ALAM CIPTA
International Journal on Sustainable Tropical Design Research and Practice

CONCEPTUAL DESIGN, FABRICATION AND VALIDATION ON PROTOTYPE OF INDUSTRIAL ERGONOMIC TROLLEY-LIFTER FOR WOOD FURNITURE INDUSTRY

Nurhanisah Mohd Hawari[1*], Ruhaizin Sulaiman[1*], Che Me Rosalam[1]
Department of Industrial Design, Faculty of Design and Architecture, Universiti Putra Malaysia, 43400, UPM Serdang, Selangor, Malaysia

ARTICLE INFO

Keywords:
ergonomic intervention,
woodworkers,
surveys,
QEC,
and REBA

ABSTRACT

Over the past several decades, ergonomics design has been demanded and considered as a main factor of efficiency and effectiveness in optimising production. Recently, a lot of research has paid attention to the risk factors on WMSDs and its prevention strategies. However, little attention has been paid to physical ergonomic intervention and its validation. This study was conducted among ten woodworkers in a medium-sized woodworking workshop in Selangor, Malaysia. Through this study, demographic surveys, QEC, and REBA were examined before and after the ergonomic intervention of the industrial ergonomic trolley-lifter. The results of QEC and REBA as well as the survey indicated that comfort perception improved when postural measurement in task performance was at an acceptable range. In addition, work time with external load was reduced by 75% due to the proposed trolley. The trolley-lifter offers an alternative solution to lifting activity by providing a lifting product to assist the handling of wood board in efficiency and occupational safety and health conditions..

1. INTRODUCTION

The workplace is important to every worker, which requires consideration to ergonomic matters. Ergonomics relates to the design for efficiency and comfort in the working environment. According to the International Ergonomics Association (IEA), ergonomics is the scientific discipline concerning the understanding of interactions among humans and other elements of a system, as well as the profession that applies theory, principles, data, and methods to design and optimise human well-being and overall system performance (IEA, 2017). Manual material handling (MMH) is a common activity in many workplaces that can lead to fatigue or injury due to activities involving the human force to perform manual lifting, lowering, pushing, pulling or carrying of objects (ISO, 2021). In many industries, MMH activities are common tasks performed by industrial workers, however, poor technique and lack of assistive devices can give a negative impact to workers' safety, productivity, and quality of work. This has also been associated with occupational injuries such as work-related musculoskeletal disorders (WMSDs) among industrial workers. Past research has shown that workers develop WMSDs on their upper extremities and lower back region when repeating manual lifting activities (Antwi-Afari et al., 2017; Fung et al., 2008)brachioradialis (BR. Similarly, other researchers have found that repetition for prolonged durations can cause pain in the shoulder and arm/hand regions (Grzywiński et al., 2014; Yang et al., 2020). Workers who are involved with repetitive manual lifting activities can sustain injuries such as tendinitis, bursitis, and nerve entrapment syndrome (Greenberg & David, 2022). Workers often perform these activities as part of their routine job, and they may spend most of their time stooped and bent over, which can cause negative effects on the body that lead to musculoskeletal pain. Hence, this situation requires designers to develop a product that can eliminate or reduce the risk of ergonomic hazards in repetitive lifting activities.

The main aspect of workplace design is to provide safety and comfort in the working environment while reducing the ergonomic risk factor. The design of the ergonomic product should be adjusted at a level at which a worker can remain comfortable without performing an unergonomic posture to constantly retrieve items. In addition, it should be at a reachable area that allows easy access between the worker and their task. The importance of implementing

*Corresponding author: mhnurhanisah@gmail.com; ruhaizin@upm.edu.my

ergonomic intervention in every industry is crucial, especially as the prevalence of WMSDs is still high. Numerous studies have examined the association between ergonomic risk factors and musculoskeletal discomfort in the woodworking industry (Akanmu et al., 2020; Björing & Hägg, 2000; Kohammadi et al., 2016; Nejad et al., 2013; Özkaya et al., 2018)furniture is mainly manufactured in small workshops, where most activities are performed manually. This study was conducted among workers of furniture workshops to determine prevalence of musculoskeletal symptoms and to assess ergonomic working conditions to identify major risk factors associated with musculoskeletal symptoms. In this study, 410 randomly selected furniture workers participated. The Nordic questionnaire and an ergonomics checklist consisting of 6 sections were used as data collection tools. An index was calculated for each section of the checklist. Action categories indicating the priority of corrective measures were also defined. The highest prevalence of symptoms was reported in the knees (39% as well as its prevention strategies (Khan & Pope-Ford, 2015; Lette et al., 2018)the manual tasks are often linked to workstations that are not ergonomically designed, which can lead to work-related musculoskeletal disorders (WRMDs. Generally, in the small to medium furniture industry, workers do not fully utilise tools or equipment such as a trolley to lift objects. Mobility aids such as forklift or battery-operated trucks may impose a higher cost for purchasing and maintenance and require specific skills as well as limited working area. In addition, from the observation of the author, workers often do tasks manually and may be unaware of safety and health risks. They also lack ergonomic understanding, especially on the bad effects of performing MMH. This was supported by a study in the timber working industry in Zimbabwe (Jerie, 2012)lifestyle and psychological factors, which found that ergonomic conditions are worse in the woodworking and sawmill industry.

The main objectives of this study are to design and develop a trolley-lifter prototype to minimise WMSDs, provide comfort and productivity, and optimise production time. Similar research have been done involving assistive devices such as trolleys and carts (Kwong, 2010; Ohnishi et al., 2016; Santosa & Muliati, 2023)little is known about such customer expectations, and hence this study aimed to examine the views of Hong Kong adults on shopping trolleys. A cross-sectional survey was conducted with a sample of 140 Chinese adults aged 40 or over with no cognitive or communication impairments. These adults were approached in markets, supermarkets, and public parks in Hong Kong. Individual face-to-face interviews using a questionnaire were used to collect the data. Fifty-six (40%. Until today, however, there are limited studies on productivity, time efficiency and comfort perception (i.e., body posture). In this study, the design was produced with the integration of the workplace layout and participatory approach in the task of handling wood boards in a furniture workshop. In this participatory approach, the involvement of workers provided a picture of the real situation on the working process and allowed them as end users to validate the design through an examination of manpower, body posture, and time efficiency. In studies that seek to integrate worker and product design, evidence has shown that products based on the ergonomic philosophy could minimise the ergonomic approach and maximise the efficiency of production flow (Norzaimi et al., 2022). Thus, the prototype was tested to compare the effects of using and not using the trolley to achieve the study's objectives. This study offers insights on the design and development of an ergonomic trolley to help the increase workers' efficiency, safety, and health in the handling of materials.

2. METHODS

2.1 Study design and procedure

This is an observational analytical study involving a questionnaire that examined the demographics, Quick Exposure Check (QEC), Rapid Entire Body Assessment (REBA), and workers' preferences. The study was performed in one medium-sized woodworking workshop in Selangor, Malaysia. The selected woodworking task for this assessment was lifting objects.

2.2 Participants

A prototype was tested with ten male subjects. All participants worked as carpenters.

2.3 Data collection

The demographic data was recorded using a questionnaire. The demographic details included age, gender, and occupation of the respondents. The data collection procedure involved video recording and picture capturing of the working process. Figure 1 shows the setting for the workstation experiment for the proposed industrial ergonomic trolley-lifter. QEC and REBA were used to determine postural measurement before and after the ergonomic intervention. The same board was used to ensure that the weight and length are the same for each lifting task. In addition, a survey was used to obtain feedback on the prototype. Two questions were asked in this survey for validation, which were, "Do you have any problem with the current task?" and "After using this product, do find it: 1) Easy to conduct; 2) Helped to complete task comfortably; and 3) Helped to complete task quickly?" This experiment was important to determine the validity and reliability of the proposed workstation model for current workers. All data were computed and analysed using IBM SPSS Statistic version 21. Table 1 shows the interpretation of the REBA scores, while Table 2 shows the interpretation of the QEC scores.

***Table 1**: Interpretation of REBA scores (Hignett & McAtamney, 2000)*

Score	Level of MSD Risk
1	Negligible risk, no action required
2 to 3	Low risk, change may be needed
4 to 7	Medium risk, further investigation, change soon
8 to 10	High risk, investigate and implement change
11 to 15	Very high risk, implement change

***Table 2**: Interpretation of QEC score (David et al., 2005)*

	Exposure level			
Score	Low	Moderate	High	Very High
Back (static)	8 - 15	16-22	23 - 29	29 - 40
Back (moving)	10 - 20	21 - 30	31 - 40	41 - 56
Shoulder/arm	10 - 20	21 - 30	31 - 40	41 - 56
Wrist/hand	10 - 20	21 - 30	31 - 40	41 - 46
Neck	4 - 6	8 - 10	12 - 14	16 - 18
Driving	1	4	9	-
Vibration	1	4	9	-
Work pace	1	4	9	-
Stress	1	4	9	16

***Figure 1:** Setting up the workstation for the experiment.*

Figure 2 shows the lifting activity conducted manually by the worker. In the figure which depicts a typical situation of the activity, the worker carries the board to the storage area. Figure 3 shows the lifting activity conducted using the proposed industrial ergonomic trolley-lifter. In this activity, the worker will lift the board onto the trolley and will push the trolley to the next machine for the next process, which was to install the Acrylonitrile Butadiene Styrene (ABS) on the edge of the board.

***Figure 2**: Lifting activity conducted in stooped posture by the worker*

Figure 3: Lifting activity conducted using proposed industrial ergonomic trolley-lifter by the worker

2.4 Fabrication of an industrial ergonomic trolley-lifter

The fabrication of this prototype was to identify the worker's comfort perception on the working table with their anthropometric dimensions. The fabrication process began by designing the working industrial ergonomic trolley-lifter, providing dimensions for detailed drawing (computer-aided design [CAD] drawing), selecting and purchasing materials, building it in the workshop, and testing the functionality. The basic dimensions such as length, width, and height were important to consider in building the prototype. Figure 4 shows the dimensions of the industrial ergonomic trolley lifter.

The working industrial ergonomic trolley-lifter works as a large table or frame on wheels, used to transport items such as a wood board. The handle is located at the side of the trolley following the top-desk height, making it easier for a worker to push and pull the trolley from machine to machine. According to studies on trolley design, the standard anthropometric of trolley design is stature height and elbow height (Rosetta et al., 2020; Sokhibi & Alifiana, 2019; Talapatra et al., 2019)these trolleys are not ergonomically designed and so many workers suffer from various musculoskeletal disorders (MSDs. This takes into consideration the handle used to perform pull and push forces. However, in this study, we recommended the size of the trolley to follow the height of the bandsaw table, which was 800 cm, together with the handle height; thus, the worker can slide the wood board without using excessive energy. The width of the top-trolley was based on the dimension of the board, which was 1200 x 600 cm. Figure 5 shows the industrial ergonomic trolley-lifter.

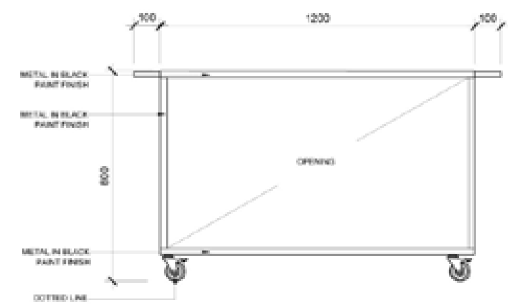

Figure 4: Dimension of the industrial ergonomic trolley-lifter, front view

Figure 5: The industrial ergonomic trolley-lifter

2.5 Measuring the layout of working space

This data was used to evaluate the existing working space and industrial ergonomic trolley-lifter setting. The distance between machine to storage and another machine was measured using a measurement tape and laser rangefinder. Figure 6 shows the measurement of the edge of the bandsaw machine to the floor. In this study, the measurement at the edge of the bandsaw machine to the floor was taken as the guideline for the proposed design. This was to ensure the worker will use less energy to carry the board from the bandsaw machine (after the cutting process) onto the industrial ergonomic trolley-lifter. The height of edge of bandsaw machine to the floor was 80 cm.

Figure 6: *Measurement of the edge of the bandsaw machine to the floor*

Figure 7 shows the distance between the bandsaw machine, storage area and ABS installation machine, which was 8 ft. In this storage area, the worker carries the wood board from the bandsaw machine to the storage are. Then, the worker from the ABS installation machine will carry the wood board from the storage area to the ABS installation machine for the next process.

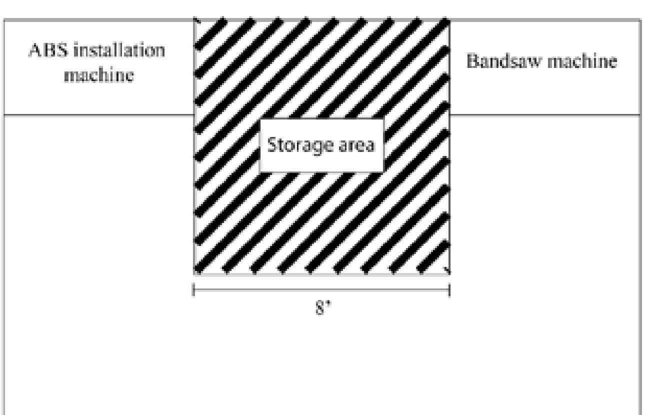

Figure 7: *Layout distance of storage area between the ABS installation machine and the bandsaw machine*

3. RESULTS

3.1 Demography

The details of the study subjects are described in Table 3.

Table 3*: Demographic of the study subjects.*

Description	N	%	Mean (S.D)
Age			
20 -30	3	30	32.1 (6.43)
31 - 40	6	60	
41 - 50	1	10	
Gender			
Male	10	100	
Occupation			
General worker	10	100	

3.2 Quick Exposure Checklist (QEC)

The QEC score was used to measure WMSD risk to the subject after performing the lifting task. Table 4 indicates the exposure level for QEC scoring on the actual working area, while Table 5 indicates a similar score for other factors on the actual working area. Table 6 indicates the exposure level for QEC scoring on the prototype, while Table 7 indicates a similar score for other factors on the prototype. The details are shown in the table below.

Table 4: *Exposure level (QEC) based on actual working area*

	Back (moving)	Shoulder/arm	Wrist/hand	Neck
Score	27.2 (1.03)	24.8 (1.03)	25.8 (1.47)	12 (0.00)
Exposure level	Moderate	Moderate	Moderate	High

Table 5: *Exposure level (QEC) for other factors based on actual working area*

Score	**Driving**		**Vibration**		**Working pace**		**Stress**	
	N	%	N	%	N	%	N	%
1	7	70	10	100	10	100	10	100
4	3	30	-	-	-	-	-	-
9		-	-	-	-	-	-	-
16		-	-	-	-	-	-	-

Table 6*: Exposure level (QEC) based on prototype*

	Back (moving)	Shoulder/arm	Wrist/hand	Neck
Score	12.8 (1.68)	12.8 (1.68)	18.8 (1.68)	8 (0.00)
Exposure level	Low	Low	Low	Low

Table 7*: Exposure level (QEC) for other factors based on prototype*

Score	Driving		Vibration		Working pace		Stress	
	N	%	N	%	N	%	N	%
1	7	70	10	100	10	100	10	100
4	3	30	-	-	-	-	-	-
9		-	-	-	-	-	-	-
16		-	-	-	-	-	-	-

3.3 Rapid Entire Body Assessment (REBA)

The REBA score was used to measure WMSD risk to the subject after performing the lifting object task. Table 8 shows the REBA score based on actual working area. Table 9 shows the REBA score based on the prototype experiment.

***Table 8**: REBA score based on actual working area*

REBA	Score		
1	Negligible		Non necessary
2 to 3	Low		Maybe necessary
4 to 7	Medium		Necessary
8 to 10	High	10	Necessary soon
11 to 15	Very high		Necessary NOW
	Total	10	

***Table 9**: REBA score based on prototype experiment*

REBA	Score		
1	Negligible		Non necessary
2 to 3	Low	10	Maybe necessary
4 to 7	Medium		Necessary
8 to 10	High		Necessary soon
11 to 15	Very high		Necessary NOW
	Total	10	

3.4 Survey on worker's preferences

A survey was conducted to validate the worker's preferences on the proposed prototype. Table 10 shows the frequency of the worker's preferences. The details are summarised in the table below.

***Table 10**: The frequency on worker's preferences*

Description	N	%
Easy to conduct		
Agree	9	90
Strongly agree	1	10
Helped to complete task comfortably		
Agree	6	60
Strongly agree	4	40
Helped to complete task quickly		
Strongly agree	10	100
Problem with current task		
Yes	1	10
No	9	90

4. DISCUSSION

This study was conducted to evaluate the risk factor exposure for WMSDs among industrial workers before and after the use of the proposed working trolley design. This study was based on REBA, QEC method, and the workers' preferences questionnaire. REBA is tool to evaluate the risk of MSDs associated with specific tasks within a job, while QEC focuses on physical workstation factors as well as psychosocial factors that enabled four body areas to be assessed. The results of study on QEC before the utilisation of the trolley indicated that woodworkers in Selangor had high scores of risk exposures for the neck (12.00 ± 0.0). However, the risk exposures for the back (moving) (27.2 ± 1.03), wrist/hand (25.8 ± 1.47) and shoulder (24.8 ± 1.03) were found to be moderate. Thus, the above result indicated that ergonomic interventions were very necessary and effective to reduce the risks of musculoskeletal disorders in the neck, followed by the back, wrist/hand, and shoulder. After the utilisation of our proposed trolley, the results showed improvements through the low scores of risk exposures for the back (moving) (12.8 ± 1.68), shoulder (12.8 ± 1.68), wrist/hand (18.8 ± 1.68), and neck (8 ± 0.00). Nonetheless, the exposure level for QEC for other factors on the prototype had the same score due to unchanged activity responses from the worker.

The results of our study on REBA indicated that woodworkers in Selangor had high scores (8 to 10), which required necessary interventions based on actual working area compared to those with low scores (2 to 3). The results showed improvement in the exposure level and scoring of REBA after the worker used the proposed industrial ergonomic trolley-lifter in their tasks. However, this score may minimise further potential risks to workers through additional investigations to the proposed trolley. As an example, the design of trolley may focus on further improvements of the posture during the lifting activity as in Figure 2. This may include switching to bigger tyres when there are heavy loads to make the trolley easier to push/pull, thus minimising the energy of the worker. In addition, the handle can be added to the left or right side of the trolley. This will allow the workers to push/pull the trolley if the boards are larger in size or exceed the trolley's top surface. As shown in Figure 2 and Figure 3, the worker's posture improved from an awkward posture to a proper posture in the lifting activity conducted before and after using the proposed industrial ergonomic trolley-lifter. The intervention of the ergonomic product may reduce excessive posture and MSDs among workers by correcting the posture while performing their tasks (Haekal et al., 2020). Adopting a correct body posture and utilising an ergonomic product have been considered to result in a lower rate of MSDs (Cordella et al., 2019; Erdinc & Vayvay, 2008). The working industrial ergonomic trolley-lifter was very significant in improving the posture of the woodworkers in performing their lifting object task. Through this ergonomic intervention, the workers were able to perform their task comfortably as the proposed industrial ergonomic trolley-lifter made the object easier to be lifted at a preferable height. The worker did not need to bend down to lift the object from the floor to the table, which had an ergonomic risk factor such as awkward posture, repetitive movement, and forceful exertion. In this study, the comfort perception improved when the body posture was within an acceptable range during task performance.

Through an interview with the workers, they strongly agreed that the proposed industrial ergonomic trolley-lifter was easy to use and they worked comfortably by using the proposed working industrial ergonomic trolley-lifter. Furthermore, all subjects strongly agreed that the industrial ergonomic trolley-lifter could save time while performing lifting activities. The workers also complained less about the discomfort caused by the lifting activities. In addition, from the observation of the author, the workers could complete the tasks within two minutes. However, with the use of the proposed industrial ergonomic trolley-lifter, they could reduce the time by about 30 seconds to complete the same tasks as before. Thus, work time with external load was reduced by 75% as a result of the proposed trolley. A previous study found that the time reduced while performing a job task could improve productivity, increase time-to-task accomplishment, and increase the quantity of the product as well as the quality of the worker's time (Bhoopathy & Karthikeyan, 2016; Luger et al., 2021)posture, heart rate, performance, usability, and wearer comfort during a course of three industrial tasks (COU; exoskeleton worn, turned-on. In the next section of the survey, which was on the workers' comments and opinions, all subjects agreed that they preferred to use the industrial ergonomic trolley-lifter to optimise production time, causing less pain and discomfort as well as increasing the productivity of the worker. However, one worker complained about the difficulty of performing the task as he suffered from wrist MSDs, so lifting activities were not suitable for him.

This study was conducted using10 board pieces of almost the same sizes. The board was the most common material handled. There were other sized materials handled by the workers, however, these were not tested in this study. Yet, the prototype showed positive results on improving productivity with the correct utilisation of the ergonomic product intervention.

Another limitation was the limited sample size involved as well as limited workplace context due to the availability of workers in an SME workshop. Overall, we could see that the effectiveness of the prototype has been proven. Hence, this proposed working industrial ergonomic trolley-lifter could reduce the risk of the lifting task activity and could also increase the comfort level among workers.

5. CONCLUSION

In this study, the ergonomic trolley-lifter had been designed and developed based on the working layout. The experiment on the proposed prototype had successfully improved work efficiency and occupational safety and health conditions. Through this experiment, the results showed the improvement of exposure level and scoring on QEC and REBA after the worker used the proposed industrial ergonomic trolley-lifter in their tasks, which allowed for better working posture. Also, the users' preferences showed positive answers after the utilisation of the trolley. Finally, this prototype allowed for increased productivity in reducing the time of transferring boards. Additionally, comfort perception improved when postural measurement in task performance was at an acceptable range by reducing the need for repetitive manual handling of the material throughout the transfer process.

ACKNOWLEDGEMENT

The authors gratefully acknowledge the financial support of Graduate Research Fellowship (GRF), Universiti Putra Malaysia.

REFERENCES

Akanmu, A., Olayiwola, J., & Olatunji, O. A. (2020). Musculoskeletal disorders within the carpentry trade: analysis of timber flooring subtasks. *Engineering, Construction and Architectural Management*, *27*(9), 2577–2590. https://doi.org/10.1108/ECAM-08-2019-0402

Antwi-Afari, M. F., Li, H., Edwards, D. J., Pärn, E. A., Seo, J., & Wong, A. Y. L. (2017). Biomechanical analysis of risk factors for work-related musculoskeletal disorders during repetitive lifting task in construction workers. *Automation in Construction*, *83*(June), 41–47. https://doi.org/10.1016/j.autcon.2017.07.007

Bhoopathy, K. M., & Karthikeyan, T. (2016). Ergonomically Designed and Fabricated Industrial Trolley for Crane Tong Jaw Bit Changing. *Asian Journal of Research in Social Sciences and Humanities*, *6*(8), 134. https://doi.org/10.5958/2249-7315.2016.00599.2

Björing, G., & Hägg, G. M. (2000). Musculoskeletal exposure of manual spray painting in the woodworking industry - An ergonomic study on painters. *International Journal of Industrial Ergonomics*, *26*(6), 603–614. https://doi.org/10.1016/S0169-8141(00)00026-3

Cordella, F., Di Luzio, F. S., Lauretti, C., Draicchio, F., & Zollo, L. (2019). A biofeedback-based posture correction system for working environments. *2019 IEEE International Workshop on Metrology for Industry 4.0 and IoT, MetroInd 4.0 and IoT 2019 - Proceedings*, *June*, 405–409. https://doi.org/10.1109/METROI4.2019.8792920

David, G., Woods, V., & Buckle, P. (2005). Further development of the usability and validity of the Quick Exposure Check (QEC). In *Ergonomics Research Report 211*.

Erdinc, O., & Vayvay, O. (2008). Ergonomics interventions improve quality in manufacturing: A case study. *International Journal of Industrial and Systems Engineering*, *3*(6), 727–745. https://doi.org/10.1504/IJISE.2008.020683

Fung, I. W. H., Tam, V. W. Y., Tam, C. M., & Wang, K. (2008). Frequency and continuity of work-related musculoskeletal symptoms for construction workers. *Journal of Civil Engineering and Management*, *14*(3), 183–187. https://doi.org/10.3846/1392-3730.2008.14.15

Greenberg, M. I., & David, V. (2022). *Work-Related Repetitive Motion Injuries*. MSD Manuals. https://www.msdmanuals.com/professional/special-subjects/occupational-and-environmental-medicine/work-related-repetitive-motion-injuries

Grzywiński, W., Wandycz, A., Tomczak, A., & Jelonek, T. (2014). The prevalence of self-reported musculoskeletal symptoms among loggers in Poland. *International Journal of Industrial Ergonomics*, *52*, 12–17. https://doi.org/10.1016/j.ergon.2015.07.003

Haekal, J., Hanum, B., & Prasetio, D. E. (2020). Analysis of Operator Body Posture Packaging Using Rapid Entire Body Assessment (REBA) Method: A Case Study ofPharmaceutical Companyin Bogor, Indonesia. *International Journal of Engineering Research and Advanced Technology*, *06*(07), 27–36. https://doi.org/10.31695/ijerat.2020.3620

Hignett, S., & McAtamney, L. (2000). Rapid Entire Body Assessment (REBA). *Applied Ergonomics*, *31*(2), 201–205. https://doi.org/10.1016/S0003-6870(99)00039-3

IEA. (2017). *Definition and Domains of Ergonomics | IEA Website*. International Ergonomic Association. https://doi.org/10.1109/TGRS.2006.872327

ISO. (2021). *Ergonomics — Manual handling — Part 1: Lifting, lowering and carrying*. https://www.iso.org/obp/ui/#iso:std:iso:11228:-1:ed-2:v1:en

Jerie, S. (2012). Occupational health and safety problems among workers in the wood processing industries in Mutare , Zimbabwe. *Journal of Emerging Trends in Economics and Management Sciences*, *3*(3), 278–285.

Khan, M., & Pope-Ford, R. (2015). Improving and Modifying the Design of Workstations within a Manufacturing Environment. *Procedia Manufacturing*, *3*(Ahfe), 4927–4934. https://doi.org/10.1016/j.promfg.2015.07.631

Kohammadi, H. Y., Sohrabi, Y., Poursadeghiyan, M., Rostami, R., Tabar, A. R., Abdollahzadeh, D., & Tabar, F. R. (2016). Comparing the posture assessments based on RULA and QEC methods in a carpentry workshop. *Research Journal of Medical Sciences*, *10*(3), 80–83. https://doi.org/10.3923/rjmsci.2016.80.83

Kwong, E. (2010). Views of Adults on Shopping Trolleys: Implications for the Development of a Shopping Trolley. *The Ergonomics Open Journal*, *3*(1), 32–37. https://doi.org/10.2174/1875934301003010032

Lette, A., Ambelu, A., Getahun, T., & Mekonen, S. (2018). A survey of work-related injuries among building construction workers in southwestern Ethiopia. *International Journal of Industrial Ergonomics*, *68*(August 2017), 57–64. https://doi.org/10.1016/j.ergon.2018.06.010

Luger, T., Bär, M., Seibt, R., Rieger, M. A., & Steinhilber, B. (2021). Using a Back Exoskeleton During Industrial and Functional Tasks—Effects on Muscle Activity, Posture, Performance, Usability, and Wearer Discomfort in a Laboratory Trial. *Human Factors*. https://doi.org/10.1177/00187208211007267

Nejad, N. H., Choobineh, A., Rahimifard, H., Haidari, H. R., & Reza Tabatabaei, S. H. (2013). Musculoskeletal risk assessment in small furniture manufacturing workshops. *International Journal of Occupational Safety and Ergonomics*, *19*(2), 275–284. https://doi.org/10.1080/10803548.2013.11076985

Norzaimi, M., Ani, C., & Azid, I. A. (2022). An Integration of Statistical and Anthropometric Measurement Approach Towards Improving Ergonomic Design for Production Workbench. *Malaysian Journal of Medicine and Health Sciences*, *18*(9), 21–26. https://doi.org/10.47836/mjmhs18.s9.3

Ohnishi, A., Takanokura, M., & Sugama, A. (2016). Evaluation of Interhandle Distance During Pushing and Pulling of a Four-Caster Cart for Upper Limb Exertion. *Safety and Health at Work*, *7*(3), 237–243. https://doi.org/10.1016/j.shaw.2016.01.005

Özkaya, K., Polat, O., & Kalinkara, V. (2018). Physical Workload Assessment of Furniture Industry Workers by Using Owas Method. *The Ergonomics Open Journal*, *11*(1), 11–19. https://doi.org/10.2174/1875934301811010011

Rosetta, A., Witjaksono, M. A., Muslim, E., & Nurtjahyo Moch, B. (2020). Ergonomics Analysis of Luggage Trolley for Airport Using Posture Evaluation Index (PEI) in Virtual Environment Modelling. *IOP Conference Series: Materials Science and Engineering*, *1003*(1). https://doi.org/10.1088/1757-899X/1003/1/012081

Santosa, I., & Muliati, N. (2023). *Analysis of the Use of Ergonomic Trolley on Musculoskeletal Complaints on Worker Transporting Gallons of Water and LPG 12Kg* (pp. 55–59). https://doi.org/10.5220/0010939800003260

Sokhibi, A., & Alifiana, M. (2019). *Ergonomic Troly Design for Increasing Productivity in PG Jatibarang Brebes*. 1–7. https://doi.org/10.4108/eai.24-10-2018.2280542

Talapatra, S., Mohsin, N., & Murshed, M. (2019). An Ergonomic Approach for Designing of an Industrial Trolley with Workers Anthropometry. *American Journal of Industrial and Business Management*, *09*(12), 2156–2167. https://doi.org/10.4236/ajibm.2019.912143

Yang, S. T., Park, M. H., & Jeong, B. Y. (2020). Types of manual materials handling (MMH) and occupational incidents and musculoskeletal disorders (MSDs) in motor vehicle parts manufacturing (MVPM) industry. *International Journal of Industrial Ergonomics*, *77*(March), 102954. https://doi.org/10.1016/j.ergon.2020.102954