

Risk Assessment in Pharmaceutical Industry by Using Relative Stress Index (RSI)

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Abstract: In recent years, ergonomic assessment of risk factors associated with musculoskeletal injuries has been widely performed in the workplace. Risk assessment methods can be categorized into two groups: Macro- and micro-ergonomic risk assessment. One of macro-ergonomic risk assessment methods is relative stress index which aim is identification and correction of jobs with high risk. In this technique multiple parameters such as frequency, duration, repetition, weight, force, travel distance and horizontal distance are taken into account in six categories. Then, by using tables, they are changed into codes and are put into identified formulas. The output is relative stress index for job, task or subtask. This technique has been performed in pharmaceutical industry. For performing this research, all jobs of production line of this industry have been observed and categorized into 11 job groups. Results show that 10 out of 11 jobs are in the green zone and one job is in the yellow zone. According to statistical tests, in two out of six categories of RSI, there is significant difference between averages of at least two jobs and there is no significant difference between other four categories of RSI. According to obtained results and work condition, following suggestions present: Performing micro-ergonomic risk assessment for categories of RSIs which are not in appropriate zone; decreasing of load weight and in result decreasing of used force by workers; elimination of performing jobs with high repetition by workers and trying to find a way for doing these works automatically.

Key words: Relative stress index, RSI, macro-ergonomy, risk assessment

INTRODUCTION

Ergonomic assessment of risk factors associated with musculoskeletal injuries has been widely performed in workplace. Risk assessment methods can be categorized into two groups: Macro- and micro-ergonomic risk assessment. Micro-ergonomic risk assessment usually follows macro-ergonomic risk assessment, provides more details about analyzed tasks and is time-consuming. On the other hand, information recorded in macro-ergonomic risk assessment gives a general analysis of possible risk of injury associated with different jobs and can assist management in decision-making on budget and time allocation for more detailed analyses (i.e., micro-risk assessment). Macro-risk assessment is usually effective when a large number of jobs is studied and job analysts have little information about different jobs.

Macro risk assessment methods have these properties:

Scope- The approach should be comprehensive and incorporate the majority of risk factors encountered in the workplace. Simplicity- The analyst should know how to

use this approach after a brief training session even though he/she may not have a profound knowledge of ergonomics. Practicality- This criterion implies that the assessment should be cost-effective. From an industrial standpoint, cost is governed by four factors: Scheduling and time required; personnel involved; materials/equipment needed; cost. The macro-risk assessment tool should allow users to analyze jobs with minimal resource utilization. Usefulness - The information collected should be useful in many ways to minimize ergonomic stresses. For example, management can prioritize jobs in terms of control action required. Medical department can use assessment data for fit-for-duty and injury/illness evaluation. Supervisors can make better decisions about job assignments specially for light-duty tasks. Human resource departments can incorporate the information in design of pre-placement tests and on-the-job training. The various company functions can make sound decisions about provision of reasonable accommodations for compliance with the Americans of Disabilities Act (ADA).

Limited research has been conducted with respect to development and testing of macro-risk assessment procedures. The use of such techniques will become an important component of a health surveillance process due to existing and anticipated promulgation of ergonomic standard in various countries around the world.

A checklist was developed to identify risk factors associated with awkward postures of the legs, trunk and neck (Keyserling *et al.*, 1992). Another checklist was designed to assess risks associated with upper extremity cumulative trauma disorders. The checklist was classified into six categories: Worker information; repetitiveness; mechanical stress; force; posture and tools, hand-held objects and equipment. The checklists developed by Keyserling and co-workers were limited to assessment of awkward postures associated with certain body parts (Keyserling *et al.*, 1993).

A checklist was proposed to evaluate upper extremity work. Twenty questions were included about physical stress, force, posture and frequency of movements. Each questions required a binary response with either positive response representing a good practice or a negative response meaning that improvement was required. Obviously, this checklist was not designed for overall job evaluation (Lifshitz and Armstrong, 1986).

A checklist was developed that included factors such as worker physical behavior, tools, equipment, materials handling equipment. The checklist was validated by sampling techniques over a period of 14 months in a foundry and a metal-working plant. Because of sampling techniques, checklist application was time consuming (Ramsey *et al.*, 1986).

A more comprehensive checklist was proposed that consisted of demographic and operational information; work organization pertinent to occupational health and safety; workstation layout; perceptual and mental demands; physical demands; physical environment; chemical environment. This list may provide excellent guidelines for designing a workstation, but it is not easy to use for assessing existing workplaces (Fraser, 1989).

This technique was performed in nuclear remediation industry. Job comparisons showed that 24 out of 26 jobs fell into the yellow zone. Painters had the lowest RSI (3.8) and traffic administration had the highest RSI (8.6). Of the six task categories defined in this 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. For example, carpenters handwork, sensory and personal protective equipment categories fell into the red zone (Guo *et al.*, 1996).

A handbook was published which described a comprehensive methodology for job analysis (The US Department of Labor, 1972). In 1982, they revised the procedure to make it more descriptive and easier to

understand. It was pointed out that these procedures overloaded some important ergonomic considerations (Smith *et al.*, 1982).

MATERIALS AND METHODS

Macro-risk assessment is structured into three major sections: Job description; checklist and relative stress index 'RSI'. Job description consists of interviewee's background, job summary, task title, task description, tools and equipment, materials, duration and frequency (Table 1). Risk assessment checklist assumes that any job requires one or more of the following task categories: Manual material handling, hand work, postural loading, sensory requirements, environmental factors and usage of personal protective equipment (Table 2). The six task categories consist of 64 risk factors (e.g., lifting, carrying). The first and second sections can be completed with reference to the Interview References Sheet (IRS) (Table 2). Definitions and instructions used during interviews are given in Table 3. The third section involves RSI computation. It is based on a quantitative evaluation of job requirements which take into account multiple variables such as load, repetition, task duration, travel distance, etc.

The process of RSI computation requires conversion of values obtained for each task element to a numeric code described in Table 4. Task elements 51 (work closely with others physically/cooperatively) and 52 (work alone with accessible aid) require the following exceptional codes:

Code	Frequency/duration
5	Not present (NP)
4	Rarely (R)-less than 1%
3	Seldom (S)-1-5%
2	Occasional (O)-5-20%
1	Frequent (F)-20-80%
0	Constant (C)-80-100%

Once conversion is completed numeric codes are entered into RSI equations. If the frequency/duration variable for a certain task element is zero, there is no need to compute RSI as it will always equal 10.

Trigger points are developed to evaluate jobs, task categories and task elements:

Red zone: Immediate actions is required (RSIs of '0-2.5').

Yellow zone: Changes are required after taking care of the red zone although changes can be made together with those made in red zone (RSIs '2.5- 7.5').

Green zone: No change is required (RSIs of '7.5' or greater).

Table 1: Interview sheet

1. Interviewee		2. Job title		3. Date				
4. Phone No.		5. Fax No.		6. Length of service				
7. Department		8. Number of workers		9. Interviewer				
10. Job summary								
No.	Task	Description	Tools/equip.	Materials	Duration	Frequency		
Job				FD	R	W	TD	HD
1		Lifting/lowering						
2		Carrying						
3		Pushing						
4		Pulling						
5		Handling						
6		Fingering						
7		Standing						
8		Sitting						
9		Reclining						
10		Walking						
11		Climbing stairs/ramps						
12		Climbing ladders/scaffolds						
13		Balancing						
14		Kneeling						
15		Crouching						
16		Crawling						
17		Stooping						
18		Trunk/head twisting						
19		Forearm twisting						
20		Reaching above shoulder						
21		Reaching below shoulder						
22		Bending head/forearm/hand						
23		Near vision (<20')						
24		Mid range vision (20'-20')						
25		Far vision (>20')						
26		Depth perception						
27		Basic color vision						
28		Intermediate color vision						
29		Color shade vision						
30		Comprehend/articulate speech-8 ft						
31		Comprehend/articulate speech-16 ft						
32		Comprehend/articulate speech - high ambient						
33		Feeling/touching						
34		Tasting/smelling						
35		Outdoor						
36		Indoor						
37		Extreme cold						
38		Extreme heat						
39		Wet						
40		Humid						
41		Noise						
42		Vibration						
43		Respiratory/pulmonary irritants/sensitizers						
44		Contact/skin irritants/ sensitizers						
45		Radiant energy						
46		Electrical energy/shock						
47		Work at heights						
48		Work below ground						
49		Work in confined spaces						
50		Work with immediately dangerous/lethal materials						
51		Work closely with others physically and cooperatively						
52		Work alone with accessible aid						
53		Work alone with poorly accessible aid						
54		Protracted or irregular hours of work						
55		Operation of heavy/hazardous vehicles/equipment						
56		Other physical hazard (specify)						
57		Other chemical hazard (specify)						
58		Other biological hazard (specify)						
59		Other radiological hazard (specify)						
60		PPE-respirator						
61		PPE-body suit						
62		PPE-Hearing protectors						
63		PPE-vision protection						
64		PPE-with close skin contact						

Table 2: Interview reference sheet

Frequency/duration		
(NP) Not Present		(O) Occasional-5 to 20%
(R) Rarely-less than 1%		(F) Frequent-20 to 80%
(S) Seldom-1 to 5%		(C) Constant-80-100%
Repetition		
Repetitive (R)-more than once every 5 min		
Non-repetitive (NR)-less than once every 5 min		
Weight/force		
Lift/lower/carry/push/pull (lbs)	Arm handling (lbs)	Fingering (lbs)
0-10	0-5	0-2.5
10-25	5-10	2.5-5
25-50	10-20	5-10
50-75	20-30	10-20
75-100	30-50	20-30
100+	50-75	30+
	75-100	
	100+	
Travel distance (TD)		
Lifting/lowering		Carrying/pushing/pulling (ft)
Floor-waist (F-W)		0-5
Floor-shoulder (F-S)		5-10
Waist-shoulder (W-S)		10-20
Floor-reach (F-R)		20-40
Waist-reach (W-R)		40-60
Shoulder-reach (S-R)		60-80
		80-100
		100+
Horizontal distance-HD (in)		
0-5		20-25
5-10		25-30
10-15		30+
15-20		

Table 3: Definitions and instructions

Term/questions	Definition/instruction
1. Interviewee	Interviewed person's full name
2. Job title	Title of interviewee's job and/or position
3. Date	Date when the interview is conducted
4. Phone No.	Work phone number
5. Fax No.	Work fax number
6. length of service	Length of time the interviewee has been in current position
7. Department	Department or division with which the interviewee works
8. Number of workers	Total number of workers performing the job covered in assessment
9. Interviewer	Interviewing person's full name
10. Job summary	Brief but comprehensive statements that describe various tasks performed including overall purpose and nature of job
No.	Serial number for each task
Task	Task title. In some instances, task title may be entire task description
Description	Task description. In some instances, it may be the same task title
Tools/equipments	All tools/ equipment used to perform the task
Materials	Raw materials and/or finished products with which workers are involved
Duration	Percentage of shift or assignment time spent for a task
Frequency	Task frequency. It could be daily, weekly, bi-weekly, monthly, quarterly, semi-annually and annually
Factors	
1. Lifting/lowering	Raising or lowering an object from one level to another. Consult IRS and estimate frequency/duration, repetition, weight, travel distance (vertical distance) and horizontal distance (between center of grasp and front of body)
2. Carrying	Moving an object, usually by holding it in hands or arms, or on shoulders. Consult IRS and estimate frequency/duration, repetition, weight, travel distance and horizontal distance (between center of grasp and front of body)
3. Pushing	Exerting force upon an object so that the object moves away from the force. Consult IRS and estimate frequency/duration, repetition, weight, travel distance (pushing distance)
4. Pulling	Exerting force upon an object so that the object moves toward the force. Consult IRS and estimate frequency/duration, repetition, weight, travel distance (pulling distance)

Table 3: Continued

5. Handling	Seizing, holding, grasping, turning, or otherwise working with hand or hands. Fingers are involved only to the extent that they are an extension of the hand, such as to turn a switch or shift automobile gears. Consult IRS and estimate frequency/duration, repetition, weight/force involved
6. Fingering	Picking, pinching, or otherwise working primarily with fingers rather than with the whole hand or arm as in handling. Consult IRS and estimate frequency/duration, repetition, weight/force involved
7. Standing	Remaining on one's feet in an upright position at a work station without moving around. Consult IRS and estimate frequency/duration and repetition
8. Sitting	Remaining in the normal seated position. Consult IRS and estimate frequency/duration and repetition
9. Reclining	Lying on one's side or in a prone or supine position. Consult IRS and estimate frequency/duration and repetition
10. Walking	Moving about on foot, including running. Consult IRS and estimate frequency/duration and repetition
11. Climbing stairs/ramps	Ascending or descending stairs and ramps, using feet and legs and/or hands and arms. Consult IRS and estimate frequency/duration and repetition
12. Climbing ladders/scaffolds	Ascending or descending ladders, scaffolding, poles and the like, using feet and legs and/or hands and arms. Consult IRS and estimate frequency/duration and repetition
13. Balancing	Maintaining body equilibrium to prevent falling when walking, standing, crouching or running on narrow, slippery, or erratically moving surfaces; or maintaining body equilibrium when performing gymnastic feats. Consult IRS and estimate frequency/duration and repetition
14. Kneeling	Bending legs at knees to come to rest on knee or knees. Consult IRS and estimate frequency/duration and repetition
15. Crouching	Bending body downward and forward by bending legs and spine. Consult IRS and estimate frequency/duration and repetition
16. Crawling	Moving about on hands and knees or hands and feet. Consult IRS and estimate frequency/duration and repetition
17. Stooping	Bending body downward and forward by bending spine at the waist. Consult IRS and estimate frequency/duration and repetition
18. Trunk/head twisting	Rotating trunk and/or head to either side. Consult IRS and estimate frequency/duration and repetition
19. Forearm twisting	Pronating or supinating forearm(s). Consult IRS and estimate frequency/duration and repetition
20. Reaching above shoulder	Extending arm(s) above shoulder(s). Consult IRS and estimate frequency/duration and repetition
21. Reaching below shoulder	Extending arm(s) below shoulder(s). Consult IRS and estimate frequency/duration and repetition
22. Bending head/forearm/hand	Bending head, forearm(s) and/or hand(s). Consult IRS and estimate frequency/duration and repetition
23. Near vision (<20")	Consult IRS and estimate frequency/duration for all following questions Clarity of vision at 20 inches or less
24. Mid range vision (20"-20')	Clarity of vision at distances of more than 20 inches and less than 20 feet
25. Far vision (>20')	Clarity of vision at 20 feet or more
26. Depth perception	Three-dimensional vision. Ability to judge distances and spatial relationships so as to see objects where and as they actually are
27. Basic color vision	Ability to identify and distinguish red/amber/green colors
28. Intermediate color vision	Ability to identify and distinguish the intermediate colors obtain from red/amber/green colors
29. Color shade vision	Ability to identify and distinguish shades of color with fine gradations
30. Comprehend/articulate speech-8 ft	Ability to comprehend and articulate speech within 8 feet
31. Comprehend/articulate speech-16 ft	Ability to comprehend and articulate speech within 16 feet
32. Comprehend/articulate speech - high ambient	Ability to comprehend and articulate speech in the presence of high ambient noise
33. Feeling/touching fingertips	Perceiving attributes of objects, such as size, shape, temperature or texture by touching with skin, particularly that of fingertips
34. Tasting/smelling	Distinguishing, with some degree of accuracy, differences or similarities in intensity of quality of flavors and/or odors, or recognizing particular flavors and/or odors, using tongue and/or nose
35. Outdoor	Exposure to hot, cold, wet, humid or windy condition, caused by the weather which results in marked bodily discomfort
36. Indoor	It is the contrary to outdoor condition
37. Extreme cold	Exposure to non-weather-related temperatures that are sufficiently low to cause marked bodily discomfort
38. Extreme heat	Exposure to non-weather-related temperatures that are sufficiently high to cause marked bodily discomfort
39. Wet	Skin contact with water or other liquids, which is non-weather-related
40. Humid	Exposure to non weather-related humid condition where humidity is sufficiently high to cause marked bodily discomfort
41. Noise	Exposure to constant or intermittent sounds of a pitch or level sufficient to cause a worker to have difficulty hearing the voice of a person three or four feet away unless voice is raised above normal conversational level
42. Vibration	Exposure to a shaking object or surface that causes a strain on the body or extremities
43. Respiratory/pulmonary irritants/sensitizers	Exposure to irritants and/or sensitizers such as dust, smoke, gases, fumes, solvents, etc.
44. Contact/skin irritants/ sensitizers	Exposure to irritants and/or sensitizers such as solvents, grease, oils, chemicals, etc.
45. Radiant energy	Exposure to radiant heat such as the heat from furnace or heat
46. Electrical energy/shock	Exposure to electrical energy and possible electrical shock
47. Work at heights	Working at high place such as ladders, scaffold, etc.
48. Work below ground	Working below ground level
49. Work in confined spaces	Working in confined spaces
50. Work with immediately dangerous/lethal materials	Working with dangerous and/or lethal materials such as explosives, firearms, etc.
51. Work closely with others physically and cooperatively	Working with other workers physically and cooperatively
52. Work alone with accessible aid	Working alone with easily accessible aid such as radio or other communication tools
53. Work alone with poorly accessible aid	Working alone without easily accessible aid such as radio or other communication tools
54. Protracted or irregular hours of work	Working for prolonged hours or at irregular hours such as night shift

Table 3: Continued

55. Operation of heavy/hazardous vehicles/equipment	Operating heavy and/or hazardous vehicles and/or equipment
56. Other physical hazard (specify)	Specify any other physical hazard such as excessive levels of electromagnetic and ionizing radiation, pressure, poor illumination, unguarded/poorly-maintained/defective equipment, ungrounded equipment, cracks/holes in sidewalks and aisles, etc.
57. Other chemical hazard (specify)	Specify any other chemical hazards such as chemical mist, vapors, gasses or solids that are in the form of dusts or fumes, etc.
58. Other biological hazard (specify)	Specify any other biological hazards such as bacteria, viruses and fungi, etc.
59. Other radiological hazard (specify)	Specify any other radiological hazards, such as alpha particles, beta particles, gamma rays, neutron particles, etc.
60. PPE-respirator	Job requires respirators
61. PPE-body suit	Job requires body suit such as anti-contamination clothing
62. PPE-Hearing protectors	Job requires hearing protections such as plugs, muffs, etc.
63. PPE-vision protection	Job requires vision protections such as glasses, goggles, etc.
64. PPE-with close skin contact	Job requires gloves, masks, etc.

Table 4: Parameter coding

Code	Parameter	Code	Parameter
	Frequency/duration (FD)		Travel distance-(TD)
0	Not present (NP)		Lifting/lowering
1	Rarely (R)-less than 1%	1	Floor-waist (F-W)
2	Seldom (S)-1-5%	2	Floor-shoulder (F-S)
3	Occasional (O)-5-20%	2	Waist-shoulder (W-S)
4	Frequent (F)-20-80%	3	Floor-reach (F-R)
5	Constant (C)-80-100%	3	Waist-reach (W-R)
	Repetition (R)	3	Shoulder-reach (S-R)
1	Non-repetitive (NR) - < once/5 min		Carrying/pushing/pulling (ft)
2	Repetitive (R) - > once/5 min	1	0-5
	Weight/force (W)	2	5-10
	Lift/lower/carry/push/pull (lbs)	3	10-20
1	0-10	4	20-40
2	10-25	5	40-60
3	25-50	6	60-80
4	50-75	7	80-100
5	75-100	8	100+
6	100+		Horizontal distance-HD (in)
	Arm handling (lbs)	1	0-5
1	0-5	2	5-10
2	5-10	3	10-15
3	10-20	4	15-20
4	20-30	5	20-25
5	30-50	6	25-30
6	50-75	7	30+
7	75-100		Relative stress index-RSI
8	100+		7.5+
	Fingering (lbs)	Green	2.5-7.5
1	0-2.5	Yellow	0-2.5
2	2.5-5	Red	
3	5-10		
4	10-20		
5	20-30		
6	30+		

The RSI equations for various task elements are given below:

Lifting/lowering

$$RSI = 10 \times \{1 - [(FD/5 + TD/3 + HD/7 + R/2 + W/6) + (FD \times TD/15 + FD \times HD/35 + FD \times R/10 + FD \times W/30 + TD \times HD/21 + TD \times R/6 + TD \times W/18 + HD \times R/14 + HD \times W/42 + R \times W/12) + (FD \times TD \times HD/105 + FD \times TD \times R/30 + FD \times TD \times W/90 + TD \times HD \times R/42 + TD \times HD \times W/126) + (FD \times TD \times HD \times R/210 + FD \times TD \times HD \times W/630) + (FD \times TD \times HD \times R \times W/1260)] / 23\}$$

Carrying

$$RSI = 10 \times \{1 - [(FD/5 + TD/8 + HD/7 + R/2 + W/6) + (FD \times TD/40 + FD \times HD/35 + FD \times R/10 + FD \times W/30 + TD \times HD/56 + TD \times R/16 + TD \times W/48 + HD \times R/14 + HD \times W/42 + R \times W/12) + (FD \times TD \times HD/280 + FD \times TD \times R/80 + FD \times TD \times W/240 + TD \times HD \times R/112 + TD \times HD \times W/336) + (FD \times TD \times HD \times R/560 + FD \times TD \times HD \times W/1680) + (FD \times TD \times HD \times R \times W/3360)] / 23\}$$

Pushing/pulling

$$RSI = 10 \times \{1 - [(FD/5 + TD/8 + R/2 + W/6) + (FD \times TD/40 + FD \times R/10 + FD \times W/30 + TD \times R/16 + TD \times W/48 + R \times W/12) + (FD \times TD \times R/80 + FD \times TD \times W/240) + (FD \times TD \times R \times W/480)] / 13\}$$

Hand/work

$$RSI = 10 \times \{1 - [(FD/5 + R/2 + W/8) + (FD \times R/10 + FD \times W/40 + R \times W/16) + (FD \times R \times W/80)] / 7\}$$

Fingering

$$RSI = 10 \times \{1 - [(FD/5 + R/2 + W/6) + (FD \times R/10 + FD \times W/30 + R \times W/12) + (FD \times R \times W/60)] / 7\}$$

Postural loading. There are 16 postural loading elements '7-22' (Table 1). The following equation applies to each task element.

$$RSI = 10 \times \{1 - [(FD/5 + R/2) + (FD \times R/10)] / 3\}$$

Sensory/environmental/personal protective equipment

$$RSI = 10 \times (1 - FD/5)$$

where:

FD = frequency/duration, R = repetition, W = weight/force, TD = travel distance, HD = horizontal distance.

The RSI equations for task categories are computed as the average of RSI values obtained for task elements and are given below. As we learn more about relative contribution of each task element, a weighing factor is necessary to take this fact into account.

Manual material handling (task elements 1-4)

$$RSI = \sum_{i=1}^4 RSI_i / 4$$

Hand work (task elements 5-6)

$$RSI = \sum_{i=5}^6 RSI_i / 2$$

Body posture (task elements 7-22)

$$RSI = \sum_{i=7}^{22} RSI_i / 16$$

Sensory (task elements 23-34)

$$RSI = \sum_{i=23}^{34} RSI_i / 12$$

Environment (task elements 35-59)

$$RSI = \sum_{i=35}^{59} RSI_i / 25$$

Personal protective equipment (task elements 60 -64)

$$RSI = \sum_{i=60}^{64} RSI_i / 5$$

Where 'i' represents a certain task element.

Analysis method: After exact describing of study, findings were analyzed. After gathering required data, for entering the data to computer and analysis of them, SPSS software has been used. For analyzing and finding relationship between data following statistical tests are used in appropriate places: One way ANOVA and Kruscal-Wallis.

RESULTS

Risk assessment of jobs in pharmaceutical industry: As regards, in relative stress index jobs and methods and ways of doing them are considered and persons and their personal information such as age, sex, etc are not considered in computing of jobs and tasks RSIs, all jobs of production line of factory have been studied. These jobs are brought in 11 job groups (Table 5).

At first, supervisors and workers were interviewed and required data was gathered. After absolute recognition of jobs, check lists were filled out and RSIs of jobs and tasks were computed. Results are brought in Table 6-10.

Table 5: List of various jobs in pharmaceutical industry

ID	Job
1	First materials preparation
2	First materials charge
3	Process and its control
4	Transfer to centrifuge
5	Centrifuge discharge
6	Wet granule
7	Drier charge
8	Drier discharge
9	Weighing and tying packages openings
10	Product final exit
11	Other jobs (supervisor, recording work report, etc.)

Table 6: Comparison of manual material handling tasks

Job	RSI	Job	RSI
First materials preparation	8.85±1.01	Drier charge	8.16±1.07
First materials charge	8.35±1.39	Drier discharge	9.40±0.48
Process and its control	9.91±0.10	Weighing and tying packages openings	9.32±0.68
Transfer to centrifuge	10.0±0.00	Product final exit	8.64±0.91
Centrifuge discharge	8.84±1.33	Other jobs	9.81±0.13
Wet granule	9.94±0.51		

Table 7: Comparison of handwork tasks

Job	RSI	Job	RSI
first materials preparation	2.89±1.50	Drier charge	2.86±1.71
First materials charge	1.98±2.00	Drier discharge	3.53±1.71
Process and its control	6.76±0.97	Weighing and tying packages openings	3.62±2.14
Transfer to centrifuge	6.99±0.67	Product final exit	3.01±1.52
Centrifuge discharge	2.50±1.32	Other jobs	6.41±0.53
Wet granule	4.78±1.66		

Table 8: Overall Comparison of jobs

Job	RSI	Job	RSI
first materials preparation	8.07±3.26	Drier charge	7.83±3.46
First materials charge	7.34±3.70	Drier discharge	7.76±3.39
Process and its control	7.80±2.81	Weighing and tying packages openings	8.30±3.00
Transfer to centrifuge	7.83±2.92	Product final exit	8.20±3.19
Centrifuge discharge	7.78±3.45	Other jobs	8.25±2.39
Wet granule	7.91±3.20		

Table 9: RSIs categories comparison

Category	Lowest RSI		Highest RSI	
	Job	RSI	Job	RSI
Manual material handling	Drier charge	8.16	Transfer to centrifuge	10.0
Hand work	First materials charge	1.98	Transfer to centrifuge	6.99
Posture	First materials charge	6.04	Other jobs	7.31
Sensory	Process and its control	7.79	Product final exit	9.16
Environment	First materials charge	8.58	Product final exit	9.49
Personal protective equipment	First materials charge	4.00	Other jobs	7.2

Table 10: Analysis of variance results for categories of RSIs

Category	p-value
Manual material handling	0.05
Hand work	0.12
Posture	0.99
Sensory	0.06
Environment	0.90
Personal protective equipment	0.97

DISCUSSION

According to Table 8, overall comparison of jobs shows that 10 out of 11 jobs fell into the green zone. First materials charge had the lowest RSI (7.34) and weighing and tying packages openings had the highest RSI (8.30). Of the six task categories defined in this study, the majority of jobs fell into the green and yellow zone (Table 6 and 7). Hand work category in first materials charge fell into the red zone meaning immediate action should be taken to remediate the hazards (Table 7).

Table 9 shows that in the manual material handling category, transfer to centrifuge had the highest RSI and drier charge had the lowest RSI. In the handwork category, transfer to centrifuge had the highest RSI and first materials charge had the lowest RSI. In the posture category, other jobs had the highest RSI and first

materials charge had the lowest RSI. In the sensory category, product final exit had the highest RSI and process and its control had the lowest RSI. In the environment category, product final exit had the highest RSI and first materials charge had the lowest RSI. In the personal protective equipment category, other jobs had the highest RSI and first materials charge had the lowest RSI.

Also Table 9 shows that between these jobs first materials charge had the lowest RSIs. So a control action is required for this job.

Analysis of variance results show that in the manual material handling and sensory categories, there is significant difference between average of at least two jobs ($\alpha = 0.10$). In the other categories of RSI, there is no significant difference between averages of jobs RSIs.

According to obtained results and work condition, following suggestions present: Performing micro-ergonomic risk assessment for categories of jobs RSIs which are not in appropriate zone; decreasing of load weight and in result decreasing of used force by workers; elimination of performing jobs with high repetition by workers and trying to find a way for doing these works automatically.

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