Working and Resting Period based on Inclination, Loads, and Lift Methods on Manual Material Handling in Mining Environment

Eko Nurmianto[1], Udisubakti Ciptomulyono[2], Suparno[3], Sudiyono Kromodihardjo[4], Hari Setijono[5], Nur Ahmad Arief[6], Abdul Rohim Tualeka[7]

[1]Research Scholar, Department of Industrial and Systems Engineering, Faculty of Industrial Technology and Systems Engineering, Institut Teknologi Sepuluh Nopember, Surabaya 60111, Indonesia, [2]Professor, Department of Industrial and Systems Engineering, Faculty of Industrial Technology and Systems Engineering, Institut Teknologi Sepuluh Nopember, Surabaya 60111, Indonesia, [3]Professor, Department of Industrial and Systems Engineering, Faculty of Industrial Technology and Systems Engineering, Institut Teknologi Sepuluh Nopember, Surabaya 60111, Indonesia, [4]Professor, Department of Mechanical Engineering, Faculty of Industrial Technology and Systems Engineering, Institut Teknologi Sepuluh Nopember, Surabaya 60111, Indonesia, [5]Professor, Department of Physical Education, Faculty of Sport Science, Universitas Negeri Surabaya, Surabaya 60231, Indonesia, [6]Professor, Department of Physical Education, Faculty of Sport Science, Universitas Negeri Surabaya, Surabaya 60231, Indonesia, [7]Professor, Department of Occupational Health and Safety, Public Health Faculty, Airlangga University, Surabaya 60115, East Java, Indonesia

Abstract

This study assessed working period and resting period in handling return roll (RR) in laboratory. Deliveries of a RR involve a shoulder/elbow-mode of carriage. Workers usually prefer the Carry On Shoulder (COS) (*Gendong)*, or Carry On Elbow (COE) (*Manggul*) modes. The objective of the research are to measure Working Period (WP) and Resting Period (RP) that converted into heart rate (HR) and oxygen uptake (VO_2). Eight healthy male subjects performed shoulder/elbow-mode carrying. The type of research was a experimental study. Lifting with the shoulder method feels lighter and takes distance much longer. The rest period for the shoulder method has shorter rest periods because the work is lighter while carrying a longer rest period based on ANOVA test on the effect of inclination, load and lifting methods on Working and Resting Periods.

Keywords: *working period, resting period, carrying on the shoulder/elbow; heart rate; VO2; manual handling, mining environment.*

Introduction

Lifting activity is very common in the manufacturing industry or service industry. Throughout the years, research has examined the physiological and biomechanical implications of load carrying. Manual handling activities at working environment can result in a wide range of Musculo Skeletal Disorders (MSDs)[1]. MSDs were most frequently reported in workers with less than 5 years or more than 20 years of mining experience.

Several studies have been conducted in mine about musculoskeletal risk factors that occur in mines[2]. Risk factors in mine; occupational and individual factors in mine[3], physiological workload evaluation when carrying a load[4]. Duration of working has been studied by researcher[5, 6]. Some of these studies do not discuss work periods when lifting.

Corresponding author
Eko Nurmianto, Department of Industrial and Systems Engineering, Faculty of Industrial Technology and Systems Engineering, Institut Teknologi Sepuluh Nopember, Surabaya 60111, East Java, Indonesia; nurmi@ie.its.ac.id; +6281330771772

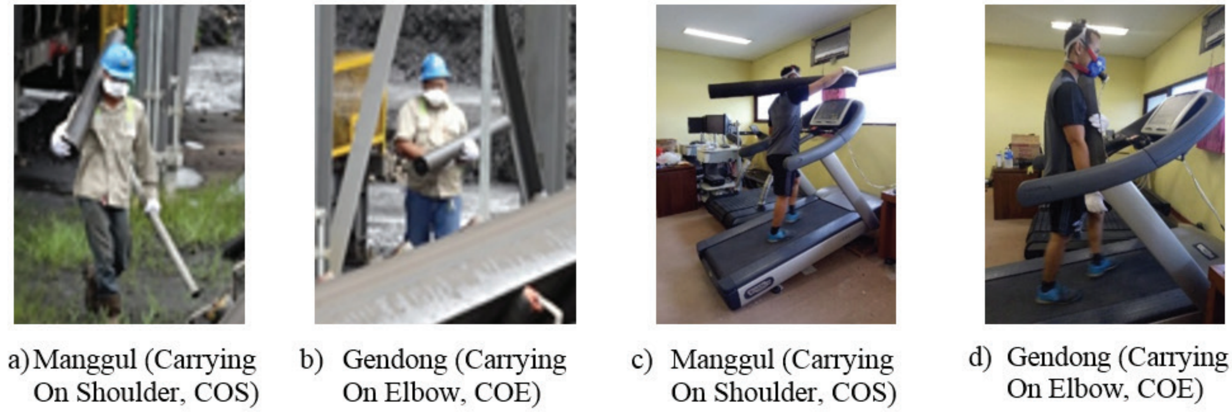

Figure 1 : Mining workers carrying RR in mining area environment (a,b) and in laboratory (c,d) using Fitmate Pro Cosmed[7]

The study of lifting methods in manuals material handling comparing mining environment and laboratory environment based on measurements of heart rate and oxygen consumption carried out experimentally is relatively rare. To overcome this gap, this study examines method between *Gendong* (Carry On Elbow, COE) and *Manggul* Carry On Shoulder (COS), how to model the relationship between COE and COS methods, inclination, and travel time when carrying RR (figure 1). Many studies have carried out[8,9], but they not include length of work period and rest period.

Material and Methods

Lifting activities are carried out on the treadmill (Woodway and TechnoGym) arranged in Figure 2. First, oxygen cells installed in FitmatePro, flow meter mask is placed on respondent's face and pole is placed on chest according to the position of the heart to detect HR. Flow meter (Figure 2) is connected to FitmatePro and pole is connected using WiFi. While participants stood on a treadmill (Woodway) and walk on a treadmill at a speed of 3.5 km/h, with an inclination vary between 10°, 20°, and 30°. Participants were walking on a treadmill carrying 20kg return rolls (RR).

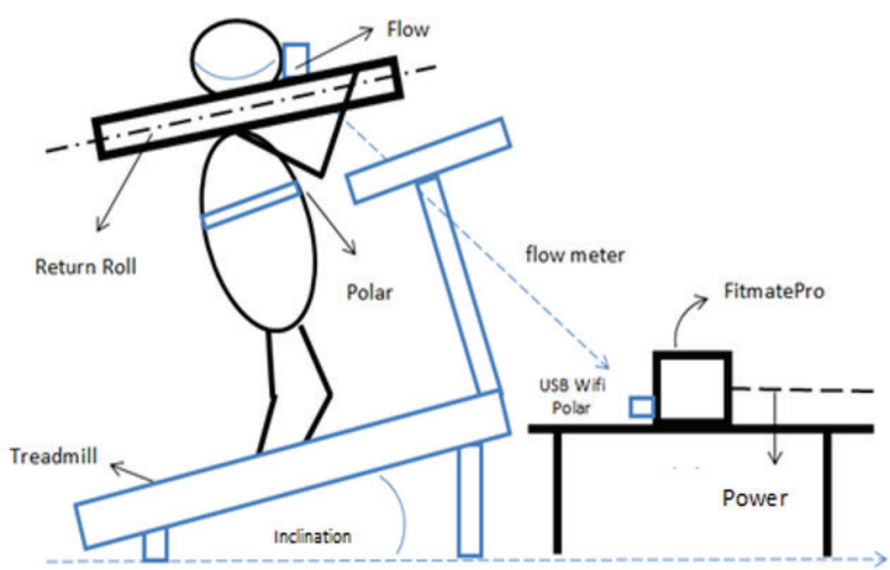

Figure 2. Schematic diagram of experimental MMH study

This research started with data sources obtained by designing an experiment[2] and the stages in WP and RP determined as follows:

Firstly, looking at the output pattern of FitmatePro for eight respondents. Secondly, determine the average. Thirdly, determine time and distance when HR 100 bpm to 160 bpm. Fourthly, determine the amount of rest time when the average decrease in HR from 160 bpm to 140 bpm. After break then start again by looking at previous pattern up to HR 160 bpm. After that, return to first step.

The following is analysis of the results of the measurement WP and RP[10] using ANOVA Method. Firstly, make a tabulation data of the Working Period (WP) and Resting Period (RP) (table 1). Then conduct ANOVA analysis for WP (Table 2)

The model formed from two factorial experiment design where first factor is level three inclination (10^0, 20^0, and 30^0) and second factor is two levels load (20 kg and 24 kg) where the block is method of lifting which are applied to WP of the compilation of respondents, lifting the load :

$$y_{ijk} = \eta + \beta_i + \alpha_j + \tau_k + (\alpha\tau)_{jk} + \varepsilon_{ijk}$$

Where :

y_{ijk} = observation at β to - i and treatment a to $-j$, treatment t to-k

h = average value of all observations

β_i = block effect (method), $i = 1, 2$ with 1 = carrying of elbow dan 2 = carrying of shoulder

α_j = inclination block effect, $j = 1, 2, 3$ with 1 = 10^0, 2 = 20^0, and 3 = 30^0.

τ_k = loads treatment effect, $j = 1, 2$ with 1 = 20, dan 2 = 24.

$\alpha\tau_{jk}$ = interaction effect of two treatments are the interaction between inclination and load

Just like the one above to calculate the RP, the model is same as the one written above, only variable y_{ijk} replaced with a RP. The model formed from two factorial experimental designs where first factor is inclination of three levels (10^0, 20^0, and 30^0) and second factor is the load of goods with two levels (20 kg and 24 kg) where the block is located. method of lifting weights. and *Manggul*) that are applied to measure RP.

Results

a) Duration Of Working Period and Resting Period When Lifting A Return Roll

After manual lifting experiment, working periods can be calculated and tabulated in table 1 which contain data of responses from 8 respondents tested carrying of shoulder method, 20 kg load and inclination 10. The responses obtained in the form of a heart rate and length of lifting weights. Working period when lifting is tabulated as well.

Table 1 contain data of responses from 8 respondents who were tested using shoulder method, 20 kg load and inclination 20. The responses obtained were in the form of a HR and duration of lifting varied. It is shown in this figure shoulder activities require distance much more far away, and the respondents have durability where one minute equals 58.3 meters.

b) Effect of Inclination, Load and Lifting Methods on Working and Resting Period

1) *Effect of Inclination, Load and Lift Method on Working Period (Minutes)*

Following is an experimental design effect of inclination, load and lift method on the WP (Minutes). Factorial Design model formed with two treatments and one block. (table 1). ANOVA results in Table 2 show that all null hypotheses state they are rejected significantly because all P values are below confidence level ($\alpha = 0.05$).

Table 1. Working Period, Resting Period and Distance Travel based on inclination, load and lifting methods (minutes)

Working Period based on inclination, load and lifting methods (minutes)				
Inclination	Lifting Methods			
	COS (Carrying On Shoulder)		COE (Carrying On Elbow)	
	Load 20kg	Load 24kg	Load 20kg	Load 24
10^{o}	7.89	3.94	5.46	2.86
20^{o}	3.64	3.46	2.70	2.51
30^{o}	2.85	2.98	2.69	2.50
Resting Period based on inclination, load and lifting methods (meters)				
Inclination	Lifting Methods			
	COS (Carrying On Shoulder)		COE (Carrying On Elbow)	
	Load 20kg	Load 24kg	Load 20kg	Load 24
10^{o}	0.79	1.01	0.91	1.01
20^{o}	1.64	0.96	0.91	0.77
30^{o}	1.00	1.38	0.98	1.98
Distance travel based on inclination, load and lifting methods (minutes)				
Inclination	Lifting Methods			
	COS (Carrying On Shoulder)		COE (Carrying On Elbow)	
	Load 20kg	Load 24kg	Load 20kg	Load 24
10^{o}	460.63	229.625	318.63	166.5
20^{o}	212.13	201.88	157.38	146.5
30^{o}	166.13	173.13	156.75	145.63

Table 2. Two-way ANOVA for working period and resting period to lifting methods, inclination, load, and inclination – load interaction treatments (1 minutes working period is equivalent to 58,3 meter working period).

Dependent variable	Source	F	P
Working Period (minutes)	Lifting methods	10.02	0.025
	Inclination	20.12	0.004
	Load	13.39	0.015
	Inclination*Load	11.05	0.015
Working Period (meters)	Lifting methods	9.94	0.025
	Inclination	20.05	0.004
	Load	13.38	0.015
	Inclination*Load	11.03	0.015
Resting Period (minutes)	Lifting methods	0.04	0.844
	Inclination	1.81	0.256
	Load	0.69	0.444
	Inclination*Load	3.23	0.126

Table 2 shows that for the working period model in the form of minutes and meters units, all the independent variables (lifting methods, inclination, load) were significant (p=0.05). However, the resting period model were not significant (p=0.05), meaning that only the working period is affected by lifting methods, inclination and load. Load, inclination and interaction inclination and load were significant (p=0.01).

Following is an experimental design effect of inclination, load and lift method on a WP (meter) where results of experiments shown in Table 1. Factorial Design model formed with two treatments and one block. ANOVA results in Table 2 show all null hypotheses are rejected significantly because all P values are below confidence level (α = 0.05).

2) *Effect of Inclination, Load and Lifting Methods on Resting Period (Minutes)*

Following is an experimental design effect of inclination, load and lift method on RP (Minutes) where experimental results in Table 1. Factorial Design model formed with two treatments and one block. ANOVA test in Table 2 show null hypotheses failed to be rejected significantly because all P values above level of confidence (p=0.05).

Discussion

Working period was time after lifting RR while HR indicate 100 bpm to 160 bpm. Resting period was time after Anaerobic Threshold (AT) was reached until time at basal metabolic conditions. Determination of rest periods based on age, KAM (Maximum Aerobic Ability) and HR recovery. VO_2 was determined by age (assumed constant), workload, air temperature, and motion. When VO_2 was in maximum condition, endurance increase.

Based on diagram analysis, results showed that for inclination 10° WP was high when COS, load 20Kg, inclination of 10°. This because light loads and low inclination were low in WP and shorter RP. For inclination 20°, foot support is large so energy expenditure is large, shorter working time. For inclination of 30°, biomechanic foot load was heavier so that ability to lift was lower so average rest time was short because it was affected by ability of a good Cardio Respiratory Vascular which results in a decrease in speed of HR.

Based on ANOVA tests on effect of inclination, expenses and lifting methods on WP and RP, all null hypotheses rejected significantly because P values below confidence level ($p=0.05$). There was difference in the response of WP when there was interaction between inclination and load. But there was no difference in response of RP when there was an interaction between inclination and load given different lift method blocks.

Conclusion

Based on ANOVA test on the effect of inclination, expenses and lifting methods on WP and RP. This shows there was a difference in response to the WP when there was an interaction between inclination and load given different lift method blocks, but there was no difference in response of the RP when there was an interaction between inclination and load given different lift method blocks.

Acknowledgement: Authors acknowledge funding support from Directorate General of Higher Education, Ministry of Technology Research and Higher Education, Republic of Indonesia.

Ethical Clearance. The present study were conducted in accordance with the principles and procedures that were approved by Health Research Ethical Clearance Commission, Universitas Airlangga, Surabaya, Indonesia

Conflicts of Interest: The authors declare no conflict of interest.

References

1. McDermott, H., Haslam, C., Clemes, S., Williams, C. and Haslam, R.. Investigation of manual handling training practices in organisations and beliefs regarding effectiveness. *Int. J. Ind. Ergon*. 2012; 42(2): 206–211.
2. William J., Wiehagen and Fred C. Turin. Ergonomic Assessment of Musculoskeletal Risk Factors at Four Mine Sites : Underground Coal, Surface Copper, Surface Phosphate, and Underground Limestone. Pittsburgh, PA, Information Circular 9475; 2004.
3. Burgess-Limerick, R. B. Reducing Musculoskeletal Risk in Open Cut Coal Mining. ACARP Proj. C11058 Final Rep.; 2004.
4. Chung, M. K., Lee, Y. J., Lee, I. and Choi K. L. Physiological workload evaluation of carrying soft drink beverage boxes on the back. *Appl. Ergon*. 2005; 36 (1): 569–574.
5. Tualeka, A. R. and Kalamillah, H. Association between Duration Working with Lung Disruption Condition using Pulmonary Vital Capacity (PVC) Lathe Worker at Yogyakarta, Indonesia test on. *Indian J. Forensic Med. Toxicol*. 2019; 13(2): 396–400.
6. Sunaryo, M., Sakinah, Z., Afwinaluthfanny, F., Abduh, M. and Tualeka, A. R.. The Relationship of Noise and Blood Pressure toward Labor in Ground Handling Section of Sultan Hasanuddin Airport Makasar. 2014; 3(12): 43–48.
7. Chung H. and Wang, M. J.. The effects of container design and stair climbing on maximal acceptable lift weight, wrist posture, psychophysical , and physiological responses in wafer-handling tasks. *Appl. Ergon*. 2001; 32 (1): 593–598.
8. Banks, A. D., Engineering, M., and Antonio, S.. Progressive Fatigue Effects on Manual Lifting Factors. *Hum. Factors Ergon. Manuf.* 2009; 19 (5): 361–377.
9. Van Der Beek, A. J., Erik Mathiassen, S., Windhorst, J. and Burdorf, A. An evaluation of met : hods assessing the physical demands of manual lifting in scaffolding. Appl. Ergon. 2005; 36 (2): 213–22.
10. Grandjean, E.. *Fitting the task to the Man*, 1st Edition. London: Taylor & Francis; 1986.