BIJAY MIHIR KUNAR
MANGALPADY ARUNA
and
MOHITH BEKAL KAR

Postural analysis of dumper operators and construction workers – a case study

This case study aims at assessing and understanding the level of ergonomics in manual material handling tasks (loading, granite cutting, concrete mixing, brickwork, and plastering) of civil construction workers and dump truck drivers working in Indian opencast mines. The study involves the determination of the level of musculoskeletal disorder and predicting the most affected body parts due to incorrect working posture. The comprehensive methodology involved in this study includes rapid upper limb assessment (RULA) and rapid entire body assessment (REBA) techniques to find the risk involved in the working posture of the construction workers and dump truck drivers. The study showed that posture adopted in civil construction work and dump truck operators (loading and unloading task) are ergonomically incorrect and may cause musculoskeletal disorder (MSD) related problems in the future. This study also showed that the trunk and wrist are the most affected parts of the body in construction workers and the neck and wrist in case of the dumper operator while performing different tasks.

Keywords: *Posture assessment, RULA, REBA, MSD, ergonomics, labour statistics, construction workers.*

1.0 Introduction

Ergonomics is the science of designing the work tasks suitable for the workers keeping in mind the capabilities and limitations of the human body. Jobs and tasks that are frustrating, uncomfortable, or inefficient and are typically not ergonomically correct. Eventually, these problems deviate the mindset of the worker and create musculoskeletal disorder (MSD) related problems. An effective ergonomic process seeks to identify and eliminate any deterrent to maximum work capacity and limit worker from musculoskeletal disorder (MSD). Studies showed that MSD is the major cause of occupational health problems and medical expenses increased annually due to MSD related problems (Ekpenyong and Inyang, 2014; Ayub and Shah, 2018; Rahman et al., 2019; Denis et al., (2008)). Tasks involving lifting heavy loads, repetitive movement, awkward postures, and vibration will cause injuries such as sprain, strains, and work-related musculoskeletal disorders (Abedi et al, (2017); Hoozemans et al, (2014); Kulkarni and Dealkar, (2018). Hence, it is necessary to focus on the safety of the workers who are exposed to repetitive movement, awkward posture and vibration during work. The survey conducted by the department of labour (United States) revealed that construction and mining are two highly unorganized industries where workers are highly prone to nonfatal and work-related musculoskeletal disorder (WMSD) related problems. Further, construction and mining are two industries having the high incident ratio of 1.6 and 1.5 (out of 100 workers) for low back disorders (Bandyopadhyay et al., (2012)). The study conducted in the year 2014 showed that 32 out of 10,000 construction workers in the United States experience WMSD (Bureau of Labour Statistics, 2014). This figure got incremented to 34 in the year 2015 (Bureau of Labor Statistics, 2016). In the developing countries like India this figure is significantly high. A cross-section study done by Reddy et al., (2016) showed that 33.8% of the construction worker in India experience WMSD related problems. Although over the years, several tasks have been mechanized or automated, the majority of the tasks are still performed manually. It is mainly because of the prevailing socio-economic conditions, availability of labor at a very low cost, expensive setup cost for fully automated machinery etc. The method of carrying out such activities may cause an adverse effect on both the physical and mental health of the workers. Study conducted in India by Reddy et al., (2016) showed that 20.8%, 11.7% and 11.7% of the construction worker with MSD problems experience back pain, shoulder and wrist pain. It is found that 37% of the low back pain worldwide is due to manual material handling (MMH) jobs (Punnett, 2005). Manual lifting has been identified as one of the physical activities likely to be associated with a low back injury. Although several attempts have been made by researchers for analyzing and designing material handling tasks in moderate to heavy work categories under varied work environments, there exists opportunities for improvement in

Blind peer reviews carried out

Messrs. Bijay Mihir Kunar, Mangalpady Aruna and Mohith Bekal Kar, Dept. of Mining Engineering National Institute of Technology Mangalore, India. E-mail: India bkunar@gmail.com / arunamangalpady@gmail.com / mohith91162gmail.com

the design of jobs (for less incidence of musculoskeletal disorders and other adverse consequences) so that they may be carried out in the new form of 'man-machine-technology' interactions in the work system. These activities as they are being carried out may be associated with poor and awkward body postures, repetitions, heavyweight of the tools/ equipment used, extreme environmental conditions, and high level of physical stress among the workers causing pain in the upper extremity and lower back. Therefore, while designing a working system for manual material handling (MMH) tasks in construction, consideration of work stress is of paramount importance to identify and minimize both short-term and long-term risks (Ray (2015)).

The mining industry is the second highly unorganized sector with high liable of injury, disease and fatal of workers after the construction industry. In the year 2013, a survey conducted by bureau of labor statistics in the United States showed that 42.5 of 10,000 workers in mines experience work-related musculoskeletal disorder (WMSD). A study done by Weston et al., (2016) showed that days lost by mine workers is more due to shoulder and knee injury in United States. In India study showed that 61.5%, 39.4%, 28.9% of mine workers suffer from low back pain, knee and shoulder pain (Ahmad and Alvi, 2017). Further, 65 out of 100 workers in Indian coal mine experience WMSD related problems (Bandyopadhyay et al., (2012)).

The above statistic shows that mining and construction workers are high liable for WMSD related problems due to long working hours, awkward working posture, whole-body vibration and repeating the same task for an entire day. Hence, it is very essential to study the effect of each factor individually on WMSD. In the present study, the author has considered the effect of posture adopted on WMSD. Mining and construction industry has many activities occurring at different instances, this article focuses only on logistic operation in mines and loading, granite cutting, concrete mixing, plastering and brickwork activities in construction site for posture study.

2.0 Methodology

A case study was conducted considering dump truck drivers working in Indian opencast iron ore mines and civil construction workers engaged in various construction activities. Ten subjects were selected with the highest experience from each observed activity. Subject name, age, height, weight, the discomfort experienced by the subject and working hour's data was collected from the questionnaire (Table 1).

The posture adopted by dumper operator while loading, unloading, full capacity travel and empty travel was recorded using Nikon D5300 camera. Similarly, the posture adopted by construction workers while loading, granite cutting, concrete mixing, brickwork, and plastering activities were recorded on the construction site for ergonomic study.

Table 1: Mean value of different personal factors

Construction workers		
Parameters	Mean	SD
Age(years)	41.56	9.56
Height(cm)	168.32	7.56
Weight(kg)	66.69	9.46
BMI(kg/m^2)	22.42	3.21
Dump truck operators		
Parameters	Mean	SD
Age(years)	48.56	7.12
Height(cm)	164.32	5.36
Weight(kg)	69.69	10.95
BMI(kg/m^2)	24.78	3.52

On the construction site the granite cutting work was carried out by two workers on the floor and provided them with one helper each. Each of them was skilled with an experience of more than 15 years and was chosen for the postural study. In this activity, the granite-cutting tool having rotary blades and a small pipe supplying water as a coolant was handled by the workers. Construction demands for granite flooring and walling of the bathrooms. The job was to cut the given amount of granite throughout the day. The task was to cut the given granite sheets of 1.5*2.5 m^2 into the required size.

The concrete mixing was carried out by a minimum of four workers at the construction site. Skilled workers with 15 years of experience were chosen for the postural study. In this activity, sand, cement and water are mixed.

The brickwork was carried out at different locations simultaneously. Each site was handled by one skilled worker, and they were provided two additional helpers for the preliminary tasks to be performed before the brickwork. Workers with the highest (more than five years) experience were chosen. There were two helpers for the completion of the work. The job was to construct a wall using concrete bricks. The brickwork was observed layer by layer until the completion of the wall. The total area completed in 8 working hours was 35 m^2 with two workers and two helpers.

Plastering of the building was done by 11 skilled workers with the highest experience of ten years. In this activity, a trowel, a bucket full of cement, sand plaster, etc. were handled by the workers. The job was to complete the terrace-level plastering work of around 80 sq. feet within eight working hour's duration.

For material transportation work, there were nine workers; all with the highest experience (more than 15 years) were selected. Cement, brick, and sand were transported to the required place by the workers. The requirement of sand was

20 bags per hour, and the weight of each brick was 25 kg. The task of transportation was done by lifting the loaded cage by lifting machine.

For posture study of dump truck driver an iron ore mine situated in the southern part of India was selected for the study. Ten dumper operators with the highest work experience were shortlisted for the study. Sitting posture of drivers while performing loading, full capacity travel, unloading and empty travel was recorded using a Nikon D3500 camera. Logistic operation includes loading 31 tonnes of iron ore from the mine site and traveling to dispatch site situated not more the 2 km from the mine site for unloading. After unloading the empty dump truck returns to the mine site for loading. On average dumper operators perform ten to eleven trips per day.

Subject consent form clearly stated that all participation is voluntary and all acquired data including images or video recordings would not reveal the subject's identity. It also states that all recordings are confidential, and will be deleted or destroyed once the study is concluded.

Based on the activities of dumper operators and construction workers the analysis was carried out using the video captured from the camera. The postural analysis tools RULA (McAtamney and Corlett, 1993) and REBA (Hignet and McAtamney (2000)) were selected to quantify the MSD related problem of the workers. The images of posture adopted by the dumper operators and construction workers while performing different activities were extracted from video footage using photo director software. Out of many postures extracted, high repeated posture was shortlisted for the analysis.These images were used to determine angles of extension, flexion, abduction, adduction, and reach using ImageJ software. For analysis of highly repeated posture, the minimum value (+1) was assigned to the working posture for which risks are minimal, while higher numbers were allocated to extreme postures indicating risk factors. The procedure followed was the same as the standard procedure of RULA and REBA.

RULA score sheet divides the body into two categories, A and B. Category A consists of the lower arm, upper arm, wrist and category B consists of the neck, trunk and limbs. Based on the posture adopted by the subject a score is allotted to the different body part. The net score of categories A and B is calculated from the RULA Tables 1 and 2. Further, muscles used and force scores are added to the category A and B scores and the final RULA score ranging from 1 to 7 is calculated from RULA Table 3.

TABLE 2: RULA SCORE WITH AN ACTION LEVEL

RULA score	Action level	Risk level	Remarks
1-2	1	Low	Posture accepted if not maintained or repeated for a long duration
3-4	2	Medium	Further investigation is needed and changes may be required
5-6	3	High	Investigation and changes are required soon
7	4	Very high	Investigation and changes are required immediately

TABLE 3: REBA SCORE WITH AN ACTION LEVEL

REBA score	Action level	Risk level	Remarks
1	0	Negligible	Changes are not necessary
2-3	1	Low	Changes may be necessary
4-7	2	Medium	Changes are necessary
8-10	3	High	Changes are necessaryas soon as possible
11-15	4	Very High	Changes are necessary immediately

Based on the final RULA score the ergonomic assessment of the posture can be done using four-level of action level as summarized in Table 2.

In rapid entire body assessment (REBA) body parts are divided into two categories (arm, forearm, wrist and neck, torso, leg). The individual score is given to the different body parts based on its orientation. Tables 1 and 2 of the REBA sheet is used to find the net score of two categories A and B. Further, grip, strength and load score is added this score and final or grand REBA score is calculated from Table 3 given in REBA score sheet.

Based on the grand REBA score the ergonomic

Fig.1: Posture adopted by construction workers while cutting granite

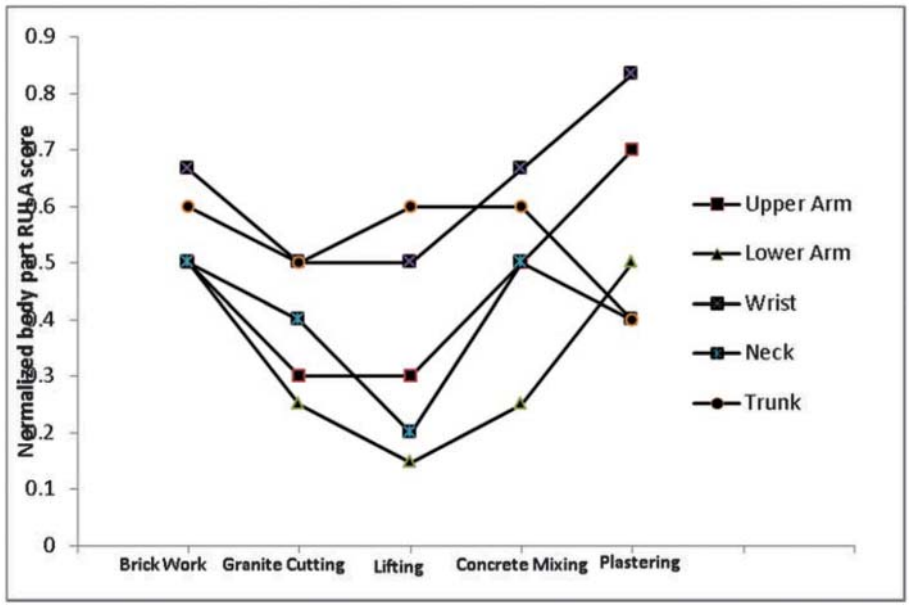

Fig.2: Normalized RULA score of the different body part of construction workers

Fig.3: Posture adopted by dump truck operators while loading

assessment of the posture can be done using five action levels and risk as shown in Table 3.

3.0 Results and discussions

Posture assessment was done on 10 construction and dump truck operators. The photograph was extracted from the video footage of the construction workers (Fig.1) and dumper operator (Fig.3) performing different activities. This image was used for calculating RULA, REBA scores. The average score of subjects for each activity was considered for deciding the level of risk involved.

The final RULA, REBA score of construction workers clearly shows, (Tables 3 and 4) all construction activities fall under high or very high risk.

Although the construction site had its administrative controls and certain engineering controls in place, the workers were still feeling distressed in their upper extremities. It is commonly observed that the workers adopted different body postures in which they felt comfortable to complete the work whether it is appropriate or not.

TABLE 4: GRAND REBA SCORE FOR CONSTRUCTION WORKERS

Activity	REBA score (average)	Results
Loading	10	High risk, changes are necessary as soon as possible
Concrete mixing	10	Changes are necessary as soon as possible
Plastering	8	Changes are necessary as soon as possible
Brickwork	7	Changes are necessary
Granite cutting	8	Changes are necessary as soon as possible

TABLE 5: GRAND RULA SCORE OF CONSTRUCTION WORKERS

Activity	RULA score (average)	Results
Loading	7	Investigation and changes are required immediately
Concrete mixing	7	Investigation and changes are required immediately
Plastering	6	Investigation and changes are required soon
Brickwork	6	Investigation and changes are required soon
Granite cutting	7	Investigation and changes are required immediately

TABLE 6: GRAND RULA SCORE OF DUMP TRUCK DRIVERS

Activity	RULA score (average)	Results
Loading	6	Further, investigate, change soon
Full capacity travel	4	Low risk, change may be needed
Unloading	6	Further, investigate, change soon
Empty travel	4	Low risk, change maybe needed

TABLE 7: GRAND REBA SCORE OF DUMP TRUCK DRIVERS

Activity	REBA score (average)	Results
Loading	8	High risk, soon necessary action to be taken
Full capacity travel	4	Medium, action is necessary
Unloading	6	Medium, action is necessary
Empty travel	4	Medium, action is necessary

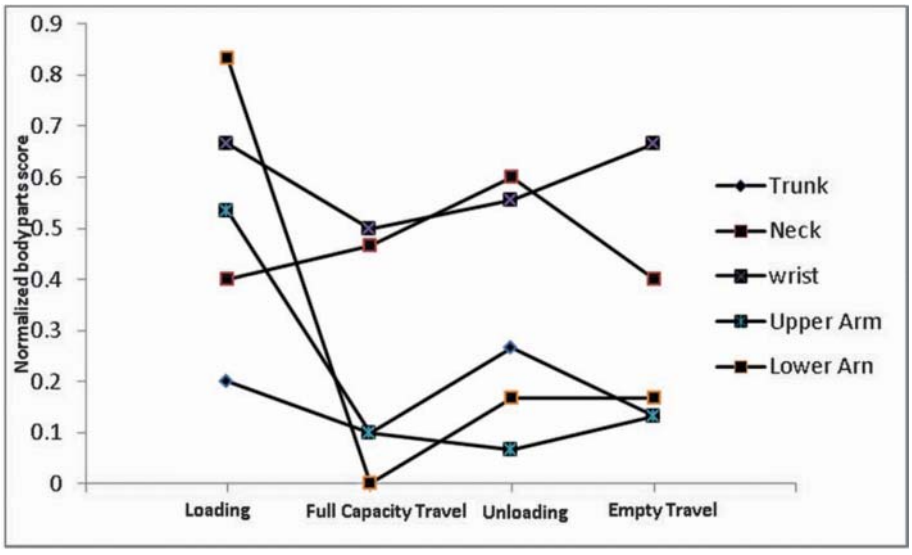

Fig.4: Normalized RULA score of different body part of dump truck drivers

RULA and REBA grand scores can be only used to finding out incorrect posture adopted by the worker. Hence, it was decided to normalize the score allotted to each body part to find out the most affected body part. A graph was plotted by taking normalized scores on the y-axis and activities on the x-axis.

As shown in Fig.2 the trunk and wrist are most affected part in construction workers. This result matches with a previous study conducted by Reddy et al., (2016) for construction workers.

Similarly, the grand RULA, REBA score for dump truck drivers showed (Table 6) that posture of the drivers during loading and unloading is ergonomically incorrect and will cause MSD related problems.

To find out the body parts which get affected most due to the posture adopted by the driver, a graph was plotted by taking the normalized score of the body parts along the y-axis and activities along the x-axis.

The graph plotted showed (Fig.4) that neck and wrist are the most affect body parts. This result matches with a previous study conducted by Reddy et al., (2016) for construction workers.

4.0 Conclusions

The data collected for RULA and REBA assessment in this study reveals that the activities performed by the workers and drivers are at high risk of muscularskeletal disorder (MSD) injuries. The normalization RULA score of different body parts showed that the posture adopted by the construction workers is incorrect especially the wrist and trunk. In the case of a dump truck operator, the posture adopted during loading and unloading are incorrect and may affect the wrist and neck. The analysis done matches with the questionnaire study done by other authors.The author observed that dump truck drivers while loading and unloading lean forward to see the rearview mirror, especially while taking reverse. This increases trunk and neck angle which in turn increases RULA, REBA score. The authors believe that discomfort experienced by the drivers can be reduced by ergonomically re-designing/placing the review mirror.

Ergonomic assessment results from visual observations in this study conclude that the civil construction workers and dump truck operators require alternate and appropriate controls to reduce the potential ergonomic risk factors.

Acknowlgements

The authors wish to acknowledge Science and Engineering Research Board (DST-SERB) for funding the project work. The support from the management, staff and workers of the mine is gratefully acknowledged.

References

[1] Ekpenyong, C.E., Inyang, U.C., (2014): Association between worker characteristic, workspace factors, and work-related musculoskeletal disorders: a cross-sectional study of male construction workers in Nigeria. *Int. J. Occup. Saf. Ergon.* 20 (3), 447-462.

[2] Ayub, Y., Shah, Z.A., (2018): Assessment of work related musculoskeletal disorders in manufacturing industry. *J. Ergonomics* 8 (3), 3- 7.

[3] Rahman, M.S., Khan, A.H., Rahman, M.S., Biswas, B., (2019): Work-related musculoskeletal disorder: a case study of sawmill workers in Bangaldesh. Curr. World Environ. 14(2), 336-345.

[4] Denis, D., St-Vincent, M., Imbeau, D., Jette, C., Nastasia, I., (2008): Intervention practices in musculoskeletal disorder prevention: a critical literature review. Appl. Ergon. 39, 1-14

[5] Abedi, K., Darvishi, E., Karimi, S., Ebrahimi,H., Yagnesh, R. C., Salimi, S. (2017): Risk factors of Musciloskeletal Disorders in Bus and Truck Drivers, 1(1), 23-8

[5] Hoozemans, M.J., Kuijer, P. P. F.,Kingma, I., Dieën, J.H.V., (2014): Mechanical loading of the low back and shoulders during pushing and pulling activities, Ergonomics, 47, 1-18

[6] Bandyopadhyay, A., Dev, S., Gangopadhyay, S., (2012): A study on the prevalence of musculoskeletal

disorders among the coalminers of Eastern, 2(2), 34-37

[7] Bureau of Labor Statistics, (2014): Nonfatal Occupational Injuries and Illnesses Requiring Days Away from Work, U.S. Department of Labor, https://www.bls.gov/bls/newsrels.htm (Accessed November 2016).

[8] Bureau of Labor Statistics, (2016): Nonfatal Occupational Injuries and Illnesses Requiring Days Away from Work, U.S. Department of Labor,https://www.bls.gov/news.release/pdf/osh2.pdf (Accessed February 2017).

[9] Reddy G.M.M., Nisha B., Prabhushankar TG., Vishwambhar V., (2016): Musculoskeletal morbidity among construction workers: A cross-sectional community-based study, Indian Journal of Occupational and Environmental Medicine, 20(3), 144-149.

[10] Punnett, L.,Pru¨ss-U¨stu¨n, A., Deborah Nelson, D., PhD, Fingerhut M. A., Leigh, J., Tak, S., and Phillips, S., (2005): Estimating the Global Burden of Low Back Pain Attributable to Combined Occupational Exposures, *American Journal of Industrial Medicine*, 48, 459-469.

[11] Weston, E., Nasarwanji, M. F., Pollard, J. P., (2016): Identification of Work-Related Musculoskeletal Disorders in Mining, *Journal of Safety, Health & Environmental Research*, 12(1), 274-283.

[12] Ahamad, A., and Alvi, R., (2017): Musculoskeletal disorders and risk factors of workers in Indian mining industry: a cross-sectional study, *International Journal of Perceptions in Public Health*, 1(4),241-248.

[13] McAtamney, L., and Corlett, E. N., (1993): RULA: a survey method for the investigation of world-related upper limb disorders, *Applied Ergonomics*, 24(2), 91-99.

[14] Hignett, S., and McAtamney, L., (2000): Rapid Entire Body Assessment (REBA), *Applied Ergonomics*, 31, 201-205