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JOURNAL INDUSTRIAL SERVICESS

Industrial Engineering Advance Research & Application

eISSN 2461-0631

Work posture analysis and complaint risk using Nordic Body Map (NBM) and Rapid Entire Body Assessment (REBA) methods

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ARTICLE INFO

Article history:
Received 13 September 2023
Received in revised form 8 November 2023
Accepted 24 November 2023
Published online 4 December 2023

Keywords:
MSDs
Nordic Body Map
REBA
Recommended Weight Limit

Editor:
Noni Setiowati

Publisher's note:
The publisher remains neutral concerning jurisdictional claims in published maps and institutional affiliations.

ABSTRACT

This research investigates work posture analysis and complaint risks associated with polyethylene pellets production at a petrochemical company in Cilegon, Indonesia. The concerns center on improper work postures among forklift operators engaged in repetitive tasks and loading personnel involved in manual handling, such as transferring bagged pellets onto trucks. The study aimed to identify the Nordic Body Map (NBM) questionnaire's primary complaint categories, assess the Rapid Entire Body Assessment (REBA) score, determine recommended weights for workers using Recommended Weight Limit (RWL) and lifting Index (LI) calculations, and propose enhancements to mitigate the risk of MSDs. According to the NBM questionnaire, both forklift operators and loading personnel reported experiencing moderate to high levels of Musculoskeletal Disorders (MSD) discomfort. REBA scores revealed forklift operators scoring between 5 and 6, while loading dock workers scored between 11 and 12. The estimated RWL for loading personnel in different positions is 6.531 kg, 3.5707 kg, and 6.0463 kg, respectively. Recommendations include improving the work system, conducting health assessments, revising hiring criteria, developing adjustable tables, optimizing packaging bags, establishing SOPs, and modifying forklift area components. These suggestions remain broad, with detailed plans intended for future research and implementation.

1. Introduction

A corporation needs to consider occupational safety and health as crucial aspects. Under favorable occupational safety and health conditions, workers can perform their tasks securely and comfortably, which enhances worker productivity. Productivity can be defined by the ability of employees to generate items or complete duties on time. Workers, as role-holders, have a close connection to the workplace. According to the International Labour Office (ILO) in 2013, more than 250 million accidents occur at work each year, leading to over 160 million workers falling ill due to workplace risks [1].

Manual activities often play a dominant role in injuries across various body regions. Such injuries can result from unnatural and forced body postures, including bending, twisting, squatting, and kneeling. Additionally, repetitive movements, like frequent gripping, lifting, and carrying objects, can contribute to injuries. Overloading, involving lifting excessively heavy objects, further escalates the risk. Calculations using the Recommended Weight Limit (RWL) method are necessary to determine whether the current load being lifted is within recommended limits or not.

The RWL method analyzes human strength during lifting or moving loads, recommending load limits that humans can lift without causing injuries, even during repetitive tasks over extended periods [2]. Static work postures, such as prolonged standing during specific activities, significantly impact work posture. The Rapid Entire Body Assessment (REBA) method can measure angles formed by body segments, such as the torso, neck, lower and upper arms, palms, and knee posture [3], [4].

Musculoskeletal Disorders (MSDs) can cause significant losses for both workers and companies [5], [6]. Workers experiencing MSD-related issues suffer health disruptions, which can worsen if left untreated over time. Untreated conditions can deteriorate, leading to prolonged discomfort. These health challenges not only affect workers' well-being but also hinder their productivity, making them unable to perform duties efficiently. Consequently, companies face losses due to reduced work hours, decreased productivity, and employee quality. These disruptions affect workflow processes and add to the burden of medical

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http://dx.doi.org/10.36055/jiss.v9i2.22004

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compensation costs and other losses linked, directly or indirectly, to MSDs [7].

A petrochemical company in Cilegon, Indonesia, operates within the petrochemical plastic industry, focusing on two main areas: Area 1 serves as the utilization unit, while Area 2 comprises Train 1, Train 2, and Train 3, forming the primary processing zone for producing polyethylene. The company manufactures Linear Low-Density Polyethylene (LLDPE) and High-Density Polyethylene (HDPE) products, subject to rigorous compliance checks. The packaging unit handles pellet bags placed on pallets using automated machinery.

The production output is stored in two warehouses with different capacities and sources. Loading activities in these warehouses involve transferring plastic pellets onto transporting trucks. Forklift operators transfer pellet bags onto pallet stacks, and loading personnel arrange the bags within the trucks.

Loading personnel's manual activities include lifting and loading 25 kg bags transferred by forklift operators onto transport trucks. Each warehouse targets an operation of approximately 1,800 tons daily, requiring collaboration between loading personnel and forklift operators. Loading personnel handle around 35-40 tons daily. Consistent lifting of such substantial weights in non-ergonomic postures poses a risk of injury or musculoskeletal discomfort [8], [9]. Similarly, repetitive movements by forklift operators also pose the risk of MSDs.

This research aims to assess work posture and muscle injury risk resulting from loads exceeding limits, proposing measures to alleviate musculoskeletal complaints. The research methodology involves administering the Nordic Body Map (NBM) questionnaire to loading personnel and forklift operators to identify body discomfort. Employing the Rapid Entire Body Assessment (REBA) method, calculating the Recommended Weight Limit, and determining the Lifting Index for loading personnel are integral parts of the research. These measures aid in understanding work postures, load limits, and the risk of injury due to physical posture, often experienced as discomfort by the operators.

2. Material and method

This research adopts a quantitative methodology, employing tools like the Nordic Body Map (NBM), the Rapid Entire Body Assessment (REBA) method, as well as techniques to evaluate the Recommended Weight Limit (RWL) and Lifting Index (LI). Its primary focus lies in assessing workers' body postures and addressing musculoskeletal complaints. The study initiated with on-site observations conducted at PT. X, involving close monitoring of workers' activities to identify prevalent workplace issues.

The research specifically targets warehouse workers, concentrating on two key roles: forklift operators and loading personnel. Following the collection of observational data, established methodologies are used to process the gathered information. The Nordic Body Map (NBM) questionnaire undergoes analysis to identify common areas of bodily discomfort. Work posture assessment occurs through the Rapid Entire Body Assessment (REBA) method, assisted by ergonomic software like Ergofellow and Image Meter. Additionally, calculations for the Recommended Weight Limit (RWL) and Lifting Index determine the appropriate load weight for workers.

Proposed improvements encompass considerations for load lifting limits, ergonomic lifting techniques, and redesigning select forklift components. These recommendations draw upon relevant literature sources.

3. Results and discussions

3.1. NBM questionaire

During the data processing phase, the Nordic Body Map (NBM) questionnaire was administered to the workers. Table 1 presents the distribution results of the NBM questionnaires provided to the workers.

Based on Table 1, the scores obtained from the Nordic Body Map (NBM) questionnaire reveal the extent of pain complaints across different body parts among the workers. Forklift operators predominantly experience discomfort in the upper and lower neck regions. On the other hand, loading personnel indicate prevalent discomfort in the upper and lower neck areas, both lower arms, the right wrist, both hands, as well as both knees. Additionally, the total scores reveal that forklift operator respondents scored 29 and 30, categorizing as moderate risk. Among the loading personnel, the highest scores were 29, 27, and 42, with the top score attributed to upper body loading positions. This trend is, in part, influenced by age.

3.2. Work posture assessment with forklift

In the assessment of work posture, three forklift operators and three loading personnel were involved. Body posture data of these workers, captured through photographs and videos, were utilized for REBA data processing. After conducting the REBA calculations, the following are the obtained results. Fig. 1 serves as an example of data processing using the REBA method for forklift operators.

Figure 1. Working posture of forklift operator

Table 1.
Results of NBM questionaire

No	Complaint Type	Score based on type of work						Total
		Forklift operators			Loading man			
		1	2	3	mid	low	up	
0	Above the neck	3	3	3	2	2	2	15
1	Under the neck	3	3	3	2	2	2	15
2	Left Shoulder	0	1	0	0	0	2	3
3	Right Shoulder	0	1	0	0	0	2	3
4	Left over arm	1	0	0	1	1	2	5
5	Back	2	1	1	1	1	2	8
6	Right over arm	1	0	1	1	1	2	6
7	Waist	0	0	0	2	2	2	6
8	Butt	2	2	2	0	0	0	6
9	The bottom of the buttocks	2	2	2	0	0	0	6
10	Left elbow	0	0	0	0	0	2	2
11	Right elbow	0	0	0	0	0	2	2
12	Left forearm	0	0	0	2	2	2	6
13	Right forearm	0	0	0	2	2	2	6
14	Left wrist	2	2	2	2	2	2	12
15	Right wrist	2	2	2	2	2	2	12
16	Left hand	2	2	2	2	2	2	12
17	Right hand	2	2	2	2	2	2	12
18	Left thigh	0	0	0	0	0	0	0
19	Right thigh	0	0	0	0	0	0	0
20	Left knee	1	0	0	2	2	2	7
21	Right knee	1	0	0	2	2	2	7
22	Left calf	1	1	2	1	0	2	7
23	Right calf	1	1	2	1	0	2	7
24	Left ankle	1	2	2	0	0	0	5
25	Right ankle	1	2	2	0	0	0	5
26	Left Foot	1	1	1	1	1	1	6
27	Right foot	1	1	1	1	1	1	6
Total score of musculoskeletal complaints		30	29	30	29	27	42	

Table 2.
REBA score of Group A (forklift operator)

Back		Neck											
		1				2				3			
	Foot	1	2	3	4	1	2	3	4	1	2	3	4
1		1	2	3	4	1	2	3	4	3	3	5	6
2		2	3	4	5	3	4	5	6	4	5	6	7
3		2	4	5	6	4	5	6	7	5	6	7	8
4		3	5	6	7	5	6	7	8	6	7	8	9
5		4	6	7	8	6	7	8	9	7	8	9	9
Load													
0		1				2				1			
< 5 kg		5-10 kg				>10kg				Sudden or rapid increase in load			

Table 3.
REBA score of Group B (forklift operator)

Upper Arm		Forearm					
		1			2		
	Wrist	1	2	3	1	2	3
1		1	2	3	1	2	3
2		1	2	3	2	3	4
3		3	4	5	4	5	5
4		4	5	5	5	6	7
5		6	7	8	7	8	8
6		7	8	8	8	9	9
Coupling							
0-Good		1-Fair			2-Poor		3-Unacceptable
The handle fits and is right in the middle, strong grip		Handrails are acceptable, but not ideal/the coupling is more suitable for use by other parts of the body			Handrails is not acceptable even if it is possible		Forced grip that is unsafe, without a coupling grip that is not suitable for use by other parts of the body

Table 4.
REBA score of Group C (forklift operator)

		A Score											
		1	2	3	4	5	6	7	8	9	10	11	12
B Score	1	1	2	3	4	5	6	7	8	9	10	11	12
	2	1	2	3	4	5	6	7	8	9	10	11	12
	3	1	2	3	4	5	6	7	8	9	10	11	12
	4	2	3	4	4	5	7	8	9	10	11	11	12
	5	3	4	4	5	6	8	9	10	10	11	12	12
	6	3	4	5	6	7	8	9	10	10	11	12	12
	7	4	5	6	7	8	9	9	10	11	11	12	12
	8	5	6	7	8	8	9	10	10	11	12	12	12
	9	6	6	7	8	9	10	10	10	11	12	12	12
	10	7	7	8	9	9	10	11	11	12	12	12	12
	11	7	7	8	9	9	10	11	11	12	12	12	12
	12	8	8	8	9	9	10	11	11	12	12	12	12
Activity Score													
+1 if 1 or more body parts are static, held for more than 1 minute					+1 if the repetition of the movement is within a short time span, repeated more than 4 times per minute (excluding walking)					+1 if the movement causes a rapid change or shift in posture from the starting position			

Figure 2. Middle position

Fig. 1 illustrates the forklift driver leaning against the driver's seat while standing upright. The position of the trunk (score: 2, angle: 15° within the flexion range of 0° to 20°) indicates a slight forward inclination. The neck maintains a slightly raised position at a 34° angle without turning to the side, denoting motion (score: 2) with an extension exceeding 20°. The load's weight distribution, scored at 2, is maintained by the forklift's gas and brake pedals, resulting in a total score of 4 in the accompanying table. Group A received a total score of 4, which was then factored into the worker's load weight. Since the operator doesn't have a load to lift, falling into the 5 kg category, they receive a score of 0.

In the calculations for group B, three body parts are considered. The upper arm receives a score of 3 with a movement angle of 30°, falling within the flexion range of 20° to 60°. The lower arm achieves a score of 1 with an angle of movement from 60° to 100°, measured at 82°. Additionally, the wrist, angled at 32° while holding and turning the forklift steering wheel, involves actions scoring 2 and flexion greater than 15°. The results are shown in Table 2.

Table 3 shows the REBA table for group B scores based on the findings of the group B angle assessment. A score of 4 was obtained in group B, which was then added to the coupling value. The coupling score remains zero due to the solid and centrally positioned grip employed. The group C score in Table 4 is calculated and combined with the activity score. The operator maintains a static body position for a considerable amount of time while operating the forklift, resulting in an additional score of 1. The operating stance of forklift operator 1 produced the following REBA score.

3.3. *Assessment of work posture using REBA for male loading workers*

The REBA score for one of the loading male workers is then calculated as follows. An example of data processing for loading male employees using the REBA approach is illustrated in Fig. 2. According to Fig. 2, the loading male worker appears bent at an angle of 71° in the torso (trunk), categorized within the movement range of >60°, resulting in a REBA score of 4. The neck shows a slightly bent position at a 25° angle, falling within a movement range of > 20° for flexion or extension, earning a REBA score of 2. The posture is deemed unstable due to the unsupported position of the legs and the uneven weight distribution, marked by a score of 2. Similarly, the unsupported position of the feet and the uneven weight distribution contribute to the instability, also scoring 2. The angle of the feet between >30° and 60° results in a 52° angle, adding +1 to the final score. The final score for the legs is 3. Below is a scoring table for group A.

Group A (see Table 5) received a score of 7, which includes the additional weight carried by the worker. As the pellet load lifted in this case was 25 kg, exceeding 10 kg, it resulted in a score of 2. In Group B calculations (see Table 6), three bodily components are considered: the wrist, forearm, and upper arm.

Table 5.
REBA score of Group A (Loading man middle position)

		1				2				3			
	Foot	1	2	3	4	1	2	3	4	1	2	3	4
1		1	2	3	4	1	2	3	4	3	3	5	6
2		2	3	4	5	3	4	5	6	4	5	6	7
3		2	4	5	6	4	5	6	7	5	6	7	8
4		3	5	6	7	5	6	7	8	6	7	8	9
5		4	6	7	8	6	7	8	9	7	8	9	9
Load													
0				1			2			1			
<5kg				5-10kg			>10kg			Sudden or rapid increase in load			

Table 6.
REBA score Group B (Loading man middle position)

Upper Arm		Forearm					
		1			2		
	Wrist	1	2	3	1	2	3
1		1	2	3	1	2	3
2		1	2	3	2	3	4
3		3	4	5	4	5	5
4		4	5	5	5	6	7
5		6	7	8	7	8	8
6		7	8	8	8	9	9
Coupling							
0-Good			1-Fair		2-Poor		3-Unacceptable
The handle fits and is right in the middle, strong grip			Handrails are acceptable, but not ideal/the coupling is more suitable for use by other parts of the body		Handrails is not acceptable even if it is possible		Forced grip that is unsafe, without a coupling grip that is not suitable for use by other parts of the body

Table 7.
REBA score Group C (Loading man in middle position)

		A Score											
		1	2	3	4	5	6	7	8	9	10	11	12
B Score	1	1	2	3	4	5	6	7	8	9	10	11	12
	2	1	2	3	4	5	6	7	8	9	10	11	12
	3	1	2	3	4	5	6	7	8	9	10	11	12
	4	2	3	4	4	5	7	8	9	10	11	11	12
	5	3	4	4	5	6	8	9	10	10	11	12	12
	6	3	4	5	6	7	8	9	10	10	11	12	12
	7	4	5	6	7	8	9	9	10	11	11	12	12
	8	5	6	7	8	8	9	10	10	11	12	12	12
	9	6	6	7	8	9	10	10	10	11	12	12	12
	10	7	7	8	9	9	10	11	11	12	12	12	12
	11	7	7	8	9	9	10	11	11	12	12	12	12
	12	8	8	8	9	9	10	11	11	12	12	12	12
Activity Score													
+1 if 1 or more body parts are static, held for more than 1 minute				+1 if the repetition of the movement is within a short time span, repeated more than 4 times per minute (excluding walking)				+1 if the movement causes a rapid change or shift in posture from the starting position					

The upper arm's position, with an angle of 72° indicating a movement exceeding 60°, receives a score of 4. The lower arm's position, with an angle of 148° and extending beyond 100°, earns a score of 2. Regarding the wrist position, when holding the weight to be raised, the hand (wrist) is angled at 22° and scores 2 for movements exceeding 15° in either direction. Table 6 shows the REBA table displaying the findings from the Group B angle evaluation.

After acquiring the score for group C (see Table 7), the activity score is then integrated. The loading procedure involves rapid movements, causing frequent changes in body position, exceeding four times per minute within a brief duration. With a score of 12, falling within the upper range of the assessment scale, it indicates a significant level of concern, warranting immediate remedial measures.

Tabel 8.
Summary of REBA scores

Respondence	Score	Level Risk	Corrective action
Operator Forklift 1	5	Currently	Need
Operator Forklift 2	6	Currently	Need
Operator Forklift 3	6	Currently	Need
Loading man middle position	12	Very high	Need it now
Loading man bottom position	11	Very high	Need it now
Loading man top position	11	Very high	Need it now

Tabel 9.
Pellet bag lift data recapitulation

Object Weight		Hand Position				Distance traveled (D) (cm)	Angle		Frequency	Time	Handle object
Respondents	Max weight	Initial Position (cm)		Last Position (cm)			Initial	Last	Appointment per min		
		H	V	H	V		A	A	F	(hour)	C
Middle spot	25 kg	38	70	32	60	120	0°	45°	3 time	4 H	Poor
Bottom spot	25 kg	35	35	30	70	150	0°	45°	3 time	4 H	Poor
Top Spot	25 kg	44	50	40	85	200	90°	90°	3 time	4 H	Poor

Tabel 10.
Recommended RWL and LI

Repondent	RWL (kg)		LI (kg)	
	Initial	Last	Initial	Last
Middle spot	6.3329	5.6531	3.9476	4.4223
Bottom spot	6.0463	6.5317	4.1345	3.8275
Top spot	3.5707	3.8839	7.0014	6.4437

Table 8 provides a concise summary of the outcomes from the risk assessment conducted on forklift operators and loading personnel. Among the three forklift operators assessed, each exhibits a moderate level of risk, necessitating the implementation of corrective measures. Meanwhile, the roles held by the three loading personnel—middle, bottom, and top—indicate a significantly elevated level of risk. Hence, it's imperative to promptly implement remedial measures to address these concerns. Implementing corrective actions is crucial to mitigate current risks and ensure the ongoing security and safety of operational activities.

3.4. Calculating RWL and LI for loading man lifting

Table 9 summarizes the lifting data for loading man workers handling pallet bags. The table includes information about the load's weight, the horizontal distance (H) between the hand holding it and the body center, the vertical distance (V) from the hand position to the floor, the vertical movement distance of the load (D) between origin and destination, the asymmetric angle (A), lifting frequency, lifting duration, and object grip. The subsequent table provides estimations of the Recommended Weight Limit (RWL) and Lifting Index (LI) for male workers involved in middle position loading tasks [10].

The initial and final RWL estimates for the middle position loading man worker are 6.3329 kg and 5.6531 kg, respectively. As the pellet bag weighs 25 kg, the recommended load weight is 5.6531 kg according to RWL calculations. Subsequently, using the LI (Lifting Index) formula, an initial LI value of 3.9476 kg and a final LI value of 4.4223 kg are calculated. Both initial and final LI values are > 3, indicating that the load being lifted exceeds the RWL value. This discrepancy occurs because the RWL is lower than the load weight. Additionally, small horizontal and vertical movement values contribute to a reduced RWL at the initial position. Lower vertical distance results in reduced vertical movement. Measures to reduce risk should be implemented. Similar calculations were applied to loading man employees in lower and 3rd positions [11].

The information provided in Table 10 presents a comprehensive summary of an individual's lifting capacity in different postures, along with suggested optimal load weights for each corresponding posture. The initial and final positions indicate the individual's location responsible for loading at the time the data was collected. The Indonesian Ministry of Manpower defines the lifting index (LI) as a metric used to evaluate ergonomic hazards associated with lifting objects. It assesses the relationship between the weight lifted by a worker and their maximum physical capability [12]. Within the table, "LI (kg)" signifies the lifting index value for each loading man position—middle, bottom, and top. The presented LI data offers a comparative analysis of factors such as the load carried by the loading man, which adheres to recommended physical capability limits set by the Ministry of Manpower.

3.5. Recommendations for enhancing occupational posture and alleviating MSDs concerns

Based on the findings obtained from the NBM questionnaire and subsequent RWL and LI calculations for male individuals involved in lifting activities, it's advisable to limit loads to 3-6 kg for optimal safety. Workers engaged in loading and unloading tasks face an increased risk of muscular injuries due to higher Loading Index (LI) values, surpassing ideal standards. To prioritize employee well-being and safety, companies are recommended to implement measures such as regular health assessments, training programs focusing on proper posture—especially during twisting

movements related to lifting tasks—and improving the work environment. Strategies like reducing lifting height and horizontal displacement should be considered. Efforts were made to minimize rotating movements and mitigate vertical disparity, incorporating assistive equipment like adjustable tables or pallet jacks to facilitate loading tasks [13, 14].

Enhancing coupling values can be achieved by modifying bag packaging for easier grip and transport. Developing Standard Operating Procedures (SOPs) for loading personnel is crucial to minimize asymmetric angles. Consideration for replacing older forklift models with enhanced capabilities aims to reduce manual loading risks and work-related accidents. Additionally, redesigning the forklift compartment, including adjustable seats and well-designed backrests, and repositioning levers for improved ergonomics, is recommended [4]. These broad recommendations stem from identifying current issues, and further design enhancements can be pursued through dedicated research efforts [15].

4. Conclusions

Based on the Nordic Body Map questionnaire findings, most respondents (5 out of 6) employed as forklift workers and loading personnel reported experiencing moderate levels of musculoskeletal discomfort. Urgent corrective measures should be implemented, especially for senior-level loading personnel facing elevated risks.

Work posture evaluations using the REBA approach reveal a cumulative REBA score of 5 and 6 for forklift operators, classifying them in the medium category, suggesting a need for improvement. Loading machinery operators received lifting activity ratings of 11 and 12, indicating an extremely high-risk level, necessitating immediate action. The forklift operator's REBA score falls within the moderate range of 5 to 6, indicating the need for corrective measures.

Calculations using the Recommended Weight Limit (RWL) method suggest load handling weights of 6.531 kg for middle position loading workers, 6.0463 kg for bottom position workers, and 3.5707 kg for top position workers. The LI values for these loading man workers surpass the ideal threshold, signifying a heightened risk of muscular injury.

Several suggestions have been proposed to enhance the work system, including prioritizing worker health and safety, conducting health assessments, reducing lifting quotas, developing adjustable tables as assistive equipment, redesigning bag packaging for better grip, establishing standard operating procedures (SOPs), and reconfiguring forklift components.

Declaration statement

Ani Umyati: **Conceptualization, Methodology, Writing-Original Draft**. Peti: **Collecting data.** Ade Sri Mariawati: **Writing-Review & Editing.**

Acknowledgement

The acknowledgement was given to anonymous refrees for constructive feedback.

Disclosure statement

The author declares that this manuscript is free from conflict of interest and is processed by applicable journal provisions and policies to avoid deviations from publication ethics in various forms.

Funding statement

The authors received no funding for this research.

Data availability statement

The authors confirm that the data supporting the findings of this study are available within the article or its supplementary materials.

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