Application work risk of manual material handling operators using different lifting methods

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Abstract. This study observed the activity of lifting and moving crates containing bottles at a pallet station in a carbonated drink factory. The activity of moving crates, each weighing 15 kg, is performed by four operators using different methods. An operator manually moves 250 crates daily and often takes rest during working. This study aims to find the most efficient method, that is using the least energy, to move crates. The workload is assessed using the method of Cardiovascular Strain Load (CVL) and energy expenditure. Operators’ arterial pulse is measured for 1 minute right before they start working and after they finish working; this is done to obtain work arterial pulse and rest arterial pulse. The way operators lift crates is analyzed using biomechanics. It is found that fatigue is experienced by all operators, with the exception of the 3rd operator who has a %CVL number below 30%. He positions the pallet to be parallel to the conveyor, and then stand in between during the lifting process. He only rotates his body to move the crate from the conveyor onto the pallet, requiring only little energy. This is one of the reasons why the %CVL number is lower than the other operators.

1. Introduction
The production process of soda drink is performed automatically using a machine, starting from washing the bottles until filling the bottles with soda water. However, moving crates containing soda bottles from the conveyor onto the pallet is performed manually by male operators. Each person moves 250 boxes per day; each containing 24 soda bottles drink weighing 15 kg. They often take rest while moving these packing cases, as they feel tired, causing crates to accumulate on the conveyor. Observation conducted on four pallet operators shows that each person uses a slightly different method of heaving and moving crates. Wrong lifting technique risk of causing pain complaint on several body parts.

The workload is of complex construction, and multi-facet, usually defined as part of resource used to develop some activity or work. Another definition is cost spent by an individual while performing specific work[1]. The combination of work demand, the condition where the work is performed, and individual skill, behavior, and perception collectively determine workload [2]. Works requiring simultaneous use of physical and mental power will negatively impact human muscle capacities, such as endurance, fatigue, and recovery. This change depends on the level of physical workload [3]. The high physical workload may lead to poor health, yet it is still not understood completely about time exposure, type of exposure, and the combination of several types of physical workload that can cause poor health [4]. Heart pulse measured and energy consumption calculated are used to classify workload in the category of very light, light, medium, and hard. The balance between sensitivity and
specificity for heavy work will contribute to improving workers’ safety [5]. Cardiovascular (CVL) workload evaluation consists of an individual factor, work capability, muscle pain, and subjective general health. Distinctive factor that affects CVL of workers is labor type, age, and fitness level [6]. Someone’s physical activity, which will affect his energy consumption significantly, can be determined from his/her oxygen consumption and heart pulse [7]. Energy for work is calculated using linear function between heart pulse and energy consumption [8]. Heavy workload possesses ergonomic risk and musculoskeletal problem [9]. Hard work will affect cardiovascular load, hence increasing heart rate. Redesigning work system will reduce pressure and increase productivity [10]. Heavy work will cause excessive muscle contraction, thus increasing the risk of muscle injury. From workers complaints, the sign of hard work side effects can be noticed, therefore work posture is assessed, distance traveled in work, work arterial pulse, and rest arterial pulse are measured. Nordic Body Map questionnaire will show workers’ pain complaints on several body parts. Work method assessment using Rapid Entire Body Assessment (REBA) and IRHR can identify problems and risk number that cause workers to suffer from muscle injury [11]. From the high rate of work arterial pulse and short rest of trapezius muscle for the morning shift and afternoon shift workers, a high workload can be observed. For night shift workers, workload and trapezius muscle load are lower [12]. Scheduling is helpful to balance alleviate operators complaints caused by excessive workload and also to increase efficiency [13].

Evaluation of operators work method of lifting and moving the crate is conducted to obtain the biggest energy consumed. The evaluation is also useful to find the best method pallet operators can use. Standardize work method can reduce the amount of energy needed, which will make work less tiring and more efficient.

2. Method

This observation is conducted in a bottling soda factory in Siantar, North Sumatera. Objects of this study are four male pallet operators, whose jobs are to move crate containing 24 bottles weighing 15 kg from the conveyor to pallet. Workers arterial pulses are measured before and after moving these boxes for five days from 08.00 to 16.00 o’clock. Measurement is done manually with indirect assessment method, i.e. measuring operators’ arterial pulse for a minute before and after work. The method used to determine workers physical workload is Cardiovascular Strain Load (CVL). CVL is a method used to determine workload classification based on arterial pulse increase compared to the maximum arterial pulse. The measured number is then divided by Rest Arterial Pulse (RAP) and Work Arterial Pulse (WAP). Equation to calculate %CVL is,

\[
\% \text{CVL} = \frac{100 \times (\text{Work Arterial Pulse} - \text{Rest Arterial Pulse})}{(\text{Max Arterial Pulse} - \text{Rest Arterial Pulse})}
\]

Maximum arterial pulse for a man is 220-age and 200-age for a woman. The obtained %CVL number is then compared to the following relation, if %CVL < 30% fatigue happens; 30%<%CVL < 60% improvement needed; 60%<%CVL < 80% work in short time; 80%<%CVL < 100% immediate action needed; %CVL > 100% no activity allowed.

Direct workload assessment means assessing physical workload based on calorie need. In order to determine workload of pallet operator, energy expenditure, and their calorie consumption are calculated. Energy expenditure is determined using interpolation method with the assumption of operators whose heartbeat at 100-125 beats per minute require 5.0 – 7.5 calories per minute. The following equation can be utilized,

\[
\frac{100 - 121}{100 - 125} = \frac{5.0 - X}{5.0 - 7.5}
\]
By determining energy consumed (Y) in kcal per hour, energy consumption can be calculated. The figure is then used to identify workload received by operators. The formula used to calculate calorie consumption is,

\[ Y = 1.80411 - 0.0229038X + 4.71711 \times 10^{-4}X^2 \]  

(3)

where \( Y \) is energy consumed (kcal), \( X \) is heart pulse rate (beats per minute).

Heart pulse data of pallet operators are employed to determine rest time of workers, by using the following equation,

\[ R_T = \frac{K}{S} \times 100 + \frac{t}{K - BM} \quad \text{if } S \leq K \leq 2S \]  

(4)

where \( K \) is total energy consumed, \( S \) is standard energy used (kcal/minute), \( t \) is total work duration (minute), BM is a basal metabolic number (1.7 kcal/minute).

3. Results and Discussions

The results are to be discussed in 2 subsections; they are work method and workload, energy consumption and rest time.

3.1. Analysis of work method and workload

The 1\textsuperscript{st} operator moves crates from the conveyor on his right side onto the pallet, requiring him to walk. The 2\textsuperscript{nd} person moves containers from the conveyor on his left side onto the pallet, requiring him to walk forward. The 3\textsuperscript{rd} worker moves packing boxes from the conveyor onto the pallet with his body position between the conveyor and the pallet, requiring him only to rotate his body. The 4\textsuperscript{th} laborer moves bottle chests from the conveyor onto the pallet ±100cm apart, where the conveyor is not parallel to the pallet, also requiring him to walk. The workload of operators is determined based on arterial pulse measured for a minute before and after the work to obtain the average arterial pulse of pallet operators for five days of observation. Work load received by these workers is classified based on \%CVL value and energy expenditure. By subtracting age from 220, the maximum arterial pulse number can be obtained. The number of \%CVL for each operator is shown in table 1.

| No | Name     | Age (years) | Operator’s arterial pulse (beat/minute) | %CVL | Workload classification |
|----|----------|-------------|------------------------------------------|------|-------------------------|
| 1  | 1\textsuperscript{st} Operator | 46          | 121 77 174 | 45.36 | Improvement needed |
| 2  | 2\textsuperscript{nd} Operator  | 45          | 116 75 175 | 41.00 | Improvement needed |
| 3  | 3\textsuperscript{rd} Operator  | 34          | 106 77 186 | 26.61 | Not experiencing fatigue |
| 4  | 4\textsuperscript{th} Operator  | 39          | 109 74 181 | 32.71 | Improvement needed |

The 3\textsuperscript{rd} operator’s workload is classified as not experiencing fatigue because his \%CVL number is below 30\%, while other workers’ workloads are classified as immediate improvement needed, as their \%CVL number is between 30\%-60\%. High arterial pulse will affect the \%CVL number. The large number of \%CVL is also affected by work method.

Energy expenditure is calculated to determine pallet work operator using interpolation method. Pallet operators whose heartbeat at 100-125 beat/minute consume 5.0-7.5 calories/minute as shown in table 2.
Table 2. Energy expenditure calculation of operator.

| No | Name       | WAP | Energy expenditure (cal/min) | Heart rate during work (beats/min) | Energy consumed (cal/min) | Workload type |
|----|------------|-----|------------------------------|-----------------------------------|--------------------------|---------------|
| 1  | 1st Operator | 121 | 5.0-7.5                      | 100-125                           | 7.1                      | Medium        |
| 2  | 2nd Operator | 116 | 5.0-7.5                      | 100-125                           | 6.6                      | Medium        |
| 3  | 3rd Operator | 106 | 5.0-7.5                      | 100-125                           | 5.6                      | Medium        |
| 4  | 4th Operator | 109 | 5.0-7.5                      | 100-125                           | 5.9                      | Medium        |

The result of operators’ energy expenditure calculation shows that operators’ workload is classified as a medium. It can be clearly seen from the table 2 that the 3rd operator consumes the least energy among the 4 operators, only 5.6 calories per minute. Whereas, the one who consumes the most energy is the 1st operator 7.1 calories/ minute. The difference in %CVL number among operators is affected by internal and external factors. One of them is work method used by each operator in doing their work. Good work method will reduce energy consumption used in work. Fatigue can be caused by either wrong movement or unneeded movement performed repetitively, leading to increased energy consumption.

The difference in work method among operators implies that differences in the technique used affect %CVL number and energy expenditure, which explains why the 3rd operator with the best work method has the lowest %CVL number and does not experience fatigue. Work methods of the 1st, 2nd, and 3rd operator are quite similar and represented by work method of the 1st operator as shown in figure 1.

![Figure 1. Work method of the 1st operator](image)

Figure 1 shows work posture and body position of the 1st operator in five work elements of moving crates containing soda drink from the conveyor onto the pallet. These five work features are operator putting a box onto the pallet, then walking toward conveyor, followed by changing his standing position and lifting the box and operator walking to move a crate from the conveyor onto the pallet, operator putting a crate onto the pallet with his trunk straight. The 1st operator moves a box from the conveyor on his right side onto the pallet, requiring him to walk. He changes his posture and position each time he moves the box. This kind of unorganized movements consumes much energy. The way the other operators perform their work is similar to the 1st person; they do many useless movements, causing their energy consumption to increase. This is a reason why their workloads, based on their %CVL number, are classified as immediate improvement needed and why their energy consumption is higher than the 3rd operator. As more energy is used, oxygen needs and work arterial pulse also increases. Nevertheless, the 3rd operator has the lowest %CVL number. His work method is better than the other operator. Figure 2 below shows how the 3rd operators do his job.
Figure 2. Work method of the 3rd operator

Figure 2 shows work posture and body position of the 3rd operator in 5 work elements of moving crates from the conveyor onto the pallet. They are operator holding a crate, operator lifting a crate in the same standing position as before, operator rotating his body without walking, operator putting a crate onto the pallet. Positions the pallet to be parallel to the conveyor, stands in between, and then lift the containers onto the pallet, requiring him only to rotate his body without moving his legs. Consequently, his energy consumption is low, as no excess energy is consumed. His good procedure is the reason why he has the lowest %CVL number among all four workers. His working method can also be thought to other operators to reduce their workload.

3.2. Analysis of energy consumption and determination of rest time

Based on calorie consumed to move the crates from the conveyor onto the pallet, this work can be categorized as medium work. The 1st operator uses the highest energy to performing this activity, 5.93 kcal/minute or 356.34 kcal/hour, which is categorized as heavy work as the number exceeds 351 kcal/hour. The other operator workloads are categorized as medium work, consuming 201-350 kcal/hour. High energy consumption of the 1st operator is the result of him being older than his colleagues, causing him to utilize more energy. The 3rd operator’s workload is categorized as medium work, even though he uses the least calorie, only 280.59 kcal/hour. The reason is he employs different work method that consumes the lowest energy in comparison with the other operators.

Energy consumption calculated is used to determine rest time for each operator. The 1st operator needs 32.65 minutes rest and the 2nd operator requires 18.63 minutes rest for 4 hours of work. Meanwhile, the other two operators do not need any rest because the total energy consumed (K) is less than the standard energy used (S) for a male operator. Operator 1 and 2 require rest time, as both of them are older than the other two operators and doing unnecessary movement during their work. Their work method can be improved to lighten their tasks.

4. Conclusions

This article aims to understand the effect of different work method of pallet operators on physiological workload and energy expenditure. Work procedure of the 3rd operator does not require him to use excess energy because he does not walk or move from his standing position. His efficient method is one factor that causes his %CVL number to be so low in comparison with the other three operators. The more energy used, the more oxygen the body needs, causing an increase in operators heart rate. Efficient work method will reduce the amount of energy used. Tiredness can be caused by either doing the wrong movement or unneeded movement repetitively, leading to an increase in energy expenditure. Work method correction will lighten operators work.

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