Manual handling methods evaluation based on oxygen consumption

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Abstract. Mining industry has become one of the largest industries in Indonesia, now competing in billions dollar market, with numbers people employed. Deliveries of a Return Rolls (RR) involve the use of a hand truck and, in many cases, a shoulder/elbow-mode of carriage. Workers usually prefer to the *Gendong* (carrying on the small of the back or the hip, supported by the waist and arm) mode or *Manggul* (carrying on some stuff shoulder) mode, because they feel safer by carrying RR on the shoulder/elbow. In this study, the physiological workload involved in shoulder/elbow-mode carrying was investigated, especially focusing on the effects of load weight and inclination. To measure heart rate and oxygen uptake while carrying on the shoulder/elbow, a laboratory experiment was conducted and safety guidelines for such tasks were proposed, based on the experimental results. Four healthy male subjects performed shoulder/elbow-mode carrying, weight between 20 and 24 kg: (1) on inclination of 10º, (2) 20º and (3) 30º. The results showed that inclination involved an increased physiological burden, and that a load of 24 kg entailed a significantly higher physiological cost than carrying a load of 20 kg. Although shoulder/elbow-mode carrying has some advantages, the worker should be advised to carry a load of less than 20 kg, to avoid a high physiological load. During shoulder/elbow-mode carrying, it is also recommended that a person prepare more training in order to have muscular strength.

1. Introduction

Coal mining continues to be an important source of musculoskeletal stress and injuries. The primary aim of this paper described here was to reduce injury risks associated with manual tasks performed by miners [1]. Coal business process is started from overburden stripping, coal mining, coal loading coal from the stockpile to hauler, coal hauling, crushing and sizing, barge loading, and ended up in coal barging. In coal mining industry, discrete-event simulation has been widely used to support decisions in

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material handling system (MHS) [2] while Bow-tie analysis combines aspects of fault-tree analysis and event-tree analysis to identify an initiating event [3].

The mining industry in this study is important to investigate because of its relatively on high incidence and severe muscle injury [4][5][6][7]. Besides working in various minerals industries (such as coal mining) is rarely considered as safe and comfortable as working in the office [3][8]. This will cause Musculoskeletal Disorders (MSDs) or muscle bone injuries. It is this injury that will increase the dangers and diseases caused by work. More importantly, the mining industry is an industry with many potential hazards that can cause injury and death [9]. Accordingly, some of the major causes of hazards in the mining industry are dust, vibration, noise, work shift and other manual tasks [8].

Several studies have been conducted related to the mining industry [10][11][12], and research on the ergonomic work environment has been done [11]. Activities in the mining industry are full of risks for both underground and over ground mines. These activities lead to high risk of occupational accidents due to lifting especially on the back of the rear. Such work accidents are more common in the mining industry than in other industries.

The formulation of the problem or research question (RQ) of this research is how the RR load and inclination conveyor affects the VO_2 value when lifting RR based on VO_2. The purpose of this research is to determine the effect of conveyor load and inclination on VO_2 value when lifting RR based on VO_2. This research recommend to the company on how the mechanics should carry the RR (Return Rolls). Theoretical implications obtaining the significance value of each factor's influence on VO_2 obtaining a lift method that impacts yields lower VO_2. The proposed managerial implications are as follows.

- Providing recommendations to companies regarding appropriate lifting methods and priority factors that are important and should be considered to minimize the possibility of injury to workers.
- Providing recommendations to companies regarding the value of the burden and inclination, appropriate to minimize the possibility of injury to workers.
- Considering lifting methods as one of the important safety factors in MMH design work as it has an effect on the physiological aspects of the respondents.

Contribution of this study contribute to the different RR lift styles and mechanical capabilities shown through VO_2 as well as the maximum time and distance traveled. The different lift styles give consideration to how RR should be raised in the mine area. In addition to the consideration, this lift style difference also makes it easier in planning the necessary actions in case of errors in lifting.

2. Definition

Manual handling of objects in an industrial setting has been a significant concern to occupational health professionals who attempt to prevent injury. Tasks that demand frequent and heavy lifting are associated with an increased risk of low back pain [4].

Manual Material Handling (MMH) defined by several researchers [16][17][18] that Manual Material Handling and movement is a part of many activities, usually it includes involves lifting, lowering, pushing, pulling, gripping, pinching, carrying and holding objects by hand. For instance of how manual material handling and movement diffuses all facet of our work life in health care involves loading and unloading trucks, carts, boxes or wooden container; lifting bags, instrument trays; moving parts, food or assemblies from one place to another; loading paper in the copier or picking binders from an overhead shelf; and handling a mop, polisher or vacuum. Equal with technology available today, manual material handling and movement will always be with us. The one thing all these tasks have in common is the potential to result in some contrary effect such as personal hurt or property loss.

3. Methodology

The current research methodology generally consists of three stages: the preparatory phase of the research, the MMH experimental stage, and the analysis and discussion stage of the MMH experiments using statistical analysis. In the preparation phase of the study discussed about the background of the research. Having obtained the background of the next stage of research is to formulate the problems to be researched followed by preparing research objectives that answer the problems that have been formulated. Also drawn up the benefits and contributions of the current research. The next step is to study the theories related to MMH from various literatures so that from the theoretical studies that have been done, obtained the responses to be measured that is VO2 and HR, the factors that are considered to give influence to the response that is load, inclination and how to lift, As well as methods to be performed for MMH experiments and analysis of MMH experimental data i.e. MANOVA (Multivariate Analysis of Variance) if correlation between high value response variable and ANOVA if otherwise. Preliminary theoretical and experimental studies are also conducted to get the right level on each factor.

After getting the response variable, the factors as well as the level, as well as the experimental method and MMH analysis, the next step is to start doing MMH experiment. Before the experiment begins, the thing that needs to be prepared is the sampling of the operator in the experiment. After that the MMH experiment was done in accordance with the general factorial design that has been made. During the experiment the VO_2 and HR values were measured with the Ergometer FitmatePro Cosmed tool and the results were recapitulated.

4. Results

4.1. The average difference of Oxygen Consumption for each lift position

Based on Figure 1 it can be seen that for the lifting method with the holding position (G) is better used when the weight conditions are 20 kg inclination 20, the weight of 20kg inclination 30°, the weight of 24kg inclination 20° and the weight of 24kg inclination 30°. As for the lifting method with the *Manggul* position (M) is more suitable when used in heavy conditions 20 inclinations 10, weight 24kg inclination 10° this is because it has a smaller value VO_2.

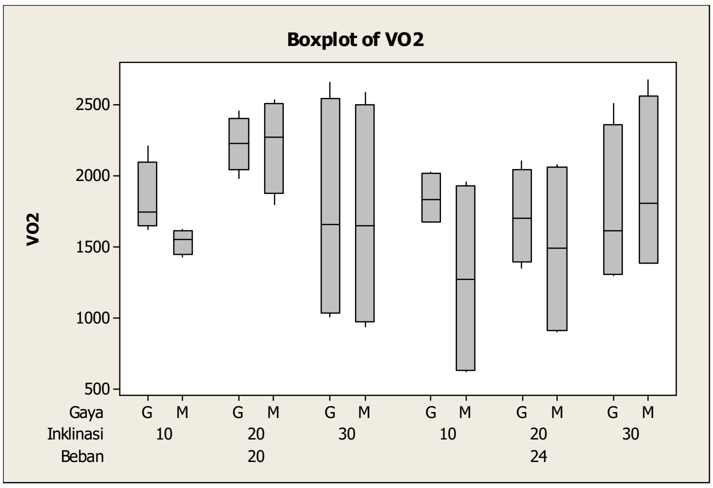

Figure 1 Boxplot for Consumption VO_2.

4.2. Distribution of plot data from oxygen consumption for each individual

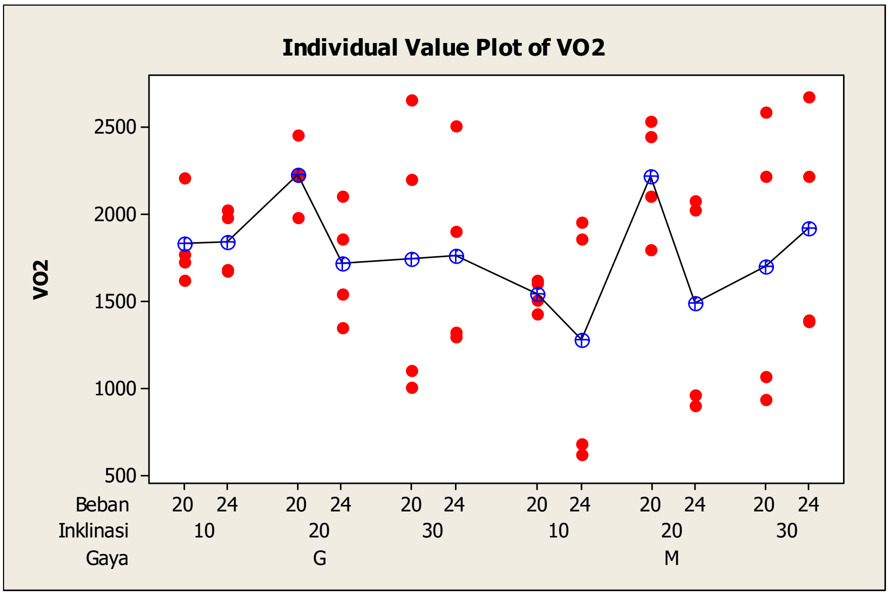

Figure 2 Differences VO_2 for each respondent and different load conditions.

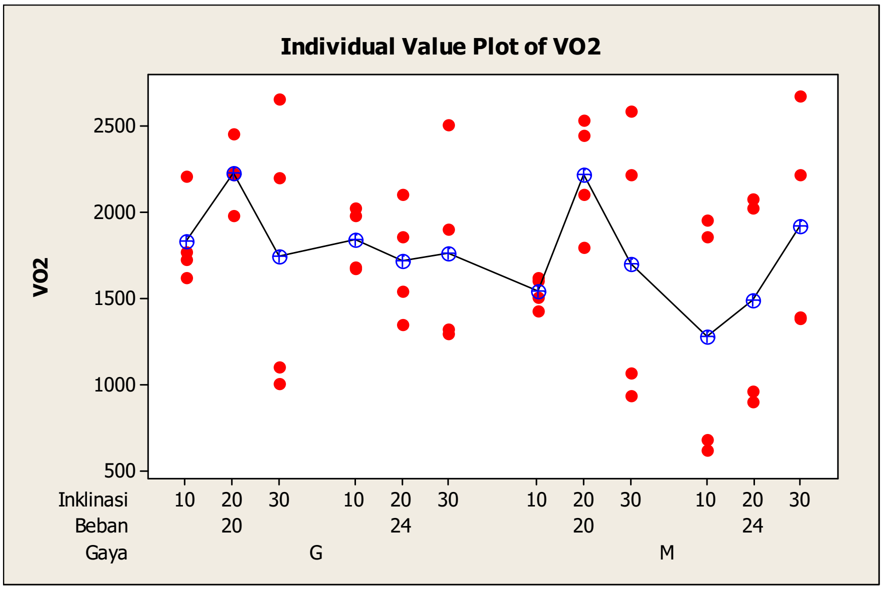

Figure 3 Difference VO_2 for each respondent and different inclination conditions.

When the VO_2 ratio is compared when the load is different, for 24 kg loads it has a higher VO_2 when compared to a 20 kg load, but when the activity with the 20 kg incubation position of the *Manggul* for 20kg and the inclination of 20° *Manggul* positions for load 20kg gives a higher VO_2 value From the 24kg load. Meanwhile, when viewed from inclination, for inclination 10° always gives higher VO_2 value, the next highest is inclination 30°. So it can be concluded that the higher the inclination the VO_2 value will be higher also. Furthermore it will also be known for which factors influence VO_2.

5. Discussion

Figure 4.a and Figure 4.b shows the output of Ergometer FitmatePro. At the output it appears 2 graphs are the red color HR and the blue color VO_2. One's lifting condition is indicated by the increase in HR and VO2 which ends with the discharge of the AT line. AT is the limit of Anaerobic Threshold where its oxygen reserves are getting thinner or almost exhausted. At that time oxygen is taken from the muscle so it will feel tired in anaerobic conditions. At that time someone doing the activity should rest to get O_2 back followed by a decline in HR.

Based on Figure 5, it can be explained that when using α by 10% then the factors affecting Heart Rate when appointment of return roll are load factor, lift / position, and inclination. In the calculation of Anova also obtained R-sq value of 39.95% which means very low so it can be concluded that for the Heart Rate is influenced by the interaction between load, lift / position of 39.95% the rest entered in other factors. Based on Figure 4 it can be explained that when using α by 10% then the factor that influences VO_2 when the appointment of return roll is inclination. In the calculation of Anova also obtained R-sq value of 69.45% which means that factors used in this study can only explain / affect VO2 of 69.45%.

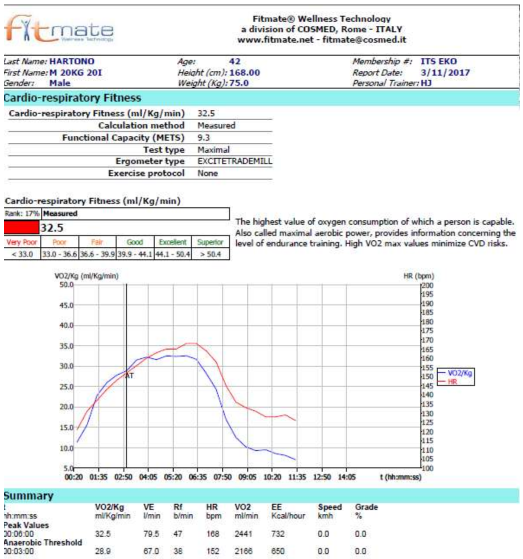

Figure 4.a. Example output FitmatePro (Hartono-*Manggul*-20kg-20°).

Figure 4.b. Manual handling in stock pile area.

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Analysis of Variance for VO2, using Adjusted SS for Tests

Source                    DF    Seq SS   Adj SS   Adj MS      F      P
Load                       1     0.213    0.213    0.213   0.02  0.880 NS
Inclination                2   681.626  681.626  340.813  37.07  0.000 S
Position                   1     0.301    0.301    0.301   0.03  0.857 NS
Load*Inclination           2    47.675   47.675   23.838   2.59  0.089 NS
Load*Position              1     2.341    2.341    2.341   0.25  0.617 NS
Inclination*Position       2    18.725   18.725    9.363   1.02  0.371 NS
Load*Inclination*Position  2     1.638    1.638    0.819   0.09  0.915 NS
Error                     36   331.020  331.020    9.195
Total                     47  1083.540


S = 3,03233   R-Sq = 69,45%   R-Sq(adj) = 60,12%
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Figure 5. Anova for VO_2 with 4 respondents.

6. Conclusion

Anova analysis result by using Minitab showed that factors influencing Heart Rate when appointment of return roll are load factor, lift / position, and inclination. For all activities with the *manggul* position have a lower HR when compared with the position of carrying. This can be used as a suggestion for the company that raising the *Manggul* way better than the way *Gendong*. Whereas when the VO_2 ratio is compared when the load is different, for 24kg loads it has a higher VO_2 when compared to a 20kg load, but when the activity with the 20kg incoordination position of the *Manggul* for 20kg load and the inclination of 20^o *Manggul* positions for load 20kg gives a higher VO_2 value High from 24kg load. Whereas when viewed from inclination, for inclination 10^o always gives higher VO_2 value, the next is highest when inclination 30^o *Gendong*. The results of this study contribute to the different RR lift styles and mechanical capabilities shown through VO_2 as well as the maximum time and distance traveled. The different lift styles give consideration to how RR should be raised in the mine area. In addition to the consideration, this lift style difference also makes it easier in planning the necessary actions in case of errors in lifting

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