Work Posture Analysis Using Rapid Upper Limb Assessment (RULA) Method in SMAW Welding Booth

Aulia Nadia Rachmat*, Nora Amelia Novitrie, and Ainur Rafika Firdausy
Program Studi Teknik Keselamatan dan Kesehatan Kerja, Jurusan Teknik Politeknik Perkapalan Negeri Surabaya, Surabaya, Indonesia
***nadia.rachmat@ppns.ac.id**

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Abstract
Surabaya State Shipping Polytechnic (PPNS) is a vocational training institution that focuses on shipping and maritime affairs. Through its education and training programs, PPNS provides in-depth knowledge of transportation engineering, including welding techniques. Welding plays an important role in the marine industry in connecting and strengthening ship structures. However, welding can pose a risk of musculoskeletal disorders (GOTRAK). This research explains the dangers of ergonomic factors that may arise in PPNS welding operations. GOTRAK results on welding work showed that 87.5% of respondents experienced complaints in the upper back and hands. The causes of GOTRAK are repetitive hand and arm movements and poor body posture. The aim of this research is to determine the possible risks of GOTRAK and evaluate using RULA for students who carry out welding operations in the PPNS welding workshop through work practice and provide a basis for workplace design changes to reduce these risks. RULA is used as an assessment method that assesses risk to the upper body. Risk assessment using the RULA method resulted in a final score of 7, namely that welding work in the PPNS workshop has a high occupational risk and requires follow-up as soon as possible.

***Keywords*:** *Ergonomic, GOTRAK, RULA, Welding*.

Abstrak
Politeknik Perkapalan Negeri Surabaya (PPNS) merupakan lembaga pelatihan vokasi yang fokus pada bidang pelayaran dan kelautan. Melalui program pendidikan dan pelatihannya, PPNS memberikan pengetahuan mendalam tentang teknik transportasi, termasuk teknik pengelasan. Pengelasan memegang peranan penting dalam industri kelautan dalam penyambungan dan penguatan struktur kapal. Namun pengelasan dapat menimbulkan risiko gangguan otot rangka (GOTRAK). Penelitian ini menjelaskan tentang bahaya faktor ergonomi yang mungkin timbul pada operasi pengelasan PPNS. Hasil GOTRAK pada pekerjaan pengelasan didapatkan 87,5% responden mengalami keluhan pada

punggung bagian atas dan tangan. Penyebab GOTRAK adalah gerakan tangan dan lengan yang berulang-ulang serta postur tubuh yang buruk. Tujuan dari penelitian ini adalah untuk mengetahui kemungkinan risiko GOTRAK dan evaluasi menggunakan RULA bagi mahasiswa yang melakukan operasi pengelasan di bengkel las PPNS melalui praktek kerja dan memberikan dasar perubahan desain tempat kerja untuk mengurangi risiko tersebut. RULA digunakan sebagai metode penilaian yang menilai risiko pada tubuh bagian atas. Penilaian risiko menggunakan metode RULA menghasilkan nilai akhir 7 yaitu bahwa pekerjaan mengelas di bengkel PPNS memiliki risiko kerja tinggi dan perlu adanya tindak lanjut sesegera mungkin.

Keywords**:** *Ergonomi, GOTRAK, Pengelasan , RULA.*

1. Introduction

Politeknik Perkapalan Negeri Surabaya (PPNS) is an educational institution in the vocational field that has been granted independence in 2014. It plays an important role in the development of skills and knowledge in the shipping and marine fields. The education and training programmes organised by PPNS facilitate students' acquisition of a comprehensive understanding of shipping technology, encompassing the ship construction process, ship maintenance and repair, and the utilisation of welding techniques in the manufacture and repair of ship structures.

One significant area of technical training provided by the PPNS is welding techniques. Welding techniques are of paramount importance in the shipping industry, particularly in the context of connecting and reinforcing ship structures. The welding workshop within PPNS provides an opportunity for students to apply their theoretical knowledge of welding techniques in a practical setting. The activities conducted within the welding workshop encompass Shielded Metal Arc Welding (SMAW) and Oxy-Acetylene Welding (OAW) welding. In the execution of welding activities, there are a number of movements and postures that have the potential to result in the development of skeletal muscle disorders due to work-related factors (GOTRAK). The duration of welding work which is 8 hours/day also can increasing the possibility of GOTRAK. As indicated by Lestari and Hendra (2022), a significant proportion of welders (80.8%) frequently engage in unnatural and repetitive movements that elevate the risk of developing a gotrak condition.

The impact of GOTRAK or *Work-Related Musculoskeletal Disorders* (WMSDs) on public health can be deleterious, affecting individuals across a range of domains, including financial, physical, and social aspects (Hidayatullah, 2021). This is because disorders that occur in the musculoskeletal system cause discomfort and pain in the skeletal muscles. The application of a static load to the muscles over an extended period of time can result in the development of more serious injuries, such as damage to the joint system, tendons and ligaments (Dwiseptianto & Wahyuningsih, 2022). These disorders may be precipitated by

repetitive activities performed over an extended period and non-ergonomic postures (Srirug et al., 2023). Welding activities that involve repetitive hand and arm movements can result in excessive strain on muscles and joints. Furthermore, poor posture during welding, such as bending or stooping, can also increase the risk of developing GOTRAK. Consequently, it is crucial to ascertain whether the posture and welding equipment utilised in PPNS present a risk of GOTRAK to the user. In order to mitigate the risk of GOTRAK, it is necessary to implement a series of corrective measures, including a redesign of the booth to avoid the occurrence of occupational diseases.

The Rapid Upper Limb Assessment (RULA) method is required in welding operations that predominantly utilise the upper body. The objective of the RULA method is to provide an assessment of the utilisation of muscles and skeletal structures in the head, neck, and upper body (Kee, 2021). The evaluation of work posture using RULA can serve as an input for researchers seeking to identify work positions that are not ergonomic. Ergonomic interventions can enhance the quality of the work environment and mitigate the risk of musculoskeletal disorders among workers (Anshari & Sheikh, 2022). Consequently, this research will investigate the prevalence of skeletal muscle disorders and evaluate work postures using RULA in the PPNS welding workshop.

2. Method

Collection of Survey Data

The data collection process was conducted via an online survey utilising the Google Form platform. The survey was distributed to students enrolled in the Welding Engineering programme at the (PPNS). The survey included questions pertaining to the frequency and types of movements performed during welding activities, commonly adopted postures, and experiences of occupational (GOTRAK).

Video and Documentation Capture

Video documentation was undertaken during practical activities in the PPNS welding workshop with the objective of recording students while welding. The objective of the video documentation was to provide a comprehensive record of the diverse range of movements, postures, and work environments observed during the welding process. The process of video documentation was observational and focused on the postures and activities of the students.

Analysis Using RULA Method

The data obtained from video documentation is employed in the context of ergonomic risk analysis, utilising the RULA method. This method will assist in the evaluation of the risk of occupational skeletal muscle disorders based on the postures and movements recorded in the video. The results of the analysis will yield a score that indicates the level of ergonomic risk associated with various activities.

Data Processing and Interpretation

The data obtained from the online survey and the subsequent analysis conducted using the RULA method will be subjected to both quantitative and qualitative analysis. The survey data will be presented in the form of descriptive statistics with the objective of identifying common

trends and patterns in students' experiences with GOTRAK. The results of the RULA method analysis will be employed to ascertain the degree of ergonomic risk associated with the postures and movements observed in the video documentation. RULA method combine two group of assessment which is group A and group B. Group A assess the posture of upper arm, lower arm, wrist position, and wrist movement. Meanwhile group B assess the position of the neck, upper body position, and leg position. The combination of group A and group B can determine the total risk of the welding posture.

3. Result and Discussion

The PPNS welding workshop comprises up to 30 individual welding booths. Each welding booth can be used for one welding worker. The welding booths have been furnished with welding tables and chairs. Welding booth as the main facility of the welding worker affect the work posture. The first step to do the research is knowing the complaints of the existing welding facility. The survey presented in Figure 1 was conducted on 30 respondents who used a welding booth for a minimum of 70 minutes per day.

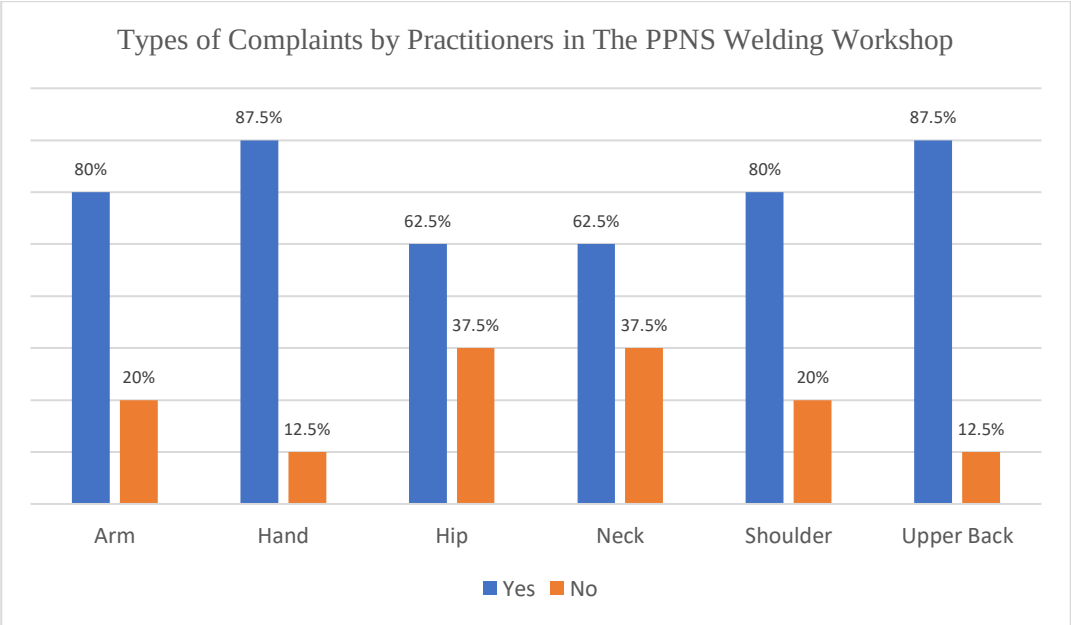

Figure 1. A Classification of Complaints Lodged by Practitioners Engaged in The PPNS Welding Workshop

In the welding workshop, practitioners reported the highest incidence of complaints in the hands and upper back. It because that body parts become the main support for holding the welding arch whether it's for SMAW or OAW. Conversely, they reported the lowest incidence of complaints in the hips and neck. Hips and neck reported as the lowest complaints because the worker usually move that body parts and strech to check the quality of their welding works.

Figure 2. Welding Booth

Complaints of muscle disease can be caused by poor design of work facilities. Work facilities of welding consist of welding booth, welding table, and welding chair. Figure 2 illustrates the concept of a welding booth, which is a three-sided cube without a roof cover. Its purpose is to reduce the risk of exposure to welding splashes from the side where the booth is located. This is because the lack of a roof cover increases the potential for dust and dirt to enter the welding booth, which can interfere with the welding process. Furthermore, ultraviolet radiation generated by the welding process can pose a risk to the health of workers. The dimensions of this welding booth are 160 cm in height, 147 cm in length, and 140 cm in width.

Figure 3. Welding Table

Figure 3 illustrates the concept of this welding table, which comprises table legs that serve as a support for work facilities. The work table is a medium for placing materials. Additionally, the table includes a ragum, a clamping tool, and a protractor, which regulates the degree of material to be worked on by workers or students. The workpieces are frequently created through welding on plates and pipes. The dimensions of this welding booth are 100 cm in height, 70 cm in length, and 40 cm in width.

Figure 4. Welding Chair

As depicted in Figure 4, the design concept of this welding chair is a circular seat shape. This type of chair is typically employed by industrial workers and students to facilitate rest and recuperation during welding activities. Its ergonomic design reduces the risk of fatigue in the legs, which can result from prolonged periods of standing. The dimensions of the welding booth are as follows: height of 70 cm, seat diameter of 86 cm, diameter of 121 cm and a thick frame diameter of 4 cm.

Figure 1 indicates that numerous practitioners in the welding workshop have experienced pain in their body parts during the welding process in the PPNS workshop. Figure 1 presented above indicates that a significant proportion of practitioners experience complaints of pain in the hands and upper back. To ascertain the underlying cause of this discomfort, further investigation was conducted on the work tools utilized in the PPNS welding workshop, as depicted in Figure 5.

Figure 5. Welding in PPNS Welding Workshop

A review of the documentation reveals that the sitting position of the welding practitioner is too low, necessitating the practitioner to look up in order to reach the work material to be welded. If this position is maintained for an extended period, it has the potential to result in injuries that are more severe than mere pain. Based on these work postures, work posture calculations were carried out using the RULA method. The RULA method comprises three tables, which are as follows:

A. Group A

- Upper Arm Position
  The angle formed is more than 50° at an angle of 57.1°. The upper arm position is therefore scored 3.
- Lower Arm Position
  The angle formed is above 100° at an angle of 155°. Consequently, the forearm position is scored 2.
- Wrist Position
  Should the wrist position not form an angle, the wrist position is awarded a score of 1.
- Wrist Twist
  The degree of wrist twist, as indicated by the up-and-down and open-and-closed movements of the palms, is scored at 2.
- Looking up Posture Score in Table 2 of Group A comprises calculations pertaining to the upper arm, forearm, wrist, and wrist twist.

The results of the previous score were used to inform the generation of a new score, which yielded a value of 4.

Table 1. Group A Comprises Calculations Pertaining to The Upper Arm, Lower Arm, Wrist, and Wrist Movement.

Upper Arm	Lower Arm	Wrist							
		1		2		3		4	
		Wrist Twist		Wrist Twist		Wrist Twist		Wrist Twist	
		1	2	1	2	1	2	1	2
1	1	1	2	2	2	2	3	3	3
	2	2	2	2	2	3	3	3	3
	3	2	3	2	3	3	3	4	4
2	1	2	3	2	3	3	3	4	4
	2	2	3	2	3	3	3	4	4
	3	2	4	3	3	3	4	4	5
3	1	2	4	3	3	4	4	5	5
	2	2	**4**	3	3	4	4	5	5
	3	2	4	3	4	4	4	5	5
4	1	3	4	4	4	4	4	5	5
	2	3	4	4	4	4	4	5	5
	3	3	4	4	5	5	5	6	6

Upper Arm	Lower Arm	Wrist							
		1		2		3		4	
		Wrist Twist		Wrist Twist		Wrist Twist		Wrist Twist	
		1	2	1	2	1	2	1	2
5	1	5	5	5	5	5	6	6	7
	2	5	6	6	6	6	7	7	7
	3	6	6	6	7	7	7	7	8
6	1	7	7	7	7	7	8	8	9
	2	7	8	8	8	8	9	9	9
	3	9	9	9	9	9	9	9	9

- Muscle Utilisation Score
  The muscle utilisation score is 1, based on the work cycle being performed for more than one minute.
- Force/Load Score
  In this posture, there is no load being lifted. Consequently, the force/load score can be assigned a value of 0.
  The score of upper arm, lower arm, wrist, and wrist twist is 4 (shown in Table 1) but it must be added up with muscle utilization score and force/load score 1. So, the total score will be 5.

B. Group B

- Position of the Neck
  The neck position, which appears to be oriented upwards and exhibits an angle of 26.1°, is awarded a score of 4.
- Upper Body Position/Trunk
  The angle formed in the range of 0°-20° at an angle of 9.7° was found to result in an upper body position score of 2.
- Legs
  In the foot calculation, a score of 2 was assigned due to the presence of an awkward posture in one of the feet, which was a consequence of the chair being too short from the work plane.
- Look up Posture Score in Table 2 Group B of neck, trunk, and leg calculations
  The posture score is derived from the recapitulation results obtained with a score of 6 being recorded in Table 2.

Table 2. Group B, Neck, Upper Body and Leg Calculations

Neck	Upper Body/Trunk							
	1		2		3		4	
	Legs		Legs		Legs		Legs	
	1	2	1	2	1	2	1	2
1	1	3	2	3	5	5	6	7
2	2	3	2	3	5	5	6	7

Neck	Upper Body/Trunk							
	1		2		3		4	
	Legs		Legs		Legs		Legs	
	1	2	1	2	1	2	1	2
3	3	3	3	4	5	6	6	7
4	5	5	5	**6**	7	7	7	8
5	7	7	7	7	8	8	8	8
6	8	8	8	8	8	9	9	9

- Muscle Utilisation Score
  A work cycle that lasts for more than one minute and is performed four times in one minute is associated with a muscle utilisation score of 1.
- Force/Load Score
  It can be seen there is no reduction in the force/load exerted on the work posture, and thus the value assigned to this section is 0.
  The score of neck, trunk, and leg is 6 (shown in table 2) but it must be added up with muscle utilization score and force/load score 1. So, the total score will be 7.

C. Group C

- Looking for Posture Scores in Group C
  The results of the summation of the position of the upper arm, forearm, wrist, wrist movement, muscle use and load assessment in group A yielded an accumulated result of 5. In contrast, the accumulated results from the calculation of the neck, upper body, legs, muscle use and load assessment values in group B were 7.

Table 3. Group C, Final Results of RULA Calculation

Score Table 3	Score Table 2						
	1	2	3	4	5	6	7+
1	1	2	3	3	4	5	5
2	2	2	3	4	4	5	5
3	3	3	3	4	4	5	6
4	3	3	3	4	5	6	6
5	4	4	4	5	6	7	**7**
6	4	4	5	6	6	7	7
7	5	5	6	6	7	7	7
+8	5	5	6	7	7	7	7

The final value of 7, obtained following the completion of the RULA calculations, represents the overall assessment of the risk level associated with the welding work conducted at PPNS. This value indicates that the welding work carried out at PPNS is of a high risk nature. The body parts at risk of injury include the neck, upper body, and legs. One potential solution to reduce the risk of injury is to replace the tables and chairs in the PPNS welding workshop. This

would enable practitioners to perform activities without the need to crane their necks or bend their legs for extended periods.

4. Conclusion

The use of PPNS welding tables has been linked to an increased risk of skeletal muscle disorders among workers. This is evidenced by the high percentage of complaints reported by PPNS workshop practitioners. These complaints include body parts of the arms, hands, hips, neck, shoulders and upper back, which have been attributed to awkward postures such as bending and looking up when welding. A risk assessment using the RULA method was conducted on a SMAW welding table with dimensions of 100 cm high, 70 cm long, and 40 cm wide. The final result, with a value of 7, indicated that welding work in the PPNS workshop has a high occupational risk and requires immediate follow-up

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