VOL. 10, NO. 6, APRIL 2015 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences


www.arpnjournals.com

EVALUATION OF WORK POSTURES - THE ASSOCIATED RISK ANALYSIS AND THE IMPACT ON LABOR PRODUCTIVITY

Chowdury M. L. Rahman, Syed Misbah Uddin, M. A. Karim, and Mohiuddin Ahmed
Department of Industrial and Production Engineering, ShahJalal University of Science and Technology (SUST), Sylhet, Bangladesh
E-Mail: basitchy_23@yahoo.com

ABSTRACT

Various musculoskeletal disorder (MSD) symptoms can be experienced by the workers performing their tasks in bad work postures which are largely static and consequently these are associated with long term risks and injuries. These postures also have a bad impact on work performance and labor productivity. In this regard, this case study research work has been conducted in a selected ceramic factory of Bangladesh with the aim of evaluation of work postures of workers working in the production section of the factory through rapid upper limb assessment (RULA) and their impact on labor productivity. The secondary objective of the research work was to draw an analysis of associated risks with the bad work posture. In order to evaluate the work postures of workers, RULA technique has been used. RULA is a widely used tool developed for the assessment of work postures which specifically examines the level of risk associated with the upper limb disorder of individual workers by scoring the different body region of the workers. The results obtained from this research work have been plotted into three main sections, namely the identification of good or bad work posture and the level of risks associated with poor work posture and their impact on labor productivity. It has been identified that most workers have been exposed to the upper limb discomfort which in turn contributes to the risk of injuries during the performance of work. Through the analysis of RULA, it has been revealed that no posture is found risk free during the investigation of work postures of workers. According to RULA grand score of 7, 43.59% of the workers need immediate investigation and changes indicating that the level of exposure to postural risks is very high and immediate ergonomics intervention to decrease the exposure to risk level seem essential. The consequence of bad work posture results in musculoskeletal disorders (MSDs) which have also been analyzed in this research work. The most commonly affected body regions found among the 39 listed workers are shoulders (92.31%), neck (71.79%), wrist (71.31%), lower back (43.59%) and upper back (41.03%). Lastly, the correlation between RULA grand score and labor productivity has been shown. The graphical analysis reveals that there is a decreasing trend of labor productivity with the higher RULA grand score establishing the fact that there exists an inverse relationship between average RULA grand score and average labor productivity.

Keywords: labor productivity, musculoskeletal disorder, posture, rapid upper limb assessment, risk.

INTRODUCTION

Musculoskeletal disorders (MSDs) are injuries and disorders that affect the musculoskeletal system of human body. Various musculoskeletal disorder (MSD) symptoms are experienced by the workers performing their tasks in bad work postures which are largely static and consequently these are associated with long term risks and injuries. The disorder occurs when the body part is called on to work harder in bad work postures. These postures do have an adverse impact on work performance and labor productivity. Labor is one of the most important factors of a business organization because it is directly related to the productivity of the system. Labor productivity is a key indicator of successful business efficiency, particularly for firms in which the production process is labor-intensive like ceramics manufacturing factory. Good and bad posture can positively and negatively affect the labor productivity. Disorders and stress which caused by bad work posture can lead to a reduction in productivity and the body's ability to work skillfully. Tuning into proper body posture can limit the amount of stress and disorders. Additionally, a strong, healthy worker is a productive worker and that productivity is reflected positively in the bottom line.

There are some criteria which have a significant impact on the ability, skills, productivity and performance of workers such as work environment, methods of production, wages, body posture of worker etc. Work posture may be regarded as the position or configuration of the limbs or body parts at the time of work. Work posture refers to the posture that an individual is required to adopt due to the layout of a workstation and/or the nature of the task. Work posture has a direct impact on worker's performance and productivity. Poor working posture is a common ergonomic hazard that can cause fatigue, discomfort and injury risk, particularly at fixed workstations such as safety cabinets, inspection or packing workstations [1].

In this connection, this case study research work has been conducted in a selected ceramic factory of Bangladesh with the aim of evaluation of work postures of workers working in the production section of the factory through rapid upper limb assessment (RULA) and their impact on labor productivity. The poor posture and movement can lead to local mechanical stress on the muscles, tendons, ligaments and joints, resulting in discomfort in the neck, back, shoulder, wrist and other parts of the musculoskeletal system. This is because, when maintaining a posture, the joints must be kept in a neutral position with the limbs, as far as possible, close to the body, thus enabling the muscles to deliver the greatest force. On the contrary good posture allows muscles to

work properly, decreases abnormal wear on joints, keeps the spine from becoming fixed in irregular positions, and prevents backache and muscular pain and resultantly contributes to an attractive appearance.

Research objectives

The objectives of this case study research work are:

a) To evaluate the work postures of workers working in the production section of a selected ceramic factory through rapid upper limb assessment (RULA).
b) To establish the correlation between the associated risks and the bad work posture.
c) To evaluate the impact of RULA grand score of various work postures on labor productivity.

Assessment of work posture

Body posture should be assessed for knowing the condition of risk level as well as validity of the posture. There are different types of methods to assess the validity and risk level of body posture.

Ergonomic work posture assessment tools

Tools are needed in working posture assessment so that the workplace that is safe to the workers can be created. This includes the method for measurement and analysis of workers physiology while they are performing a task. In designing a proper workplace, it is necessary to obtain relevant information on tasks, equipment, working postures and environments.

Many of the methods such as observation method, direct measurement method can be used for the purpose of evaluation of work posture. The objectives of such methods are to measure and analyze the physiology of workers in the workplace and to make recommendations for changes to reduce risk of injuries and disorders. Occupational diseases have been found to be associated with numerous occupational risk factors such as physical work load factors including excessive force, awkward postures and vibration. These physical postures are being measured by ergonomic assessment tools [2].

Review of past research works

A research work was done by D. N. Agrawal, T. A. Madankar and M. S. Jibhakate in 2011 on 'Study and Validation of Body Postures of Workers Working in Small Scale Industry through RULA'. This paper has focused the attention on the ergonomics consideration required to be governed in the small scale industries; a specific case of tractor trolley manufacturing unit was considered. Welding in this industry has been done on kneeling posture as the fixture used for welding is placed on the ground. Worker has to sit constantly on that posture and has to perform the assigned welding work. It has been observed and found that due to continuous kneeling posture worker got fatigued frequently and musculoskeletal problems were identified which have been then validated by using RULA [4].

An important research work was carried out by Tirthankar Ghosh, Banibrata Das and Somnath Gangopadhyay in 2010 on 'Work-related Musculoskeletal Disorder: An Occupational Disorder of the Goldsmiths in India'. MSDs were discussed in their papers which have been reported in different occupations due to improper body posture and work load. Poor design of workstation is the mail cause of improper postures such as twisting, bending and over reaching. These postures increase the discomfort and pain at different body parts such as back, neck and shoulders. By providing proper work desk, the working condition could have been improved [5].

Another research study was conducted by Alireza Choobineh, Sayed Hamidreza Tabatabaei, MarziehTozihian, and Fatemeh Ghadami in 2007 on 'Musculoskeletal problems among workers of an Iranian communication company'. In their research, they used Nordic musculoskeletal questionnaire and RULA in order to find out the work related MSDs and it was observed that there has been very high score of RULA (action level 3 and 4). RULA score can be reduced by designing ergonomic workstation and it may reduce the WRMDs among the workers. RULA shows that the awkward working postures and static work are found to be the major risk factors that the workers encountered. Improper design and poor arrangement of workstation are the causes of postural problems and could be cured by redesigning the workstations based on ergonomics principles that will reduce the RULA Grand Score [6].

METHODOLOGY

The action plan followed in conducting this case-study research work is shown in Figure-1.

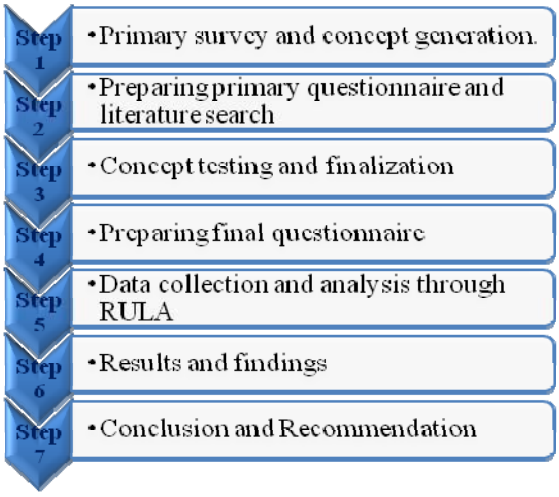

Figure 1. Research methodology.

Work posture evaluation method using RULA

Among the assessment tools to evaluate the work posture however, RULA - a pen paper based observation method is widely being applied in many industries. RULA is a commonly used tool developed for the assessment of work postures which specifically examines the level of risk associated with the upper limb disorder of individual workers by scoring the different body region of the workers. In this research work, the RULA work sheet scoring system has been used to gather the overall score for the designated workers working in the production section of the selected ceramic factory.

The Rapid Upper Limb Assessment (RULA) was developed by Dr. Lynn McAtamney and Dr. Nigel Corlett of the University of Nottingham's Institute of Occupational Ergonomics. It was first described in a 1993 issue of the journal 'Applied Ergonomics'. This ergonomic technique evaluates individuals' exposures to work postures, forces and muscle activities that have been shown to contribute to Repetitive Strain Injuries (RSIs). Use of this ergonomic evaluation approach results in a risk score between one and seven, where higher scores signify greater levels of apparent risk. A low RULA score does not guarantee that the workplace is free of ergonomic hazards and a higher score does not assure that a severe problem exists. It was developed to detect work postures or risk factors that deserve further attention [3].

DATA COLLECTION AND ANALYSIS

The objective of data collection and analysis is to screen and format the data of various work postures into necessary form and then to analyze the structured data to identify the good or bad posture of workers in order to find out the rapid upper limb assessment (RULA) grand score.

Data analysis through RULA worksheet

At first the various work postures of workers have been observed in the view point of RULA. Then the observed work postures have been evaluated in terms of RULA score sheet. According to this method, a score is calculated for the position of arms, wrists, neck, trunk and leg. Score 1 indicates the most neutral posture and gradually increasing scores shows the worst position. The combined individual scores for arm and wrist provide group A score and neck, trunk and leg provide group B score of RULA worksheet. Muscle use and muscle force are attributed to a score of 0 or 1. These scores are added to Table A and B scores to obtain the final arm and wrist score as well as final neck, trunk and leg position score. After that these two scores are compiled in table C of RULA worksheet in order to obtain the RULA grand score.

The range of RULA grand score is 1 to 7 which indicates different terms and conditions. Higher RULA score indicates the lower validity of work posture and higher risk. On the contrary, lower RULA score indicates the higher validity of work posture and association of lower risk. The various ranges of RULA grand score and the regarding decisions about work posture is shown in Table-1. According to the table, green color is used for good work posture and red color is used for bad work posture.

Table 1. Elaboration of RULA grand score.

RULA Grand Score	Decision about Posture
1-2	Posture is acceptable if it is not maintained or repeated for long periods.
3-4	Further investigation is needed and change of posture may be required.
5-6	Further investigation and changes are required soon.
7+	Investigation and changes are required now.

Evaluation of RULA grand score

After the evaluation of RULA grand scores through RULA worksheet for various work postures of a certain number of workers working in the production section of the selected ceramic factory, these 39 workers have been arranged according to their relevant scores and the percentage of workers for different scores is shown in the Table-2 accordingly.

Table 2. RULA grand score of different workers

RULA grand score	Number of worker	Percentage
4	6	15.38%
5	6	15.38%
6	10	25.64%
7	17	43.59%

It has been found that the RULA grand score for 6 workers is 4 and 5 respectively. Moreover, for 10 workers the grand score is 6 whereas for 17 workers the score is 7. From the Table-2, it is evident that the no

workers have acceptable work posture and most of the workers are working in high posture related risk.

The relative percentage of the workers for various RULA grand scores is plotted in the Figure-2 accordingly. It has been identified that no existing posture is valid according to the standard of RULA. Further investigation or change may be required of 15.38% workers because their RULA grand score is 4. Further investigation or rapid changes of posture is required of 41.02% (15.38%+25.64%) workers as they have the score of 5 or 6. Must investigation and immediate changes of posture is needed for 43.59% workers because they have the very high RULA grand score of 7+.

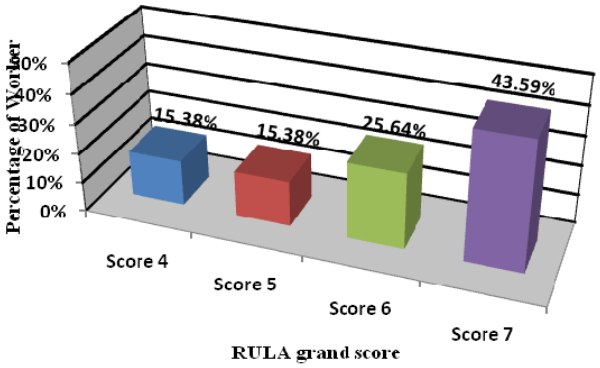

Figure-2. RULA grand score Vs percentages of workers.

Analysis of risk level by RULA grand score

The RULA grand score has been compared to different levels of risk. However this comparison provides us with a guide line for further action. In most cases, this guide line is used as an aid in efficient and effective control of any risks identified, the actions lead to a more detailed investigation. Table-3 represents the risk level of 39 workers according to RULA grand score. In this table different risk levels have been categorized with the different ranges of RULA grand score.

Table 3. Analysis of risk level.

RULA grand score	Risk level	Percentage
1-2	Low	-
3-4	Intermediate	15.38
5-6	High	41.02
7+	Very High	43.59

The relative percentage of workers in association with various RULA grand scores against different risk levels is plotted here in the Figure-3.

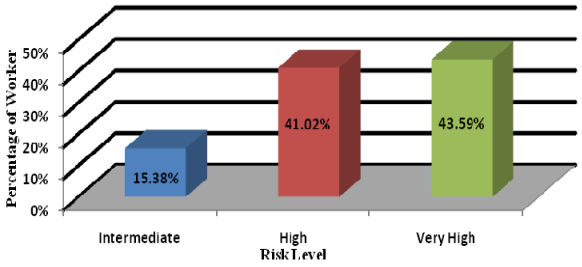

Figure-3. Risk levels Vs percentages of workers.

Figure-3 shows that there have been no workers found in low risk level. It has been observed that the RULA grand score of 15.38% of the studied workers is in between 3 and 4 which represents the intermediate risk level and indicates the level of exposure to postural risks needed considering. The RULA grand score of 41.02% (15.38%+25.64%) workers is in between 5 and 6 indicating that the level of exposure to postural risks is high and ergonomics intervention to decrease exposure level seems necessary. The RULA grand score of 43.59% workers is 7 indicating that the level of exposure to postural risks is very high and immediate ergonomics intervention to decrease the exposure to risk level seems essential.

Analysis of risk frequency

The data of the pain and discomfort of five body regions (shoulder, elbow, wrist, upper back, lower back) have been collected and categorized into three levels. If the disorders occur quarterly the risk is considered to fall in intermediate level, if the disorders occur monthly the risk is in high level and if the disorders occur weekly or daily, the risk is considered to fall in very high level. These terms and condition have been tabulated together with the categorization of three levels of risk frequency in Table-4.

Table-4. Risk frequency category.

If disorders occur	Risk frequency
Never	No
Quarterly	Intermediate
Monthly	High
Weekly	Very High

In the following Table-5, the percentage of risk frequency of five important body regions of 39 workers has been tabulated. The association of risks level with these body regions has also been found out here with the help of *t-test*.

Table 5. Analysis of risk frequency and association of risks with body regions

Areas of disorder	Risk frequency			Number of sample = 39, Degree of freedom = 38, significance level = .05.			
	Intermediate (%)	**High** (%)	**Very high** (%)	**t-value**	**Critical t-value**	**p-value**	
Shoulder	25.64	28.21	38.46	6.1664	2.02	0.00001	p<.05
Elbow	7.69	5.13	7.69	4.0508		0.000121	P<.05
Wrist	12.82	23.08	35.90	3.3172		0.001005	p<.05
Upper back	15.38	17.95	7.69	1.595		0.059498	p>.05
Lower back	20.51	12.82	10.26	1.3889		0.086475	p>.05

One sample t-test was used to determine the association among the shoulder, elbow, wrist, upper back and lower back pain and discomfort. Table-5 represents the prevalence rate of reported symptoms in different body regions in three levels of exposure to risks among the 39 workers studied. One sample t-test revealed that for the disorders of shoulder, elbow and wrist, the calculated t-values are higher than the critical t-value and consequently the corresponding p-values are less than 0.05, which is significant. However for the disorders of upper back and lower back, the calculated t-values are lower than the critical-t value, and consequently the corresponding p-values are greater than 0.05 which is insignificant. These results indicate that there is a significant association between RULA risk frequency and prevalence rate of reported musculoskeletal disorders (MSDs) in shoulder, elbow and wrist (P<0.05). The statistical significance of this score reflects the high loading of this part while performing the assigned task. The various disorders occurred in a month corresponding to the % of workers exposure to high risk frequency is now plotted in Figure-4.

The Figure-4 shows the various MSDs reported in a month in association with the percentage of workers of high level of risk frequency. It reveals that maximum number of workers (28.21%) has experienced shoulder pain and minimum number of workers (5.13%) has had elbow related problems.

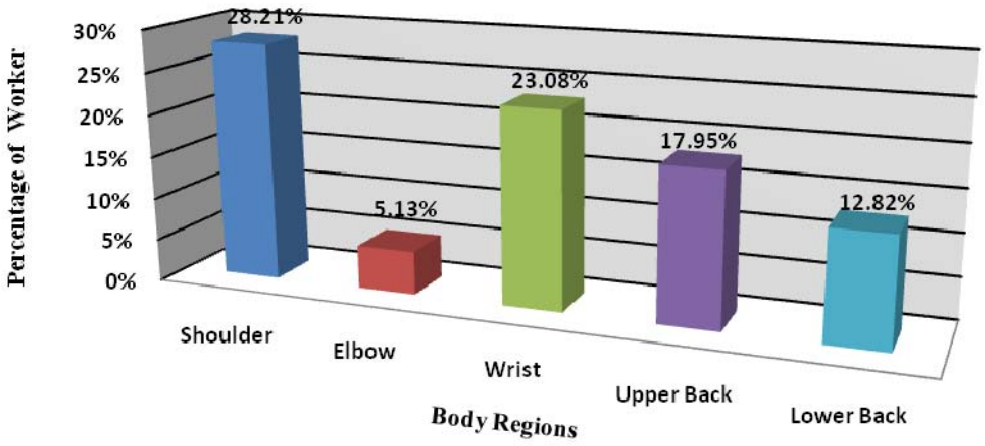

Figure-4. Percentage of workers of high risk frequency Vs areas of disorder.

Analysis of MSDs of very high risk frequency

The frequency of various MSDs occurred daily and weekly corresponding to the percentage of workers exposure to very high risk frequency is now plotted in Figure-5. The bar chart illustrates the weekly and daily frequency of MSDs occurred in various body parts corresponding to percentage of workers of very high risk frequency.

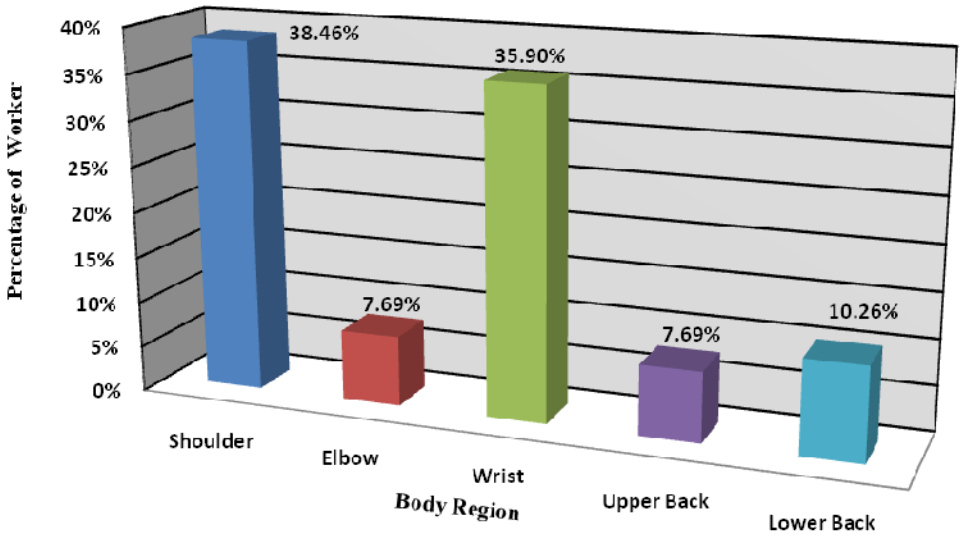

Figure-5. Percentage of workers of very high risk frequency Vs areas of disorder.

Like the quarterly and monthly occurred disorders in different body regions corresponding to percentage of workers of intermediate and high risk frequency, shoulder pain is very common for workers exposure to very high risks and it is the highest number of workers (38.46%) and importantly the same number of workers have experienced elbow and back pain (7.69%) and this is the least Figure.

IMPACT OF WORK POSTURE ON LABOR PRODUCTIVITY

Labor productivity measures the amount of goods and services produced by one hour of labor. More specifically, labor productivity measures the amount of real GDP produced by an hour of labor. Labor productivity is the rate of output per labor per unit of time compared with an established standard or expected rate of output.

There are many standard formulas for measuring the labor productivity. Labor productivity can be measured as a ratio of the total output (goods or services) in dollars to the number of man-hours to produce the output [7]. Labor productivity can also be measured as the ratio of total output to the number of workers used to produce the output. In the analysis of labor productivity, the formula used for measuring the labor productivity is given below.

Labor Productivity = Total Output /Total Man-Hours.

Calculation of labor productivity

The calculation is based on the total number of workers working on the total machines which are fully utilized in the production section of the selected ceramic factory. In this calculation other factors like the skill of the workers and the machines condition have been considered as invariant.

In the existing condition,

Each machine includes three workers (One operator + two helpers)

Total number of running machines = 12

Total number of operators = 12

Total number of helpers = 24

As for instance, on Machine - 1,

Daily production of ceramic tiles = 1600 (pieces)

Time required per worker = 8 hours

Number of worker = 3.

So, the Labor productivity on machine -1

$= 1600/ (3\times8) = 66.66 \approx 67.$

Similarly the productivity calculations of all other workers on the respective machines have been performed and tabulated in Table-6.

Table 6. Hourly labor productivity calculation.

Worker	RULA grand score	Machine	Average RULA grand score	Number of workers	Hourly production (Pieces)	Daily production (Pieces)	Labor productivity per hour in terms of production
1	5	Machine 1	6.00	3	200	1600	67
2	7						
3	6						
4	4	Machine 2	5.00	3	225	1800	75
5	7						
6	4						
7	4	Machine 3	5.00	3	210	1680	70
8	6						
9	5						
10	5	Machine 4	5.67	3	190	1520	63
11	6						
12	6						
13	5	Machine 5	6.00	3	180	1440	60
14	7						
15	6						
16	5	Machine 6	5.67	3	200	1600	67
17	7						
18	5						
19	7	Machine 7	6.00	3	170	1360	57
20	7						
21	4						
22	7	Machine 8	6.00	3	190	1520	63
23	7						
24	4						
25	7	Machine 9	6.33	3	160	1280	53
26	7						
27	5						
28	6	Machine 10	5.33	3	225	1800	75
29	6						
30	4						
31	4	Machine 11	6.00	3	200	1600	67
32	7						
33	7						
34	4	Machine 12	5.00	3	210	1680	70
35	7						
36	4						

The relation between RULA grand score and the corresponding labor productivity has been shown in Table-6. The results represent the RULA grand score of 36 workers in total working on 12 different machines. Average RULA Grand score of each machine's worker is also calculated here. Hourly production as well production per day on each machine and the hourly labor productivity in terms of production are also listed in the table.

On the basis of labor productivity calculations, the relation between RULA grand score and the labor productivity per hour in terms of production is drawn in the Figure-6.

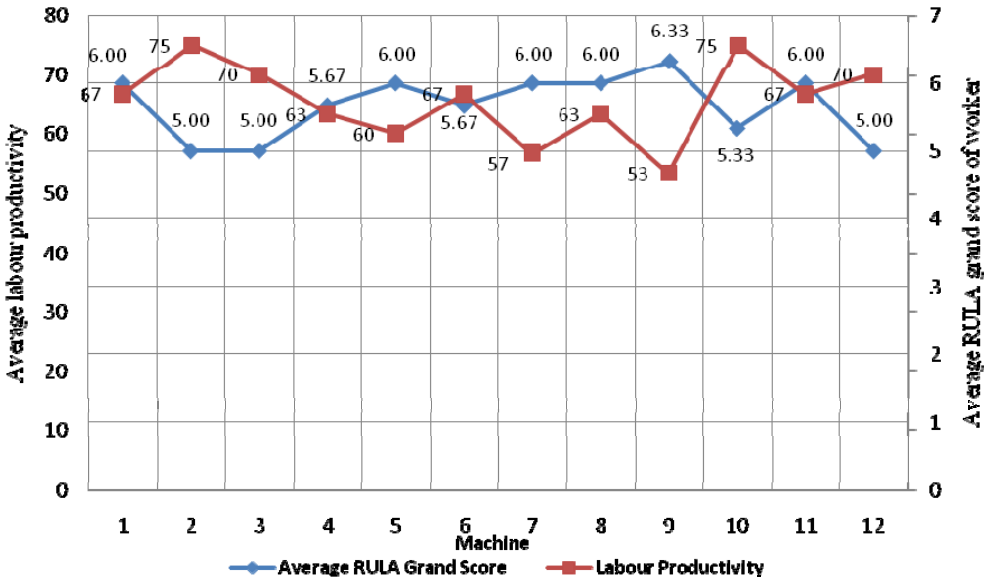

Figure-6. RULA grand score Vs productivity per hour in terms of production.

It has already been identified that higher RULA grand score indicates the bad working posture. On the contrary relatively lower score represents the good working posture. At the time of working, body posture has a significant effect on productivity. It is evident from the above relationship that the good work postures corresponding to lower RULA grand score ultimately results in higher productivity and inversely bad work postures corresponding to higher RULA grand score decrease the labor productivity. Moreover, it has been observed that for machine 1, the average RULA grand score is 6 and the corresponding labor productivity is 67 whereas for machine 2, the average RULA grand score is 5 and the corresponding labor productivity is 75. It can be concluded here that the labor productivity has been increased as the RULA grand score gets decreased. However, the labor productivity has been decreased from 75 to 70 for machine 3 though the average RULA grand score is same for machine 2 and 3. This is because the individual RULA scores for workers working on machine 2 are (4, 7, and 4) respectively and on machine 3 the individual scores are (4, 6, and 5) respectively. On machine 2, though a worker has high RULA grand score of 7, another two workers have a unique lower score of 4. However on machine 3 only one worker has low score of 4 but another two workers have relatively high score of 5, and 6. The same conclusion can be drawn for machines 2 to 5; the labor productivity has got decreased with the increase of average RULA grand score.

Relation between average RULA grand score and average labor productivity

The following table represents the average labor productivity data corresponding to average RULA grand score for workers working on 12 different machines.

Table-7. Avg. RULA grand score Vs labor productivity.

Average RULA grand score	Average labor productivity
5	71
5.33	75
5.67	65
6	62.2
6.33	53

Table-7 provides information on average RULA grand score and the related labor productivity of workers as well. It shows that labor productivity value of 75 is the highest for the average RULA grand score of 5.33 whereas the lowest labor productivity Figure of 53 has been found for the highest average RULA grand score of 6.33 for workers working on machine 9.

This same relationship has been plotted in the Figure-7 accordingly. The correlation between average RULA grand score and average labor productivity is shown in the graph. Therefore, it can be concluded that there exists an inverse relationship between these two and there is a decreasing trend of labor productivity for the higher RULA grand scores except the initial minimum value of average RULA grand score.

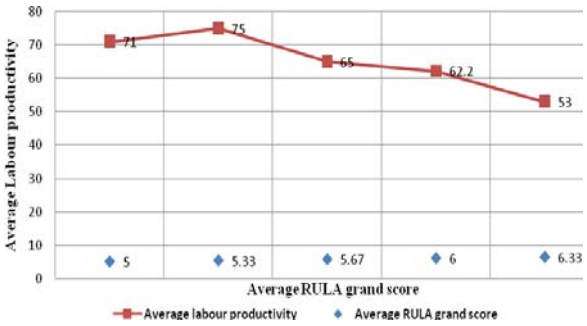

Figure-7. Relation between average labor productivity and average RULA grand score.

CONCLUSIONS

In this case study research work the various work postures of workers working particularly in the production section of a selected ceramic factory have been evaluated in the view point of RULA. After the evaluation of RULA grand scores through RULA worksheet for various work postures of a certain number of workers, it has been observed that no workers have acceptable work posture and most of the workers are working in high posture related risk. The obtained scores indicate the condition of work posture of the workers studied and low grand scores (1 or 2) indicate an acceptable working posture. Through the analysis of RULA grand score, it has been identified that with the grand score of 7, 43.59% of the workers need immediate investigation and changes to sustain the desired level of performance. With the increase of RULA grand score, the validity of work posture has got decreased resulting in the increase of associated risks for the bad posture.

The consequence of bad work posture results in musculoskeletal disorders (MSDs) which have also been analyzed in this research work. The RULA grand score has been compared to different levels of risk frequency. This comparison provides us with a guide line for further action and in most cases this guide line is used as an aid in efficient and effective control of any risks identified. Moreover, the weekly, daily and monthly frequency of MSDs occurred in various body parts corresponding to percentage of workers of intermediate, high and very high risk frequency have been shown with the help of bar charts.

Lastly, the relation between RULA grand score and the corresponding labor productivity has been established in the analysis. The relationship between work posture and productivity of workers working on various machines shows that the higher RULA grand scores have an adverse effect on labor productivity. For the bad condition of the posture workers do not apply their full efforts to their work which results in lower productivity. The correlation between average RULA grand score and average labor productivity establishes the fact that there exists an inverse relationship between these two and there is a decreasing trend of labor productivity for the higher RULA grand scores.

REFERENCES

[1] Leslie J. K. Fountain. 2010. Examining the relationship between rapid upper limb Assessment's (RULA) postural scoring system and selected physiological and psycho physiological Measures. Dalhousie University Halifax, Nova Scotia, Canada.

[2] Sarini bt Ramli. 2007. Assessment of Working Posture in Manufacturing Industry Using RULA Method. Faculty of Manufacturing Engineering, Universiti Teknikal Malaysia Melaka, Malaysia.

[3] Lueder R. 1996. A Proposed RULA for Computer Users- Proceedings of the Ergonomics Summer Workshop. UC Berkeley Center for Occupational and Environmental Health Continuing Education Program, San Francisco., USA.

[4] D. N. Agrawal, T. A. Madankar and M. S. Jibhakate. 2011. Study and Validation of Body Postures of Workers Working in Small Scale Industry through RULA. International Journal of Engineering Science and Technology. 3(10), ISSN: 0975-5462.

[5] T. Ghosh, B. Das and S. Gangopadhyay. 2010. Work-related Musculoskeletal Disorder of the Goldsmiths in India. Indian Journal of community. Medicine. 35(2): 321-325.

[6] Alireza C., Sayed H. T., Marzieh T., and Fatemeh G. 2007. Musculoskeletal problems among workers of an Iranian communication company. Indian Journal of Occupational and Environmental Medicine. 11(1): 32-36, ISSN: 0019-5278.

[7] Mao Zhi, Goh Bee Hua and Wang Shouqing. 2003. Forecasting Construction Industry-level Total Factor Productivity Growth using Neural Network Modeling. Ph.D Thesis, Department of Building, National University of Singapore.