Analysis of transport workers' postures in the loading process of manual material handling activities by using the photogrammetric method

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Analysis of transport workers' postures in the loading process of manual material handling activities by using the photogrammetric method

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Abstract. This research was conducted on the loading process of manual material handling of cup mineral water activity at PT. PA, Aceh Besar, Indonesia. With samples of 12 transport workers, the observed loading activity includes the position of lifting, walking, and loading. The loading process is done manually from the warehouse into the truck. This work is done continuously by a transport worker with each transported load reaching 48 kilograms. In a one-time loading process, a transport worker performs as many as 33 trips and the timing for each transport loading process is 20 seconds. With the work done continuously and the loads transported are weighty; therefore there are risks of experiencing musculoskeletal disorders by the transport workers. Thus, questionnaires, interviews, and observations were used as instruments to obtain data. Calculations were further conducted to analyze the postures of transport workers by using the Photogrammetric Method. The results show that the moment force calculation at L5/S1 is greatest in the position of lifting the load at 5.756,81 N; meanwhile, the NIOSH provision is 3,400 N for a normal lift limit. Hence, the solutions proposed to this problem are to reduce the load to 24 kilograms/loading and the utilization of the trolley.

1. Introduction

Human activities in daily life cannot be separated from lifting activities. However, without being realized by humans themselves, there are several ways to lift an object that is not accurate or effective. The way a person performs work activities is called work posture. An incorrect work posture that is carried out daily and continuously will certainly result in an injury that can endanger a person's safety and health. Risks typically to occur in work posture are the Musculoskeletal Disorders (hereafter, MSDs). MSDs are injuries to muscles, nerves, tendons, ligaments, joints, cartilage, and or spinal discs. MSDs are usually the results of any brief or severe incident (such as slip, travel, or fall) that can cause occasional or chronic development [10].

There are several factors why human power is still used in the industrial world. Movement flexibility is a strong reason for the use of human power, especially in manual material handling. Material manual handling activities, which consist of rising, lowering, encouraging, attracting and carrying, are the main causes of several complaints to manual transport workers. Accordingly,

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transport workers most often feel back pain. Factors that affect pain in the back are due to the direction of the load being lifted and the frequency of transfer activity [13].

There are some studies in Indonesia that have focused on MSDs of transport workers. Among them is the material handling manual of rice transport workers [12]. The analysis was done by using the biomechanical methods to identify the risk of spinal cord injury on the rice transport workers. The results revealed that these workers were at risk of causing spinal injury because the value of Lifting Index (LI) is 5.52 when lifting a load of 75 kilograms. This exceeds the legal limit of transport [12].

Another research focused on improving the work posture of cassava transport workers to reduce musculoskeletal complaints. The analysis was done using the OWAS method approach. The results showed that the work postures identified had the potential of going through injuries. The results of the analysis with OWAS was in Category 3, which meant that it needed improvement immediately because the current posture was dangerous. Meanwhile, Category 2 meant that it needed improvement in the future. Improvements were then given and made by the transport workers. They were changes in the workers' postures, which included to tilt the back while working and to stand upright when cutting cassava, draining and cleaning the ends. Thus, after repairs, the results of Category 1 were obtained; this means that there are no longer problems with the musculoskeletal system [18].

Further research was done on ergonomics evaluation of material handling manual activities in the bottles production section. Observations were made to all workers in charge of handling the filled bottles at a company in Bangkalan, Indonesia. The results showed that the evaluation with the revised NIOSH appointment equation in 1991 obtained the lifting index (LI) that is greater than 3. To solve this problem, some modifications were made to the multiple factors of the try method and failed in calculating the Recommended Weight Limit (RWL), but the results also do not provide an LI value below 1. Therefore, the recommendation given is to add a bench and a rolling track at the end of the conveyor belt [20].

The cases described above are among the problems often encountered in material handling manual activities. They often happen due to ignorance and improper work posture that go beyond the recommended lift limits. Most transport workers lack the knowledge on this issue, and some employers even ignore the risks of their workers. When risk and health become issues for workers, therefore further research is essential so that solutions can be provided to these workers. Consequently, the researchers of this study are interested in studying and analyzing the loading and unloading activities done by transport workers at a local distributor company in Banda Aceh. By using the photogrammetric method, it is expected that the analysis is more precise with fewer constraints.

The photogrammetric method is a technique used to analyze an activity visually. This method records an on-going activity and then analyses it based on the equation of the photogrammetric formula to determine the coordinates of the object under study [2]. Based on research using this method, it has been proven accurate in analyzing three-dimensional, and two-dimensional reconstruction needs. The research assessed the effect of camera parameters on 3D object reconstruction by using digital photogrammetric techniques. It revealed that the benefits and results of reconstruction showed a maximum difference of 11 mm or 0.0035 times the size of the object under study. In other words, this digital photogrammetric technique is precise to use for reconstruction needs of both three-dimensional and two-dimensional reconstructions [11].

2. Literature Review

2.1. Laborer

Laborer is those who work in individual businesses and are rewarded on a daily or wholesale basis in accordance with the agreement of both parties (i.e., between employers and employees), both verbally and in writing [9].

2.2. Ergonomics

Ergonomics is known in Greek, that is from the words *ergos* and *nomos* that have the meaning of "work" and "rules or rules," from these two words in a free sense in accordance with its development, ergonomics is a rule or principle adhered to in the work environment [10].

2.3. Body injury due to work errors

In general, there are three types of body injury due to errors in doing work, namely Cumulative Trauma Disorders (CTS), Repetitive Strain Injuries (RSI), and Musculoskeletal Disorders (MSDs). Explanations on these types of body injury are as the following [10].

a. Cumulative Trauma Disorders (CTS)
   Cumulative Trauma Disorders (CTS) is often called repetitive strain injuries. They are defined as disorders of the muscles, tendons, nerves and blood vessels that are caused or distorted by exertion or repetitive movements [10].
b. Repetitive Strain Injuries (RSI)
   Repetitive Strain Injuries (RSI) is a general term used to refer to several discrete conditions that can be attributed to repetitive tasks, the exertion of power, vibration, and mechanical compression that is sustainable [10].
c. Musculoskeletal Disorders (MSDs)
   Musculoskeletal Disorders (MSDs) are injuries to muscles, nerves, tendons, ligaments, joints, cartilage, or spinal discs. MSDs are usually the result of any momentary or acute event (such as slip, travel, or fall), in addition to reflecting a more gradual or chronic development [10].

2.4. Biomechanics

Biomechanics is the science that applies the laws of mechanics to the structure of life, especially the locomotor system of the body (locomotor = activity where all parts of the body move because of their strength and are generally assisted by gravity). Biomechanics studies the forms and kinds of movements on the basic principles of mechanics and analyses them [7].

Measurement of the torque that occurs on the lower spine (L5-S1) can be done using the following formula:

$$\sum TL5, S1 = 0 \quad (1)$$

$$(F_m \text{ x } E) - \sum(W x d) = 0 \quad (2)$$

where:
Fm = Force on the spinal muscles (L5-S1)
E = The perpendicular distance of the spinal muscles to the Sacrum center 1 (S1)
W = Human body weight (head, arms, torso, and weight of the weight lifted) (n)
d = The horizontal distance between the L5-S1 center to the center of the body part (head, arms, and torso) and the distance of the L5-S1 to the center of the body mass (cm)

2.5. Segment body weights

Body weight point is the point where the body's weight or body parts work or points that represent a person's body [3].

2.6. Lumbar 5 sacrum 1 (L5/S1)

The lower backbone (Lumbar) is the most critical part of injury. Back pain occurs because the plate (disc) which is cartilage located between the spine (especially the lower part) experiences a force that exceeds that of the plate. As a result, damage to this plate is a permanent pain in the spine. Factors that

cause injury include posture or work position that is uncomfortable (incorrect) during work, the weight of the load lifted, and the frequency of transfer activity [6].

2.7. Nordic Body Map (NBM)
Nordic body map is one of the most frequently used questionnaires in the industry to collect complaints on the cause of musculoskeletal disorders. A questionnaire on NBM is equipped with 27 questions related to complaints that are felt in body parts. These include the neck, shoulders, upper back, elbows, lower back, wrists, waist, knees, heels, and feet. This questionnaire is also equipped with pictures of body parts to ease respondents in comprehending the questions asked [8].

2.8. Body posture and work posture
Body posture is a form and structure in the human body that can be observed. In carrying out daily activities, humans have work postures that are formed due to movements produced by themselves. Some movements can even pose risks to the human's health if they are not controlled and regulated [10].

2.9. Manual Material Handling (MMH)
Manual Material Handling (Figure 1) are all the work of lifting loads or objects carried out by workers without other assistive devices to move them from one place to another [20].

Figure 1. Manual Material Handling (MMH).

2.10. Photogrammetric method
Photogrammetric is a technique used to determine the coordinates of a point in a three-dimensional space derived from two or more two-dimensional images. This method is often used in biomechanics [2].

3. Research Method

3.1. Place, time and samples
This research was conducted from March 5 to April 5, 2018. It focused on the loading process of manual material handling of cup mineral water cupping activity at PT PA, Aceh Besar, Indonesia.

With samples of 12 transport workers, the observed loading activity included the position of lifting, walking, and loading. The loading process was done manually from the warehouse into the truck. This work was done continuously by a transport worker with each transported loads reaching 48 kilograms in one loading process. In a one-time loading process, a transport worker performed as many as 33 trips, and the timing for each transport was 20 seconds. With the work done continuously and the loads transported were weighty; therefore there were risks of experiencing musculoskeletal disorders by the transport workers. Complaints by the workers had been given, and they included pain in the shoulders and hips.

Thus, questionnaires, interviews, and observations were used as instruments to obtain data. Calculations were further conducted to analyze the workers' postures during loading by using the Photogrammetric Method.

3.2. Research stages

The research was carried out based on the stages starting from the identification of the problem to the stages of data analysis that derived results as output of this study. The following are the stages of research, presented in Figure 2 the form of a flow chart:

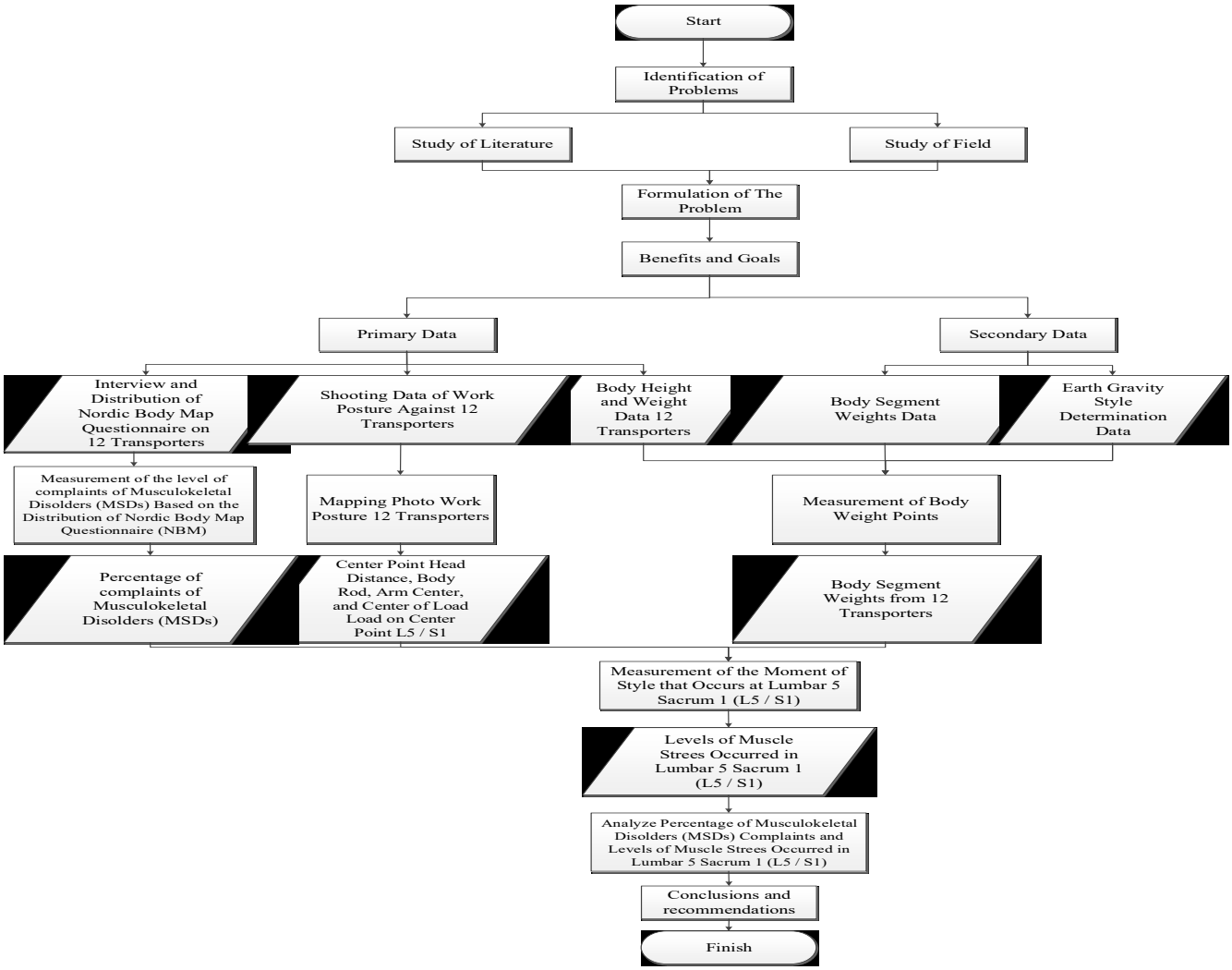

Figure 2. Flowchart of research stages.

4. Results and Discussion

4.1. Nordic Body Map (NBM) Questionnaire

Recapitulation stages were carried out based on the results of distributing the Nordic Body Map questionnaire to 12 transport workers. The goal was to find out the percentage of pain complaints or MSDs. The results showed that the biggest pain complaint and most felt by these workers were at the waist (92%) and back (83%). About 8% of the workers ticked to be "in severe pain" on these body parts. The percentage of complaints of MSDs can be seen in Figure 3.

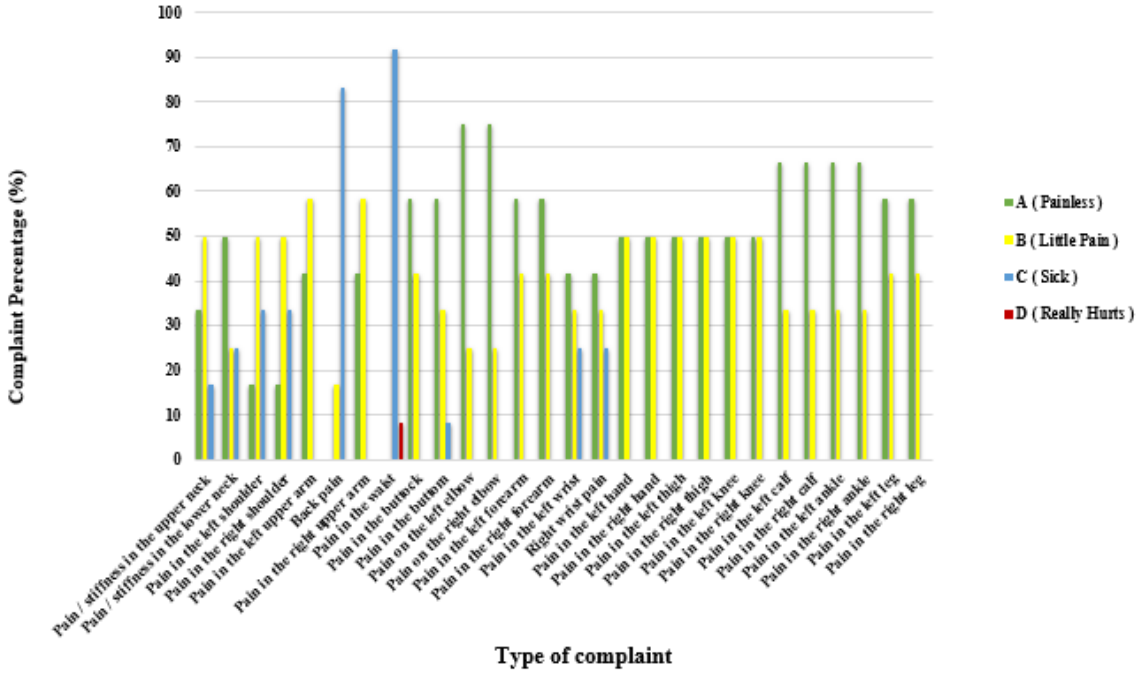

Figure 3. Percentage graph of pain complaints.

In conclusion, the pain complaints felt by the transport workers were caused by the carrying continuously heavy loads of 48 kg/each. This caused severe back pain. Other factors that caused pain are their age factor and working periods.

4.2. Torque on L5-S1

Calculations of torque on L5-S1 included several positions. Namely, the position when they were ready to lift a load, walked with a load, and put down a load. Moment of style obtained in order to find out the level of muscle stress occurs in L5-S1. The magnitude of the torque that occurs in L5/S1 when a worker was ready to lift weights is at an average of 3,956.56 N, with a difference of 556.56 N compared to the provision determined by NIOSH at 3,400 N. Whereas the torque when carrying loads had the average of almost equal to 3.960.66 N. In addition, the moment of force at the position of putting a load had an average of 2766.38 N. The results of the torque calculation for each position can be seen in Table 1.

4.3. Comparison of torque for different lifting weights

Recapitulation of torque comparisons for lifting a load, walking while carrying a load and placing a load with the weight of the loads at 24 kg, 36 kg, 48 kg and 60 kg can be seen in Table 2.

Based on Table 2, it can be concluded that the recommended load limit for material handling manual activities at PT PA is 24 kg/load. This is by taking into account the overall torque of 6766.00 N. Based on this consideration, the load limit of 24 kg/load can reduce the risk of MSDs and can

minimize the risks of injury. However, regular monitoring for material handling manual activities to prevent risky things is still necessary.

Table 1. Torque in the all position.

No	Name	Torque in the lifting position		Torque in the carrying position		Torque in the placing position	
		Body Weight (Kg)	Torque (N)	Body Weight (Kg)	Torque (Kg)	Body Weight (Kg)	Torque (Kg)
1	Transporter 1	58	4377,92	58	2985,20	58	2120,76
2	Transporter 2	47	3756,33	47	3657,76	47	2711,34
3	Transporter 3	55	5330,93	55	3266,59	55	1796,81
4	Transporter 4	68	3318,52	68	3439,14	68	3044,89
5	Transporter 5	53	2882,74	53	4003,37	53	2707,63
6	Transporter 6	55	3081,04	55	4008,01	55	3252,45
7	Transporter 7	51	3102,02	51	3987,94	51	3338,30
8	Transporter 8	55	4998,01	55	3706,94	55	2404,22
9	Transporter 9	63	4283,82	63	4565,90	63	2323,93
10	Transporter 10	55	3422,67	55	4585,81	55	2511,56
11	Transporter 11	53	5756,81	53	4488,04	53	4090,79
12	Transporter 12	52	3167,93	52	4833,17	52	2893,87
	Average		3956,56		3960,66		2766,38

Table 2. Comparison of torque for different lifting weights.

Position	Torque (N)			
	24 kg	36 kg	48 kg	60 kg
Lifting	3183,63	3952,73	4378,55	2736,70
Carrying	2035,94	3534,02	2949,87	3066,06
Placing	1546,43	2145,06	2139,33	2635,70
Total Torque	6766,00	9631,81	9467,75	8438,46

4.4. Analysis

4.4.1. Percentage of Nordic Body Map questionnaire (NBM)

The percentage of MSDs complaints level from the questionnaires revealed that the waist was the vulnerable part that can cause serious injury. The cause of the pain was due to the squeezing of the disk (plate) which is a bone of bone that lies between the spine and experiences a force that exceeds that of the plate.

For the pain complaints, most workers felt “sick” at the waist (92%) and back (83%) with “very sick.” These pains caused their risks of MSDs injury that can endanger their health and life. Injuries experienced were not immediately felt by the workers when they conducted material handling manual activities but were felt when they rest at night.

Other factors that affected the level of complaints of MSDs are the age and length of employment of the transport workers. Their age was at vulnerable stages of between 19-57 years old. Their average working periods were 4 months for new employees of transport workers and 4.6 years for old employees of transport workers. Based on the analysis, transport workers who experienced a lot of pain were those aged 36-57 years old with working periods of 2 years. Whereas transport workers between 21-29 years old and working periods between 1.5 - 4.6 years experienced a little more pain. For transport workers aged 19 - 27 years old with working periods of 2-8 months, they claimed to feel no pain but sometimes did felt the symptoms with little pain.

4.4.2. Torque on L5-S1

Based on the calculations of the torque, it was found that the position at risk of causing injury in the L5/S1 section from manual material handling activities was the position of ready to lift a load (bending the body) and walking while carrying a load weighing at 48 kg in one loading process. Whereas for the position of placing a load was still in the safe category. This is because the average moment of force is still acceptable. The position of placing a load did not cause injury to the L5-S1 because when a worker is ready to put on a load, the work posture is close to the center of gravity (L5-S1). Therefore, L5-S1 does not experience excessive pressure when manual material handling activities take place. The magnitude of the torque that occurred in L5/S1 when a worker was ready to lift a load was at an average of 3,956.56 N, where the difference is at 556.56 N to the provision determined by NIOSH at 3,400 N. Meanwhile, the torque when carrying loads had an average equal to 3.960.66 N. In addition, the moment of torque at the position of putting the load had an average of 2766.38 N.

4.5. Proposed improvement

4.5.1. Recommended load limits for lifting

The calculation of the torque on L5/S1 for transport workers by taking into account the load of 24 kg, 36 kg, 48 kg, and 60 kg, it can be concluded that the load limit is still in the safe category. It is still below the standard of normal lift force determined by NIOSH (National of Occupational Safety and Health) (at 3,400 N on L5/S1), which is to lift 24 kg (2 boxes of cardboard) in one loading. This has been clarified earlier in which the moment of force when lifting weights, carrying weights and putting a load are 3,183.63 N for lifting loads, 2,035.94 N when carrying loads and 1,546.43 N for loading positions.

Whereas for transported loads reaching 60 kg, the difference is also not much from the load carried at 24 kg, that is with the torque lifting position at 2736.70 N for walking position, 3066.06 N for carrying position, and 2635.7 N for putting the position of a load. The choice of the recommended lift limit is 24 kg compared to 60 kg because of the total moment of the overall obtained force, the load weight of 24 kg has a total torque of 6766 N.

The load weight of 60 kg has a total torque of 8438.46 N. The magnitude of the load weighing 60 kg can cause injury to certain parts of the body but not to the L5-S1 due to excessive pressure if the transport worker with good and straight standing bodies. For loads that are at 36 kg and 48 kg, the moment value is greater compared to the transported load of 24 kg and has a higher risk of MSDs.

4.5.2. Use of assistive devices in material handling manual activities

The use of trolleys would not be optimal if there are uneven floor surfaces, and this was what was found on site. This situation made it difficult for loading operations when loading goods into the truck. The time needed by three transport workers to lift as many as 12 boxes was 1 minute. When using a trolley, 12 boxes could be transported with a time of 1.5 minutes; this is a difference of 50 seconds with manual lifting. Therefore, the use of trolleys can be considered with the condition that the floor surface of the warehouse must be flat so that the time taken for the use of trolleys can be more efficient or faster than loading items done manually by transport workers.

5. Conclusions

Based on the research results, some conclusions are drawn:

The material handling manual activities that take place showed that there was no standardization for the load transported by workers. Transport workers could transport 48 kg - 60 kg in one loading is thus depended on their physical ability, and not based on the predetermined standards.

The results of data processing on the distribution of Nordic Body Map (NBM) questionnaires to 12 transport workers showed that the highest level of "sick" complaints was at the waist (92%), back (83%), and "very painful" at the waist (8%). Other factors that affected pain complaints were age and

years of service. Transport workers who experienced a lot of pain were workers aged 36 - 57 years old with work periods of 2 years.

The calculation of moment force on L5/S1 showed the highest average force moment at 3,956.56 N on weight lifting activity. Whereas for walking activities on carry the burden and put the burden obtained an average of 3,960.66 N and 2,766.38 N. The position of lifting and carrying loads had exceeded the normal lifting load limit of the NIOSH (National Institute for Occupational Safety and Health) standard, which is 3,400 N. The moment of force obtained showed the level of muscle stress in L5/S1.

Therefore, two proposed improvements to be considered are reducing the transport load from 48 kg to 24 kg/loading, and the use of trolley. However, this can only be efficient and optimal if the warehouse fixes their flooring condition to be more flat and smooth.

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