JOURNAL OF SUSTAINABLE MANUFACTURING IN TRANSPORTATION
e-ISSN: 2821-2835

JSMT

Vol. 4 No. 1 (2024) 1-8
https://publisher.uthm.edu.my/ojs/index.php/jsmt

Ergonomic Risk Assessment for Manual Handling Activities in Automotive Workshop

Muhamad Luqman Hakem Suhimi[1], Mohd Nasrull Abdol Rahman[1]*

[1] *Department of Manufacturing Engineering, Faculty of Mechanical and Manufacturing Engineering Universiti Tun Hussein Onn Malaysia, Batu Pahat, Johor, 86400, MALAYSIA*

*Corresponding Author: mnasrull@uthm.edu.my
DOI: https://doi.org/10.30880/jsmt.2024.04.01.001

Article Info

Received: 29 January 2024
Accepted: 24 May 2024
Available online: 30 September 2024

Keywords

Ergonomic assessment, manual handling, automotive workshop, KIM-MHO, MAC

Abstract

Ergonomic risk assessment tools are tools that have been designed to solve the problem of ergonomics in the workplace from manual material handling activities. The objective of this study is to investigate Musculoskeletal Discomfort among workers related to manual handling activities using Cornell Musculoskeletal Discomfort Questionnaires (CMDQ); to assess an ergonomics risk factor among workers related to manual handling activities using Manual Handling Assessment Chart (MAC), NIOSH Lifting Equation(NLE), and Key Indicator Method for Manual Handling Operation (KIM-MHO) method and; to compare the results between CMDQ and assessment tools. This case study was conducted in Parit Raja, Johor, Malaysia involving 34 male mechanics workers. The tools used are as stated in the objective with the help of measurement tools such as a goniometer. The result of the CMDQ reveals that the body part with the highest discomfort level among the workers in the lower back, shoulder right and shoulder left with the percentage from the total discomfort score of 20.91%, 13.57%, and 13.36% respectively. From the result of the assessments, it is concluded that the highest risk factor contributing to the MSDs is the bad posture of the worker during the manual handling operation followed by the frequency of lifting and the weight of the load. By comparing assessment tools, the first comparison is made between the CMDQ versus KIM-MHO, MAC Tools and NLE. In this comparison that, it is highlighted the result type from CMDQ are different from the KIM-MHO, MAC Tools and NLE as its questionnaire result shows us the discomforts levels on the body of workers and the body parts affected on their body for the last seven days but the assessment tools results show us the risk factor that contributes to the MSDs. For the comparison between the three assessment tools, it can be said that the tools that have the highest correlation with CMDQ are MAC Tools. In conclusion, most workers suffer from MSDs in their lower back due to their bad posture during manual handling. KIM-MHO is the best assessment tool among the three as it has the highest significance value while being the easiest tool to be used.

1. Introduction

Risk Assessment is one of the tools used by professionals to assess the risk factor involves in an activity. This tool provided a detailed assessment of risk factors related to each step in a systematic work environment management in a broad range including the manual handling activities to assist the practitioners of occupational

safety and health of an organization. These tools are designed to help minimize the exposure to harmful hazards (risk factors), interventions, and strategizing job design. [1]By evaluating the probability, exposure, and effect of the assessed and identified risks which consist of basic hazards and existing hazards, the level of risk can be determined and action can be taken.[2]

Automotive workshops are industries that have been a staple in Malaysia for at least a few decades. For the mechanics of these workshops, manual handling such as lifting car components and tools is one of their daily jobs. From the literature review, it can be said that these workers are exposed to the risk factor that can contribute to Musculoskeletal Disorders (MSDs) in their bodies. Therefore, if we can analyze and raise awareness of the symptoms of MSDs, we should be able to reduce the number of victims and at the same time increase the productivity of our workforce and boost our economy. [3] But since there is so many risks assessment available in the current era, a comparison needed to be made to choose which risk assessment is the best to be used to determine the risk factor during the manual handling activity. [4–6]

Therefore, the objective of this study is firstly to investigate Musculoskeletal Discomfort among workers related to manual handling activities using Cornell Musculoskeletal Discomfort Questionnaires (CMDQ). Next, is to assess an ergonomics risk factor among workers related to manual handling activities using Manual Handling Assessment Chart (MAC), NIOSH Lifting Equation(NLE), and Key Indicator Method for Manual Handling Operation (KIM-MHO) method. Finally, it is to compare the results between CMDQ and MAC, NLE, and KIM-MHO.

The scope of study involves about 34 mechanics in workshop industries in Parit Raja, Johor. The study has been focused on their manual handling activities which are lifting. Musculoskeletal discomfort among workers related to manual handling activities has been investigated using Cornell Musculoskeletal Discomfort Questionnaires (CMDQ). The risk factor in these activities has been assessed using Manual Handling Assessment Chart (MAC), NIOSH Lifting Equation, and Key Indicator Method for Manual Handling Operation (KIM-MHO). The data has been analyzed using IBM SPSS statistical software.

2. Methods

2.1 Sampling Size and Selection of Work Area

The scope of this study involved 34 automotive mechanic workers in around Parit Raja, Johor, Malaysia as the sample size and sample area.

2.2 Cornell Musculoskeletal Disorders Questionnaire (CMDQ)

The CMDQ is a 54-item questionnaire that contains a body chart as well as questions concerning musculoskeletal ache, pain, or discomfort that occurred in 20 different regions of the body in the previous week. It has been employed in working groups such as healthcare providers and machine operators in the evaluation of musculoskeletal discomfort. The CMDQ scoring rules for determining the rate of discomfort and quantifying the discomfort level were used to produce the musculoskeletal discomfort score. [7]

2.3 Key Indicator Method for Manual Handling Operation (KIM-MHO)

KIM-MHO assesses the physical workload relating to uniform, repetitive motion, and force exerted by the upper extremities when using instruments, small tools, or hand-held machinery and equipment, usually in a stationary seated or standing position to approximately 3 kg. Risk factors include the type of force exertion (finger/hand), force transfer/gripping conditions, hand/are position and movement, unfavourable working conditions, body posture/movement, and work organization/temporal distribution. The physical workload associated with consistent, repeated motion and force exerted by the upper extremities when utilizing instruments, tiny tools, or hand-held machinery and equipment, generally in a stationary seated or standing posture is measured with the KIM-MHO. Type of force exertion (finger/hand), force transfer/gripping circumstances, hand/are position and movement, unfavourable working conditions, body posture/movement, and job organization/temporal distribution are all risk variables to consider. [8,9]

2.4 NIOSH Lifting Equation (NLE)

The revised lifting equation for computing the Recommended Weight Limit (RWL) is based on a multiplicative model that gives each of the six task variables a score. NIOSH lifting equation is often considered as the formula for evaluating manual lifting with an emphasis on the back. The weight, horizontal and vertical location, twisting angle, duration, frequency, and coupling of the item are all considered.[10,11]

2.5 Manual-Handling Assessment Chart (MAC)

The Manual Handling Assessment Chart (MAC) is a tool designed to help health and safety inspectors assess the most common risk factors in lifting (and lowering), carrying, and team handling operations.[12] Manual

J. of Sustainable Manufacturing in Transportation Vol. 4 No. 1 (2024) p. 1-8

Handling Assessment Charts. MAC was developed by Health Safety Executive (HSE), Health & Safety Laboratory (HS&L), and local English authorities. This initial screening tool identifies high-risk manual-handling activities and incorporates a numerical scoring system to assist with prioritizing interventions, with a colour scheme indicating which elements of the material-handling task are high risk.[13,14]

3. Results and Discussion

The data collected for the research is presented in this chapter. The result was taken from the Cornell Musculoskeletal Disorders Questionnaires (CMDQ), Key Indicator Method for Manual Handling Operation(KIM-MHO), Manual-handling Assessment Chart(MAC) and NIOSH Lifting Equation(NLE) score sheets.

3.1 Results of CMDQ

The CMDQ is divided into two parts. The first part is the demographic part. In this part of the questionnaire, the data of age, weight, height, work hours and workday are collected. The second part involves the data on the body part affected by MSDs. From these data, we determined the most affected body part and the least affected ones.

Table 1 *Result of CMDQ part B*

Body Part	Range	Min. score	Max. score	Mean	SD	Total Discomfort score	%
Lower Back	45.00	0.00	45.00	4.40	8.50	149.50	20.91
Shoulder Right	20.00	0.00	20.00	2.85	5.24	97.00	13.57
Shoulder Left	20.00	0.00	20.00	2.81	5.26	95.50	13.36
Thigh Right	20.00	0.00	20.00	1.35	4.19	46.00	6.43
ThighLeft	20.00	0.00	20.00	1.31	4.19	44.50	6.22
Foot Right	20.00	0.00	20.00	0.94	3.55	32.00	4.48
Upperback	20.00	0.00	20.00	0.90	3.55	30.50	4.27
Foot Left	20.00	0.00	20.00	0.85	3.55	29.00	4.06
Upper Arm Right	20.00	0.00	20.00	0.85	3.55	29.00	4.06
Upper Arm Left	20.00	0.00	20.00	0.81	3.55	27.50	3.85
Lower Leg Right	14.00	0.00	14.00	0.68	2.59	23.00	3.22
Lower Leg Left	14.00	0.00	14.00	0.63	2.59	21.50	3.01
Wrist Right	6.00	0.00	6.00	0.53	1.16	18.00	2.52
Neck	6.00	0.00	6.00	0.44	1.46	15.00	2.10
Wrist Left	6.00	0.00	6.00	0.40	1.13	13.50	1.89
Knee Right	6.00	0.00	6.00	0.31	1.09	10.50	1.47
Hip	6.00	0.00	6.00	0.26	1.07	9.00	1.26
Knee Left	6.00	0.00	6.00	0.26	1.07	9.00	1.26
Forearm Right	6.00	0.00	6.00	0.22	1.05	7.50	1.05
ForearmLeft	6.00	0.00	6.00	0.22	1.05	7.50	1.05

3.1.1 Result of CMDQ (Part A) - Demographic

This study consisted of 34 automotive mechanics workers involved in manual handling in the workshops around Parit Raja. All the respondents are male. The mean working age for the worker is 28.85 with a standard deviation of 6.54. The range is from 18 to 41 years old. The height of staff is averagely 169.35cm (SD=7.05). The range for height is between 152cm to 187cm. The mean for weight is 65.82kg (SD=9.21) with a range from 50kg to 90kg. The BMI for the worker is averagely 22.99(SD=3.29) with a minimum of 16.90 to a maximum of 32.46. Averagely these worker works 6 days per week (SD=0.30) but the minimum only works 5 days but the maximum work for 7 days. Other than that, the mean for mechanics' work hours per day is 9.29 hours (SD= 0.52) with a minimum of 8 hours and a maximum of 10 hours. It can be said that on averagely these mechanics smokes 0.35 packs per day(SD=0.40) with a maximum of 1 pack per day and 0 packs as a minimum. As for the

stress during work, about 19(55.9%) workers admit that they never have stress during work. The majority 27(79.4%) of the worker usually take a rest after finishing one car before working on another. 28(82.4%) workers told us that they usually receive support from other mechanics when they are working. Finally, out of 34(100%), only 8(23.5%) workers admit that their work is repetitive while another 26(76.5%) deny it.

3.1.2 Result of CMDQ (Part B) - Body Part Affected by MSDs

The results show that from 34 mechanics workers, 20.91%, 13.57%, and 13.36% are the highest percentage for the body part discomfort score among the workers which are the lower back, shoulder left and shoulder right respectively. In terms of average in the table below, we can see that the mentioned body parts have the highest mean for the discomfort score. This show that among all the 20 different body part, these aforementioned body part are the most severe in terms of discomfort and have the highest risk of developing Musculoskeletal Disorders (MSD). On the other hand, the three least percentages from the total score of discomforts are for the hip, knee left, forearms left and forearm right with the percentage of 1.26%, 1.26%, 1.05% and 1.05% respectively.

3.2 Results of KIM-MHO

From the tables, we can see that the highest risk factor comes from the bad posture of the mechanic posture with the percentage of total discomfort score is 36.21% with a mean of 2.59, and a standard deviation (SD) of 0.92. 24(70.59%) of mechanics have a posture rating of 2, where they bend forward slightly or twist their trunk while keeping the load close to their body while lifting. The rest of the mechanic workers (N=10, 29.41%) commit to low bending or bending their body far forward while having the load far from their body giving them a higher rating score of 4. [15,16]

The next highest risk factor from the result of our assessment is the times rating with a mean of 2.53, and an SD of 0.90. On a working day, the majority (N=25, 73.53%) of the mechanic workers conducted a lifting operation on the automotive parts or tools more than 10 but less than 40 times per day. For example, lifting tyres or batteries to be installed on the car which can reach up to 15kg, not including the weight of the rim of the wheel from our interviews with some of the mechanic's workers. Despite that, a minority (N=9, 26.47%) of the worker had to operate manual lifting more than 40 times, up to a hundred times on their working day which gives them a time rating point of 4.

Other than that, the risk factor for injury due to the load lifted by the workers are lower than both previously mentioned risk factor. This is because only 8(23.53%) workers were involved in manually lifting loads higher than 10 kg but lower than 20kg while the rest of the workers only lift the load below 10kg. This is the effective load measured when lifting the items, which mean the real action necessary to move the items in for men because all(N=34, 100%) of our respondent and interviewee are male.[17]

The working conditions' risk factors are at the lowest. With adequate space, no physical barriers inside their workstation, solid, level flooring, adequate lighting, and appropriate gripping conditions on the objects they lifted, 11 (32.35%) of the employees have no complaints about their decent working conditions. 19(55.88%) of the workers complained that their work area has an uneven floor, and the grip conditions are poor. Only 4(11.76%) of the workers said that their movements are strongly constrained by their work area, giving them their highest rating (2) in working conditions rating points.

Table 2 *Result of KIM-MHO*

KIM-MHO rating scoresheet					Mean	SD	Total score	%
Rating	0	1	2	4				
Time	0	0	25	9	2.53	0.90	86	35.39
Load	0	26	8	0	1.24	0.43	42	17.28
Posture	0	0	24	10	2.59	0.92	88	36.21
Condition	11	19	4	0	0.79	0.64	27	11.11

3.3 Result of MAC Tools

From the results of the Manual-handling Assessment Chart (MAC), it can be concluded that the highest risk factors come from the risk factors due to hand distance to the lower back. From the percentage of the total score, these risk factors sum up to 99(41.67%) as 30(88.24%) mechanics workers are categorized in the Amber colour band with scores of 3 for each person. For this risk factor, the amber colour code means that the hand of the worker is at a moderate distance from their lower back. In this situation, the level of risk is medium, but the task needs to be examined closely to avoid the risk of injury to happen to the workers.

J. of Sustainable Manufacturing in Transportation Vol. 4 No. 1 (2024) p. 1-8

The second highest risk factors come from grip conditions where all the worker's lifted items were deemed to be reasonable(amber) according to the MAC score sheet. Finally, the third-highest risk factors according to the results the load lifting frequency. 8(14.81%) of the workers are colour coded as amber due to their load lifting frequency as referred from the load weight/frequency graph for the lifting equation. The majority (N=26, 76.47%) of the workers fall under the green colour zone where the risk levels are very low. Repetitive lift of light things will fall within the graph's green colour zone, although it may also be related to issues with the upper limbs. [13,14,18]

On the other hand, the third three lowest risk factors according to the results of the MAC scoresheets are the body twist during lifting, posture constraint, and the other factors with the percentage of 0.93%, 2.31% and 5.56% respectively. The total data are summarized in the following table where all the data for each risk factor are included except the colour code of red and purple since none of the workers falls under those colour codes for any of the risk factors.

Table 3 *Result of MAC tools*

MAC Tools / Risk Factors	Colour Code		Total Discomfort Score (Total=216)	Mean	SD	% from the total score
	Green	Amber				
Hand Distance to Back	4	30	90	2.65	0.98	41.67
Grip Condition	0	34	34	1.00	0.00	15.74
Load Lift Frequency	26	8	32	0.94	1.72	14.81
Vertical Lift Region	10	24	24	0.71	0.46	11.11
Floor Condition	17	17	17	0.50	0.51	7.87
Other	22	12	12	0.35	0.49	5.56
Posture Constraint	29	5	5	0.15	0.36	2.31
Body Twist	33	1	1	0.06	0.34	0.93

3.4 Result of NLE

From the result of the NIOSH Lifting Equation(NLE) assessment tool, many task variables data were obtained as tabulated in the table below. Some of the important parts to be highlighted are the mean of the original hand position which is 34.94 cm. When translated into the Horizontal Multiplier, it is valued at 0.72 which means that the item lifted should be lifted closer to the body of the worker, or the size of the item should be reduced. It is best if the value is closer to 25 cm, which is considered a minimum. Other than that, the final vertical position mean is 89.32 cm while 169.35cm is the mean for the height of workers that we get from the demographic section. This means that the items lifted usually did not involves shoulder or head activities.

By using the NIOSH Lifting Calculator Apps available in Google Playstore, the Recommended Weight Limit (RWL) and the Lifting Index of the workers were calculated. The Mean (SD) for both RWL and LI is 9.99(2.83) and 0.76(0.39) respectively.

From the app, the constant value for the equation component used to calculate the RWL and LI was also determined. The mean and SD of these constants are calculated to give use the overall result for all the mechanics. The multiplier with the least means value means that it involves a higher risk for the worker. In this case, the horizontal multiplier has the lowest mean, because most of the worker's hands when doing the lifting operation are far from their body. Other than that, the low mean in the vertical multiplier also describes that when the lifting operation is done, the worker tends to lift the item with a high vertical distance difference. For example, lifting an automotive part from the floor level, up to their lower back level. These two mentioned multipliers can be translated as a risk factor due to the worker having bad posture during lifting. Finally, the third-worst multiplier is the frequency multiplier (FM) where the worker has usually had their lifting rate, higher than it should be which is around 0.2 lift/min where the lifting frequency means 0.38 lift/min. This can be translated as the risk factor due to the load-lifting frequency being too high. At the same time, it can also be observed that the highest mean for the equation component is the Asymmetric Multiplier (AM) which is 1.00 with a standard deviation of 0.02 as from the assessment, only 1(2.94%) of the worker involves in a twist on their body during lifting.

Table 4 *Result of NLE*

Task Variables	Mean	Standard Deviation(SD)
Average Load(kg)	6.78	2.91
Maximum Load(kg)	10.41	4.06
Original Hand Position (cm)	34.94	9.23
Original Vertical Position(cm)	19.76	25.35
Final Vertical Position(cm)	89.32	9.90
Vertical Distance(cm)	69.56	25.55
Angle Destination(º)	0.88	5.14
Frequency (Lift/min)	0.38	0.23
Work Duration (Hours)	8.00	0.00
Recommended Weight Limit (RWL)	9.99	2.83
Lifting Index (LI)	0.76	0.39

Table 5 *Analyzed data of NLE*

Equation Components	Mean	Standard Deviation(SD)
Horizontal Multiplier(HM)	0.74	0.18
Vertical Multiplier(VM)	0.83	0.06
Distance Multiplier(DM)	0.89	0.04
Asymmetric Multiplier(AM)	1.00	0.02
Frequency Multiplier(FM)	0.83	0.03
Coupling Multiplier(CM)	0.95	0.00

3.5 Comparison of CMDQ, MAC, KIM-MHO, and NLE

From all the questionnaires and assessments done on the workers, the result of these tools can finally be compared.

The first comparison is the comparison of the Cornell Musculoskeletal Disorders Questionnaire (CMDQ) with the Key Indicator Method for Manual Handling(KIM-MHO), Manual Handling Assessment Chart(MAC), and NIOSH Lifting Equation(NLE). Using the CMDQ, the types of data that can be obtained are the number of symptoms for musculoskeletal and their discomfort score on the body of workers for the past seven weeks. Using these data, the body part location where most of the workers suffer from musculoskeletal disorders can be obtained and, in this study, it is the lower back. Comparing these to the three assessment tools, the type of data obtained from the assessment tools are the risk factors that may contribute to the musculoskeletal disorder's symptoms obtained in CMDQ. Other than that, the CMDQ also did not require any tools other than pen and paper to be conducted unlike the assessment tool such as NLE where the uses of the Goniometer were required to measure the body angle and the uses of measuring tape to measure the distance from the item lifted to the floor. The other comparison that was made is the comparison between the three assessments tool. (MAC, KIM-MHO, NLE). The result gained from the three assessment tools is very similar to one another. As mentioned in a few of the previous sub-chapter, the main risk factors that contributed to musculoskeletal disorders among the worker due to manual handling operations are bad body posture during lifting, having a high frequency of lifting and having a load higher than the recommended weight limit with their body posture. For ease of use, it can be said that the KIM-MHO is by far the easiest tool to be used as the number of variables which is 4 used to calculate the score is the lowest among the three-assessment tool. Other than that, it also has a different score for load according to the gender of the worker compared to the other two that did not relate to any gender. For MAC tools, it required a lot of reference to the colour code chart to provide the numerical score for the risk factor score. The number of variables data needed is also higher than the KIM-MHO which is 8 variables for solo lifting operations. The use of the interactive version of MAC Tools provided by HSE UK was a good solution to reduce the difficulty of using these assessment tools. Finally, NLE is the hardest to use among all these assessments tool.

These assessment tools required very accurate data to be used and they also contain the highest number of variables which is 12. Some of the data required the use of measuring tools such as a weighing scale, goniometer and measuring tape. Then, the data are used to get the multiplier value from the tables of constant for the multipliers. The data that was in between the values in the tables need to be extrapolated to get the most accurate results. This can happen up to six times per person data to get all the values of the multiplier so that the value of the lifting index and recommended weight limit can be obtained. But the plus side of this difficulty is that the data obtained are very precise for each worker.

4. Conclusion

In conclusion, the objectives of this research were achieved successfully. The first objective is to investigate Musculoskeletal Discomfort among workers related to manual handling activities using CMDQ. In part A, the demographic data was able to be collected. In part B, from this, the discomfort score and total discomfort score on body parts of the mechanic's workers are determined successfully. The body part with the highest percentage of discomfort score is the lower back, shoulder right, and shoulder left with the value of the percentage from the total discomfort score of 20.91%, 13.57%, and 13.36% respectively. These musculoskeletal discomfort scores are the result of manual handling operations done by the workers in the past seven days of working.

Furthermore, the assessment of an ergonomics risk factor among workers related to manual handling activities using the MAC, NLE, and KIM-MHO methods was also conducted successfully. The results obtained were analysed completely to determine the risk factor that contributed to the musculoskeletal disorders among the workers. From the result of the assessment, it is concluded that the highest risk factor that contributes to the MSDs of mechanic workers is the bad posture of the worker during manual handling activities.

Finally, the last objective of this case study was also achieved after the comparison made among the CMDQ, MAC, KIM-MHO, and NLE. There are 2 types of comparison being made because CMDQ result types are different from the MAC, KIM-MHO and NLE as it is a questionnaire made to determine the assess the level of musculoskeletal discomfort among workers related to their ergonomic situation. The comparison of the three risk assessments tool concluded that KIM-MHO is the easiest tool to be used by an ergonomic trained person as it requires fewer tools and fewer variables that need to be recorded. But the MAC Tools have the highest correlation value with the CMDQ compared to the other tools[4,19]

Acknowledgement

The authors would like to thank the Faculty of Mechanical and Manufacturing Engineering, Universiti Tun Hussein Onn Malaysia for its support. Special thanks are also given to the respondent and the workshops involved in this study.

Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

All authors reviewed the results and approved the final version of the manuscript.

References

[1] Lind C 2017 Assessment and design of industrial manual handling to reduce physical ergonomics hazards-use and development of assessment tools ed Technology and Health
[2] Buchari, Matondang N and Sembiring N 2018 Work environment engineering using HIRARC and 5S method *AIP Conf. Proc.* 1977
[3] Tee K S, Low E, Saim H, Zakaria W N W, Khialdin S B M, Isa H, Awad M I and Soon C F 2017 A study on the ergonomic assessment in the workplace *AIP Conf. Proc.* 1883
[4] Abdullah S, Deros B, Kamaliana N, Ghani J A and Abdullah S 2020 An approach to work design: in-depth audit to determine the modifiers of musculoskeletal disorder symptom among vehicle maintenance personnel *J. Kejuruter.* 32 281–7
[5] Lop N S, Kamar I F M, Aziz M N A, Abdullah L and Akhir N M 2017 Work-related to musculoskeletal disorder amongst Malaysian construction trade workers: Bricklayers *AIP Conf. Proc.* 1891
[6] Selamat M N, Omar N H, Mohd R H, Abd Aziz S F and Hamid F N A 2021 Analysis on Ergonomic Factor of Duties and Organizations towards Stress and Occupational Disease in Manufacturing Industry in Malaysia *Int. J. Acad. Res. Accounting, Financ. Manag. Sci.* 11 177–90
[7] Çakıt : Erman 2019 Ergonomic Risk Assessment using Cornell Musculoskeletal Discomfort Questionnaire in a Grocery Store *Ergon. Int. J.* 3
[8] Kadikon Y and Rahman M N A 2016 Manual Material Handling risk assessment tool for assessing exposure

to risk factor of work-related musculoskeletal disorders: A review *J. Eng. Appl. Sci.* 11 2226–32
[9] McCormack P, Read G J M, Goode N and Salmon P M 2021 Do hazardous manual handling task risk assessment methods align with systems thinking? *Saf. Sci.* 140
[10] Niosh 2006 *Ergonomic Guidelines for Manual Material Handling*
[11] Ghousi R 2020 Archive of SID Developing a New Vertical Multiplier to Modify the Revised NIOSH Lifting Equation *Int. J. Occup. Hyg.*
[12] Abedini R, Choobineh A, Soltanzadeh A, Gholami M, Amiri F and Hashyani A A 2013 Ergonomic Risk Assessment of Lifting Activities; a Case Study in a Rubber Industry Roghayeh
[13] Health and Safety Executive (HSE) 2018 Manual Handling Assessment Charts (the MAC tool) *Heal. Saf. Exec.* 1–11
[14] EU-OSHA 2014 The MAC - Tool - Manual Handling Assessment Charts *Occup. Saf. Heal. Adm.* 1–15
[15] Klussmann A, Steinberg U, Liebers F, Gebhardt H and Rieger M A 2010 The Key Indicator Method for Manual Handling Operations (KIM-MHO) - Evaluation of a new method for the assessment of working conditions within a cross-sectional study *BMC Musculoskelet. Disord.* 11 272
[16] BAuA/ASER/ArbMedErgo/ebus 2019 Key Indicator Method for assessing and designing physical workloads with respect to manual Lifting , Holding and Carrying of loads ≥ 3 kg
[17] Yarmohammadi H, Ziaei M, Poursadeghiyan M, Moradi M, Fathi B, Biglari H and Ebrahimi M H 2016 Evaluation of occupational risk assessment of manual load carrying using KIM method on auto mechanics in Kermanshah City in 2015 *Res. J. Med. Sci.* 10 116–9
[18] Mawle S 2005 The health and safety executive manual handling assessment chart (MAC) benefits *Contemp. Ergon. 2005* 42–6
[19] Shariat A, Tamrin S B M, Arumugam M and Ramasamy R 2016 The Bahasa Melayu version of Cornell Musculoskeletal Discomfort Questionnaire (CMDQ): Reliability and validity study in Malaysia *Work* 54 171–8