original article

Macro-ergonomic risk assessment with the relative stress index method in textile industry

Meghdad Kazemi, Shahram Safari, Jafar Akbari, Mohammad Amin Mououdi[1], Behzad Mahaki[2]

Department of Occupational Health Engineering, School of Health, Isfahan University of Medical Sciences (IUMS), Isfahan, Iran, [1]Department of Occupational Health Engineering, School of Health, Mazandaran University of Medical Sciences, Sari, Iran, [2]Department of Biostatistics and Epidemiology, School of Health, IUMS, Isfahan, Iran

Address for correspondence:
Eng. Jafar Akbari, Isfahan University of Medical Sciences, Hezar Jerib Avenue, Isfahan, Iran.
E-mail: akbari_jafar@hlth.mui.ac.ir

ABSTRACT

Aims: The aim of present study was macro-ergonomic risk assessment with a relative stress index (RSI) in textile industry.

Materials and Methods: This study was conducted based on the Census method among 154 workers in textile industry in Isfahan (IRI) that work on three shifts. Risk assessment based on RSI is divided into three main sections: job description, check list, and RSI. For computation of this method, different equations have been defended that by their computation was being performed. The final values for the RSI area scale between zero and 10 where zero implies on dangerous, insecure, not efficient and number 10 indicated safe, secure, and being efficient.

Results: ANOVA test showed that, hand work and sensory in different shifts among textile industry had significant relationships with occupational hazard ($P < 0.05$). Also, posture with a mean 6.19 ± 0.11 and manual material handling with a mean 9.14 ± 0.41 had the lowest and highest score, respectively.

Conclusion: Based on the findings from the study, the posture at work and hand work were the most influential factor to the incidence of occupational hazards among workers with in the textile industry. So keeping a good posture and reducing the level of hand work activity during each shift can have a significant impact in reducing occupational hazards.

Key words: Macro-ergonomic, riskassessment, relative stress index, textile industry

INTRODUCTION

In recent years, a wide use of ergonomic risk assessment methods was valued in workplace. These risk assessment methods can be categorized into two groups: macro-and micro-ergonomic risk assessment.[1] Macro-ergonomics requires equal consideration to all major components of the system such as human, hardware, software, and organizational structures. Indeed, it is quite important to pay serious attention to human and organizational aspects of the macro-ergonomics process from early design phase.[2] Hendrick (2007) reported that using of macro-ergonomics in work, causes a 50% to 90% increase in efficiency of organization and also a 200% increase inproductivity.[3]

Review of macro-ergonomic methods by 1996, the development of new methods for macro-ergonomic analysis, design, and evaluation of work systems had reached the point

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where the U.S. Human Factors and Ergonomics Society's Organizational Design and Management (ODAM) Technical Group formally changed its name to the Macro-ergonomics Technical Group.[4]

The Macro-ergonomic Organizational Questionnaire Survey (MOQS) is an adaptation of the organizational questionnaire survey method by Pascale Carayon and Peter Hoonakker of the University of Wisconsin.[5] These surveys can be very useful for quickly and inexpensively identifying symptoms of work-system design problems and locating where these problems may be occurring within the work system.[6]

Participatory ergonomics (PE) is an adaptation of participatory management that was developed for both micros and macro-ergonomic interventions.[7] A major advantage to this approach is that the employees are in the best position to know the problem symptoms and to identify the macro-ergonomic intervention approach that will be most acceptable to them.[6]

The cognitive walk-through method (CWM) is a usability inspection method that rests upon the assumption that evaluators are capable of taking the perspective of the user and can apply this user perspective to a task scenario to identify design problems.[8] Also, Kansei engineered, a method for translating consumers' affective responses to new products into ergonomic design specifications.[9,10] Other models that were used for the field of macro-ergonomic include: HITOP Analysis™ (a step-by-step manual procedure for industry practitioners who must implement technological change) ,[11] TOP-Modeler© (a decision support system for manufacturing organizations to help them identify the organizational changes required when new process technologies are being considered),[12] and The CIMOP (computer-integrated manufacturing, organization and people) System© (It was developed for evaluating computer-integrated manufacturing, organization, and people system design).[13]

New methods designed for macro-ergonomic applications: anthropotechnology, systems analysis tool (SAT), macro-ergonomic analysis of structure (MAS), and macro-ergonomic analysis and design (MEAD).

Anthropotechnology deals, specifically with analysis and design modification of systems for effective technology transfer from one culture to another.[14] The Systems Analysis Tools (SAT) is a method developed for conducting systematic trade-off evaluations of work-system intervention alternatives. SAT has proven useful in enabling both ergonomists and managerial decision-makers to determine the most appropriate strategy for making work-system changes.[15] MAS was developed for the purpose of assessing the structure of work systems in terms of their compatibility with their unique sociotechnical characteristics. These include the key aspects to the work system's technology, personnel subsystem, and the external environment to which the organization must respond to survive and be successful. Although MEAD address work-system structure, the main value of MEAD is its ten-step process for evaluating work-system processes.[4]

These macro-ergonomics methods focus on organizational structure and less attention to assessment of risk factors in jobs. Relative stress index (RSI) is a macro-ergonomic risk assessment tool that was introduced by Guo. *et al*(1996).[16] RSI was developed based on criteria of scope, simplicity, practicality, usefulness, reliability, and job-specificity. An RSI was formulated to take into account multiple parameters, such as frequency, duration, repetition, weight, force, travel distance, and horizontal distance. RSI assessed jobs with collecting data about jobs, completing six categories of risk assessment, and calculating the RSI score. Then risk level of tasks and its components is specified based on scores between 0 and 10 and finally decision about job's status and correct it.

Bararian *et al*. (2006), was assessed the job risk factors by using of the RSI in the pharmaceutical industry. The results showed that 10 out of 11 jobs was in the green or safe zone and these job groups do not need to take corrective measures. [17] And in a study by Guo. *et al*, in order to do job's comparisons among nuclear remediation industries, the RSI risk assessment showed that 24 out of 26 jobs fell into the yellow zone. Of the six task categories defined in the study, the majority of jobs fell within the yellow zone. A number of job tasks fell into the red zone meaning immediate action should be taken to remediate the hazards.[16]

Working in textile industries is consider as the jobs in which employees are exposed to job hazards and various job-related risk factors, such as excessive noise (more than 85dB), vibration, thermal discomfort, humidity, shift work, workload, repeated activities, manual handling, performing task's upright for the long period of time, that increase the probability of hazard occurrence and job-related incidents.[18] Assessment of job conditions and its risk factors is necessary in order to control occupational hazards, health of employees and increase productivity. Therefore, the aim of this study, was the risk assessment of job groups from the perspective of macro-ergonomics by using of RSI method in textile industry.

MATERIALS AND METHODS

Subjects

This cross-sectional study was conducted between 154 male workers of QaemBaft Textile Company (Isfahan, IRI) in Oct. and Nov. 2012; participant were selected by the census method. For assessing ergonomic risk, the RSI was used, which is a method for evaluating macro-ergonomic risk recognition in workplaces. The risk assessment was done in three work shifts, including: morning shift; (7 am-3 pm), evening shift; (3 pm-11 pm), and night shift; (11 pm-7 am).

The research was carried out on 13job groups, including: Ring, Carding, Batting, Auto Kenner, Double twist, Flyer, Sizing, Technical, Shift supervisor, Services, Weaving, Designing, Warp coil.

Assessments

RSI has been developed according to the comprehensive range principles, practicality, usefulness, reliability, and simplicity in reflecting occupation. According to the RSI, the main structure of evaluating risk includes three parts: job description, checklist, and RSI. Job description includes general information of interviewee`s background, job summary, and details related to jobs and relevant tasks [Figure 1]. In the second part, six categories of tasks for each job have been completed to include manual material handling, hand work, posture, senses, environment and personal protective equipment (PPE). These six categories include 64 high-risk factors as lifting loads, inappropriate posture, etc. [Table 1]. The third part includes occupation needs qualitative evaluation in the form of RSI score. In this level, general index of RSI and the elements have been defined by the mathematical formula by considering that job variables have two main and interacted effects [Table 2]. Final score of RSI is between 0 and 10. Zero indicates that the occupation is dangerous, unsafe, and nonproductive and score 10 indicates non dangerous, safe, and productive occupation. Based on the above issues' occupation evaluation, task levels, and occupation elements is as follows: RSI score between 0 and 2.5 shows red zone and means it requires immediate action, RSI score between 2.5 and 7.5 shows

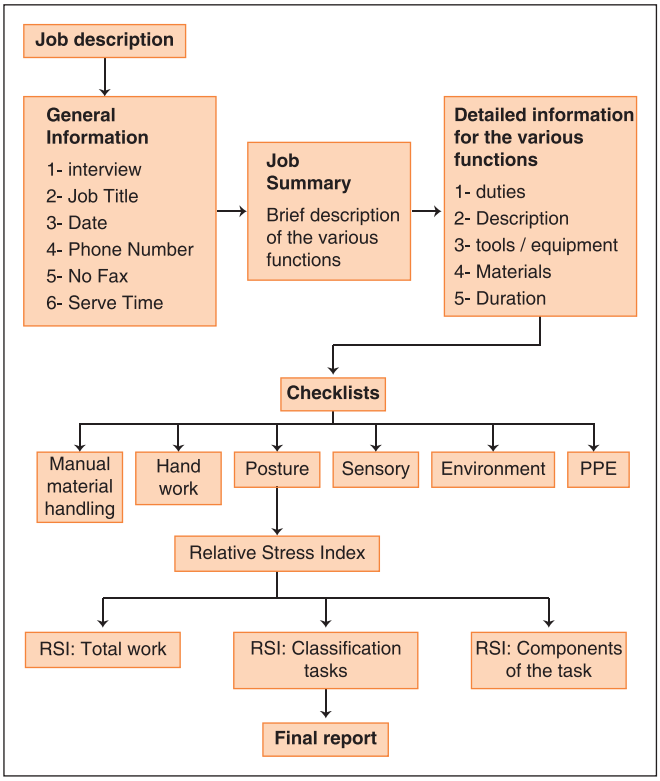

Figure 1: Details of the RSI procedure

Table 1: Checklist of Relative Stress Index (RSI)

Tasks	FD	R	W	TD	HD
Lifting/lowering					
Carrying					
Pushing					
Pulling					
Handling					
Fingering					
Standing					
Sitting					
Reclining					
Walking					
Climbing stairs/ramps					
Climbing ladders/scaffolds					
Balancing					
Kneeling					
Crouching					
Crawling					
Stooping					
Trunk/head twisting					
Forearm twisting					
Reaching above shoulder					
Reaching below shoulder					
Bending head/forearm/hand					
Near vision (<20″)					
Mid range vision (20″-20′)					
Far vision (>20′)					
Depth perception					
Basic color vision					
Intermediate color vision					
Color shade vision					
Comprehend/articulate speech-8 ft					
Comprehend/articulate speech-16 ft					
Comprehend/articulate speech-high ambient					
Feeling/touching					
Tasting/smelling					
Outdoor					
Indoor					
Extreme cold					
Extreme heat					
Wet					
Humid					
Noise					
Vibration					
Respiratory/pulmonary irritants/sensitizers					
Contact/skin irritant/sensitizers					
Radiant energy					
Electrical energy/shock					
Work at heights					
Work below ground					
Work in confined spaces					
Work with immediately dangerous/lethal materials					
Work closely with others physically and cooperatively					
Work alone with accessible aid					
Work alone with poorly accessible aid					
Protracted or irregular hours of work					
Operation of heavy/hazardous vehicles/ equipment					
Other physical hazard (specify)					
Other chemical hazard (specify)					
Other biological hazard (specify)					
Other radiological hazard (specify)					
PPE-respirator					
PPE-body suit					
PPE-hearing protection					
PPE-vision protection					
PPE-with close skin contact					

FD: Frequency/Duration, R: Repetitation, W: Weight/Force, TD: Travel distance, HD: Horizontal distance

yellow zone and means; changes are required after taking care of the red zone, although changes can be made together with those made in the red zone. Eventually RSI score equals to 7.5 or more shows green zones and means no changes is required.[16] Figure 1 shows schematic format of different categories of RSI.

Finally, the information was analyzed using SPSS-20 and statistic tests, namely ANOVA statistical tests have been used for comparing categories of RSI for three working shifts. In addition, the Tukey test was used for assessing most hazardous job-related factors for three working shifts. A *P*-value less than 0.05 were considered to be statistically significant.

RESULTS

The workers were between 28 and 57 years old, and their mean age was 40 ± 6.35 years. All subjects who responded were men. The average period during which participants had been working at their current workplace was 8.61 ± 8.25 years with a range of 1-27 years. Among participants, 149 (96.8%) were married and 5 (3.2%) were single. 9 (5.9%) had bachelor's degree, 14 (9.1%) had associated degree, 48 (31.16 %) had the high school diploma, 44 (28.52%) had middle school certificate, and 39 (25.32%) had primary educations or did not have any formal education. In order to calculate the RSI for each occupation in textile industries, the RSI was calculated for 6 different working categories. These categories were included: manual material handling, hand work, body posture, senses, environment, and personal protection equipment. Finally, total RSI was calculated by finding averages of these six categories.

Table 2: RSI scores for different tasks

Tasks	Task elements*	RSI equations
Manual material handling	1-4	$RSI = \sum_{i=1}^{4} RSI_{i/4}$
Hand work	5-6	$RSI = \sum_{i=5}^{6} RSI_{i/2}$
posture	7-22	$RSI = \sum_{i=7}^{22} RSI_{i/16}$
Sensory	23-34	$RSI = \sum_{i=23}^{34} RSI_{i/12}$
Environment	35-59	$RSI = \sum_{i=35}^{59} RSI_{i/25}$
Personal protective equipment	60-64	$RSI = \sum_{i=60}^{64} RSI_{i/5}$
Total RSI	1-64	$RSI = \sum_{i=1}^{64} RSI_{i/64}$

* task elements in this method are defined according to 1-64 tasks.[16]

The study results showed average and standard deviation of total RSI in textile industries being 8.08 ± 0.28. The related results of RSI for six categories and also total RSI for various occupational groups are presented in Table 3.

In Table 3 descriptive indices associated to six categories of RSI in addition to total RSI among different occupational groups in textile industries are shown Also, in order to assess which six areas of RSI has higher effect on occurring hazardous issues on other categories for participants for the study, a comparison was done among these six categories and results are provided in Table 3.

After comparing six working categories, in addition to total RSI for working shifts among different occupational groups in textile industries, the ANOVA statistical test showed a significant correlation between work shifts and senses with job hazards occurrence ($P < 0.05$) In other words, these areas may have higher effect on job hazard occurrence. However, relationship between manual load handling, body posture, environment, and personal protection equipment with job hazard occurrence for various working shifts was not significant ($P > 0.05$).

The Tukey statistical test showed that there is a significant relationship between the manual work scores for nightshift

Table 3: Average of RSI score for existing occupations in textile industries

	Manual Material Handling		Hand work		Posture		Sensory		Environment		Personal Protection Equipment		Total RSI	
Job group	mean	SD	mean	SD	mean	SD	mean	SD	mean	SD	mean	SD	mean	SD
Ring	8.98	0.48	8.6	0.43	7.54	0.44	7.78	0.46	8.62	0.52	7.86	0.45	8.15	0.27
Weaving	9.14	0.41	9.02	1.04	7.3	0.3	7.58	0.36	8.61	0.72	7.64	0.24	8.1	0.27
Carding	8.77	0.4	8.15	1.4	7.37	0.28	7.83	0.56	8.54	0.41	8.0	0.56	8.07	0.25
Batting	8.75	0.29	7.8	1.29	7.34	0.64	8.23	0.83	8.39	0.6	8.17	0.72	8.09	3.80
Auto Kenner	8.97	0.23	8.20	1.01	7.14	0.44	7.53	0.37	8.67	0.45	8.47	0.42	8.05	0.35
Sizing	8.66	0.83	9.06	1.04	7.2	0.48	7.68	0.26	8.61	0.41	8.06	0.64	8.08	0.29
Double twist	9.02	0.06	8.45	0.48	7.5	0.27	7.98	0.52	8.68	0.47	7.76	0.35	8.18	0.16
Technical	8.54	0.21	8.31	0.35	6.99	0.11	7.83	0.77	8.05	0.62	8.16	0.61	7.93	0.23
Flyer	8.68	0.35	7.37	0.72	6.94	0.29	7.77	0.82	8.14	0.47	7.97	0.49	7.74	0.24
Services	9.05	0.33	8.6	0.99	7.54	0.17	7.37	0.31	8.44	0.53	7.6	0.00	7.99	0.26
Warp coil	8.85	0.28	8.30	1.3	7.49	0.53	8.33	0.91	8.44	0.36	8.80	0.40	8.15	0.14
designing	8.77	0.15	7.56	0.39	6.99	0.38	7.05	0.19	8.29	0.4	8.26	0.83	7.73	0.23
Shift supervisor	7.8	0.32	8.38	0.00	7.04	0.24	8.08	1.06	8.24	0.00	8.4	0.00	7.95	0.16

workers and day shift workers, and also between day shift and evening shift workers ($P < 0.05$). In addition, the Tukey test indicated a significant difference between a sense scores for evening shift with day shift and nightshift ($P < 0.05$).

DISCUSSION

Evaluation of macro-ergonomic risk considers one of the risk assessment methods for recognition of job hazards, and it has been proven useful widely in working environments.[19] Until now, there are many research works done around job hazards occurrence risk factors evaluation with use of the macro-ergonomic risk evaluation method.[3,20]

In the current study, we benefited from RSI as a macro-ergonomic risk assessment method for recognition of risk factors related to job hazard occurrence in textile industries. As it has been shown in Table 3, the results of assessment were shown for 13 job groups in textile industries, which signify all these job groups have a RSI score higher than 7.6. This result is in contrast to the study by Guo. *etal*, among nuclear remediation industry that the RSI risk assessment showed that 24 out of 26 jobs fell into the yellow zone, and a number of job tasks fell into the red zone meaning immediate action should be taken to immediate the hazards.[4] One of the most effective factors of RSI score is environmental risk factor such as height, closed space, noise, humidity, working outdoor, extreme cold, extreme heat, wet, vibration which in textile industrial from these adverse physical agents, only noise and humidity were reported by workers.

The results for average RSI evaluation among occupation groups showed the highest value for double twist job, with average and standard deviation of 8.18 ± 0.16 and lowest value obtained for designing job with average and standard deviation of 7.73 ± 0.23, which means the job groups within the study had been higher than 7.6 RSI score and were in the green or safe zone. Also, in the study for comparison of total RSI among working shifts, the evaluation results showed that the index score for day shift was lower compared to evening and night shifts. However, the index score was more than 7.6 for all three working shifts which showed they are in the green or safe zone. One of the reasons may be the lack of environmental effective risk factors for calculating RSI. Other noteworthy study findings include a comparison of six categories of RSI among occupational groups and various working shifts.

Results of Study in Table 3 showed that among six categories of RSI, highest score was given to manual material handling, with an average and standard deviation of 9.14 ± 0.41 for weaving job and lowest score was given to posture for Flyer, with an average and standard deviation of 6.99 ± 0.11, which indicated that flyer job is in yellow zone and there is need for some modifications. However, the changes can be achieved by changing the causing alarms issues which are in the red zone.

The results from this study were consisted of obtained results by Bararian *et al*, for RSI evaluation in pharmaceutical industries, study results showed that 10 out of 11 jobs fell into the green zone that indicated no change is required.[17] In a comparison done between six categories of RSI for various working shifts, the results showed that the posture average scores for all three working shifts and also the sense average score for day shift was less than 7.6, generating evidence indicating they were in yellow zone, and potential modifications for improvement of condition must be done. However, due to higher average score for the RSI in other categories and being in the green zone, no need was felt for reformation and improvement of condition. We can point out to another research finding such as a relationship between manual work and sense with occurrence of hazardous issues for various working shifts. ANOVA statistical test displayed a significant relationship between two indices with job hazards. In other words, manual work category and sense showed a higher effect for the occurrence of hazardous issues among workers in various working shifts compare to other four categories RSI in textile industries.

However, finding did not show any significant relationship between manual load handling, posture, environment, and personal protection equipment with hazard occurrence among a worker in different working shifts. The Tukey test showed that nightshift and evening shift workers have higher scores for manual work compared to day shift workers. In other words, manual work category was considered as an effective factor in the occurrence of hazards in textile industries. As it has been mentioned in results, the Tukey test showed a higher score for sense for evening shift compare two other working shifts among workers, which means this category has the lower effect on hazard occurrence among working evening shift people.

CONCLUSION

Based on obtained results from the study, total RSI showed that all of job groups were in productive condition for employees. This means that every job is considered safe for each employee. But the results from RSI score of tasks, body posture, and hand work consider effective risk factors in job injuries such as musculoskeletal disorders among various occupational groups and employees in textile industries. Therefore, in order to eliminate and reduce the intensity of these risk factors among personnel, taking measures such as workload reduction, the load carrying times reducing in each working shift, the proper educational technique for lifting and load transfer and having a proper body posture in time of task's and duties performing, providing breaks and rest periods during working hours, reducing repeated activities by workers,

and finally attempt to finding methods for mechanized the activities were recommended.

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