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Ergonomic Risk Analysis of Working Postures of Motor Vehicle Inspectors During Emissions Testing Using the NBM, REBA, and RULA Methods

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Abstract

Motor vehicle inspection plays an essential role in ensuring that vehicles comply with roadworthiness requirements and transportation safety standards. One stage of inspection with potential ergonomic risks is emissions testing, because motor vehicle inspectors must insert a probe into the vehicle exhaust pipe, operate a smoke tester or gas analyzer, and observe the test results while adopting various working postures. These activities are often performed in bent or squatting positions and involve repeatedly maintaining static postures, which may lead to musculoskeletal disorders (MSDs). This descriptive quantitative study analyzed the working postures of 30 motor vehicle inspectors during emissions testing using the Nordic Body Map (NBM), Rapid Entire Body Assessment (REBA), and Rapid Upper Limb Assessment (RULA), supported by posture simulation with Siemens Jack 8.4 software. NBM was used to identify musculoskeletal complaints based on respondents' perceptions, whereas REBA and RULA objectively evaluated whole-body and upper-body postural risk. NBM classified 53.3% of inspectors as low risk and 46.7% as moderate risk, with complaints most frequently involving the neck, shoulders, back, lower back, and knees. REBA classified 30.0% of postures as low risk, 36.7% as moderate risk, and 33.3% as high risk. RULA classified 6.7% as low risk, 26.7% as moderate risk, 13.3% as high risk, and 53.3% as very high risk. The principal contributing factors were low exhaust-pipe height, trunk flexion during probe insertion, prolonged static postures, and repetitive movement. The contrast between subjective complaints and observational scores suggests that hazardous postures may be present before severe symptoms are consistently perceived. Ergonomic improvements are therefore required, including assistive devices, work rotation, feasible adjustment of working height, and training in appropriate postures to reduce MSD risk and improve occupational safety and health.

Keywords: emissions testing, musculoskeletal disorders, Nordic Body Map, REBA, RULA.

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INTRODUCTION

Motor vehicle inspection is one of the government's measures to ensure that vehicles operating on public roads meet technical and roadworthiness requirements, thereby improving transportation safety. An important stage in the motor vehicle inspection process is exhaust emissions testing, which measures the level of emissions produced by a vehicle against established quality standards. During the procedure, motor vehicle inspectors must insert a gas-analyzer probe into the vehicle exhaust pipe, operate the testing equipment, observe the measurement results, and document the test results. These activities are performed repeatedly on vehicles of various types and dimensions, often requiring inspectors to work in bent, squatting, or twisted postures or to maintain static postures for certain periods (Indonesia, 2021).

Non-ergonomic working postures are a major factor contributing to musculoskeletal disorders (MSDs). MSDs are disorders affecting the muscles, tendons, ligaments, joints, nerves, and other supporting tissues due to continuous occupational exposure. According to the World Health Organization (WHO), musculoskeletal disorders are a leading cause of disability among working-age populations worldwide and contribute to reduced productivity and increased occupational healthcare costs (Organization, 2022). Bridger further explains that bent postures, repetitive movements, static work, and long working durations are dominant factors that increase workers' risk of musculoskeletal disorders (Bridger, 2018).

Emissions-testing activities have work characteristics that differ from administrative and manufacturing tasks. Motor vehicle inspectors must adjust their body positions to varying vehicle heights, particularly for passenger vehicles, freight vehicles, and public-transport vehicles. When inserting the emissions-testing probe into a vehicle's exhaust pipe, the inspector generally performs trunk flexion, knee flexion, and neck rotation to ensure that the instrument is correctly positioned. This activity is performed repetitively throughout service hours and may increase the biomechanical load on the musculoskeletal system when it is not supported by ergonomic work design (Bridger, 2018; Wilson and Corlett, 2005).

Ergonomic risk can be evaluated using several complementary methods. The Nordic Body Map (NBM) is an instrument used to identify workers' subjective complaints based on body regions experiencing pain or discomfort due to work activities. This instrument is widely used in ergonomics research because it is simple, easy to understand, and able to provide an initial overview of the locations of musculoskeletal complaints (Beatrix and Wijayanto, 2023). However, the NBM captures only workers' perceptions and should therefore be combined with an observational method capable of objectively assessing postural risk levels (Umyati and Mariawati, 2025).

One widely used observational method is the Rapid Entire Body Assessment (REBA). This method was developed to evaluate ergonomic risk based on whole-body posture, including the neck, trunk, legs, upper arms, lower arms, and wrists, while considering load and work-activity factors. REBA is particularly suitable for work involving dynamic postural changes or manual-handling activities (Hignett and McAtamney, 2000). In addition to REBA, the Rapid Upper Limb Assessment (RULA) method is widely used to evaluate the risk of musculoskeletal disorders in the upper body, particularly the neck, shoulders, arms, and wrists, arising from non-ergonomic working postures (McAtamney and Corlett, 1993). Combining the NBM, REBA, and RULA methods provides a more comprehensive assessment by integrating workers' subjective complaints with objective observations of working posture.

Previous studies have demonstrated that the NBM, REBA, and RULA methods can identify ergonomic risks across various industrial sectors. Beatrix and Wijayanto reported that the combined use of REBA and NBM successfully identified high-risk working postures in the automotive industry and could therefore serve as a basis for improving workstation design (Beatrix and Wijayanto, 2023). Ajid *et al.* showed that applying the RULA and NBM methods in combination with a Lean Ergonomics approach reduced ergonomic risk levels in production activities (Ajid *et al.*, 2025). Another study by Umyati *et al.* also found that the combined NBM and REBA methods were effective in evaluating the risk of musculoskeletal disorders in various manual work activities (Umyati and Mariawati, 2025).

Although working-posture analysis has been widely applied in manufacturing, healthcare, construction, and automotive sectors, research on motor vehicle inspectors during emissions testing remains limited. Previous studies have mainly addressed vehicle assembly, material handling, or visual inspection, whereas inspection work involves different levels of repetition, postural variation, and environmental conditions (Umyati and Mariawati, 2025; Ajid *et al.*, 2025). An evidence gap therefore remains regarding the integrated evaluation of subjective complaints and observed postural risk. This study addresses that gap by combining NBM, REBA, and RULA during motor vehicle emissions testing.

RESEARCH METHODS

This descriptive quantitative study involved 30 motor vehicle inspectors assigned to emissions-testing activities. Data were obtained from questionnaires and direct postural observation. The study was conducted at UPPKB Jagakarsa, Jl. Moch. Kahfi II, Cipedak, Jagakarsa, South Jakarta.

Data Collection

Data were collected through direct observation of the study subjects. Working postures were documented photographically during emissions-testing activities. Respondents completed the NBM questionnaire to identify work-related musculoskeletal complaints. The documented postures were assessed using the REBA observational worksheet, whereas corresponding upper-body postures were reconstructed and evaluated using RULA in Jack 8.4 software to determine postural-risk levels.

Figure 1. Inspector in a squatting position

Figure 2. Inspector in a bent posture

Data Processing

Three complementary procedures were used: the Nordic Body Map (NBM) questionnaire, the Rapid Entire Body Assessment (REBA) observational worksheet, and RULA analysis using Jack 8.4 software. NBM data were processed by calculating the score for each body region and summing the scores to determine the overall complaint-risk category (Rizky Hernantya & Azzahra, n.d.).

The working-posture documentation was analyzed using the REBA worksheet and the RULA procedure in Jack 8.4 software to obtain postural-risk scores based on body position, workload, and the activity performed. The REBA assessment began by determining the Group A score (neck, trunk, and legs), which was adjusted for load/force, and the Group B score (upper arms, lower arms, and wrists), which was adjusted for coupling quality. The scores from both groups were then combined in Table C, and the activity score was added to obtain the final REBA score (Rizky Sya'bana & Herwanto, 2023).

The RULA assessment was conducted by dividing body posture into Group A (upper arms, lower arms, and wrists) and Group B (neck, trunk, and legs). The score for each group was determined using Tables A and B while considering muscle use and workload; the scores were then combined in Table C to obtain the final score (Merdiana Dewantari et al., 2023).

RESULTS AND DISCUSSION

This study involved 30 motor vehicle inspectors during emissions testing, which comprised gas-analyzer testing for gasoline-powered vehicles and smoke-tester testing for diesel-powered vehicles.

Figure 4. Gasoline-powered vehicles

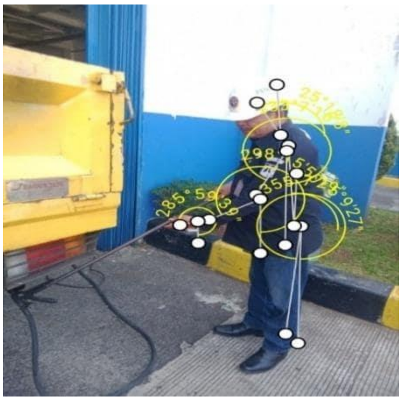

Figure 4. Smoke-tester testing

The figures show inspectors in bent and upright standing postures while conducting emissions testing. The inspectors' trunk angles ranged from approximately 10° to 60°.

Nordic Body Map (NBM)

Under the NBM method, inspectors completed a questionnaire using a four-point scale: 1 (no pain), 2 (slight pain), 3 (pain), and 4 (severe pain). Body-region scores were summed to determine each respondent's total score and risk category. Table 1 summarizes the results.

Table 1. NBM Scores and Risk Levels

Inspector	Total Score	Risk Level
Inspector 1	44	Low
Inspector 2	30	Low
Inspector 3	33	Low
Inspector 4	40	Low
Inspector 5	45	Low
Inspector 6	45	Low
Inspector 7	37	Low
Inspector 8	40	Low
Inspector 9	36	Low
Inspector 10	40	Low
Inspector 11	58	Moderate
Inspector 12	63	Moderate
Inspector 13	57	Moderate
Inspector 14	56	Moderate
Inspector 15	68	Moderate
Inspector 16	57	Moderate
Inspector 17	70	Moderate
Inspector 18	56	Moderate
Inspector 19	62	Moderate
Inspector 20	57	Moderate

Inspector	Total Score	Risk Level
Inspector 21	41	Low
Inspector 22	50	Moderate
Inspector 23	30	Low
Inspector 24	50	Moderate
Inspector 25	49	Low
Inspector 26	30	Low
Inspector 27	53	Moderate
Inspector 28	30	Low
Inspector 29	51	Moderate
Inspector 30	30	Low

The mean NBM score was 46.9 (range: 30-70). Sixteen respondents (53.3%) were classified as low risk and 14 (46.7%) as moderate risk; none were classified as high or very high risk. Complaints most frequently involved the neck, shoulders, back, lower back, and knees. These body regions receive substantial loading during probe insertion and removal. Although no high-risk NBM category was recorded, the concentration of discomfort is consistent with trunk flexion, squatting, and sustained positioning.

Rapid Entire Body Assessment (REBA)

REBA was applied as an observational assessment using the worksheet developed by Hignett and McAtamney (2000), rather than as a respondent questionnaire. The assessment covered work activities at the emissions-testing station and included 30 documented working postures. Each posture was evaluated to identify the angles and positions of the neck, trunk, arms, wrists, and legs while the inspector conducted motor vehicle emissions testing (Berty Dwi Rahmawati and Eka Anggraini, 2024). Load/force, coupling, and activity factors were also considered. The complete results obtained using the Rapid Entire Body Assessment (REBA) method are presented below.

Table 2. REBA Scores and Risk Levels

No	Inspector	REBA Score	Risk Level
1.	Inspector 1	8	High
2.	Inspector 2	2	Low
3.	Inspector 3	8	High
4.	Inspector 4	2	Low
5.	Inspector 5	10	High
6.	Inspector 6	8	High
7.	Inspector 7	8	High
8.	Inspector 8	4	Moderate
9.	Inspector 9	5	Moderate
10.	Inspector 10	3	Low
11.	Inspector 11	5	Moderate
12.	Inspector 12	6	Moderate
13.	Inspector 13	3	Low
14.	Inspector 14	8	High

No	Inspector	REBA Score	Risk Level
15.	Inspector 15	6	Moderate
16.	Inspector 16	3	Low
17.	Inspector 17	8	High
18.	Inspector 18	9	High
19.	Inspector 19	3	Low
20.	Inspector 20	5	Moderate
21.	Inspector 21	7	Moderate
22.	Inspector 22	7	Moderate
23.	Inspector 23	3	Low
24.	Inspector 24	2	Low
25.	Inspector 25	3	Low
26.	Inspector 26	6	Moderate
27.	Inspector 27	8	High
28.	Inspector 28	3	Low
29.	Inspector 29	5	Moderate
30.	Inspector 30	7	Moderate

Table 3. Summary of Risk Levels

Risk Level	**Number of Respondents**	**Percentage**
Low	9	30%
Moderate	11	36.7%
High	10	33.3%
Very High	0	0%
Total	**30**	**100%**

Based on the REBA analysis of 30 inspectors during motor vehicle emissions testing, scores ranged from 2 to 10, with a mean of 5.5. Nine inspectors were classified as low risk, 11 as moderate risk, and 10 as high risk. The moderate-risk category accounted for the largest proportion (36.7%), followed by high risk (33.3%) and low risk (30.0%). Thus, 70.0% of the observed postures were moderate or high risk. These results indicate that bending, squatting, asymmetric positioning, and sustained static postures during emissions testing require ergonomic attention and corrective action.

Rapid Upper Limb Assessment (RULA)

Rapid Upper Limb Assessment (RULA) calculations were performed using Jack 8.4 software to analyze upper-body working postures, including the neck, back, upper arms, lower arms, and wrists, based on the postural angles formed during the activity. Jack is ergonomics software capable of realistically visualizing human postures in a virtual work environment. The following stages were performed in the Jack 8.4 simulation:

1. Virtual Human Modelling

   Virtual human modelling is the process of creating a digital human model for use in ergonomic simulation. The model was developed using workers' anthropometric data, such as height, weight, sex, and other body dimensions, so that the simulation closely represented the inspectors' actual field conditions. The initial step involved selecting the Custom Human option and configuring each option in Build Human.

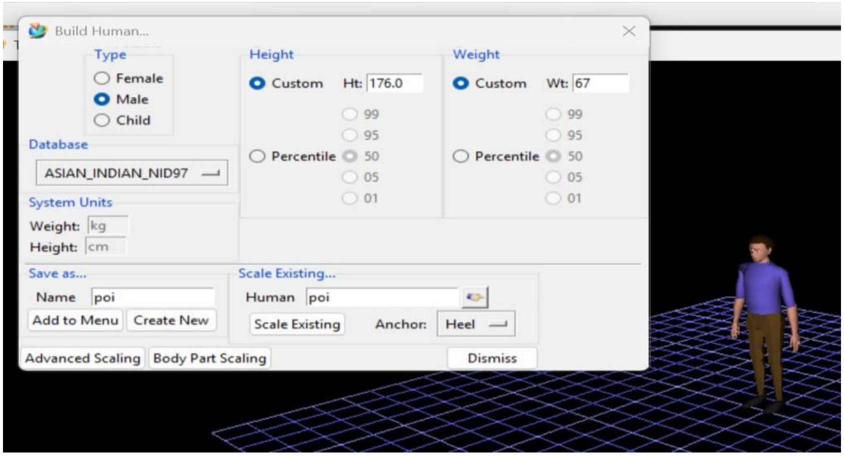

Figure 5. Creating the Virtual Model

2. Simulation of Work Activities and Adjustment of the Virtual Human's Body Posture

   The work-activity simulation was conducted to represent the body postures of motor vehicle inspectors using a virtual human model. This stage began by adjusting the body posture through the Posture feature in Jack 8.4 software, which allows body positions to be manipulated manually. The Human Control feature was used to adjust the positions of body parts, including the neck, back, arms, legs, and head, according to the observed work activities.

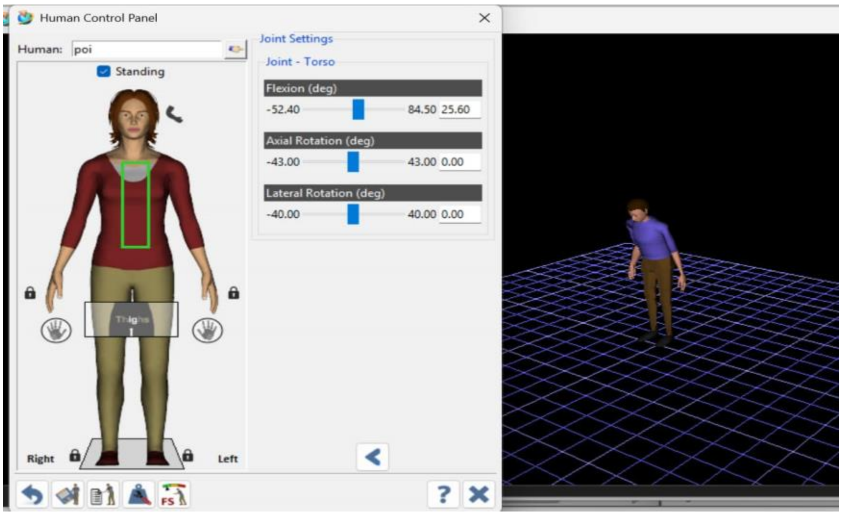

Figure 6. Creating the Work Simulation

3. *Rapid Upper Limb Assessment* (RULA) Analysis

   The next step was to select the Analysis menu in Jack 8.4 software, which displays several options in the *Task Analysis Toolkit* (TAT). Among the available analytical methods, RULA was selected to evaluate the risk of upper-body disorders. After selecting RULA, the next stage was to access *Task Entry*, which assigns a workload or activity to the virtual human model. The following figure shows the *Task Entry* interface used in the RULA analysis.

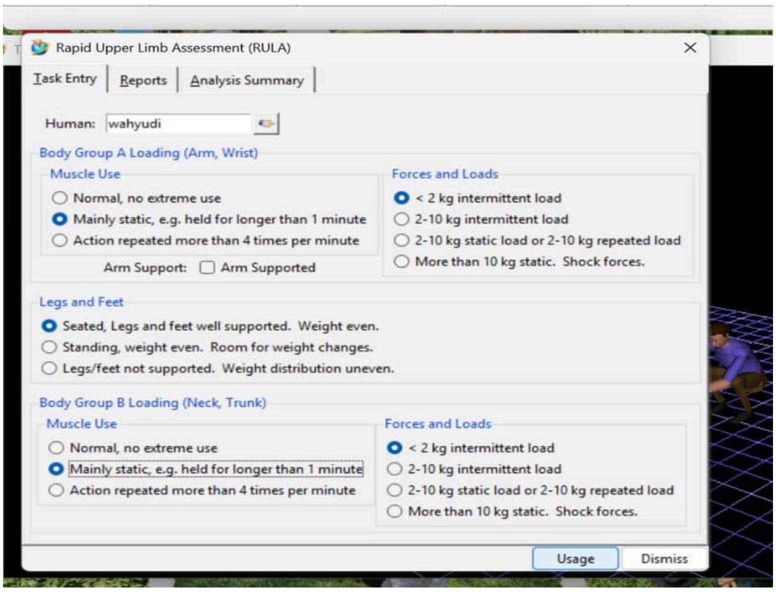

Figure 7. RULA Analysis

After all posture parameters had been configured in Jack 8.4 software, the RULA analysis results were automatically generated through the *Task Analysis Toolkit* feature.

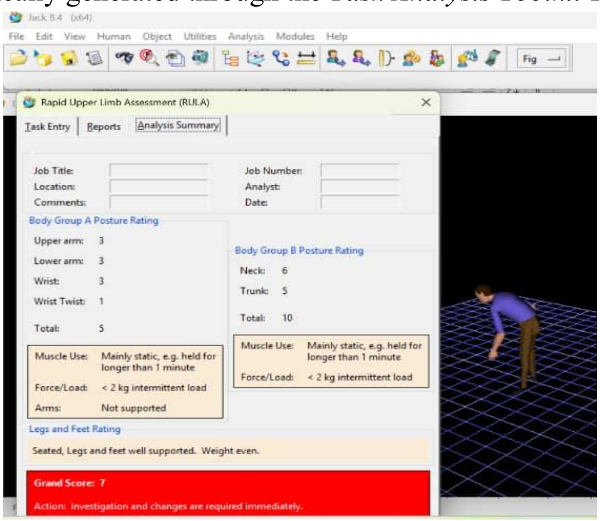

Figure 8. RULA Analysis Results

The complete results of data processing using the *Rapid Upper Limb Assessment (RULA)* method in the *Jack 8.4* software simulation are presented below.

Table 4. RULA Scores and Risk Levels

No	Inspector	RULA Score	Risk Level
1.	Inspector 1	7	Very High
2.	Inspector 2	7	Very High
3.	Inspector 3	7	Very High
4.	Inspector 4	3	Moderate
5.	Inspector 5	4	Moderate

No	Inspector	RULA Score	Risk Level
6.	Inspector 6	4	Moderate
7.	Inspector 7	7	Very High
8.	Inspector 8	7	Very High
9.	Inspector 9	7	Very High
10.	Inspector 10	7	Very High
11.	Inspector 11	5	High
12.	Inspector 12	7	Very High
13.	Inspector 13	6	High
14.	Inspector 14	5	High
15.	Inspector 15	2	Low
16.	Inspector 16	3	Moderate
17.	Inspector 17	3	Moderate
18.	Inspector 18	4	Moderate
19.	Inspector 19	7	Very High
20.	Inspector 20	7	Very High
21.	Inspector 21	6	High
22.	Inspector 22	7	Very High
23.	Inspector 23	7	Very High
24.	Inspector 24	2	Low
25.	Inspector 25	7	Very High
26.	Inspector 26	3	Moderate
27.	Inspector 27	4	Moderate
28.	Inspector 28	7	Very High
29.	Inspector 29	7	Very High
30.	Inspector 30	7	Very High

RULA scores ranged from 2 to 7, with a mean of 5.53. Two inspectors (6.7%) were classified as low risk, eight (26.7%) as moderate risk, four (13.3%) as high risk, and 16 (53.3%) as very high risk. The higher RULA ratings, compared with the generally low-to-moderate NBM ratings, suggest that hazardous upper-body postures may be detected before severe discomfort is consistently reported.

CONCLUSION

Based on the study results, the working postures of motor vehicle inspectors during emissions testing present ergonomic risks that may contribute to musculoskeletal disorders (MSDs). NBM identified low-to-moderate perceived complaints, whereas REBA classified 70.0% of observed postures as moderate or high risk and RULA classified 66.7% as high or very high risk. The combined findings identify the neck, shoulders, back, lower back, knees, and upper limbs as priority areas for intervention. Applying ergonomic principles through improved working postures, appropriate assistive devices, work rotation, and feasible adjustment of working height is expected to reduce MSD risk and improve safety, comfort, and work effectiveness. Because this descriptive study was conducted at one site, further multi-site research should evaluate the effectiveness of these interventions.

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