A study of biomechanical risk factors in an elevator manufacturing company

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Abstract. The aim of this study was to identify tasks with high risk of causing musculoskeletal disorders, biomechanical risk factors and body regions at risk by conducting an ergonomic workplace analysis at an elevator manufacturing company. Assessment tools included Muscle Fatigue Assessment, Moore Garg Strain Index, Key Indicator method, Revised NIOSH Lifting Equation and REBA. 80 tasks were evaluated. All the tasks starting from the store area to manufacturing area and cleaning area were assessed. The biomechanical risks identified ranged from low to very high. The commonest body regions that were considered at high risk were the lower back, neck and shoulder.

Keywords. Elevator company, EWA, MFA, REBA

1. Introduction

Manufacture of elevators involves significant manual material handling such as lifting, carrying, pulling, unloading raw materials, transporting materials, loading finished products for delivery, packing etc. Many of these tasks can result in musculoskeletal disorders (MSDs). However, not all manual handling is hazardous. Hazardous manual handling may include repetitive or sustained application of force, repetitive or sustained awkward posture, repetitive or sustained movement, exposure to sustained vibration and unstable or unbalanced loads or loads which are difficult to grasp or hold.

No previous studies have reported the biomechanical risk factors involved in an elevator manufacturing company. It is necessary to understand the causes of MSDs before implementing effective preventive measures in order to prevent MSDs. A study to identify the biomechanical risk factors may assist the company to determine controls that may prevent MSDs or reduce the risk exposure that may lead to financial loss, legal loss, or quality loss due to the processes involved in the each assembly line.

2. Methods

2.1 Aim

The aim of this study was to identify tasks with high risk of causing musculoskeletal disorders, biomechanical risk factors and body regions at risk by conducting an ergonomic workplace analysis at an elevator manufacturing company.

2.2 Study design and settings

The ergonomic workplace analysis was conducted as per the request of an elevator manufacturing company to identify risky tasks and biomechanical risk factors among the

workers with the intention of implementing corrective ergonomics measures. A team of ergonomists went on a floor to floor visit to know the various processes and 80 tasks which they felt to have some risk were selected for detailed assessment. The 61 year old company is one of India's leading manufacturer and service provider of elevators, escalators and moving walkways.

Video recording and photographs were taken in different sections like handling the input material, transferring the finished goods, stretch wrapping, loading and unloading of panels, handling oil barrels, handling scrap, hand operated pallet transporter handling, deburring of panels, sandering, cutting using power tools, maintenance activity etc. to record different movements and postures of the workers during that particular task. Assessment tools to assess posture, muscle fatigue and body part at risk were selected based on the tasks to be evaluated. Each task was assessed separately by a team of ergonomists and the results were analysed to make the final recommendations.

2.3 Assessment tools

2.3.1 REBA

REBA (Rapid Entire Body Assessment) was developed to provide a quick and easy observational postural analysis tool for whole body activities (static and dynamic giving musculoskeletal risk action level (Hignett, S. and McAtamney, L. 2000). The development of REBA is aimed to divide the body into segments to be coded individually with reference to movement planes. The design of REBA is very similar to that of RULA method and special attention is devoted to the external load acting on trunk, neck, and legs and to the worker–load coupling using the upper limbs. Postures of individual body parts are observed and postural scores increase when postures diverge from the neutral position. Group A includes trunk, neck, and legs, while group B includes upper and lower arms and wrists. Other items including the load handled, couplings with the load, and physical activity are specifically scored and then processed into a single combined risk score using a table provided. These scores are summed up to give one score for each observation, which can then be compared to tables stating risk at five levels, leading to the necessity of actions. Unlike RULA, REBA provides five action levels for estimating the risk level. REBA combines two scores, one for body (Score A for Group A) and a second for hand/arm posture (Score B for Group B). These are then amalgamated to give an overall score, which provides a risk assessment for the posture. These risk levels starting from 1 to 15 are corresponding to negligible, low, moderate, high and very high risk level.

2.3.2 KEY INDICATOR METHOD

Key Indicator Method - Manual Handling Operations (KIM-MHO). In accordance with the principle of the KIMs, it contains an objective requirement and load description, and identifies potential threats to physical overload. The KIM-MHO includes job characteristics and their interaction. The key indicators to be considered in the KIM-MHO are:

- Daily duration of manual work processes,
- Type, duration, and frequency of executing forces,
- Body posture during manual work processes,
- Hand-arm posture during manual work processes,
- Work organization, and
- Work conditions.

The key indicators are classified in different scales. The scales correspond to conditions in practice and Range from a minimum/optimum to maximum/poor. The

classification of these scales indicates potential bottlenecks for each category/indicator. By multiplying the scale value of the daily duration of activity with the sum of the other scale scores, a total value can be calculated. This calculated sum score can be used as a risk score. This score can be allocated to a risk range (Klussmann A et al, 2010)

2.3.3 MFA

Rodger's Muscle Fatigue Assessment scale is used to provide a method of evaluating the physiological demands of a task against published criteria of acceptable levels of oxygen consumption for whole body or upper bodywork. This scale covers body regions like neck, shoulder, hand, wrist, arm, back, legs, elbow, and knee. This scale is appropriate for jobs that require high frequency and duration, and involve awkward postures.

2.3.4 Revised NIOSH Lifting Equation

The purpose of the 1991 Revised NIOSH (National Institute of Occupational safety and Health) Lifting Equation is to provide a means of quantifying the relative risk or acceptability of a specific lifting task, to subsequently be able to identify specific task deficiencies, and then plan for their elimination. Lifting Index is a term that provides a relative estimate of the level of physical stress associated with a particular manual lifting task. The estimate of the level of physical stress is defined by the relationship of the weight of the load lifted and the recommended weight limit.

2.3.5 Moore-Garg Strain Index.

Moore-Garg Strain Index method is used to examine tasks for risk of distal upper extremity disorders .It is a semi-quantitative analysis method in which most aspects are quantitative, but there are several measures which are qualitative. The calculation of the score is based on multiplicative interactions among task variables that are consistent with currently accepted physiological, biomechanical, and epidemiological principles. Although not specifically intended, it may also be used to predict the occurrence of distal upper extremity symptoms. The tool should be used to evaluate the specific tasks on a task and not individual performance. The prediction of hazardous tasks is based largely on the belief that localized muscle fatigue is a contributing factor to distal upper extremity injury (Moore & Garg, 199).

3. Result and Discussion

Out of 80 tasks selected, 27 tasks were assessed using REBA since the work involved static loading over the workers entire body. The results obtained from the REBA assessment worksheet are shown in Table 1. The high and very high risk score were obtained in tasks like manual handling and feeding the input and output materials, cutting with power tools, scrap handling, manual packing of carline, metal sheet handling, deburring, CO^2 welding operation, assembly work, paint job using spray gun and maintenance of powder coating cabin.

Table-1 REBA Score distribution

Out of 80 tasks selected, 19 tasks were assessed using Strain Index as the task mostly involved the distal upper extremity movements and leading to a risk of localised muscle fatigue and injury. The result obtained from the assessment reveled that 8 tasks has high risk in right hand (manually handling the input material, assembly work, door assembly, scrap handling, platform assembly, COP assembly and testing, wiring and testing) and 3 task had high risk in both left and right hand (belt cutting, hoist way lintel assembly, functional testing operations)

Strain Index Score distribution		**Score Obtained**			
Strain Index	**Risk Level**	**Left**	**Percentage**	**Right**	**Percentage**
SI<3	Job is probably safe	11	58	5	26.30
3<SI< 7	Job may place individual at increased risk for distal upper extremity disorder	5	26.30	3	15.70
SI>=7	Job is probably hazards	3	16	11	58

Table-2 Strain Index Score distribution

REBA Score	**Risk level**	**Action**	**No. of Task**	**Percentage of Task**
1	**None**	Not	-	-
2-3	**Low**	May be necessary	2	7.40%
4-7	**Medium**	Necessary	2	7.40%
8-10	**High**	Necessary and soon	3	11.11%

Out of 80 tasks selected, 8 tasks were assessed using Revised NIOSH Lifting Equation. Lifting index score more than 3 (high risk task) included parts loading and unloading from conveyer, manually handling of the output and input material, and debarring area. Lifting index score less than 3 (mild to moderate risk) was observed in door FMS line.

Table-3 NIOSH Score distribution

	Revised NIOSH		
Lifting Index	**Risk Level**	**Number of Tasks**	**Percentage**
LI< 1	Low Risk	-	
L1>1< 3	Mild/Moderate Risk	1	12.50%
LI> 3	High Risk	7	87.50%

Out of 80 tasks evaluated, 29 tasks were assessed with KIM-MHO as the task involved

push/pull operations and moving/carrying. Eight tasks were identified with high load situation and 10 tasks were identified with highly increased load situation.

Table-4 KIM-MHO Score distribution

KIM-MHO				
Risk Range	**Risk Score**	**Corrective Measure**	**No. of Task**	**Percentage of Task**
1	<10	Low load situation, physical overload unlikely to appear	8	27.60%
2	10 bis <25	Increased load situation, physical overload also possible for normal person. For that group redesign of workplace is helpful	3	10.34%
3	25bis <50	Highly increased load situation, physical overload also possible for normal person, redesign of workplace is recommended.	10	34.48%
4	>50	Highly load situation, physical overload is likely to appear. Workplace redesign is necessary.	8	27.60 %

Out of 80 task evaluated, 18 tasks were assessed using MFA as task involved body regions like neck, shoulder, hand, wrist, arm, back, legs, elbow and knee. MFA is appropriate for jobs that require high frequency and duration, and involve awkward postures. The 18 tasks that were assessed are summarised in table-5 & table-5.1.

Table -5 Distributions of MFA Score

Total Number of Task Assessed =18	**Area**	**Neck**	**Shoulder**		**Back**	**Arms/Elbow**		**Wrist/Fingers**		**Leg/Knee**		**Ankle/Feet/Toe**	
	Scores		**Left**	**Right**		**Left**	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**
	Very High	14	8	16	9	**3**	**8**	**3**	**8**	-	-	-	-
	High	4	6	7	11	6	12	**11**	**3**	2	2	**2**	**2**
	Moderate	9	**6**	**7**	**8**	12	12	8	7	9	10	7	7
	Low	5	**12**	**2**	**4**	**11**	**-**	**10**	**4**	21	20	23	23

Table- 5.1 Percentage wise distribution of MFA score

Total Number of Task Assessed =18	**Area**	**Neck**	**Shoulder**		**Back**	**Arms/Elbow**		**Wrist/Fingers**		**Leg/Knee**		**Ankle/Feet/Toe**	
	Scores		**Left**	**Right**		**Left**	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**
	Very High	43.7	25	50	28.12.	9.40	25	9.40	25	-	-	-	
	High	12.50	19	21.90	34.40	19	37.50	34.40	40.60	6.25	6.25	6.25	-6.25
	Moderate	28.12	19	21.90	25	37.50	37.50	25	21.90	28.12	31.25	21.80	21.80
	Low	15.60	37.50	6.25	12.50	34.40	-	31.25	12.50	65.60	62.50	71.80	71.80

4. Conclusion

From the analysis of results and scores obtained by all the five tools it can be concluded that the workers of the elevator manufacturing industry were adopting awkward postures which involved frequent twisting, bending, and over-reaching, forceful exertions, high repetition, and localised vibration. All these biomechanical risk factors have a strong association with WRMSD of the lower back, neck, and shoulders. The workers were under moderate to high risk and in some postures at a very high risk of developing WRMSD. The measures recommended to reduce the risk include environmental and workstation modification, training, job redesign, application of ergonomic principles and organizational changes.

References:

Rodgers SH. A functional job analysis technique. Occup Med 1992 Oct-Dec; 7(4): 679-711.

Kivi P, Mattila M. Analysis and improvement of work postures in the building industry: application of the computerised OWAS method. Appl Ergon. 1991 Feb; 22(1):43-8.

Monteiro J, Vaz M, Calvão J, Pinho ME. Ergonomic assessment of a workstation in a paints production line. Arezes P, et al (ed.). Occupational Safety and Hygiene II, Taylor & Francis 2014: 193-197.

Waters TR, Lu ML, Piacitelli LA, Werren D, Deddens JA. Efficacy of the revised NIOSH lifting equation to predict risk of low back pain due to manual lifting: expanded cross-sectional analysis. J Occup Environ Med 2011 Sep;53(9):1061-7.

McAtamney L, Nigel Corlett E. RULA: a survey method for the investigation of work-related upper limb disorders. Appl Ergon 1993 Apr; 24(2): 91-9.

Klussmann A, Steinberg U, Liebers F, Gebhardt H, Rieger MA. The Key Indicator Method for Manual Handling Operations (KIM-MHO)-evaluation of a new method for the assessment of working conditions within a cross-sectional study. BMC Musculoskelet Disord. 2010 Nov 25; 11: 272.

Pourmahabadian M, Saraji JN, Aghabeighi M, Saddeghi-Naeeni H. Risk assessment of developing distal upper extremity disorders by strain index method in an assembling electronic industry. Acta Medica Iranica 2005; 43(5): 347-354.