Work Physiology Evaluation of Laundry Workers

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Abstract. This study aimed to assess cardiovascular strain during laundry operations in terms of physical workload, based on heart rate changes and level of pain complaints. Researchers measured resting and working heart rates and calculated cardiovascular load (%CVL), cardiovascular strain (%CVS), reserve heart rate (%RHR), energy expenditure, oxygen consumption, and measure level of pain complain in 6 laundry workers using Nordic Body Map questionnaire (NBM). Based on the result of %CVL and %CVS, the work in laundry was classified as acceptable level. Similarly, a high-level category was recorded for %RHR in moderate of energy expenditure. However, there are very pain level complain for hand using NBM questionnaire. Thus, there is a need to redesign the work content of equipment used and keep the physical workload in acceptable level, as this will increase their productivity and reduce their health risk.

1. Introduction

Ergonomics field of study includes Ergonomics of physical science, Cognitive Ergonomics, Ergonomics of Organization [1]. Physical ergonomics include human anatomy, anthropometry, work physiology and biomechanics. Work physiology approach is an aspect in industrial engineering that focuses on the metabolic requirements, the performance of the functions of the body and its components in the design of work and workplaces. Measurement of human physical activity aiming to do a job that can be measured by two criteria: operational criteria and physiology criteria [2]. Based on the physiology criteria, energy that is needed for human to work in the industry with 8 hours work should not exceed 30% - 40% of maximal aerobic capacity (VO2 max) of workers concerned. Physical workload that can exceed those limit will result in a number of adverse effects, for example: decrease of work performance, excessive fatigue, including the potential for injuries and accidents[2].

The laundry business developed in many towns where there are many students, workers and households using the laundry services to facilitate everyday activities [3]. Especially in Jogjakarta, the industry development is also due to tourism and education. The high human need for laundry services gives good impact to economic development and employment equity. Some work elements in the laundry job includes weighing and sorting dirty clothes, washing, drying, ironing and packing the clean clothes. Based on preliminary survey of Tarwaka et al [4], the work process of ironing is the most exhausting job among other work processes. This was due to the static work position of the worker at work, the work station and facilities did not correspond with the user’s anthropometry, and
the ambient temperatures are quite hot. This study aimed to assess cardiovascular strain during laundry operations in terms of physical workload, based on level of pain complaints and heart rate changes.

2. THEORETICAL REVIEW

2.1 Physical Workload
The workload is the number of activities that must be completed by a person or group of people during a specific time period under normal circumstances [5]. The workload arising from the interaction between the needs of the task/job, working conditions, skills, behavior, and perception of the operator. While capacity is the ability of man to do a job. The workload is the difference between workload demands of an assignment with a maximum capacity of a person's mental load in motivated condition [6]. The workload includes physical workload and mental workload [7]. Physical workload can be found in workers who are more physically utilize to complete their work such as lifting, carrying, and holding.

2.2 Measurement of Physical Workload
Physical work is something that can be done if a worker has energy, because it is useful to support muscle contraction. The result of extensive research on work physiology have shown that energy expenditure rate of a work is linearly related to the amount of oxygen consumed by the body and to heart rate [8].

2.2.1 Oxygen Consumption
The human body needs energy to sustain/maintain the basic functions of life eventhough no similar activities carried. The lowest energy expenditure that is needed to maintain the basic functions of life are called basal metabolism (basal metabolism) [8]. Each individual has different basal metabolic rate, some of the factors that influence these differences are gender, age, and weight.

Based on the explanation, physical workload can be grouped into several levels based on expended energy (energy expenditure). Several studies of work physiology showed that the energy expended to work directly proportional to the amount of oxygen consumed and heart rate [8]. Dr. Lucien Brouha has classification tables of workload in physiological reactions, to determine severity of a job, as shown in Table 1.

| Work Level    | Energy expenditure | Heart Rate | VO₂      |
|---------------|--------------------|------------|----------|
|               | Kcal / min         | Kcal / 8h  | Rate / min | Liter / min |
| Unduly Heavy  | >12.5              | >6000      | >175      | >2.5        |
| Very Heavy    | 10.0 – 12.5        | 4800 – 6000| 150 – 175 | 2.0 – 2.5   |
| Heavy         | 7.5 – 10.0         | 3600 – 4800| 125 – 150 | 1.5 – 2.0   |
| Moderate      | 5.0 – 7.5          | 2400 – 3600| 100 – 125 | 1.0 – 1.5   |
| Light         | 2.5 – 5.0          | 1200 – 2400| 60 – 100  | 0.5 – 1.0   |
| Very Light    | < 2.5              | < 1200     | < 60      | < 0.5       |

2.2.2 Heart Rate
Heart rate, the number of heart beats per minute, is another commonly used physiological measure of physical workload. Heart rate is commonly used to estimate energy expenditure or physical strain during sports, work or daily activities [9]. Extensive research has shown that for moderate work, heart rate is linearly related to oxygen consumption [10]. Based on Rodahl (1989), an increase in the potential of the pulse of rest until maximum employment measured by HR reserve.

\[
\% \text{ HR Reserve} = \frac{HR_W - HR_R}{HR_{max} - HR_R} \times 100
\]

2.2.3 Physical Strain

The classification of workload based on the comparison between working heart rate and maximum heart rate that caused by cardiovascular load (%CVL) [11]. It can be stated as:

\[
\% \text{CVL} = 100 \times \frac{(HR_W - HR_R)}{(HR_{max} - HR_R)}
\]

Furthermore, cardiovascular strain (CVS) was determined as the ratio of change in heart rates between heart rate of work and heart rate of rest to the initial (resting heart rate) as stated to the formula below [9].

\[
CVS = 100 \left[ \frac{HR_W - HR_R}{HR_R} \right]
\]

Where HR\(_W\)= working heart rate and HR\(_R\)= resting heart rate, Astrand and Rodahl’s categories of work intensity were used to classify %CVS: light (HR\(_W\)< 90); moderate (90 ≤ HR\(_W\)< 110); heavy (110 ≤ HR\(_W\)< 130), very heavy (130 ≤ HR\(_W\)< 150) and extremely heavy (150 ≤ HR\(_W\)< 170). Consequently, %CVS was classified as follows: 0%–50% = acceptable, no action required; 51%–80% = moderate, action required within a few months; 81%–120% = high, action required within a few weeks; 121%–150% = very high, action required within a few days and 151%–180% = intolerable, action required immediately [10]

2.2.4 Nordic Body Map

Nordic Body Map is a subjective measurement tools like questionnaire used to determine the parts of muscle experiencing symptoms ranging from discomfort (mildly ill) to very pain [12], here are four indicators in the level of complaints that indicate the pain level of body; A indicates no pain felt; B indicates moderate pain; C indicates painful; D indicates very painful. This questionnaire using the image of the human body which is divided into 9 main body part that is the neck, shoulders, upper back, elbows, lower back, hips, knees and ankles. From 9 body parts are then broken down into 28 parts of the body.

3. METHOD

3.1. Subject and Object

The research was conducted among 6 healthy laundry workers in range of age between 25 to 40 years old who volunteering on research. Participants are female worker who work in average period of 8 hours a day. They worked in Cuisine Laundry, Sleman, Yogyakarta. All participants were engaged in operations that involved at work such as washing, material handling, ironing, cleaning and so on. In addition, the object of research is the heart rate of work and rest.

3.2 Research Procedure
Heart Rate Measurement
Heart Rate measurement at 30 minutes before break time
Heart Rate measurement at 30 minutes after break time
Interview & Nordic Body Map Questionnaire

Figure 1. Research Procedure

Based on Figure 1, there are three times measurements to determine the value of working heart rate. The pulse rate measured by placed the second, third, and fourth fingers upper the radials artery, the examiner then count the pulse in one minute [13]. The value of working heart rate was measured at 30 minutes after the worker starts the job, 30 minutes before break time, and 30 minutes before the worker finish the job. Each measurement was conducted twice measurement for 1 minute for each and calculate the average value in order to get the final value. In addition, resting heart rate was measured at 30 minutes after break time while the worker does nothing. On the research process, the worker does the job naturally. Based on the result of working heart rate and resting heart rate, it can be calculated as cardiovascular load and strain in order to know the emergence level of heart, heart rate condition, energy expenditure and oxygen consumption needed by workers to do the job. In addition, the interview directly and fulfilling Nordic body map questionnaire was conducted at the end of session in order to identify the level of complaints for each part of body and its cause.

4. RESULT AND DISCUSSION

Based on the data collected, it can be shown the result as following Table 2 that shows the basic statistics of range, mean, median and standard deviation value. The participants’ mean age was 31.67 years (in range 29-38), mean of body height is 1.575 m (in range 1.53-1.62), mean of body mass is 53.33 kg (in range 47-56), while mean of body mass index (BMI) is 21.50 (in range 20.08-22.77). Normal BMI is 18.5–24.9, while 20.08–22.77 is regarded as normal [14], so none of the workers were underweight or more than slightly obese. In addition, mean of heart rate of rest is 90.33 bpm (in range 88.5-91.5 bpm), heart rate of work is 102.81 bpm (in range 99.17-105.84 bpm), and maximal heart rate is 168.33 bpm (in range 162-173 bpm).

The median of age is 30.5 years (standard deviation: 4.18), median of body height 1.58m (standard deviation: 0.034), median of body mass is 54.5 kg (standard deviation: 3.44) and body mass index’ median is 21.96 bpm (standard deviation: 1.28). In addition, median for heart rate of rest is 90.25 bpm (standard deviation: 1.125), heart rate of work is 103.17 bpm (standard deviation: 2.57), and maximal heart rate is 169.5 bpm (standard deviation: 4.18).

Table 2. Data collected of laundry workers

| Statistics | Age (years) | Body Height (m) | Body Massa (Kg) | BMI (Kg/m2) | HRrest (bpm) | HRwork (bpm) | HRmax (bpm) |
|------------|-------------|----------------|-----------------|-------------|-------------|-------------|-------------|
| Range      | 29 - 38     | 1.53 - 1.62    | 47 – 56         | 20 - 22.7   | 88.5 - 92   | 99.2 - 106  | 162 - 173   |
| Mean       | 31.67       | 1.575          | 53.33           | 21.50       | 90.33       | 102.81      | 168.33      |
| Median     | 30.5        | 1.58           | 54.5            | 21.96       | 90.25       | 103.17      | 169.5       |
| StDev      | 4.18        | 0.034          | 3.44            | 1.28        | 1.125       | 2.57        | 4.18        |

The table 3, represents value of %CVL, %CVS, %RHR, Energy expenditure and Oxygen consumption. The mean value of %CVL is 15.99% (in range 11.32-23.6), it means the %CVL data was classified on the acceptable level or in range <30%. Then, value of %CVS is 13.69% (in range 9.8-19.6%) that can be classified on acceptable level or in range 0-50%(Astrond & Rodahl, 1986). On the
other side, %RHR is 15.99% (in range 11.3-23.6%), energy expenditure is 5.292 Kcal/min (in range 4.99-5.58 Kcal/min), and oxygen consumption is 1.057 liter/min (in range 0.99-1.116 liter/min). In addition, the median value of %CVL is 15.61% (standard deviation: 4.55), %CVS is 13.69% (standard deviation: 3.76), %RHR is 15.61% (standard deviation: 4.55), energy expenditure is 5.32 Kcal/min (standard deviation: 0.24), and oxygen consumption is 1.063 liter/min (standard deviation: 0.0494).

Table 3. Cardiovascular load, strain, reserve heart rate, energy expenditure and oxygen consumption

| Statistics | %CVL | %CVS | %RHR | Energy Expenditure (Kcal/min) | Oxygen Consumption (liter/min) |
|------------|------|------|------|-----------------------------|-------------------------------|
| Range      | 11.32-23.6 | 9.8-19.6 | 11.3-23.6 | 4.99-5.58 | 0.99-1.116 |
| Mean       | 15.99 | 13.81 | 15.99 | 5.292 | 1.057 |
| Median     | 15.61 | 13.69 | 15.61 | 5.32 | 1.063 |
| StDev      | 4.55 | 3.76 | 4.55 | 0.24 | 0.0494 |

The table 4 represents the results of Nordic body map questionnaire in order to identify the level of complaint for each part of body that has complaint during completing the work. The research was collected data for 18 parts of body that has complained by respondents. The result was following the table below that shows the percentage of participants to fulfill the questionnaire.

Table 4. Results of Nordic body map questionnaire

| No | Location       | Level of Complaints (%) | A | B   | C   | D   |
|----|----------------|--------------------------|---|-----|-----|-----|
| 1  | Left shoulder  | 33.33                    | 16.67 | 50.00 | 0   |
| 2  | Right shoulder | 33.33                    | 16.67 | 50.00 | 0   |
| 3  | Back           | 50.00                    | 0   | 50.00 | 0   |
| 4  | waist          | 50.00                    | 16.67 | 33.33 | 0   |
| 5  | left elbow     | 0                        | 33.33 | 66.67 | 0   |
| 6  | right elbow    | 0                        | 33.33 | 66.67 | 0   |
| 7  | Left lower arm | 0                        | 50.00 | 50.00 | 0   |
| 8  | Right lower arm| 0                        | 50.00 | 50.00 | 0   |
| 9  | left wrist     | 33.33                    | 33.33 | 33.33 | 0   |
| 10 | right wrist    | 33.33                    | 33.33 | 33.33 | 0   |
| 11 | left hand      | 33.33                    | 16.67 | 33.33 | 16.67 |
| 12 | right hand     | 33.33                    | 16.67 | 33.33 | 16.67 |
| 13 | left knee      | 0                        | 50.00 | 50.00 | 0   |
| 14 | right knee     | 0                        | 50.00 | 50.00 | 0   |
| 15 | left ankle     | 83.33                    | 0    | 16.67 | 0   |
| 16 | right ankle    | 83.33                    | 0    | 16.67 | 0   |
| 17 | left foot      | 16.67                    | 50.00 | 33.33 | 0   |
| 18 | right foot     | 16.67                    | 50.00 | 33.33 | 0   |

Based on the table 4 above, A indicates no pain felt; B indicates moderate pain; C indicates painful; D indicates very painful. It can be seen that the highest level of complaints in the very painful level is left hand (16.67%) and right elbow (16.67%). The complaint of moderate pain are highest rate on left lower arm, right lower arm, left knee, right knee, left foot and right foot for each part of body is in
percentage 50% of respondent's complaints. In addition, part of body that listed in no pain complaint as shown on the table above.

5. CONCLUSION
The work physiology content of laundry workers usually was normal and not pose high risk to the cardiovascular strain of the workers, that were classified as acceptable level in range < 50%. On the other hand, there are two part of body which need attention that were right hand and left elbow. Therefore, it is necessary to redesign the working steps of laundry worker to reduce the level of painful and increase productivity of the workers. Two main improvements suggested based on this research are to minimize lifting activity and provision equipment which could make laundry workers activity easier. Thus, it would reduce pain of the workers during laundry activity.

REFERENCES
[1] Scott, P., Kogi, K., & McPhee, B 2010 Ergonomics guidelines for occupational health practice in industrially developing countries. Darmstadt: International Ergonomics Association.
[2] Sitohang, D. R., Winaisingthias, M., &Iridiastadi, H 2010Evaluasi Beban Fisik Pada Industri Manufaktur (Industri Pembebanan Komponen Pesawat Terbang Dan Industri Sepatu). J@ TI TEKNIK INDUSTRI, 5(2), 119-126.
[3] Husain, S., Lisi, I. Z., & Susanti, E 2013 Evaluasi Beban Fisik pada Industri Manufaktur (Laundry) (Studi di Kecamatan Samarinda Ulu). JURNAL BERAJA NITI, 2(10).
[4] Tarwaka, S. H., & Sudiajeng, L 2004 Ergonomi untuk keselamatan, kesehatan, kerja dan produktivitas UNIBA, Surakarta.
[5] Herrianto 2010 in Ginting, S. Pengaruh Beban Kerja terhadap Status Gizi Pekerja Peternakan Ayam di Desa Silebo-lebo Kabupaten Deli Serdang. Medan: Politeknik Kemenkes. 2013.
[6] Henry R. Jex 1988 in Akriyanto, L. A. Pengukuran dan Analisis Beban Kerja Fisik dan Mental Pengemudi Bus AKDP Rute Solo-Semerang. Surakarta: Universitas Muhammadiyah Yogyakarta. 2014.
[7] Wignjosoebroto & Wiratno 2000 Evaluasi Ergonomis Dalam Proses Perancangan Produk. Proceeding Seminar Nasional Ergonomi, 1-4.
[8] Wicken, C. D. 2004 An Introduction to Human Factors Engineering. New Jersey: Pretince Hall
[9] Ismaila S O, Oriolowo K T, and Akanbi O G 2013 "Cardiovascular Strain of Sawmill Workers in South-Western Nigeria." International Journal of Occupational Safety and Ergonomics 19, no. 4 (2013): 607-611.
[10] Rodahl & Astrand 1986 Text Book of Work Physiology New York: McGraw-Hill Book Company
[11] Tarwaka, Solichul HA, and Sudiajeng L 2004 "Ergonomi untuk keselamatan, kesehatan, kerja dan produktivitas" UNIBA, Surakarta
[12] Corlett, E.N 1992 Static Muscle Loading and the Evaluation of Posture Edited by Wilson, J.R. & Corlett, E.N Evaluation of Human Work a Practical Ergonomics Methodology London: Tailor & Francis.
[13] Swartz, Mark H 1995 "Bukuajadiagnostikfisik." EGC
[14] Singh, D., Park, W., & Levy, M. (1-7). 2009. Obesity does not reduce maximum acceptable weights of life. ApplErgon