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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 demandingworking 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 theworkplace. The presents study is focused on posture analysis of the workers working in a automotive coach manufacturing company (bus body building) company. The study wasconducted on 38 workers engaged in various process of manufacturing. The different activities of the workers were recorded by Video and still photography, and these images were used for analysis. Posture analysis toolsRULA, 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 andabout 28.95% of the workers were at lower risk levels. The results of REBA showed that about26.32% of the workers wereunder 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 inhigh 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 risksof WMSD.

Keywords: Posture analysis, WMSD, bus body building

1. Introduction

The field of ergonomics is rapidly becoming a key area of interest to industrialorganizations, which are concerned with providing a comfortable, safe, and pleasantworking area for their employees as well as producing high quality user-friendlyproducts to customers at the same time stressing on continuous improvement inproductivity. This interest in applying ergonomic principles to industrial workplacesand products is most likely a result of correlations established between the design of aworkplace on ergonomics principles and the resulting productivity and health of theworker (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 manufacturingindustries, the primary concern has usually been theimprovement of the performance of the equipment alone. Little consideration is given towards matchingthe abilities of the operator with the taskrequirements (Das & Sengupta 1996). Consequently, many industrialworkstations are poorly designed, resulting in lowerworker productivity and unnecessary injury at theworkplace leading to development of work related musculoskeletal disorders.

WMSD are diseases related and/or aggravated by work that can affect the upper limbextremities, the lower back area, and the lower limbs. WMSD can be defined byimpairments of bodily structures such as muscles, joints, tendons, ligaments, nerves, bonesand the localized blood circulation system, caused or aggravated primarily by work itself orby the work environment (Nunes2009a).The ageing of the workforce are also acontribution to the widespread of WMSD , since the propensity for developing a WMSD isrelated more to the difference between the demands of work and the worker's physicalwork capacity that decreases with age (Okunribido& Wynn 2010). WMSD have also heavy economic costs to companies and to healthcare systems. The costsare due to loss of productivity, training of new workers and compensation costs (Isabel Nunes& Pamela McCauley 2008). (Kourinka et al 1987) reported ergonomicfactors such as awkward working postures, staticload and task invariability to be some of the mostimportant factors contributing to occurrence ofmusculoskeletal 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, Qutubuddinet.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 stationthe objective should not only be to maximize workerproductivity, but also try to improve workersatisfaction and minimize safety hazards. It ispossible to achieve such a desirable goal through proper application of ergonomics principles andanthropometric data (Qutubuddin S.M,2012a). An ergonomics approach tothe design of an industrial workstation attempts toachieve an appropriate balance between the workercapabilities and work requirements (Das &Sengupta1996).The origins of ergonomic risk factors includethe workstations, tools, equipments, workmethods, work environment, worker personalcharacteristics, metabolic demands, physicalstress, and emotional stress. Professionals from mechanical engineering, industrial engineering,occupational hygiene, occupational medicine,occupational therapy, kinesiology, psychology,and many other fields, provide unique insightsinto the relationship between worker/workplaceand WMSDs (MajidMotamedzade et.al.2011).Understanding ergonomic riskfactors are essential because there is indicationthat ergonomic risk factors are causally relatedto musculoskeletal disorders of the upper extremitiesand the low back (Drinkaus Pet.al 2003).

There are a number of ergonomic assessmenttools that attempt to evaluate the ergonomicrisk of a job or task. For example, the Rapid Upper Limb Assessment (RULA), theRapid Entire Body Assessment (REBA) andQuick Exposure Check (QEC) are more holisticergonomic risk assessment tools that measurethe ergonomic risks of both upper and lowerparts of the musculoskeletal system. Biomechanicalassessments can be done for all theregions of the musculoskeletal system especiallyshoulder moments and moments about thelow back. Evaluations of several ergonomicobservational methods revealed that these methodswere applicable undervarious workplace conditions. Each methodhas its own posture classification procedure,which is different from other methods andtherefore may lead to assign different posturalscores for a given posture, depending on particularmethods 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 engagedin 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 assessmenttools namely RULA (Rapid Upper Limb Assessment),REBA (Rapid Entire Body Assessment) and QEC (Quick Exposure Check) to assess the working postures and recommend thechanges to be made.

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

This tool requires nospecial equipment in providing a quick assessment ofpostures of the neck, trunk and upper limbs along withmuscle function and the external loads experienced bythe body. A coding system is used to generate an actionlist which indicates the level of intervention required toreduce the risks of injury due to

physical loading on theoperator.Briefly, the upper arm, lower arm, and wrists postures are evaluated and scores are given foreach body part posture. Then, the scores are combined (using a specially developed scoring table) togenerate the upper limb posture score. Similarly, the neck, trunk, and legs postures are evaluated andscores are also given. They are combined to generate the neck-trunk-legs score. For both combinedscores, scores for muscle use and force are added. Finally, the grand score is determined and actionto be taken is recommended.
REBA (Rapid Entire Body Assessment) wasdeveloped (Hignett, S. and McAtamney, L. 2000), toprovide a quick and easy observational postural analysistool for whole body activities (static and dynamic givingmusculoskeletal risk action level. The development ofREBA is aimed to divide the body into segments to becoded individually with reference to movement planes. Thedesign of REBA is very similar to that of RULAmethod and special attention is devotedto the external load acting on trunk, neck, andlegs and to the worker–load coupling using theupper limbs. Postures of individual body partsare observed and postural scores increase whenpostures diverge from the neutral position.Group A includes trunk, neck, and legs, whilegroup B includes upper and lower arms and wrists. Other items including the load handled,couplings with the load, and physical activityare specifically scored and then processed intoa single combined risk score using a table provided.These scores are summed up to give onescore for each observation, which can then becompared to tables stating risk at five levels,leading to the necessity of actions. UnlikeRULA, REBA provides fiveaction levels for estimating the risk level.These risk levels starting from 0 to 4 are correspondingto negligible, low, moderate, highand 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		

InQEC to achieve an overall score, total scoresobtained from four body parts are added andthe product is divided by the maximum possiblescore, i.e., 176 for manual material handlingtasks and 162 for others. Score of (<40%)indicates low risk, for a score of 41% to 50%, indicates moderate risk and further investigation is neededand changes may be required. A score of 51% to 70% indicateshigh 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 therisk level. These risk levels are named from 1 to 4 i.e. low, moderate, high andvery 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.lal. 2003). QEC is used to assess the level of exposureto ergonomic risks. The methodincludes the assessment of the back, shoulder/upper arm, wrist/hand and neck, withrespect 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 taskand difficultiesto sustain with the work as well as the stressfulness of the work are also obtained from the worker. The ratings areweighted into scores and added up to summary scores for different body parts and other itemsdriving, 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 wascollected to ensure the completion of ergonomicrisk 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 ergonomicrisk of a job or task, the Rapid Upper Limb Assessment (RULA),theRapid Entire Body Assessment (REBA) andQuick Exposure Check (QEC) are used.
The RULA score sheet was used to assess the upper limbs mainly arms and wrist of posture; eachbody part is divided into sections depending on the range of movement and these sections arenumbered so that the number 1 is assigned to the rangeof movement or working posture where minimal risk is involved. Higher numbers are assigned to parts of the movement range with moreextreme postures indicating an increasing presence ofrisk factors causing load on the structures of the bodysegment. The exposure scores according to RULAwere divided into four risk categories:negligible, low, medium and high. Medium and highrisk actions should be urgently addressed to reducethe level of exposure of risk factors. For thoseactivities wherethe whole body and limbs motion are to be assessed REBA was used. In REBA the body parts are dividedinto sections and each body part is scored accordingto its range of movement. Lower scores are given tothe body parts where presence of risk factors isminimal and higher scores are given to those body parts wherepresence of risk factors ismore. The REBAscores were divided into five categories: negligible,low, medium, high and very high. Medium, high andvery high needed an immediate action to avoid anymusculoskeletal 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 be alerted. Metal sheets, sections, angles and rodsare 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 thechassis 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 readymade 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 theworkers are shown in Table 2. According to thistechnique of posture analysis 10.53% of workers areworking in acceptable posture and requires nocorrective 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, $X_{max}MH = 176$

For other tasks, Xmax = 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 riskas the workers adapt 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 sccording 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.

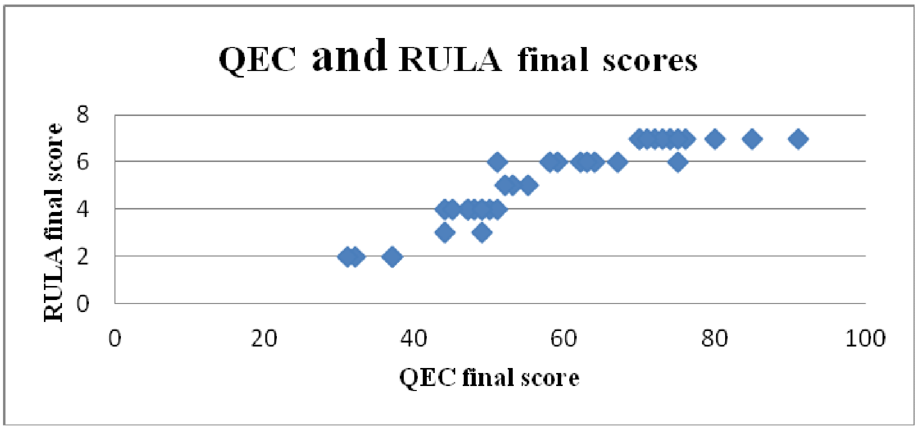

Figure 1. Scatter plot showing RULA and QEC scores

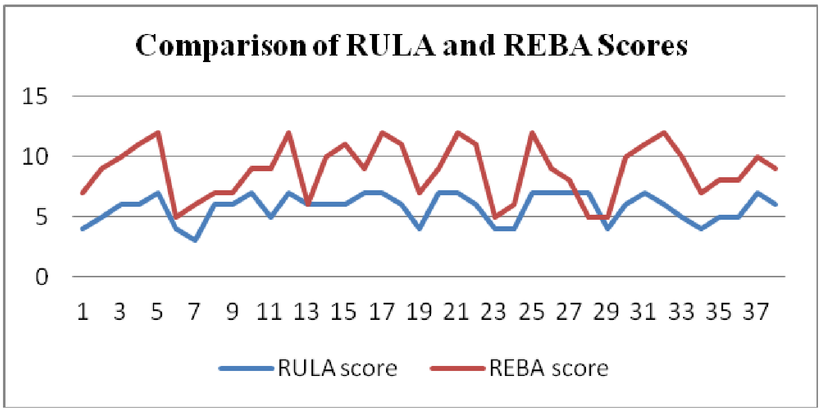

Figure 2. Comparison of RULA and REBA scores

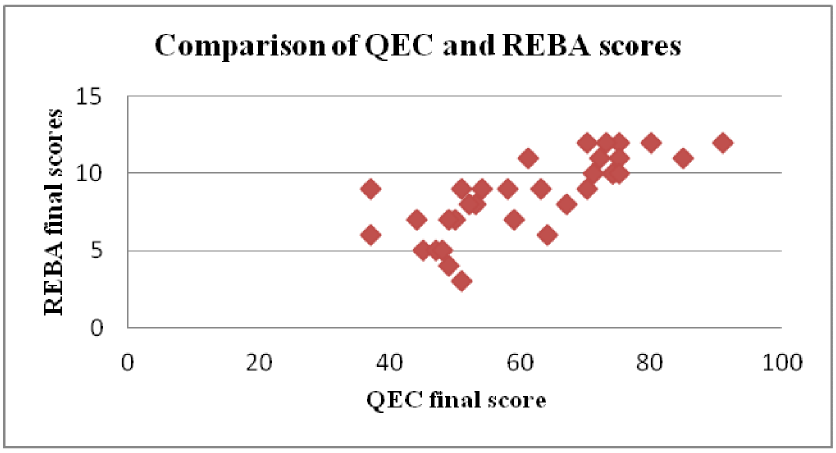

Figure 3. Comparison of QEC and REBA scores

5. Conclusion

From the analysis of results and scores obtained by all the three tools it can be concluded that thereis 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 thatincreases the overall discomfort and pain at the lower back, neck, andshoulders.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 andoccurrence of WMSD. The present studyrecommended that there is dire need ofimplementation of ergonomics interventions withproper 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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