

Ergonomic Risk Assessment using Postural Analysis Tools in a Bus Body Building Unit

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Abstract

Work-related musculoskeletal disorders (WMSD) which are related with repetitive and demanding working conditions continue to represent one of the biggest problems throughout the world. Assessment of exposure levels to MSD risk factors can be an appropriate base for planning and implementing interventional ergonomics programs in the workplace. The present study is focused on posture analysis of the workers working in an automotive coach manufacturing company (bus body building) company. The study was conducted on 38 workers engaged in various processes of manufacturing. The different activities of the workers were recorded by video and still photography, and these images were used for analysis. Posture analysis tools RULA, REBA and QEC were used. The results of RULA showed that about 31.57% of the workers were under high risk level and needed a necessary action immediately. About 28.95% of the workers were under medium risk levels and about 28.95% of the workers were at lower risk levels. The results of REBA showed that about 26.32% of the workers were under very high risk levels and required immediate change. About 23.68% of the workers were at high risk levels and a change is necessary soon, and 42.10% of the workers were at medium risk levels. According to the QEC method of assessment, it was found that 10.53% of the workers needed no corrective measures. About 31.58% of the workers needed further investigation and 34.21% of the workers were at high risk and required immediate change. It can be concluded that there are ergonomic deficiencies in the planning and work methods. A significant proportion of the workers are working in high risk postures. Thus the workers are under moderate to high risk of Work-related Musculoskeletal disorders (WMSDs). The study recommended a proper implementation of ergonomics interventions program with awareness and training among workers to reduce the risk of WMSD.

Keywords: Posture analysis, WMSD, bus body building

1. Introduction

The field of ergonomics is rapidly becoming a key area of interest to industrial organizations, which are concerned with providing a comfortable, safe, and pleasant working area for their employees as well as producing high quality user-friendly products to customers at the same time stressing on continuous improvement in productivity. This interest in applying ergonomic principles to industrial workplaces and products is most likely a result of correlations established between the design of a workplace on ergonomics principles and the resulting productivity and health of the worker (Qutubuddin et al. 2012a). The elements of a work system, such as the worker, equipment, environment, task, and organization interact when work is performed. Ergonomics aims to make sure that task, equipment, environment and the information suits the workers.

In the design of work systems in manufacturing industries, the primary concern has usually been the improvement of the performance of the equipment alone. Little consideration is given towards matching the abilities of the operator with the task requirements (Das & Sengupta 1996). Consequently, many industrial workstations are poorly designed, resulting in lower worker productivity and unnecessary injury at the workplace leading to development of work related musculoskeletal disorders.

WMSD are diseases related and/or aggravated by work that can affect the upper limb extremities, the lower back area, and the lower limbs. WMSD can be defined by impairments of bodily structures such as muscles, joints, tendons, ligaments, nerves, bones and the localized blood circulation system, caused or aggravated primarily by work itself or by the work environment (Nunes 2009a). The ageing of the workforce are also a contribution to the widespread of WMSD, since the propensity for developing a WMSD is related more to the difference between the demands of work and the worker's physical work capacity that decreases with age (Okunribido & Wynn 2010). WMSD have also heavy economic costs to companies and to healthcare systems. The costs are due to loss of productivity, training of new workers and compensation costs (Isabel Nunes & Pamela McCauley 2008). (Kourinka et al 1987) reported ergonomic factors such as awkward working postures, static load and task invariability to be some of the most important factors contributing to occurrence of musculoskeletal symptoms.

Work-related musculoskeletal disorders (WMSDs) are a major concern in industry which can also compromise competitiveness due to costs related to worker compensation, labour turnover, absenteeism, poor quality and

reduced productivity (Andersson1992). It would, therefore, be extremely difficult to attain the objectives of the manufacturing industries without giving proper consideration to ergonomics. Effective application of ergonomics in work system design can achieve a balance between worker characteristics and task demands. This can enhance worker productivity; provide worker safety, physical and mental well-being and job satisfaction. Many research studies have shown positive effects of applying ergonomics principles in workplaces, occupational health and safety, machine design, job design, environment and facilities design (Das &Sengupta 1996,Shikdar& Al-Hadhrami2005, Ayoub M.A.1990a, Qutubuddin et.al.2012b).

Musculoskeletal disorders (MSDs) are related to high repetitive work processes and working in bad postures. Therefore to improve the efficiency of the workers and reduce the risks of musculoskeletal disorders their postures should be assessed and corrective measures adopted. The literature review and epidemiological studies have shown that in the genesis of the WMSD three sets of risk factors can be considered (Nunes, 2009a).

- Physical factors - e.g., sustained or awkward postures, repetition of the same movements, forceful exertions, hand-arm vibration, all-body vibration, mechanical compression, and cold;
- Psychosocial factors - e.g., work pace, autonomy, monotony, work/rest cycle, task demands, social support from colleagues and management and job uncertainty;
- Individual factors - e.g., age, gender, professional activities, sport activities, domestic activities, recreational activities, alcohol/tobacco consumption and, previous WMSD.

Therefore, in designing a manufacturing work station the objective should not only be to maximize worker productivity, but also try to improve workers satisfaction and minimize safety hazards. It is possible to achieve such a desirable goal through proper application of ergonomics principles and anthropometric data (Qutubuddin S.M,2012a). An ergonomics approach to the design of an industrial workstation attempts to achieve an appropriate balance between the worker capabilities and work requirements (Das &Sengupta1996). The origins of ergonomic risk factors include the workstations, tools, equipments, work methods, work environment, worker personal characteristics, metabolic demands, physical stress, and emotional stress. Professionals from mechanical engineering, industrial engineering, occupational hygiene, occupational medicine, occupational therapy, kinesiology, psychology, and many other fields, provide unique insights into the relationship between worker/workplace and WMSDs (Majid Motamedzade et.al.2011). Understanding ergonomic risk factors are essential because there is indication that ergonomic risk factors are causally related to musculoskeletal disorders of the upper extremities and the low back (Drinkaus Pet.al 2003).

There are a number of ergonomic assessment tools that attempt to evaluate the ergonomic risk of a job or task. For example, the Rapid Upper Limb Assessment (RULA), the Rapid Entire Body Assessment (REBA) and Quick Exposure Check (QEC) are more holistic ergonomic risk assessment tools that measure the ergonomic risks of both upper and lower parts of the musculoskeletal system. Biomechanical assessments can be done for all the regions of the musculoskeletal system especially shoulder moments and moments about the low back. Evaluations of several ergonomic observational methods revealed that these methods were applicable under various workplace conditions. Each method has its own posture classification procedure, which is different from other methods and therefore may lead to assign different postural scores for a given posture, depending on particular methods used.

An ergonomically deficient workplace can cause physical and emotional stress, low productivity and poor quality of work. Assessment of exposure levels to MSD risk factors can be an appropriate base for planning and implementing interventional ergonomics programs in the workplace. The objective of this study is to conduct an ergonomic risk assessment and to analyze the working postures of workers engaged in various manufacturing processes in automotive coach industry (busbody building industry), by applying different postural analysis tools, and to identify the various risk factors associated with MSDs.

2. Ergonomic tools for assessing WRMSD risk factors

The study used three assessment tools namely RULA (Rapid Upper Limb Assessment), REBA (Rapid Entire Body Assessment) and QEC (Quick Exposure Check) to assess the working postures and recommend the changes to be made.

The Rapid Upper Limb Assessment (RULA) was developed earlier by McAtamney and Corlett, to provide a rapid objective measure of musculoskeletal risk caused by mainly sedentary tasks where upper body demands were high and where work related upper limb disorders are reported. RULA assesses the posture, force and movement associated with sedentary tasks; such tasks include computer tasks, manufacturing or retail tasks where the worker is seated or standing without moving about. The use of RULA results in a risk score from one to seven, where higher scores signify greater levels of apparent risk (McAtamney & Corlett, 1993).

This tool requires no special equipment in providing a quick assessment of postures of the neck, trunk and upper limbs along with muscle function and the external loads experienced by the body. A coding system is used to generate an action list which indicates the level of intervention required to reduce the risks of injury due to

physical loading on the operator. Briefly, the upper arm, lower arm, and wrists postures are evaluated and scores are given for each body part posture. Then, the scores are combined (using a specially developed scoring table) to generate the upper limb posture score. Similarly, the neck, trunk, and legs postures are evaluated and scores are also given. They are combined to generate the neck-trunk-legs score. For both combined scores, scores for muscle use and force are added. Finally, the grand score is determined and action to be taken is recommended.

REBA (Rapid Entire Body Assessment) was developed (Hignett, S. and McAtamney, L. 2000), to provide a quick and easy observational postural analysis tool for whole body activities (static and dynamic) giving musculoskeletal risk action level. 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. These risk levels starting from 0 to 4 are corresponding to negligible, low, moderate, high and very high risk level respectively.

Table 1. Classification of Risks according to Scores of Assessment Tools

RULA		REBA			QEC	
RULA Score	Action Required	Action level (Risk level)	REBA Score	Corrective Measure	QEC Score %	Action required
1-2	Acceptable	0 (Negligible)	1	None necessary	≤40%	Acceptable
3-4	Change may be necessary	1 (Low)	2-3	May be necessary	41-50%	investigate further
5-6	Change necessary soon	2 (Medium)	4-7	Necessary	51-70%	investigate further and change soon
7	Change immediately	3 (High)	8-10	Necessary soon	>70%	investigate and change immediately
		4 (Very High)	11-15	Necessary NOW		

In QEC to achieve an overall score, total scores obtained from four body parts are added and the product is divided by the maximum possible score, i.e., 176 for manual material handling tasks and 162 for others. Score of (<40%) indicates low risk, for a score of 41% to 50%, indicates moderate risk and further investigation is needed and changes may be required. A score of 51% to 70% indicates high risk and timely investigation and changes are required soon, and a score over 70% falls under very high risk where urgent investigation and changes are required. Finally, QEC provides 4 categories for estimating the risk level. These risk levels are named from 1 to 4 i.e. low, moderate, high and very high risk level respectively. The classification of risks according to RULA, REBA and QEC is shown in Table 1.

Quick Exposure Check (QEC) is an observational method that was developed by (Li and Buckle 1998) and enhanced by (David et al. 2003). QEC is used to assess the level of exposure to ergonomic risks. The method includes the assessment of the back, shoulder/upper arm, wrist/hand and neck, with respect to their postures and repetitive movement. Information about maximum weight handled, time spent on task, level of hand force, application of vibrating tools, visual demand of the task and difficulties to sustain with the work as well as the stressfulness of the work are also obtained from the worker. The ratings are weighted into scores and added up to summary scores for different body parts and other items driving, vibration, work pace, and stress. The QEC checklist/assessment sheet includes questions that need to be answered by both the user and the worker. These questions are designed to quantify the exposure risk for the four main areas of the body (back, shoulder/arm, wrist, and neck).

3. Methods

This cross-sectional study was conducted in order to investigate the ergonomic risks involved in a automotive coach (bus body building) manufacturing company, in which 38 workers were involved. The company is a 40

year old firm and is one among India's largest automobile body builders. The company manufactures automotive coaches (bus body building) catering to the needs of the various sectors like buses for road transport corporation, schools and colleges, ambulances, mobile clinics, para military vans, and special purpose bodies to suit various needs and applications of the customers. All the jobs were observed before start of the study and detailed job information was collected to ensure the completion of ergonomic risk assessment tools. A video recording and photographs were taken in different sections like press shop, sheet cutting, welding, drilling and riveting, painting, fitting and fixtures etc. to record different movements and postures of the workers during work. The video was cropped every ten seconds to get snapshots of the workers and these snapshots were analyzed to fill the scores in RULA and REBA. To evaluate the ergonomic risk of a job or task, the Rapid Upper Limb Assessment (RULA), the Rapid Entire Body Assessment (REBA) and Quick Exposure Check (QEC) are used. The RULA score sheet was used to assess the upper limbs mainly arms and wrist of posture; each body part is divided into sections depending on the range of movement and these sections are numbered so that the number 1 is assigned to the range of movement or working posture where minimal risk is involved. Higher numbers are assigned to parts of the movement range with more extreme postures indicating an increasing presence of risk factors causing load on the structures of the body segment. The exposure scores according to RULA were divided into four risk categories: negligible, low, medium and high. Medium and high risk actions should be urgently addressed to reduce the level of exposure of risk factors. For those activities where the whole body and limbs motion are to be assessed REBA was used. In REBA the body parts are divided into sections and each body part is scored according to its range of movement. Lower scores are given to the body parts where presence of risk factors is minimal and higher scores are given to those body parts where presence of risk factors is more. The REBA scores were divided into five categories: negligible, low, medium, high and very high. Medium, high and very high needed an immediate action to avoid any musculoskeletal disorder.

3.1 Manufacturing process

The manufacturing process starts with the arrival of a chassis from automobile manufacturer's plant. The design department prepares the specifications as per the requirements of the customer. These specifications are sent to the respective departments. Metal cutting department is the first to be alerted. Metal sheets, sections, angles and rods are cut into appropriate length for forming different parts. These sheets, sections and rods are sent through a treatment plant to make them corrosion resistant. After the treatment, these metal components are sent to jigs and fixtures section. Here with the help of fixtures the skeleton of the bus body is formed. At this stage only partial welding is done to facilitate realignment.

After proper fixing of the parts a few workers manually take that part to the chassis. The structure is welded to the chassis and is tightened with U-bolts to hold the floor. Flooring begins with laying of a large metal sheet on the chassis platform. On this metal sheet a plywood board of appropriate size is laid and on this the classic cross hatched aluminium sheet is laid. The structure is completed with the fitting of ready-made fibre reinforced plastics front and rear end. These are joined to the structure through riveting. Once the structure is ready the outer sheet of the bus body is made and joined to the body.

First the metal sheets are marked according to dimensions, and cut to the required dimensions. Depending on the requirement of final shape some sheets are sent for pressing or else they are directly taken to be fitted to the chassis. At the chassis the sheets are first glued with adhesives, joined to the structure and then soldered. The outer body is now visible. Doors and windows are fabricated by forming an outer structure of aluminium sections and soldering a metal around it. The design of the doors and windows is always flexible, depending on the customers' needs. The bus body is now ready for painting. The body is checked for imperfections like bulges, bends etc. These imperfections are removed by applying putty. Primer is applied on the whole body. Painting is done after baking the body in oven for 2 hrs. Finally the bus is fitted with seats and electrical equipment. The complete body is painted as per the requirements of the customer. Shower test is carried out for checking any leakage in the bus. The entire manufacturing process and the awkward postures adapted by the workers are shown in pictures in Appendix A.

The entire manufacturing process was observed for finding out ergonomic deficiencies in the system. It was found that there was a considerable involvement of manual element in every stage of manufacturing. The workers were subjected to awkward postures and improper loading while working, poor working conditions, noisy work environment and very little use of personnel protective equipments. The workplaces were unorganised and the work tables were designed poorly without any anthropometric considerations. Hence the present work focuses on finding out the ergonomic risk factors leading to MSD's using the analysis tools like QEC, RULA and REBA. Also the noise levels were measured using a sound level meter.

4. Results and Discussion

The results of the RULA assessment of the workers are shown in Table 2. According to this technique of posture analysis 10.53% of workers are working in acceptable posture and requires no corrective measures. About 28.95%

workers posturedemand corrective actions in near future. Around31.57% workers are working in posture of high risklevel and require corrective action as soon aspossible. The RULA scores are distributed process wise and the results are shown in Table 3. The workers in loading and unloading are at low risk whereas the workers in sheet metal section are at low to medium risk which requires changes to be made soon. The structure welding requires workers in awkward postures and the risk involved is medium to high risk. This means the postures have to be corrected immediately. The roof fixtures process falls under high risk category and immediate change is necessary. High risks were encountered in outer panel fixing and doors and windows fabrication. The seat fixing and electrical work involves low to medium risk, and the painting work is at low risk postures.

Table 2. Distribution of RULA Score

RULA Score	Risk level	Action	No. of workers	% age of workers
1-2	Negligible	Acceptable	4	10.53
3-4	Low	Further investigation and changes may be needed	11	28.95
5-6	Medium	Investigation and changes required soon	11	28.95
7	High	Investigation and changes required immediately	12	31.57
		Total	38	

Table 3. Process wise distribution of RULA Score

Job Description	RULA Score				Total (n=38)
	1-2	3-4	5-6	7	
Loading and unloading	1	4	-	-	5
Sheet cutting and metal sections cutting	2	3	2	-	7
Press work	-	-	1	1	2
Structure welding	-	-	2	2	4
Structure drilling and riveting	-	-	2	-	2
Doors and windows fabrication	1	1	-	2	4
Outer panel and fixing	-	-	1	2	3
Painting and putty	-	2	-	-	2
Roof fixtures	-	-	-	4	4
Electrical fittings	-	1	2	-	3
Seat fitting	-	-	1	1	2
Total	4	11	11	12	38

The results obtained from the REBA assessment worksheet are shown in Table 4 and reveals the different categories of the risk levels. Around 26.32% of the workers are at very high risk level and needs an urgent change, whereas 23.68 % workers were found at high risk levels and needs a necessary action soon. Around 42.10% of the workers were at medium risk level and needs a necessary change soon whereas 7.90% of the workers are working in acceptable posture.

The process wise distributed REBA scores are shown in Table 5. The workers in loading and unloading are at medium to high riskand very high risk;whereas the workers in the press work have medium to high risk. The postures in sheet cutting are evenly distributed from low risk to very high risk. This is due to the manual involvement of the workers in awkward postures.The workers involved in such work as structure drilling and riveting, painting and putty and electrical fittingsexhibit low to medium risk. Some of the postures in roof fixing fall under very high risk category. The structure welding work reveals high to very high risks and the some of the postures have to be corrected immediately. The door and windows fabrication work highlights the postures from low to medium and high risk. This depends on how and where the worker is working.

Table 4. Distribution of REBA Score

REBA Score	Risk level	Action	No. of workers	% age of workers
1	None	Not necessary	0	0.00
2-3	Low	May be necessary	3	7.90
4-7	Medium	Necessary	16	42.10
8-10	High	Necessary and soon	9	23.68
11-15	Very high	Necessary urgent	10	26.32
		Total	38	

Table 5. Process wise distribution of REBA score

Job Description	REBA Score					Total (n=38)
	1	2-3	4-7	8-10	11-15	
Loading and unloading	-	-	1	2	2	5
Sheet cutting and metal sections cutting	-	1	3	1	2	7
Press work	-	-	1	1	-	2
Structure welding	-	-	-	2	2	4
Structure drilling and riveting	-	-	2	-	-	2
Doors and windows fabrication	-	1	1	1	1	4
Outer panel and fixing	-	-	2	1	-	3
Painting and putty	-	-	2	-	-	2
Roof fixtures	-	-	2	-	2	4
Electrical fittings	-	1	2	-	-	3
Seat fitting	-	-	-	1	1	2
Total	0	3	16	9	10	38

The Quick Exposure Checklist was administered by the observer and the “Observer’s Assessment” checklist to conduct a risk assessment for a particular task was noted down. If the job consisted of multiple tasks, each task was assessed separately. Where a job could not be easily broken down into tasks, the “worst” event within that job when a particular body part in question is most heavily loaded was observed and assessed accordingly. The assessment was carried out by direct observation and the worker was asked to complete the workers assessment. For each body area, it is important to look for interactions between the scores that contribute to the exposure score for the body area. If the risk level is high or very high, it is likely that one or two factors for each body area have been given a maximum score which suggests that addressing these factors will reduce the overall risk to the body area. Exposure scores for driving, vibration, work pace and stress have also been categorized into four exposure categories although the fourth category (very high) is only used for stress.

The exposure level E is calculated as a percentage rate between the actual total exposure score X and the maximum possible total X_{max}

For manual handling tasks, $X_{max} \cdot MH = 176$

For other tasks, $X_{max} = 162$

The exposure level E (%) = $X/X_{max} \times 100\%$

The results obtained from the QEC assessment score sheet are shown in Table 6. It is observed the about 10.53% of postures are at a low risk and no change is necessary. 31.58% of postures exhibit medium risk and further investigation is necessary. About 23.68% workers are under high risk category and further investigation and change is required. The QEC score reveals that 34.21% of the postures fall under very high risk and further investigation and change is required immediately.

Table 6. Distribution of QEC Score

QEC Score (E) (percentage total)	Action	No. of workers	% of workers
≤ 40%	Acceptable	4	10.53
41-50%	investigate further	12	31.58
51-70%	investigate further and change soon	9	23.68
>70%	investigate and change immediately	13	34.21
Total		38	

Table 7. Process wise distribution of QEC score

Job Description	QEC Score				Total (n=38)
	≤ 40%	41-50%	51-70%	>70%	
Loading and unloading	1	4	-	-	5
Sheet cutting and metal sections cutting	2	4	-	1	7
Press work	-	-	1	1	2
Structure welding	-	-	2	2	4
Structure drilling and riveting	-	-	2	-	2
Doors and windows fabrication	1	1	-	2	4
Outer panel and fixing	-	-	1	2	3
Painting and putty	-	2	-	-	2
Roof fixtures	-	-	-	4	4
Electrical fittings	-	1	2	-	3
Seat fitting	-	-	1	1	2
Total	4	12	9	13	38

The process wise distribution of QEC score reveals that the loading,unloading and sheet cutting and painting workers are at medium risk suggesting further investigation may be required. The workers doing the roof fixtures are at a very high risk and immediate investigation and change is necessary. The outer panelling work indicates a risk level of high to very high requiring immediate change. In structure welding the scores are high to very high risk as the workers adopt awkward postures like bending, twisting and working above the shoulders, while welding the structure. The door and windows fabrication work reveals a low,medium and very high risks.

4.1 Comparison of RULA,REBA and QEC

Percentages of action levels of RULA, REBA and QEC for 38 studied jobs are presented in Table 8.

Table 8. Percentages of action levels of RULA,REBA and QEC showing the risk level

Assessment tool	Action required/ risk level (% of postures)				
	Acceptable	Low risk	Medium risk	High risk	Very high risk
RULA	10.53	28.95	28.95	31.57	-
REBA	0	7.90	42.10	23.68	26.32
QEC	10.53	31.58	23.68	34.21	-

It can be seen from the above table that according to RULA 31.57% of the workers are placed under high risk category whereas QEC also gives almost similar results at 34.21% of workers at high risk requiring further investigation and immediate change. QEC shows that 31.58% of workers are at low risk indicating further investigation whereas RULA gives 28.95% of workers at low risk . In the medium risk category 28.95%ofworkersare at medium risk scording to RULA and 23.68% of workers are at medium risk in QEC assessment.A scatter plot showing the results of RULA and QEC is shown in figure 1.

The comparison of RULA and REBA shows that 23.68% of workers are at high risk and 26.32% of workers are at very high risk as a result of REBA assessment. The RULA scores for high risk are 31.57% of workers. If the scores of high and very high risk are combined in REBA then the total score of high to very high risk is 50%. The high scores in REBA is due to the awkward postures adopted by the entire body in doing such work like loading and unloading, structure welding, roof fixtures. REBA analysis shows about 42.10% of workers are at medium risk while RULA gave 28.95% postures as medium risk. RULA classifies 28.95% of workers under low risk category whereas REBA results show only 7.90% of workers as under low risk. Thecomparison of both the RULA and REBA scores are shown in figure 2.

The results of QEC and REBA are shown in figure 3. REBA analysis shows that 7.90% of workers are at low risk whereas the low risk level according to QEC is 31.58%. According to REBA 42.10% of workers fall under medium risk while QEC shows 23.68% as medium risk requiring further investigation. Under the high risk category QEC gave 34.21% of workers, while REBA shows 23.68% of workers possess high risk and further 26.32% fall under very high risk.

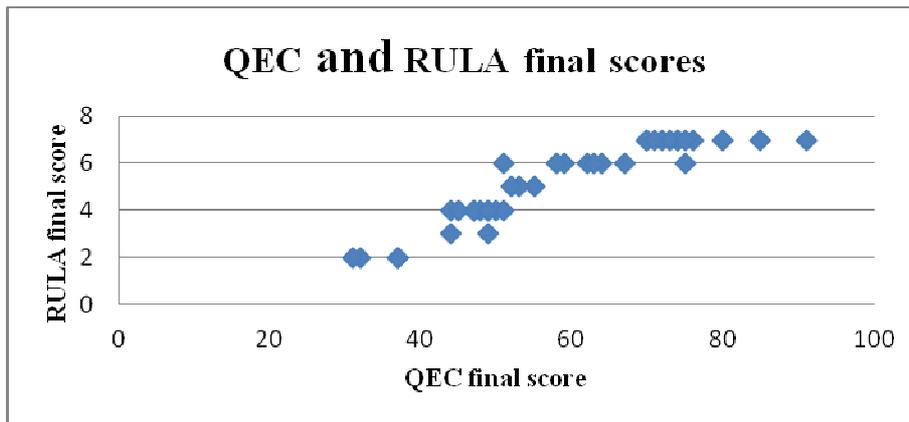


Figure 1. Scatter plot showing RULA and QEC scores

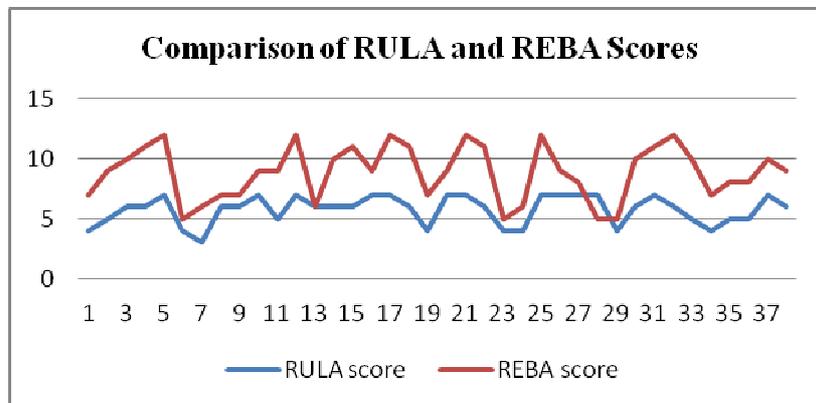


Figure 2. Comparison of RULA and REBA scores

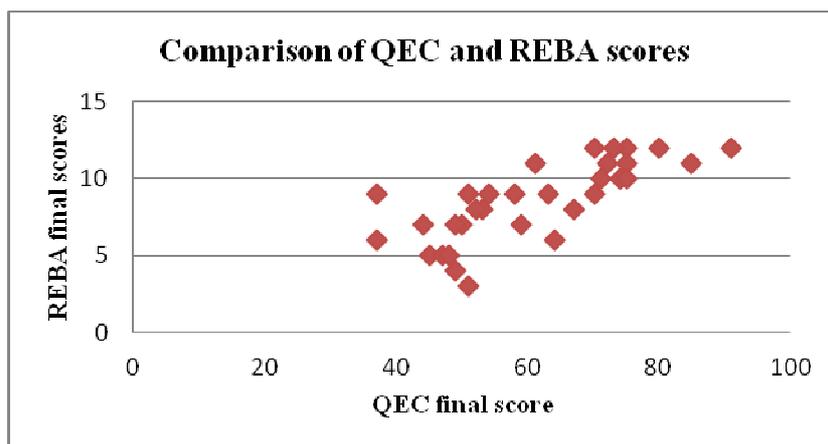


Figure 3. Comparison of QEC and REBA scores

5. Conclusion

From the analysis of results and scores obtained by all the three tools it can be concluded that there is a lack of awareness about ergonomics in the working methods in the bus body building company. The workers adopt awkward postures involving frequent twisting, bending, and over-reaching, which are a result of poorly designed workplace and working methods. These actions force them into a non-neutral position that increases the overall discomfort and pain at the lower back, neck, and shoulders. Almost one third of the study populations claimed to feel uncomfortable to their lower back, neck and shoulders. Thus the workers are under moderate to high risk and in some postures at a very high risk of Work-related Musculoskeletal disorders (WMSDs). Application of ergonomic principles, biomechanical and engineering principles can be effective in reducing the risks

and occurrence of WMSD. The present study recommended that there is dire need of implementation of ergonomics interventions with proper awareness and training among workers.

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Appendix A



CHASIS



JIGS AND FIXTURES



STRUCTURE



BODY FITTED ON CHASIS



SHEET METAL CUTTING



SHEET METAL CUTTING



PRESS WORK



BODY FABRICATION



POWER HACKSAW



DOOR FABRICATION



WELDING



PAINTING

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