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Analysis of Manual Material Handling Using Niosh Lifting Equation Method in Indonesian Bureau of Logistics (Bulog) Warehouse Makassar

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Abstract. Improper manual material removal activities can lead to accidents for workers especially if the works are carried out continuously. One of the accidents is an injury in the musculoskeletal system or musculoskeletal disorder. The study is intended to assess the activity of the one-shoulder carrying workers who carry the rice in the rice warehouses of the Indonesian Bureau of Logistics (Bulog) Makassar by employing the NIOSH Lifting Equation and to identify the amount of energy consumption released by the workers. From the results of measurement from 10 workers who perform the rice removal activities, it obtained the value of 1.0 to 1.5 which means that the activities are included in moderate/medium activities based on the calculation of the energy consumption. According to the results of RWL and LI calculation, however, these removal activities are included to have the potential of causing injury to the backbone because the value of LI obtained exceeds 1 (one). Consequently, it is recommended to have an improvement over the activity of workers who do the manual removal.

INTRODUCTION

Indonesia is a country that still uses manpower in the material removal activities although several industries have started using machines to assist the material removal activities [1]. *Manual Materials Handling* (MMH), however, is still very necessary because it can be carried out in a limited space and the workers rely heavily on their physical to lift goods in doing their activities [2]. *Manual Material Handling* is a transporting activity that is carried out by a worker or more which involves the use of muscle force to perform activities of removal, unloading, pushing, pulling, carrying, and moving goods [3].

Manual material handling (MMH) activity that is improperly performed can lead to loss or even an accident in the worker's [4–7]. One of the consequences that are resulted from improperly performed MMH activities is *musculoskeletal disorder*[8]. *Musculoskeletal disorder* is a disorder on the parts of skeletal muscles which is perceived by someone starting from very mild pain to severe pain. When the muscle receives a static load repetitively for a long period of time, it may lead to a disorder in the form of damage to the joints, ligaments, and tendons [9–11].

A job can provide risks to workers. This occurs because of the workload as a result of the activity of the work that is performed every day. Workload has a direct impact based on the amount of load that is felt/received by workers [12]. Every workload received by a person must be appropriate and balanced with the physical ability and psychological condition of the worker accepting the workload [2]. The impact which occurs when the workload is too excessive will lead to work stress, both physical and psychological, and emotional reactions. On the other hand, when the workload is too little, it can result in a lack of attention on the work and cause boredom. From in ergonomics point of view, the working ability of a worker is different between one worker and the other, and it is subjected to the conditions of the skill level, the physical freshness, the nutritional condition, the type of gender, the age, and the body size of every worker [13].

Indonesian Bureau of Logistics Public Company (Perum Bulog) is a food institution in Indonesia that takes care of the commerce of rice. Bulog was established on May 10, 1967, based on the Decree of the Cabinet Presidium

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Number 114/U/Kep/5/1967. Since 2003, Bulog has changed its status into a State-Owned Enterprise. One of the Bulog warehouses is located in Makassar city.

The workers at Bulog carry out the activity of loading the rice from the warehouse to the trucks and unloading the rice from the truck to the warehouse by carrying the rice on their shoulders, and this activity is carried out repetitively. Because the removal activities are performed continuously and the lifting burden is excessive, the workers suffer from a *musculoskeletal disorder*.

Based on the problem above, the researchers aimed to evaluate the activity of *manual material handling* on the workers who perform rice removal in the warehouse by using the NIOSH *lifting equation* method. NIOSH *lifting equation* is a practical method that was introduced and developed by NIOSH as an evaluation tool for *manual lifting task* activities according to a basic *biomechanical* (the ability of the body to receive pressure), *physiological* (energy use in the body), and *psychophysical* (the ability of the body to lift weights) studies. This equation is able to recommend the limit of *lifting* load *index* that can be lifted by humans (*Recommended Weighting Limit*/RWL and *Lifting Index*/LI). Compared to other methods, this equation is the only equation that examines dimension and mass variables according to vertical horizontal distance, asymmetric degrees, and frequency until the time of *lifting task* [14]. Furthermore, it provides improvement recommendations for the activities of workers who perform manual removal.

RESEARCH METHOD

Time and Place of Research

The retrieval of data for this research was carried out in April 2019 and the location of the research is in Bulog Warehouse Makassar while the data processing was carried out in the Laboratory of APK & Ergonomics FTI-UMI.

The method used in this research is the NIOSH *Lifting Equation* method with the equation of *Recommended Weight Limit (RWL)* which is the recommendation of a limit load that can be lifted by humans without causing injury even though the work is performed repetitively over a long period of time. The following is the formula:

$$RWL = LC \times HM \times VM \times DM \times AM \times FM \times CM$$

Description :
LC (Lifting Constanta) = 23 kg
HM (Horizontal Multiplier) = 25/H
VM (Vertical Multiplier) = 1 – 0,003 [V – 75]
DM (Distance Multiplier) = 0,82 + 4,5/D
AM (Asymentric Multiplier) = 1 – 0,0032 A(0)
FM (Frequency Multiplier)
CM (Coupling Multiplier)
Note:
H = Horizontal distance of the position of the hand that holds the load with the center of the body.
V = Vertical distance of the position of the hand that holds the load to the floor.
D = Vertical distance of the displacement of the load between the original point to the destination.
A = Symmetrical rotation angle that is formed between the hands and the feet.
For Frequency Multiplier (FM), there are:
1. Short duration: 1 hour or less.
2. Medium duration: between 1-2 hours.
3. Long duration: 2 - 8 hours.

For Coupling Multiplier (CM), there are:
1. Good Criteria is a container or box with optimally designed handles. The material is not slippery, the goods inside are not easily spilled and hands can hold the box comfortably.
2. Fair Criteria is container or box without handles and hands cannot hold the box easily.
3. Poor Criterion is a box without handles/grip. It is difficult to hold (slippery, sharp, etc.), the goods inside are unstable (broken, fall, spilled, etc.), and it needs gloves to lift.

After the RWL value is identified, the *Lifting Index* calculation is carried out to determine the removal *index* that does not contain the risk of injury to the backbone, with the equation of:

$$LI = \frac{Load\ Weight}{RWL}$$

If LI > 1, the load weight which is lifted is beyond the recommended removal limit; hence, the activity contains the risk of injury to the backbone. On the contrary, if LI < 1, the weight load that is lifted does not exceed the recommended removal limit; thus, the activity does not contain the risk of injury to the backbone [15].

In addition to calculating RWL and LI, the calculation of the value of the energy consumption of the workers aims to determine whether the job that includes mild, moderate, or severe loads of work is also performed. The formula for the calculation of energy consumption is:

$Y = 1.80411 – 0.0229038X + 4.71733.\ 10^{-4}X^2$

Note:

Y = Energy (kcal/minute)

X = Heart rate speed/pulse (beats/minute)

Once the magnitude of the heart rate speed/pulse is input in the form of energy, the energy consumption is obtained mathematically from the following: KE = Et − Ei

Note:

KE = Energy consumption (kcal/minute)

Et = Energy expenditure during the work (kcal/min)

Ei = Energy expenditure at break time (kcal/min) [16].

RESULTS AND DISCUSSION

In this research, there are 10 people as the samples performing the removal of rice from trucks to the warehouse. It can be seen in Table 1.

TABLE 1. Results of Recapitulation of Energy Consumption

No	Name	Pulse/ Heart Rate		Energy *Expenditure*		Energy consumption (kcal/ minute)
		Initial	Final	Initial	Final	
1	Akbar	80	103	2.9909	4.4496	1.4587
2	Irwan	88	110	3.4417	4.9926	1.5509
3	Anhar	79	104	2.9388	4.5244	1.5856
4	Gani	86	109	3.3233	4.9123	1.589
5	Erna	64	90	2.2705	3.2656	0.9951
6	Yati	68	88	2.428	3.8645	1.4365
7	Agus	82	103	2.6005	3.8865	1.2851
8	Malik	87	107	2.7394	4.09	1.3506
9	Haryono	86	110	3.3233	4.9927	1.6694
10	Rudi	87	109	2.7394	4.9123	2.1729

Based on the results of research on the difference in initial heart rate (before lifting) and final heart rate (after lifting), the value of the initial and final energy *expenditure* as well as the operators' energy consumption can be obtained.

From the results of the research, it appears that the final energy expenditure is higher than the initial energy expenditure. The reason is that the final heart rate after the work is higher than the initial heart rate before the work. Therefore, it is very clear that the energy consumption during the work is larger than the energy consumption before the work. The workers' calorie need is as follows: Akbar needs 1.4587 kcal/min, Irwan needs 1.5509 kcal/min, Anhar needs 1.5856 kcal/min, Gani needs 1.589 kcal/min, Erna takes 0.9951 kcal/min, Yati takes 1.4365 kcal/min, Agus takes 1.2851 kcal/min, Malik requires 1.3506 kcal/min, Haryono requires 1.6694 kcal/min, and Rudi requires 2.1729. Thus, it can be concluded that the energy consumption that is released by the workers is still within the criteria of medium workload.

The result showing the criteria of medium workload may occur because the workers are already accustomed to performing the work. The workers, however, should also be provided a sufficient amount of break time in order to

avoid serious fatigue and the occurrence of undesirable injuries. The results of RWL Recapitulation and lifting index it can be seen in Table 2.

TABLE 2. Results of RWL Recapitulation and Lifting Index

No	Name	RWL	Lifting Indeks
1	Akbar	9.009	5.550
2	Irwan	14.972	3.339
3	Anhar	10.768	4.643
4	Gani	11.215	4.458
5	Erna	13.850	3.610
6	Yati	13.023	3.839
7	Agus	19.981	2.502
8	Malik	15.678	3.189
9	Haryono	12.911	3.873
10	Rudi	14.512	3.445

RWL calculations are carried out based on horizontal, vertical, Asymmetric, Frequency, and Coupling. On the other hand, the LI calculation is performed based on the weight of the load and the results of RWL with the criteria that if the value of LI < 1, there is no risk of injury, but if the value of LI > 1, the work has the risk of causing backbone injury.

In accordance with the results of the calculation above, every worker has different RWL and LI values. Akbar has RWL value of 8.178 and LI value of 6.393, Irwan has RWL value of 14.972 and LI value of 3.339, Anhar has RWL value of 10.768 and LI value of 4.643, Gani has RWL value of 11.215 and LI value of 4.458, Erna has RWL value of 13.850 and LI value of 3.610, Yati has RWL value of 13.023 and LI value of 3.839, Agus has RWL value of 19.981 and LI value of 2.502, Malik has RWL value of 15.678 and LI value of 3.189, Haryono has RWL value of 12.911 and LI value of 3.873, and Rudi has RWL value of 14.512 and LI value of 3.445.

The differences are largely attributable for different horizontal values when lifting the goods between one operator and the other so that the measurement is different. The vertical values are also different because the height of the goods from the floor between each operator is not the same. Asymmetric at the time of lifting also varies because the angle that is formed between one operator and the others is not the same due to the factors of vertical removal and the height of workers. Consequently, from the calculation of the lifting index above, it can be concluded that the process of rice removal in Bulog warehouse has the risk of causing injury to the backbone since the value of LI > 1.

An overview of the distance of the horizontal position of the hand holding the load with the center point of the body (Horizontal Multiplier)

On the work of unloading the rice from the truck, the horizontal multiplier value is associated with the distance of the load to the body of workers, the value of H > 25 cm. This causes the calculation of H value to be increasingly smaller than the one that affects the value of the risk index of each removal, LI > 1. The number indicates that the workers have the risk of experiencing muscle or bone disorder as a result of the work.

Ergonomic improvement efforts

Controlling the distance of the body with the load is highly possible to perform by bringing the body closer to the load. The control is not going to hamper the productivity of workers and is not associated with other factors either. By setting the distance of load to the body (H) < 25 cm, the NIOSH calculation value becomes (HM) = 1. Intervention on other factors, however, is still required in order the removal risk index becomes less than 1.

An overview of the distance of the load to the floor (Vertical Multiplier)

In performing rice removal, the value of the distance of the load that will be moved to the floor (vertical location) at the time of initial removal (origin) and at the final removal (destination) has a very significant effect. The distance of the load to the floor (vertical location) at the initial removal, which is very far from the workers' reach or very close to the floor, will lead to a position that is not good (bending). Therefore, the bottom bags of rice have a high-risk value of causing low back pain compared with the top bags of rice.

Ergonomic improvement efforts

The optimum distance of the load to the floor is 75 cm to produce a vertical multiplier = 1.

An overview of the lifting angle between the workers and the position of load (Asymmetric Multiplier)

Lifting angle is the angle that is formed between the position of the workers with the position of the load at the time of the removal. At the work of unloading the rice from the trucks, the angle that is formed is 30 to 45 degrees or even bigger if the position of the final displacement destination is very far.

Ergonomic Control Efforts

The control that can be performed based on ergonomics science to avoid the occurrence of removal angle is that a worker must perform the material removal appropriately by moving not only the backbones but also the whole body during the removal activity. Hence, the workers are expected to carry out *manual lifting* with A = 0°.
The following are some other control measures that can be taken, which are:

1. When the rice is going to be put on the shoulders, widen out the legs slightly, push your buttocks out and always try to bend the knees a little.
2. Keep the head straight ahead, and the rice removal will be more balanced with the position of the backbones remaining straight.
3. Put the load on the shoulder so that the position of the backbones is not bending too much.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Based on the calculation of the energy consumption, it is distinct that the energy expenditure is included in the conditions of light workload. Based on the calculation of *the Recommended Weight Limit* (RWL) by calculating the factors of ergonomic risks on *NIOSH* such as a *horizontal multiplier, vertical multiplier, distance multiplier, asymmetric multiplier, frequency multiplier,* and *coupling multiplier* at the rice removal work in Bulog warehouse in Makassar city, the value of Li > 1, which means that from an ergonomic point of view, the work is risky. *Li*The *Lifting Index* (LI) exceeds 3 which means that the worker has a high risk of experiencing muscle disease or injury to the lower backbones. The steps that can be taken to minimize the risks is to provide repairing recommendations to the workers regarding the proper ways of removal for reducing the risks of injury to the backbones.

Suggestions

Companies need to consider the importance of health and safety for the workers through health inspection in order to reduce the risks of injuries to the employees. Workers should pay attention to the appropriate ways of removal and attempt the creation of a health and safe environment when working.

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