Postural evaluation of notching action in WAG_7 railway goods-locos (indicates correction necessities)

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Abstract: Electric loco pilots of Indian Railways are high-risk group for musculoskeletal disorders, facing de-categorisation and low retirement age. Their working environment needs be considered as a stress factor affecting their health status. About 31 male electric loco pilots of Indian Railways were considered as sample and have been evaluated by using RULA. In this study, the driving posture of the electric loco pilots is observed, and focus is given on the most frequently adopted posture, like notching for accelerating and decelerating the train. For notching, a hand wheel is moved by producing a jerk by wrist movement. This postural information was collected in situ in running trains. All other information is gathered by using modified standardised Nordic questionnaires. Only WAG_7 old variant electric locomotives were considered for this study. The mean age of the loco pilots is 41.1. The final RULA score mode at rank 4 indicates a little bit higher overall loading on the body segment and the job is somewhat strenuous. The statistics also shows the distribution is skewed to the right.

Keywords: Indian Railways; railway; driving ergonomics; electric loco pilots; rapid upper limb assessment; RULA.

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1 Introduction

Guo et al. (2017) revealed that steering or notch handle shape influenced the wrist angles and hand pressures, as holding pattern of handle by the train controller depends on it. Hoy et al. (2005) found that whole body vibration and driving postures are jointly responsible for low back pain on forklift truck drivers. Massaccesi et al. (2003) established that the rapid upper limb assessment (RULA) is a suitable tool to evaluate the working posture of professional truck drivers. Kushwaha and Kane (2016) reported that ergonomic intervention in re-designing of crane cabin and scrutiny by RULA yield more comfortable workplace for crane operator.

Electric loco pilots are a high-risk group for musculoskeletal disorders; result in de-categorisation in job assignment and low retirement age. The electric loco pilot's working condition and working environment, i.e., exposure to vibration, noise, magnetic radiation, varying climatic conditions, driving posture, irregular and against the nature job condition, needs to be considered as stress factors, and probably affect their health status.

A sample of 31 electric loco pilots, working in WAG_7 old variant locomotive was studied. Both standing and sitting postures during driving were observed and evaluated by using RULA method.

RULA method is a body indexing tool, introduced by McAtamney and Corlett (1993), evaluates the loads sustained by the musculoskeletal system due to working posture, muscle use and force exerted, and predict the risk associated with it.

1.1 Indian Railways and its objective

Railway, from the early steam power to today's giants on tracks, is the land-based transportation system in the world. It is one of the most economic and rapid transit systems for both freight and passengers. Geographical spread of our country has helped to develop world's one of the largest operating system, the Indian Railway, highlighted in Ministry of Railway (2017a).

The Indian Railways dedicated to the service of the nation add score to the GDP through the efforts of 1.331 million employees, working 24 × 365 days highlighted in Ministry of Railway (2017b). Full of thousand kinds of job in specialised works, locomotive drivers represent a unique segment of its own kind. Drivers, whatever is the mode of transport, have a great responsibility, as any mistake may bring irreversible loss to lives and property.

1.2 Procedure of present ergonomic study

In this study, the driving posture of the electric loco pilots are recorded by camera and analysed. By using modified Nordic questionnaires, earlier developed by Kuorinka et al. (1987), general information is gathered and analysed. The study is conducted on a most frequent action posture, i.e., notching. Operating of notching wheel is required to accelerate or decelerate the train. About 31 male loco pilots working on WAG_7 old variant locomotive were surveyed and the participation was voluntary.

2 Materials and methods

2.1 Subjects

General information about the loco pilots is shown in Table 1.

Table 1 Age distribution of subjects

Measures	*Range*	*Mean*	*SD*
Age (years)	34 to 55	41.1	±5.0

About 31 male electric loco goods pilots with mean age of 41.1 (range 34 to 55) and SD ±5.0 years participated as subjects. Their main function during the duty is to drive the electric locomotives with or without loaded and empty wagons. The job demands high alertness and vigilance, both physical and cognitive, during driving.

2.2 Electric locomotives

The WAG_7 old variant is a conventional locomotive indigenously designed by Chittaranjan Locomotive Works with 6,000 hp hauling capacity. Its production started at Chittaranjan Locomotive Works in 1992 and stopped during 2015–2016 financial year.

Both at CLW and Bharat Heavy Electricals Ltd. (BHEL) successfully manufactured this variant of locomotive (http://www.cr.railnet.gov.in/department/elect/CETITHK/WAG7.pdf). The cab space in this type loco is a constraint.

Figure 1 (a) CLW make WAG7 (b) BHEL make WAG7 (see online version for colours)

(a) (b)

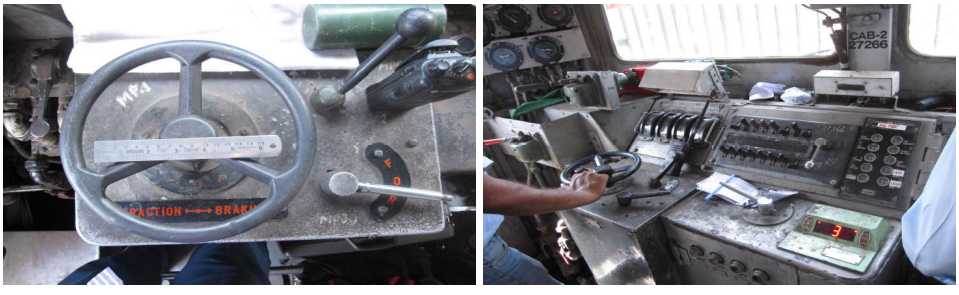
2.3 Data collection

The postural information was collected in situ in running trains. A Canon compact camera was used to video record the driving postures of each subject and evaluated using RULA method.

2.4 Notching

Notching, a frequent activity, is performed by the loco pilots to accelerate or decelerate the train. Normally performed by right hand only, but in few cases both hands are seen to be used. The therbligs of this posture is USE and its sequence is Pre-position → Position → Grasp → Use → Hold → Use → Hold → Position → Pre-position (http://gilbrethnetwork.tripod.com/therbligs.html).

Figure 2 (a) Notching wheel (b) Hand posture prior to notching (see online version for colours)



(a) (b)

The loco pilots turn a wheel, i.e., notch wheel, kind of steering, but by applying a jerk clockwise to accelerate the train and anti-clock to decelerate. This action takes a fraction of second by twisting and bending the wrist to a certain angle with pressure of the order of 3 1/2 kg, as opined by the loco inspectors. The frequency of notching activity is high

and depends on signal condition. The pictorial presentation of a notching cycle is shown in Figure 3, where the changes in wrist and neck postures are clearly visible.

Figure 3 (a) Beginning of notch cycle (b) During notching – 1 (c) During notching – 2 (d) During notching – 3 (e) During notching – 4 (f) End of notch cycle (see online version for colours)

(a) (b) (c)

(d) (e) (f)

2.5 RULA method

RULA is a survey method well developed for use in ergonomics investigations of workplaces where work-related upper limb disorders are reported, and is well documented, hence needs no detailing. The coding system, as suggested by McAtamney and Corlett (1993), is used to generate an action list. This action list indicates the level of intervention required to reduce the risks of injury due to physical loading on the operator.

2.6 Questionnaire

A modified standardised Nordic questionnaire, originally suggested by Kuorinka et al. (1987), modified to suit this study, was used to collect general information of the subjects in a face-to-face interview for subsequent analysis.

3 Results

3.1 General information

About 31 male electric loco goods pilots participated as subjects voluntarily. The subjects were also chosen randomly. The age of the subjects are varying from 34 to 55 with a mode value of 39 years. The mean age of the subjects is 41.1 years with standard deviation of ±5.0 and mean deviation of 3.7.

Table 2 Statistical details of age distribution

Measures	*Range*	*Mean*	*Mode*	*SD*	*MD*
Age (years)	34 to 55	41.1	39	±5.0	3.7

3.2 RULA scoring limits

RULA score delivers a discrete variable. According to that, 1 or 2 is acceptable. As higher values, the tasks become more stressful and need be avoided, as suggested by McAtamney and Corlett (1993). The ideal frequency distribution should be reverse J shaped, or it should have a positive skewness, i.e., skewed to the right. Microsoft Excel is used for statistical analysis. The same is verified using formula available in standard textbook of Spiegel (1972).

3.3 RULA scores during notching

The posture scores A, muscle use score and force/load score together yield wrist and arm score. Similarly, the posture scores B, muscle use score and force/load score yield neck, trunk and leg score. Finally, these two scores lead to the final RULA score, as suggested by McAtamney and Corlett (1993). The complete statistics are computed in tabular format for drawing inferences. The corresponding frequency distributions are depicted respectively in Figures 4 to 8. The final score in ‘more than’ Ogive is shown in Figure 9.

The mode value for wrist and arm score shifts to the rank 5 compared to the mode value of posture score A at rank 3. The skewness for both of these two is positive.

Table 3 Scores during notching

Score values	*Frequencies*					*Cuml. fq.*
	Posture score A	*Wrist and arm score*	*Posture score B*	*Neck, trunk and leg score*	*Final score C*	*Final score Ogive*
Figure	Figure 4	Figure 5	Figure 6	Figure 7	Figure 8	Figure 9
1	0	0	15	14	0	31
2	12	0	1	2	0	31
3	15	1	15	15	13	31
4	4	12	0	0	15	18
5	0	14	0	0	3	3
6	0	4	0	0	0	0
7	0	0	0	0	0	
Mode	3	5	1 & 3	3	4	
Median	3	5	3	3	4	
Mean, $\overline{X}$	2.74	4.68	2.0	2.03	3.68	
MD	0.574	0.633	0.968	0.937	0.568	
SD, s	0.682	0.748	1.0	0.983	0.653	
Variance, s^2	0.465	0.56	1.0	0.966	0.426	
Skewness, +/–	0.374 to right	0.109 to right	0.0	(–)0.068 to left	0.436 to right	
Skew. coeff., a_3	0.356	0.081	0.0	(–)0.064	0.416	
Kurtosis	(–)0.735	(–)0.351	(–)2.103	(–)2.056	(–)0.612	
Kurto. coeff., a_4	2.197 platy	1.582 platy	1.033 platy	1.074 platy	2.292 platy	
MD/SD	0.843	0.846	0.968	0.953	0.871	

The mode value for neck, trunk and leg score remain more or less same as in posture score B, and both are having zero and negative skewness, respectively. All the above distributions are platykurtic, and moderately skewed compared to a normal distribution.

The grand score mode at rank 4 suggest a little bit high overall loading during notching. The frequency distribution is skewed to the right (positive skewness).

4 Discussion

The sample of 31 male electric loco goods pilots was studied by using RULA method. The driving is done either in standing or in sitting posture. The posture is more or less static, and they rarely flex, bent or rotate their body parts. The job obviously demands high degree of alertness. But in the present study focus is only made on the most frequently adopted posture, i.e., notching.

In-situ observation reveals that the frequently adopted postures during driving are taken in notching to accelerate or decelerate the train.

4.1 Notching

Loco pilots stand close to the notching post and work around the midline of the body. The notching is a most frequent action posture and involves applying force intermittently with a jerk. This repeating action probably causes pain in shoulder region, as reported by few loco pilots, but not severe, as it disappears after few hours of rest.

It was observed that the loco pilots are using right hand only for notching action, and probably this may the main reason for shoulder pain. Notching by both hands may eliminate the problem as RULA score in that case as found during observation (only one) is quite low, but this requires further study before implementation.

4.2 RULA score

Figure 4 shows posture score A during notching by right hand, the mode is at rank 3, SD = 0.682. The distribution is skewed to the right and platykurtic.

Figure 4 Histogram of posture score A (see online version for colours)

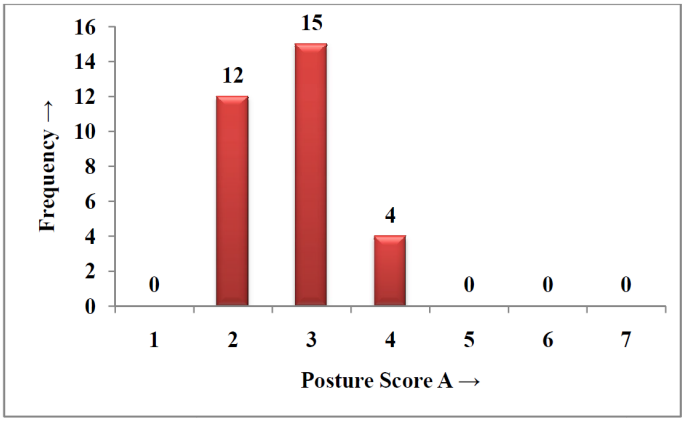


Figure 5 shows the wrist and arm score during notching by right hand, the predominant mode is at rank 5, SD = 0.748. The distribution is skewed to the right and platykurtic.

Figure 5 Histogram of wrist and arm score (see online version for colours)

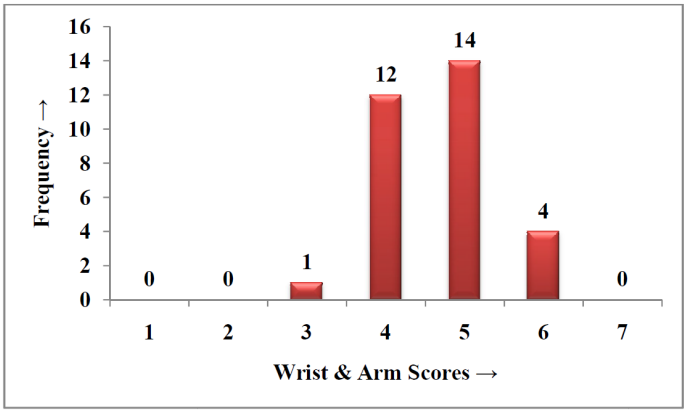
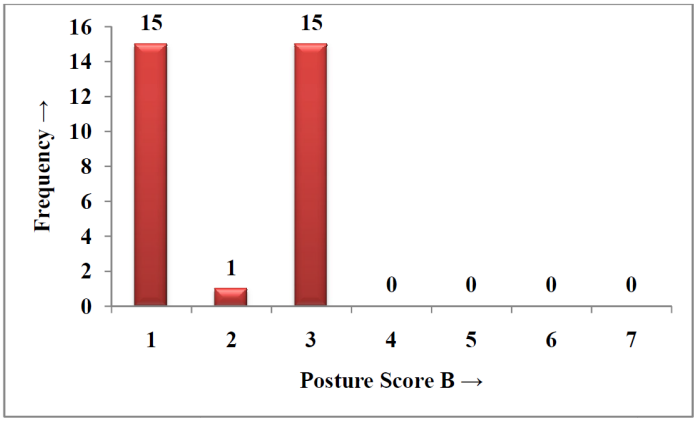


Figure 6 Histogram of posture score B (see online version for colours)



The rise of mode value from 3 → 5 for posture score A to wrist and arm score are due to addition of muscle score, as notching is a repetitive action, and force/load score, as force required to operate the notching wheel is around 3 1/2 kg.

Figure 6 shows the posture score B during notching by right hand; the mode is at rank 3, SD = 1.0. The symmetrical distribution is having zero skewness, but platykurtic.

Figure 7 depicts the neck, trunk and leg score during notching and dynamic braking is represented. The mode is at rank 3, SD = 0.983. The distribution is skewed to the left but platykurtic. Since there is no shifting in the mode value, the distribution pattern remains more or less unchanged, compared to Figure 6.

No shifting of mode value is observed in posture score B to neck, trunk and leg score; this indicates absence of muscle use score and force/load score.

Figure 7 Histogram of neck, trunk and leg score (see online version for colours)

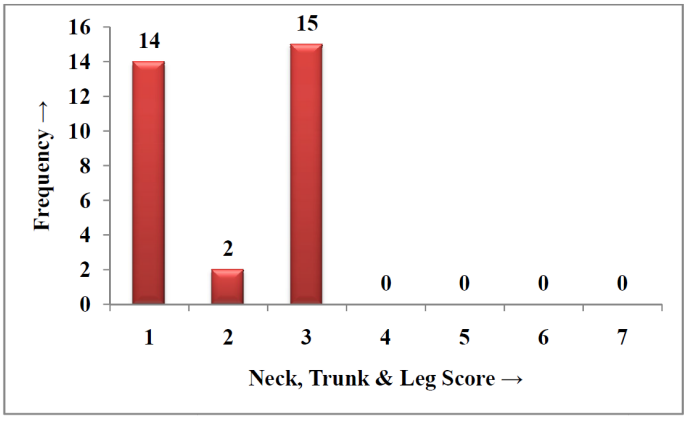


Figure 8 Histogram of final RULA score C (see online version for colours)

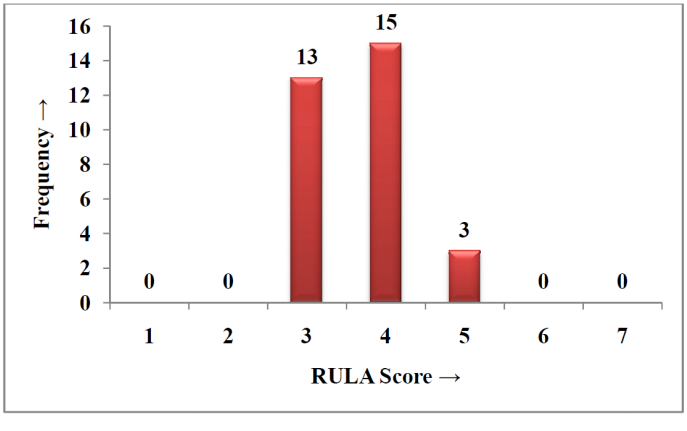


Figure 9 Final score 'more than' Ogive (see online version for colours)

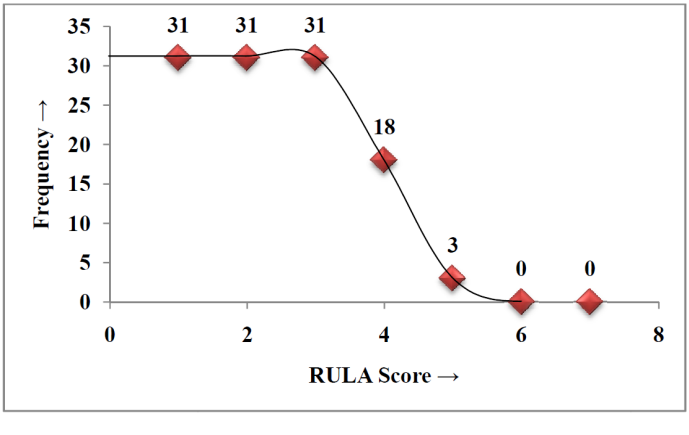


Figure 8 represents the final score of total body during notching by right hand, the mode is at rank 4, and SD = 0.653. The distribution skewness is to the right and platykurtic. The mode value of final score is due to the cumulative effect of both wrist and arm score and neck, trunk and leg score.

As total 28 subject out of 31 are having either 3 or 4 final score, hence the predominant RULA recommendation is 'action level 2', i.e., "further investigation, change may be needed."

Figure 9 shows the 'more than' Ogive for the grand score rank corresponding to Figure 8. Only about three loco pilots out of 31 do have rank score ≥ 5, may be due to the then temporal health conditions of the individuals. Remaining are belonging the group of 3 to 4, indicates job is little bit strenuous.

5 Conclusions

5.1 RULA assessment

RULA ranking system provides a method of discrete level assessment, convenient to adopt and apply. The method is quite reliable and acceptable. It gives directives 'what to do' and 'how soon to do'. The activity of the loco pilots identified here for RULA assessment is notching.

As the RULA scores are discrete, hence rod graphs have been plotted for frequency distribution (Figures 4 to 8). All relevant statistics, viz. mode, median, mean, MD, SD, variance, skewness, a_3, kurtosis, a_4, and MD/σ have been calculated using Microsoft Office Excel and basic formulations from standard textbook of Spiegel (1972) to compare the actual distribution with a normal distribution.

The ideal distributions of any task involving musculoskeletal loading should be reverse J distribution, but which occur rarely. RULA ranks 3 to 4 corresponds to 'action level 2', "further investigation, change may be needed."

The grand scores of notching with mode at 4 (Figure 8), reveal that these particular task demand some due attention even of the cab-room design for layout of the control. The 'more than' Ogives (Figure 9) reveals that three pilots out of 31, i.e., less than 10% of the population are put to the risk factor level at ≥ 5 in the notching operation.

5.2 Indian scenario

High alertness and high vigilance are required during locomotive driving. Due to closed, constraint cab-room environment and prolong duty hours, the job is quite stressful and monotonous. Moreover, the loco pilots are also not happy due to low social participation and 'against the nature' job condition. However, the 'take-home-pay-packet' keeps them satisfied on an average.

5.3 Suggestion

Following suggestion is hereby made to reduce the RULA score as well as probable risk of musculo skeletal disorder (MSD):

1 Instead of using only the right hand mostly for notching action, use of both hands in notching action (steering wheel type, or bicycle handle type) is recommended. This will help reduce the upper limb force/load score and wrist twist score, which ultimately reduce the final RULA score as well as pain in shoulder region.

2 Suitable modification in notching mechanism is recommended. Such modification should aim to reduce the force required in notching action to half a kg or less.

3 A set of push switch has been observed in vertical wall of driving desk, from which the notching action can also be controlled. But its location is quite odd. By relocating the switches in driving desk and converting it to a lever type switch, postural risk can be eliminated.

4 Installation of GPS system in goods train as well for multifarious, but dedicated, scopes. This will make driving tension free severally.

5 Easily adjustable, say, with dedicated hydraulic arrangement, foot rest needs be arranged to lessen the legs score. Also, leg and trunk movement during driving is recommended to prevent static loading.

6 The suggested facilities in this regard are under progress.

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