Assessment of Driving Posture Ergonomics in LPDT Operators using the Rapid Upper Limb Assessment Method

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Abstract
This study aimed to determine the postural risk of Low-Profile Dump Truck (LPDT) operators working in an underground metal mine. A total of 38 LPDT operators aged between 18 and 56 years, with at least 6 months of professional driving experience and no history of injuries, were selected for this study. The postural data of operators were collected by placing the Nikon D5600 camera inside the 20-ton capacity LPDT cabins which are equipped with various ergonomic features such as gas seat suspension, adjustable seat height and backrest. The driving postures of operators were recorded in the sagittal plane while performing various job cycles such as loading, loaded travel, unloading and empty travel. The ergonomic assessment of these postures was done using the standard Rapid Upper Limb Assessment (RULA) chart. The results of this analysis showed that LPDT operators were sitting in the driving posture corresponding to the low (86%) and medium (14%) risk of Work-Related Musculoskeletal Disorders (MSDs).

Further, it was observed that the mean RULA score during the dynamic operations (i.e. loaded and empty travel) was relatively high compared to the static operation (i.e. loading and unloading). The visual examination of the video footage showed that the operators faced visibility issues and were compelled to lean forward to see the road clearly. This resulted in a high RULA score during dynamic operation. The study highlighted the need for ergonomic intervention to prevent the LPDT operators from MSDs.

Keywords: Postural risk, LPDT operators, Musculoskeletal disorders, Rapid Upper Limb Assessment (RULA).

Introduction

The proper posture is essential for the health and safety of LPDT operators working in the mines, as it helps to reduce the risk of musculoskeletal disorders and fatigue and to increase productivity[8,10,11]. Despite the importance of proper posture, research has shown that LPDT operators often adopt poor postures during their work which can increase the risk of injury[12]. In recent years, there has been an increasing interest in the analysis of posture in order to identify and address the factors that contribute to poor posture[8,9]. There are several techniques available for measuring postural risk in LPDT operators, each with its own advantages and limitations. These techniques include biomechanical analysis[4], wearable technology[7] and observational methods[3].

Biomechanical analysis involves the use of mathematical models and computer simulations to analyze posture of HEMM operators[2]. This technique allows for the quantification of the posture risk and can provide detailed information about the joints, muscles and ligaments that are involved in posture[4].

In case of wearable technology, posture sensors and accelerometers are used to monitor posture in real-time[1]. This technique allows for the continuous monitoring of posture and can provide objective data[12]. The observational methods involve the direct observation of LPDT operators while they perform their work activities. This technique is widely used as it is non-invasive, easy to implement, cost-effective and can provide a quick assessment of posture[5,6].

There are several techniques used in observational methods, including Rapid Upper Limb Assessment[6] and Rapid Entire Body Assessment[5]. The Rapid upper limb assessment (RULA) is a technique used to assess posture and to identify areas of risk for musculoskeletal disorders. This technique involves observing workers in their natural work environment and analyzing the posture of the upper limb and trunk. The RULA allows for the identification of postures that may be associated with an increased risk of musculoskeletal disorders and it can be used to inform the design of interventions to improve posture.

The Rapid entire body assessment (REBA) is another technique used to assess posture and to identify areas of risk for musculoskeletal disorders. Like RULA, REBA involves observing workers in their natural work environment, but it analyzes the posture of the entire body including the upper and lower limbs and trunk. RULA allows for the identification of postures that may be associated with an increased risk of musculoskeletal disorders (MSD) and it can be used to inform the design of interventions to improve posture. In this research work, authors made an attempt to study the posture of LPDT operators and the activities that are associated with highest risk due to poor posture. Additionally, the research will provide a better understanding of the ergonomic risk factors of the LPDT operators which can be used to improve the working conditions and safety of the LPDT operators.

Material and Methods

Background of case study mine: An underground metal mine situated in the southern part of India was considered to study the postural risk involved in LPDT operators. The working duration of workers at mines was eight hours per day, six days per week and two shifts/day. The salient geological and mining-related information of the case study mine is shown in table 1.

Study population: In total, 38 LPDT operators were considered for the analysis from the study population using random sampling approach. The inclusion criteria of the study sample was: (i) permanent employee of the mining company (ii) age is between 18 and 56 years (iii) minimum of six months of professional driving experience and (iv) no history of injury. The anthropometric parameters such as age (mean=38.47; SD=7.65; range=18-60), height (mean=1.71; SD=0.066; range=1.58-1.88), weight (mean=76.5; SD=10.13; range=62-103) and BMI (mean=25.9; SD=3.06; range=21.2-31) were retrieved from the mine dispensary.

Data collection: The objectives of this research work and the respective data to be collected from the mines were initially discussed with the safety officer and the mine management.

Table 1
Background of case study mine

Waste disposal area	0.756 Km²
Infrastructure and road area	1.54 km²
No of active dumps	1
No of dead dumps	2
No of excavators	2
No of wheel loaders	14
Capacity of LPDT	20 Ton
No of water tankers	3

Table 2
LPDT operators demographics data

	Number of LPDT operators	Mean	Range	Standard Deviation
Age (in years)	38	38.47	24-56	7.65
Height (in meter)	38	1.71	1.58-1.88	0.066
Weight (in kg)	38	76.5	62-103	10.13
Body Mass Index (BMI)	38	25.9	21.2-31	3.06

Fig. 1: LPDT operator seating posture while loading

After receiving approval from the mine management, data collection was conducted on-site. The posture data of the LPDT operators was collected using a Nikon D5600 camera. The camera was positioned in a way that it would record the driving posture in a sagittal frame. The LPDT operators were instructed to continue their routine work without any alterations. The video footage of the operators during loading, traveling at full capacity, unloading and traveling empty was recorded. During loading, the operators were positioning the LPDTs in the right location for filling material, aligning the LPDT bed with the loaders.

In hauling operation, the operators transport the loaded material from loading point/face to the unloading location. The unloading involves the dumping of the transported material from the LPDT by aligning the LPDT bed with the unloading area and emptying it. Finally, empty travel is the transportation of the LPDT to the loading point/face, without any material.

RULA method: The RULA is a tool used to evaluate the potential for developing MSD in the upper body of HEMM operators. The method was developed in 1993 by McAtamney and Nigel Corlett[6] which provided a quick and easy way for employers to assess the risk for their employees.

The RULA divides the body into two parts: part A which includes the arm and wrist and part B which includes the neck, trunk and leg. For each body part, a score is calculated based on the orientation of the body parts and adjusted based on the type of task being performed and its duration.

The scores for each body part are then combined using table 3 and table 4 of the RULA worksheet. The final RULA score was obtained by adding the scores for coupling and force and combining the upper and lower body scores. The grand RULA score ranges from one to seven, with one being the lowest risk and seven being the highest risk for MSDs. The higher is the final score, the greater is the risk of MSDs.

To help employers to understand and interpret the RULA scores, there are also action levels associated with each score. For scores of one or two, there is a low risk of MSDs and no action is required. For scores of three or four, there is a medium risk of MSDs and some action is required to reduce the risk. For scores of five or six, there is a high risk of MSDs and immediate action is required to reduce the risk. Finally, for scores of seven, there is a very high risk of MSDs and urgent action is required to reduce the risk.

Ethical Considerations: Approval for this study was obtained from the institutional review board. All methods were performed in accordance with the relevant guidelines and regulations set by the institutional review board. The participants were informed about this study and consent was obtained from them. Confidentiality of the participant's personal and medical information was ensured.

Results

The driving posture during different activities such as loading, hauling, unloading and empty travel was extracted from the video footage using video editing software (PowerDirector version 14). A total of 442 postures were extracted with respect to 38 drivers which included 117 postures during loading, 96 postures during full capacity travel, 126 postures during unloading and 103 postures during empty travel (Table 4).

The postural risk of LPDT operators was determined using the RULA postural analysis tool. Out of the various postures recorded, the most frequently repeated posture for each activity was selected for the analysis. These images were imported into Ergomaster software (version 4.0) to calculate extension angles, flexion, abduction, adduction and reach. In the analysis of the most frequently repeated posture, the least risk posture was assigned a value of +1, while more extreme postures were assigned higher numbers to indicate risk factors. The procedure followed was consistent with the standard RULA procedure.

Table 3
RULA score and action levels

RULA Score	Action Level
1-2	Negligible risk, no action required
3-4	Low-risk, Modification may be needed
5-6	Medium risk, Further investigation is needed
7	Very high risk, Modification is required immediately

Table 4
Posture counts by activity

Activity	Number of postures
Loading	117
Hauling	96
Unloading	126
Empty travel	103
Total	**442 postures**

The results of the postural analysis conducted in this study showed that the majority of LPDT operators were found to be at medium risk of facing MSDs problems while performing loading activities. During the loading operation, majority of the operators were found to be seated in a driving posture with a RULA score of five (Figure 2), which falls under action level medium risk. The highest RULA score obtained during the loading operation was eight which is considered as high risk and requires modification and the least being three.

During the unloading activity, a similar trend was observed, with the majority of the operators having a RULA score of five. However, during hauling and empty travel trips, the RULA score was found to be in a narrow range of 3 to 6, with most of the operators having a RULA score of five. When the MSD risk for all the activities was combined, as shown in figure 3, it was found that 86% of the operators were operating at medium risk while only 9% of the operators were at low risk level. Furthermore, 5% of the operators were found to be performing driving in a high-risk posture. This indicates that the operators' stance was unsatisfactory and they may need to change their driving posture to prevent MSDs problems.

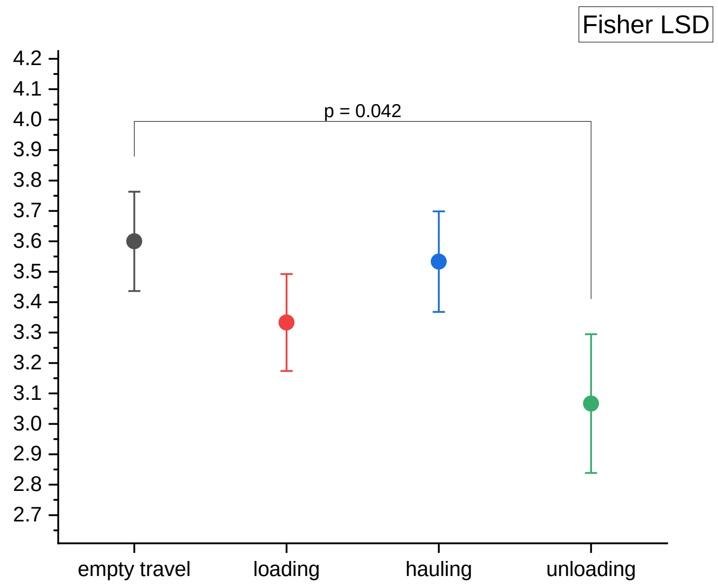

Fig. 2: Mean RULA score Vs activity

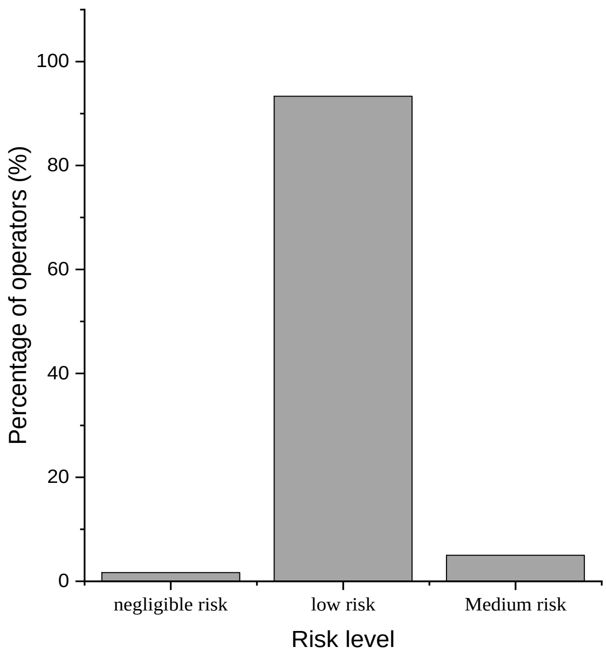

Fig. 3: RULA score distribution in LPDT population

Conclusion

The outcome of this study has shown some interesting results with respect to health and safety of LPDT operators. The majority of LPDT operators tend to sit in a driving posture with a RULA score of five during loading activities which falls under action level five, inferring that LPDT operators are at medium risk of facing MSDs problems[5]. The highest RULA score of eight, which is considered as high risk and requires modification, was obtained during the loading operation. Similarly, during the unloading activity, the majority of operators had a RULA score of five. Compared to hauling and empty travel operation, in loading and unloading the RULA score varied in wider range.

The results of this study indicate that 86% of the operators were operating with medium risk, while just 9% of the operators were found to be at the low risk level and 5% of the operators were performing driving in a high-risk posture. The outcome of this study corroborates with the results of earlier studies that has used RULA to assess the postural risk in mining workers[13]. This highlights the importance of developing ergonomic interventions that target the specific needs of LPDT operators. These interventions may include training programs that educate LPDT operators on the importance of maintaining a good posture, the use of seat designs that provide adequate support and the implementation of task rotation programs to reduce the frequency and duration of high-risk postures.

In general, the results of this study demonstrate that LPDT operators in the mining industry are at a moderate to high risk of developing MSDs. Therefore, it is crucial to implement ergonomic interventions to reduce the postural risk and to prevent the occurrence of MSDs among LPDT operators.

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