. In the RULA, 2.4%, 22.1%, 48.8%, and 26.7% of predicted risk levels were at low, moderate, high, and very high risk levels, respectively. Finally, in the NERPA method, 36.2%, 30.8%,

Table 4) Prevalence of musculoskeletal disorders based on the percentage in the limbs of the participants according to the type of occupational task

Task	Limb									
	Neck (%)	Shoulder (%)	Elbow (%)	Hand/Wrist (%)	Back (%)	Waist (%)	Knee (%)	Leg/Ankle (%)	Hip/Thigh (%)	Total (%)
General repairs	65.3	79.2	45.6	33.8	55.5	65.4	36.4	39.8	48.3	52.14
Adjusting machines	58.5	63.4	41.5	28.6	36.6	46.3	39	43.9	17.1	41.65
Periodic servicing of machines	39	61	44.1	33.9	37.3	47.5	40.7	47.5	39	43.33
Periodic checking and inspecting of machines	50	66.7	50	36.7	43.3	60	56.7	43.3	23.3	41.77
Cleaning and washing machines	84.6	84.6	38.5	38.5	15.4	53.8	53.8	30.8	15.4	46.15
Lathing	71.4	71.4	42.9	14.3	14.3	57.1	14.3	14.3	26.8	36.31

27.3%, and 5.7% of predicted risk levels were at low, moderate, high, and very high risk levels, respectively. The findings related to the frequency percentage of the risk levels obtained in the REBA, RULA, and NERPA regarding the levels of musculoskeletal disorders were depicted in Figure 1.

In addition, Figure 2 illustrates the frequency percentage of the risk levels obtained in these three methods in terms of the studied occupational tasks.

The results obtained from investigating the

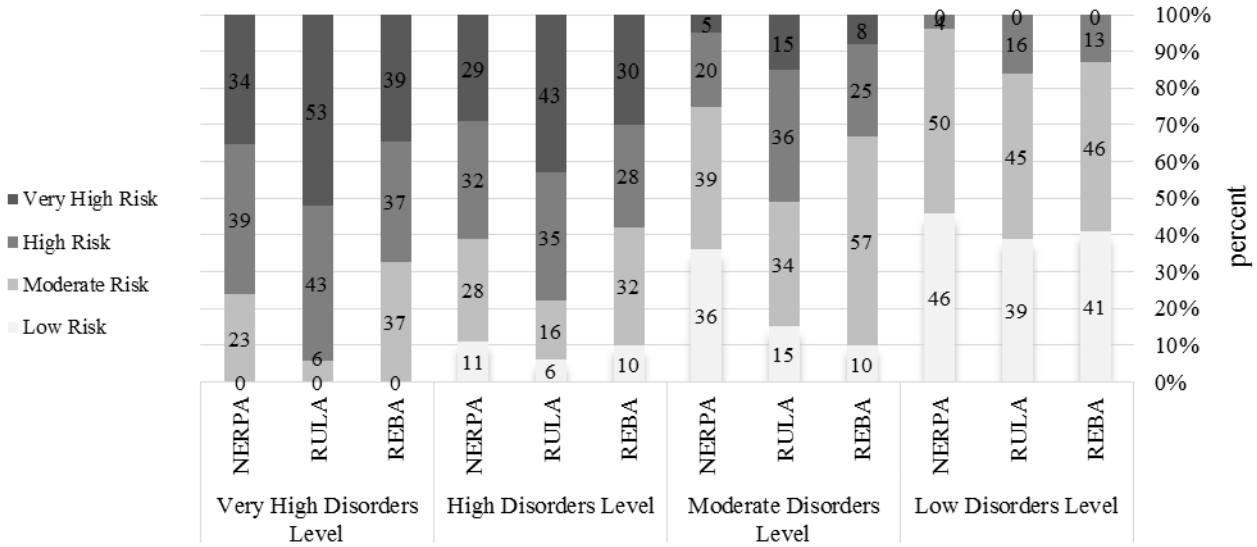

Figure 1) Frequency distribution of the risk levels obtained from Rapid Entire Body Assessment, Rapid Upper Limb Assessment, and Novel Ergonomic Postural Assessment methods regarding the levels of musculoskeletal disorders

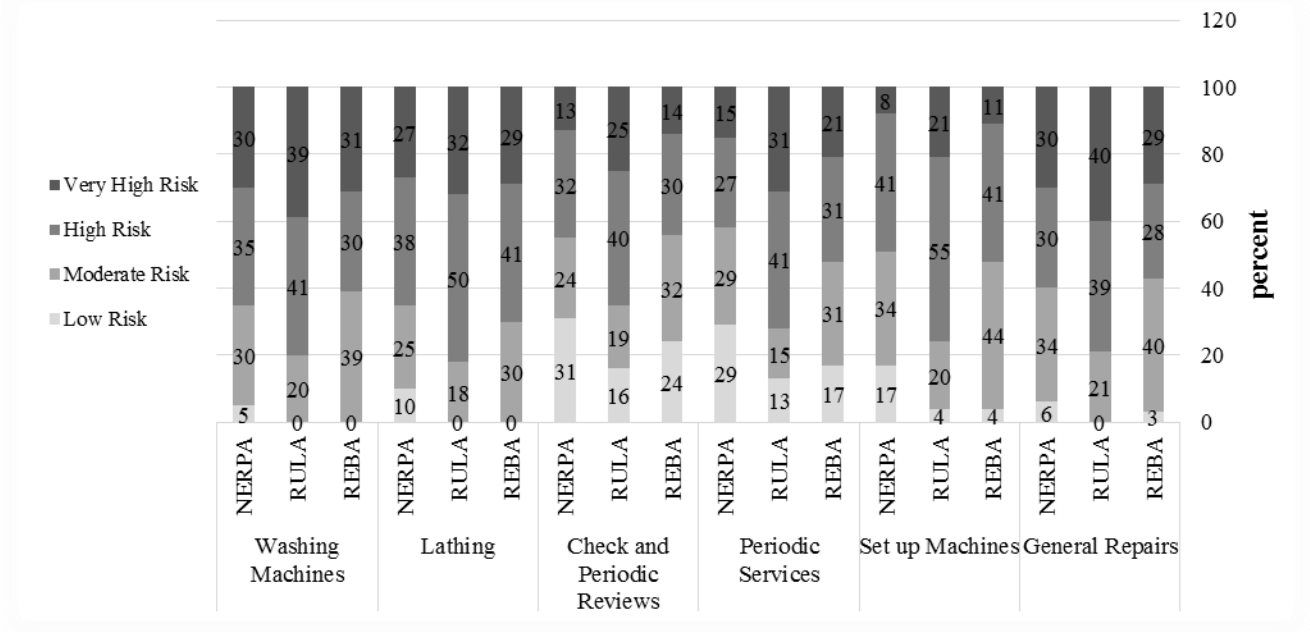

Figure 2) Frequency distribution of the risk levels obtained from Rapid Entire Body Assessment, Rapid Upper Limb Assessment, and Novel Ergonomic Postural Assessment methods in terms of occupational tasks

normality of data distribution using the Kolmogorov-Smirnov and Shapiro-Wilk tests

indicated that the data distribution was not normal (P<0.05). Accordingly, Spearman's rank correlation coefficient and kappa agreement coefficient were used in this study. The correlation values between the risk levels predicted by the three aforementioned methods and levels of musculoskeletal disorders obtained by the General Nordic Questionnaire are presented in Table 5.

In addition, the extent of correlation between the risk levels predicted by the three aforementioned methods and levels of musculoskeletal disorders based on the General Nordic Questionnaire in different occupational tasks were shown in Table 6.

The results obtained from Spearman's rank

Table 5) Correlation values between the risk levels predicted by Novel Ergonomic Postural Assessment, Rapid Upper Limb Assessment, and Rapid Entire Body Assessment methods and levels of musculoskeletal disorders based on the General Nordic Questionnaire

Parameter	Correlation coefficient				P-value			
	Level of musculoskeletal disorders	NERPA level	RULA level	REBA level	Level of musculoskeletal disorders	NERPA level	RULA level	REBA level
Level of musculoskeletal disorders	1.00	0.723	0.764	0.689	-	<0.001	<0.001	<0.001
NERPA level	0.723	1.00	0.767	0.66	<0.001	-	<0.001	<0.001
RULA level	0.764	0.767	1.00	0.62	<0.001	<0.001	-	0.001
REBA level	0.689	0.66	0.62	1.00	<0.001	<0.001	<0.001	-

NERPA: Novel Ergonomic Postural Assessment
RULA: Rapid Upper Limb Assessment
REBA: Rapid Entire Body Assessment

Table 6) Correlation values between the risk levels predicted by Novel Ergonomic Postural Assessment, Rapid Upper Limb Assessment, and Rapid Entire Body Assessment methods and levels of musculoskeletal disorders based on the General Nordic Questionnaire in different occupational tasks

Task	Parameter	Correlation coefficient				P-value		
		Level of musculoskeletal disorders	NERPA level	RULA level	REBA level	NERPA level	RULA level	REBA level
General repairs	Level of musculoskeletal disorders	1	0.724	0.766	0.692	<0.001	<0.001	<0.001
	NERPA level	0.724	1	0.783	0.659	-	<0.001	<0.001
	RULA level	0.766	0.783	1	0.613	<0.001	-	<0.001
	REBA level	0.692	0.659	0.613	1	<0.001	<0.001	-
Adjusting machines	Level of musculoskeletal disorders	1	0.712	0.746	0.503	<0.001	<0.001	0.003
	NERPA level	0.712	1	0.754	0.613	-	<0.001	<0.001
	RULA level	0.746	0.754	1	0.423	<0.001	-	0.005
	REBA level	0.503	0.613	0.423	1	<0.001	0.005	-
Periodic servicing of machines	Level of musculoskeletal disorders	1	0.689	0.711	0.649	<0.001	<0.001	<0.001
	NERPA level	0.689	1	0.703	0.512	-	<0.001	0.002
	RULA level	0.711	0.703	1	0.611	<0.001	-	<0.001
	REBA level	0.649	0.512	0.611	1	0.002	<0.001	-
Periodic checking and inspecting of machines	Level of musculoskeletal disorders	1	0.697	0.723	0.634	<0.001	<0.001	<0.001
	NERPA level	0.697	1	0.613	0.591	-	<0.001	<0.001
	RULA level	0.723	0.613	1	0.567	<0.001	-	<0.001
	REBA level	0.634	0.591	0.567	1	<0.001	<0.001	-

Table 6) Continued

Cleaning and washing machines	Level of musculoskeletal disorders	1	0.612	0.682	0.374	<0.001	<0.001	0.006
	NERPA level	0.612	1	0.652	0.652	-	<0.001	<0.001
	RULA level	0.682	0.652	1	0.564	<0.001	-	<0.001
	REBA level	0.374	0.652	0.564	1	<0.001	<0.001	-
Lathing	Level of musculoskeletal disorders	1	0.685	0.709	0.593	<0.001	<0.001	<0.001
	NERPA level	0.685	1	0.674	0.611	-	<0.001	<0.001
	RULA level	0.709	0.674	1	0.514	<0.001	-	<0.001
	REBA level	0.593	0.611	0.514	1	<0.001	<0.001	-

NERPA: Novel Ergonomic Postural Assessment
RULA: Rapid Upper Limb Assessment
REBA: Rapid Entire Body Assessment

Table 7) Kappa agreement coefficients between the risk levels obtained by Novel Ergonomic Postural Assessment, Rapid Upper Limb Assessment, and Rapid Entire Body Assessment methods in different occupational tasks

Method	Task						
	Adjusting machines	General repairs	Periodic servicing of machines	Periodic inspecting of machines	Cleaning machines and devices	Lathing	Total
RULA and NERPA	0.712*	0.760*	0.582*	0.612*	0.591*	0.658*	0.661*
RULA and REBA	0.532*	0.542*	0.491*	0.514*	0.483*	0.512*	0.532*
REBA and NERPA	0.511*	0.532*	0.466*	0.521*	0.496*	0.519*	0.568*

RULA: Rapid Upper Limb Assessment
NERPA: Novel Ergonomic Postural Assessment
REBA: Rapid Entire Body Assessment
*P<0.05

Table 8) Scoring values obtained in Rapid Upper Limb Assessment, Novel Ergonomic Postural Assessment, and Rapid Entire Body Assessment methods according to the organs

Organ	Prevalence of WRMSDs (%)	Score (Mean [SD])		
		RULA	NERPA	REBA
Arm	64.1	2.66 (0.23)	3.26 (0.31)	2.09 (0.15)
Forearm	43.7	2.62 (0.41)	2.43 (0.26)	1.16 (0.21)
Wrist	32.5	2.34 (0.41)	2.13 (0.19)	1.21 (0.23)
Trunk	48.4	3.61 (0.26)	3.32 (0.18)	3.20 (0.41)
Neck	56.3	4.39 (0.28)	3.11 (0.24)	1.62 (0.29)
Legs	38.0	1.44 (0.19)	1.32 (0.18)	3.37 (0.36)

WRMSDs: Work-related musculoskeletal disorders
SD: Standard deviation
RULA: Rapid Upper Limb Assessment
NERPA: Novel Ergonomic Postural Assessment
REBA: Rapid Entire Body Assessment

correlation coefficient in tables 5 and 6 indicated that the correlation coefficients between the risk levels obtained in the RULA and NERPA were considerably higher than the correlation coefficients between the risk levels obtained in the RULA and REBA. Accordingly, Table 7 tabulates the kappa coefficient values between the results obtained from examining the risk levels in the NERPA, RULA and REBA methods in different occupational groups. The findings showed that the maximum correlation coefficient and kappa coefficient between the three methods were observed in the tasks related to general repairs.

Scoring values of the three studied methods based on the organs of the participants are also studied and presented in Table 8.

The relationship between the scores obtained

Table 9) Correlation values between the scores of Rapid Upper Limb Assessment, Novel Ergonomic Postural Assessment, and Rapid Entire Body Assessment and prevalence of musculoskeletal disorders in each organ

Organ	Parameter	Correlation coefficient			
		Prevalence of WRMSDs (%)	score NERPA	RULA score	REBA score
Arm	Prevalence of WRMSDs	1	0.699*	0.619*	0.573*
	score NERPA	0.699*	1	0.721*	0.681*
	score RULA	0.619*	0.721*	1	0.703*
	score REBA	0.573*	0.681*	0.703*	1
Forearm	Prevalence of WRMSDs	1	0.623*	0.671*	0.593*
	score NERPA	0.623*	1	0.728*	0.530*
	score RULA	0.671*	0.728*	1	0.512*
	score REBA	0.593*	0.530*	0.512*	1
Wrist	Prevalence of WRMSDs	1	0.602*	0.631*	0.514*
	Score NERPA	0.602*	1	0.739*	0.546*
	score RULA	0.631*	0.739*	1	0.512*
	score REBA	0.514*	0.546*	0.512*	1
Trunk	Prevalence of WRMSDs	1	0.614*	0.655*	0.501*
	score NERPA	0.614*	1	0.632*	0.611*
	score RULA	0.655*	0.632*	1	0.578*
	score REBA	0.501*	0.611*	0.578*	1
Neck	Prevalence of WRMSDs	1	0.746*	0.812*	0.291**
	score NERPA	0.746*	1	0.581*	0.303**
	score RULA	0.812*	0.581*	1	0.231**
	score REBA	0.29**	0.303**	0.231**	1
Legs	Prevalence of WRMSDs	1	0.290**	0.281**	0.699*
	score NERPA	0.290**	1	0.625*	0.311**
	score RULA	0.281**	0.625*	1	0.298**
	score REBA	0.699*	0.311**	0.298**	1

WRMSDs: Work-related musculoskeletal disorders
NERPA: Novel Ergonomic Postural Assessment
RULA: Rapid Upper Limb Assessment
REBA: Rapid Entire Body Assessment
*P<0.001
**P<0.05

in the three studied methods and prevalence of WRMSDs in different organs are also presented in Table 9.

Discussion

The results obtained from the present study indicated that the periodic prevalence rates of musculoskeletal disorders among the studied individuals in the neck, shoulders, elbow, hand/wrist, back, waist, knee, leg/ankle, and hip/thigh were 56.3%, 64.1%, 43.7%, 32.5%, 44.4%, 52.5%, 39.3%, 38%, and 34.6%, respectively. Ekpenyong et al. in 2014 examining repairmen concluded that 45.8% of the aforementioned disorders were related to the neck and upper limbs, which is in line with the results of the present study (4). Furthermore, the levels of the aforementioned disorders categorized into four groups as low, moderate, high, and very high risk levels were reported as 26%, 40%, 21%, and 13% among the subjects in this study, respectively. These results revealed that most tasks in repair and maintenance occupations have a dangerous risk in developing musculoskeletal disorders, highlighting the necessity of paying attention to these occupations.

Furthermore, the results of the present study generally revealed that overall the NERPA method predicted a low risk level of musculoskeletal disorders better than the two other methods. In addition, the REBA predicted the moderate levels better, and the RULA predicted the high and very high risk

levels better than the two other methods (Figure 1). Even the results of analyzing the risk of musculoskeletal disorders in different occupations also confirmed this finding (Figure 2).

Results of a study conducted by Kee and Karwowski in 2007 also showed that the RULA predicted 56% of the risk of musculoskeletal disorders of occupations at moderate and high levels. However, the Ovako Working Posture Analyzing System (OWAS) and REBA demonstrated 79% of the risk of musculoskeletal disorders of the same occupations at low and very low levels (23). Sanchez et al. (2013) also concluded that the RULA method does not have adequate power for the prediction of low risks. Specifically, the results showed that the RULA did not categorize any of the operations at a low risk level; nevertheless, the NERPA classified 16.30% of operations as low risk (21).

Chaisson et al. (2012) conducted a study to compare eight methods for the risk assessment of musculoskeletal disorders, and they observed that the RULA cannot identify low risks. On the other hand, 76% and 24% of working stations were categorized with high and moderate risks, respectively (14).

Results of the present study also revealed that the RULA can identify low risks; however, its predictive power for low risks is lower, compared to that of the REBA and NERPA. Possibly, the reason for this discrepancy is that the occupations examined in other studies were mostly reported with high risk. In any case, comparing the angles of methods showed that in the RULA, there are only a few categorizations for the angles of different parts of the body. Furthermore, in comparison to the two other methods, high-risk scores are assigned to smaller angular ranges. These factors cause the RULA to overestimate a certain risk.

On the other hand, the results of a study performed by Haghshenas et al. in 2016 indicated that the NERPA has a good ability in the identification of low risks. Specifically, in the investigated postures, Quick Exposure Check (QEC) method identified 51.72% of cases with high risk; however, the NERPA indicated only 33.33% of subjects with high risk (24). However, the power of the NERPA method for the prediction of high and very high risks is low. The NERPA method was developed only based on correcting the angles of the RULA. Nevertheless, the results indicated that this correction of angle has not been very successful. Although the correction of angles, elevation of the classification number of angles, and consideration of larger angular ranges for higher risks resulted in the enhanced predictability of low risks, it has reduced the ability to identify high risks.

Concerning the REBA as a method developed based on the RULA, Kee and Karwowski (2007) concluded that the OWAS and REBA are less sensitive to postural stress than the RULA, and they underestimate the postural load for the states of interest (23). In addition, the results of a study conducted by Chiasson et al. (2012) revealed that among the eight methods of QEC, Finish Institute of Occupational Health, RULA, REBA, Hand Activity Level, Job Strain Index, Occupational Repetitive Action, and EN standard 1005-3, the REBA had the maximum correlation with the RULA. However, the two aforementioned methods were not able to predict any low risk (14).

Evaluation of the relationship between the obtained scores in the three studied methods and prevalence of WRMSDs in different organs showed that the scores obtained in the RULA method had the highest correlation coefficient with the prevalence of WRMSDs in the forearm, wrist, trunk, and neck. The scores obtained in the NERPA method had the highest correlation coefficient with the prevalence of WRMSDs in the arm. Finally, the scores obtained by the REBA method also correlated the most with the prevalence of WRMSDs in the legs (Table 9). Consequently,

as most activities in repair maintenance occupations affect the extremity of the upper limbs, the REBA method is not a suitable technique for screening WRMSDs in these professions.

Overall, the above-mentioned results suggested that the REBA underestimates very high risks; nonetheless, it is not able to properly identify low risks. These findings are in line with the results of the present study. The reason might be attributed to the fact that in the RULA, some angular ranges of limbs are corrected and enlarged; however, the division of angles has not changed. However, the results showed that none of these three methods were comprehensive enough for assessing the risk of musculoskeletal disorders in repair and maintenance occupations, and the correction of RULA angles has not been successful in the REBA and NERPA. Therefore, a desirable method should be achieved by changing the scoring and angles.

In addition, a major drawback of all three methods in the present study is that the angles of extension and lateral movements are not categorized, and only one general score was considered in this regard. However, the results indicated that among the three methods, the RULA had the maximum correlation with the level of musculoskeletal disorders suggesting that the risk prediction power of the RULA was still higher than that of the two other methods. On the other hand, the REBA and NERPA were developed based on the RULA and for resolving its problems. The aforementioned results are in line with the findings of Yazdanirad et al. (2018) who showed that among the RULA, NERPA, and LUBA, the RULA had the maximum correlation with musculoskeletal disorders (22).

Furthermore, the results of the present study revealed that Spearman's rank correlation coefficient and kappa coefficient between the NERPA and RULA were greater than those between the REBA and RULA. Moreover, the obtained findings showed that following the RULA, the NERPA had a higher predictive power for musculoskeletal disorders. The results obtained from a study carried out by Yazdanirad et al. (2018) also showed that the maximum correlation existed between the risk levels of the NERPA and RULA, which was reported as 0.72 (22).

A study carried out by Sanchez et al. for the development of an ergonomic assessment method known as the NERPA in 2013 reported the maximum extent of relationship and correlation between the NERPA and RULA (21). However, the RULA is still superior to the two other methods but not comprehensive that highlights the necessity of developing new methods.

Conclusion

In general, the results showed that the RULA method was the best method among the three studied techniques for predicting the prevalence of musculoskeletal disorders in different studied tasks. It was also observed that the NERPA in tasks with low and moderate risks of developing musculoskeletal disorders, REBA in tasks with a moderate risk of developing musculoskeletal disorders, and RULA in tasks with high and very high risks of developing musculoskeletal disorders offered better predictions. There was a significant correlation among the scores obtained from each of the three used assessment methods. However, as none of these methods are comprehensive enough for assessing all four levels of risk, it is proposed that newer methods should be developed based on the correction of angles and better division of angles, especially for extension and lateral movements.

Footnotes

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Conflict of Interest

The authors declare that there is no conflict of interest.

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