IMPROVEMENT OF WORK QUALITY BY APPLYING ERGONOMIC APPROACH INCREASES PERFORMANCE OF TRADITIONAL PORTERS IN BADUNG MARKET DENPASAR

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ABSTRACT

Female traditional porters work every evening at Badung market from 7 pm to 3.30 am. Age interval of the porters is 18 – 40 years. The weight of goods carried by a single porter is 60 – 100 kilograms plus 1-2 kilograms of the basket's weight, carried on the head. The distance of each porting activity is 100 meters. From ergonomic concept, the burden is excessive and may cause injuries such as damage of intervertebral discs, pain, excessive fatigue and head and neck muscles disorder. The symptoms are more obviously seen in those over 40 years old for most of them are not very capable of working, even some of them need medical treatment. To overcome this non-ergonomic work condition, a work quality improvement was carried out to 11 sampled porters, including work position, method, carrying weight and equipment design in order to improve the unnatural work position and to give chance to them to have an active rest as well as to alter the static work system to be more dynamic. Results of this study were: (1) average of pressure force on L5/S1 before improvement was 7,967.65 ± 66.78 N and after improvement was 2,983.26 ± 16.63 N; (2) average of musculoskeletal complaints before improvement was 61.07 ± 0.72 and after improvement was 42.76 ± 1.21; (3) fatigue average before improvement was 77.44 ± 3.93 and after improvement was 50.36 ± 2.21; (4) pulse rate average before improvement was 150.61 ± 1.06 pulses/minute and after improvement was 119.51 ± 1.39 pulses/minute; and (5) average productivity before improvement was $1.78 \times 10^{-2} \pm 0.01 \times 10^{-2}$ and after improvement was $2.24 \times 10^{-2} \pm 0.03 \times 10^{-2}$. The results analysis showed that improvement of work quality by applying ergonomic approach could decrease the pressure force on L5/S1 of 60.94 % ($p<0.05$), musculoskeletal complaints of 29.99 % ($p<0.05$), level of fatigue by 34.97 % ($p<0.05$) and work load by 42.59 % ($p<0.05$), as well as could increase the work productivity to 26.04 % ($p<0.05$). Therefore, it is conclused that the improvement of work quality by applying ergonomic approach increases performance of traditional porters.

Key words: work quality, ergonomic approach, performance, traditional porters.

INTRODUCTION

The number of female traditi onal porters working on irregular basis in the evening is estimated to be around 50 – 100 persons, and they do not have permanent customers nor certain base. While those female porters working regularly every evening are 159 porters who start to work at 7 pm until 3.30 am. The age range of the porters is 18 – 40 years. The estimate weight carried by a single porter is 60 – 100 kilograms plus 1 – 2 kilograms of the basket's weight, carried on the head. The distance that the porters have to carry the goods is 100 meters. The porters at Badung traditional market are therefore not free from getting fatigue during work. According to Manuaba (1983), the effect of improper working posture is easy fatigue if the ill posture is maintained for too long without rest. This condition is caused by unnecessary contraction of certain non-relevant muscles or of those that do not connect directly or by contrac tion of static muscles.

According to the ergonomic concepts, the above process is described as excessive and it can be the causal factor of several injuries such as intervertebral discs damage, pain, severe fatigue, and muscles disorders around the head and neck areas. Result of an interview done to the porters revealed that they had experienced the above conditions but had ignored them due to the work demand, inadequate knowledge, and economical factors. When their ages reached 40 years or above, the injuries would occur in more obvious manners, even some would never be able to work again or would need medical treatment (Hutagalung, 2007). According to Adam and Hulton (1981), rupture of the spinal cord segment was associated with breakage of the upper and lower part of the intervertebral discs, which resulted from a pressure force of 10,025 Newton. While the permitted maximum limit of weight as recommended by NIOSH (National Institute of Occupational Safety and Health) is a pressure force of 6,400 Newton on L5/S1 (NIOSH, 1981; Chaffin and Andersson, 1991). Other than that, use of propulsion/power device that is actually needed to carry the goods is not efficient. This is due to the fact that the shape of the basket for carrying goods has over-sized diameter causing the distance between porter's weight force position and the goods' weight force to become longer, thus results in increase of the moment. Moreover, the non-ergonomic work posture makes the propulsion/lifting capacity to move the load (goods and basket) become greater. Thus, the pressure force on the vertebrae L5/S1 increases and the workload gets heavier.

Improvement measure should be taken to overcome the above problem such as on work posture, workload and tool's design to develop a natural work posture and to provide resting time to the porters as well as to change the work system from static to dynamic.

MATERIALS AND METHODS

This study was causal comparative research with a treatment by subject design. Subjects of this study were 11 porters and all were females with discussing characteristics of age, body weight, height, work experience, resting pulse rate and education. Target population of this study was all female traditional porters at Badung market, Denpasar who worked both regularly and irregularly every evening of a total of 259 porters, but covered population was 159 female porters who worked daily in the evening. Variables of this study were identified and classified as follows: (a) independent variable is work quality improvement, which is combination of several improve ments related to ergonomic concepts such as work posture, work method, basket design (modification) and porting load; (b) dependant variable is performance related to aspect of musculoskeletal complaints, level of fatigue, workload and productivity; and (c) control variable is subject condition (age, gender, body weight, working experience, level of education, health and anthropo metry) and environmental condition (wet temperature, dry temperature, humidity and wind velocity).

Before treatment, the subjects were asked to carry weight as far as 100 meters according to their usual condition from 8 pm to 2 am for one week and they were assessed on several aspects such as environmental condition, resting pulse rate, working pulse rate, musculoskeletal complaints, and work productivity, followed by giving them two days of washing out period. Next, the subjects worked by applying ergonomic approach such as reducing the load according to biomechanical calculation, utilizing an ergonomic basket, giving regular rest and sweet tea. Working hours and measurement were similar to those before improvement and the results were analyzed statistically using t-test.

RESULTS

Age interval of subject was 20 – 35 years with average 29.27 ± 3.50 years. Body weight of subjects was 44 – 69 kilograms with average 50.96 ± 5.05 kilograms. Height was in the range 144.50 – 160.00 cm with 153.28 ± 8.27 cm in average. Average of work experience was 7.64 ± 2.38 years with interval 4 – 12 years.

Subjects' anthropometry used in designing work tools (basket) was average height of upper most position of hand 181.14 ± 6.27, average of body height 153.23 ± 5.05, average of arm's length 16.36 ± 1.00, average of hand's width 8.05 ± 0.47.

Calculation of photography showed that referential point before improvement, when the load was in position of (a) Initial Ho, height before load was carried (32 cm); (b) parallel with center of moment M4, as tall as knee (35 cm) with angle $\alpha_4 = 55 \pm 0.78°$; (c) parallel with center of moment M3, as tall as L5/S1 (68 cm) with angle $\alpha_3 = 131 \pm 0.89°$; (d) parallel with center of moment M2, as tall as part between shoulder and neck (90 cm) with $\alpha_2 = 62 \pm 0.63°$; and (e) maximum height, load was on porter's head when porting activity (118 cm), with angle $\alpha_1 = 48 \pm 0.63°$, while angle degree of lower arms and upper arms to horizontal surface was $15 \pm 0.78°$ and $60 \pm 0.78°$ respectively (figure 1 and figure 2). The referential point after improvement, when the load was in position of (a) initial Ho, height of before load was carried (32 cm); (b) $\alpha_4 = 60.64 \pm 1.12$ °; (c) $\alpha_3 = 124.46 \pm 1.13°$; (d) $\alpha_2 = 70.64 \pm 0.67°$; and (e) $\alpha_1 = 55.64 \pm 0.92°$, while angle degree of lower arm and upper arm to horizontal surface was $17.91 \pm 0.83°$ and $85.73 \pm 0.91°$ respectively.

DISCUSSION

Based on the above findings, a conclusion was made that the study subjects were proper, skilled and capable of undertaking their job. Frequency of resting pulse was 69.25 – 85.77 pulse/minute with average 79.14

± 2.08 pulse/minute. From educational aspect, the number of subjects with level of education of junior high school (SMP) was 18.18 % and elementary school (SD) level was 81.82 %. Thus, level of education was considered as suffi cient for doing porting job.

Meanwhile, for calculating biomechanics, the above data needed to be supplemented with other anthropometric data such as average of shoulder's height 126.32 ± 5.06, average of thigh's height 51.27 ± 4.15, average of knee's height 48.14 ± 2.31, average of belly's width 24.82 ± 2.09 and average of thigh thickness 12.14 ± 1.47. On the basket designing, height of upper most position of hand was measured by using 5 cm percentile, but body height, arm's length, hand's width were measured by that of 95 cm.

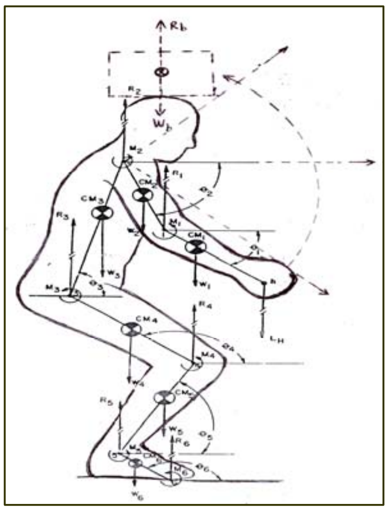

Figure 1 Model of Reaction Force and Moment Analysis on Static Force System

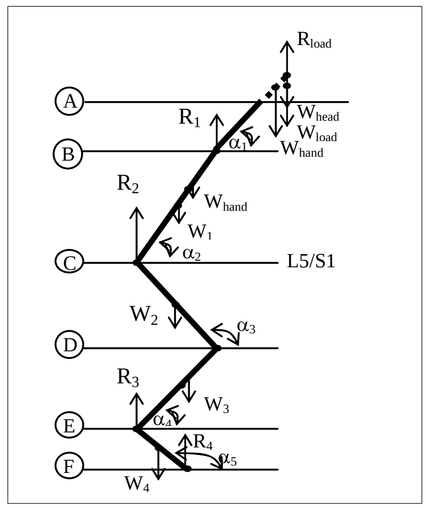

Figure 2 Reaction Force and Moment Analysis on Static Force System

Simple Modeling and Pressure Force on L5/S1

Measurement of pressure force on L5/S1 before improvement was 7,637.15 ± 66.78 N and that after improvement was 2,983.26 ± 16.63 N. The difference of pressure force on L5/S1 before and after improvement was 4,653.89 N or decreased by 60.94 %. Adam and Hulton (1981) stated that the rupture of intervertebral disc happened with a pressure force of 5,448 N. The most effective effort to reduce effect of risk is by improving work quality to make the performance of traditional porters increase (Hutaga lung, 2007). According to the pres sure force on L5/S1, working with workload after treatment of 29.21 kilograms.

T-test result showed proba bility score of 0.00 ($p < 0.05$), meaning that significant change had occurred after improvement of work quality. The limit of normal lifting capacity suggested by NIOSH was in accordance with pressure force of 3,500 N on L5/S1 and maximum porting weight of 6,500 N (Van der Beek, et. al., 2000). Therefore, the power of pressure force on L5/S1 before work quality improvement exceeded normal porting capacity of 4,237.15 N or around 124.62 % and passed over the limit of maximum porting capacity of 1,137.15 N or about

17.49 %. After improvement, L5/S1 decreased below normal or lessened by 416.74 N.

Ergonomic Design of Basket

The results of basket measurement before treatment were height 50.25 cm, upper diameter 63.55 cm, lower diameter 54.24 cm, weight 1.35 kilograms and volume 123,762.14 cm^3. These measure ments were not ergonomic if compa red to the subjects' anthropometry, hence a new design was required. Regarding the aspects above, calculations data of an ergonomic basket were height 32 cm, diameter 32 cm, weight 1.01 kilograms and volume 25,722.88 cm^3. With this volume capacity, the basket should be able to carry load at a maximum of up to 28 kilograms. The volume design matched with biomechanical calculation that maximum porting load was 30.25 kilograms.

Work Environment

The result of before improve ment showed that: (a) temperature around 26.40°C to 27.50°C with average 26.96 ± 0.12°C; (b) humidity around 63% to 67% with average 64.29 ± 0.38°C; and (c) wind velocity around 0.20 m/sec to 0.50 m/sec with average 0.34 ± 0.11 m/sec. After improvement, the result of measurement were (a) temperature around 26.40°C to 27.50°C with average 26.95 ± 1.95°C; (b) humidity around 63% to 67% with average 64.33% ± 2.16°C; and (c) wind velocity around 0.2 m/sec to 0.6 m/sec with average 0.35 ± 0.01 m/sec. Manuaba (1998) stated that a simple category of work had temperature limit of 30°C to 35°C and that of moderate category had temperature limit of 29°C to 30°C. Limit of ourdoors' comfort was at temperature 29°C to 31°C. Oetoko (1980) asserted that temperature indicator allowed on work environment minimum 21°C – 30°C. Limit of outdoors' environmental comfort was at temperature 22 - 28°C with relative humidity 70 – 80% (Jaya, 2008), which means that these aspects do not affect significantly on the increasing of workload.

Based on difference test of work environment by using t-independent, probability score of temperature was 0.94 or above 0.05 ($p>0.05$), of humidity was 0.77 or more than 0.05 ($p>0.05$) and of wind velocity was 1.00 or more than 0.05 ($p>0.05$), which mean there were no significant changes of before and after intervention.

Musculoskeletal Complaints

The average score before working on before and after treatment is 35.60 ± 0.55 and 35.29 ± 0.41, with average difference was 0.31. Based on t test, the probability is 0.14 ($p > 0.05$), meaning that there was no significant difference of musculoskeletal complaint before working prior to and after treatment. Musculoskeletal complaint score after working showed an average before treatment was 61.07 ± 0.72 and after treatment was 42.76 ± 1.21. From t test it was found that there was significant difference between before and after work quality improvement.

On the work quality improve ment, from the beginning this research involved laborers actively, technicians, basket makers, basket distributors, and government. Manuaba (2006) explains that the implementation of SHIP approach is important for defining, analyzing and solving problem in order to get a continuing result by involving efficient technologies and laborers actively. The explanation is clarified by Caple (2006) that in order to be more effective in solving the ergonomic problems, technicians and other stake holders should be collaborating as a team to obtain a continuing result based on holistic approach.

Fatigue

Average of the calculation of fatigue valuation during the lapse of before working to before treatment was 39.95 ± 2.26 and after treatment was 40.01 ± 2.11. From the calculation of t test, the probability was as high as 0.18 ($p > 0.05$), it means that there is no significant difference between before working and after treatment. It shows that the level of fatigue of laborers before working and after treatment is in the same condition.

Generally, the fatigue score after working prior to treatment is 77.44 ± 3.93 and after treatment is 50.36 ± 2.21 with average difference of 27.08, or there is a fatigue reduction after work quality improvement in the amount of 34.97 %.

The highest categories of fati gue that were experienced by the laborers were in this order: activity weakening was as high as 30.00 or 38.75 %, physical fatigue as high as 29.04 or 37.50 % and motivation weakening was as high as 18.39 or 23.75 %. After improvement of work quality, it was found that activity weakening score was 19.52 or decreased to 34.76 %, the physical fatigue score was 18.89 or decreased to 34.95 % and motivation weakening score was 11.96 or decreased to 34.97%. From the calculation of t test, the probability was as high as 0.00 ($p < 0.05$), meaning there was a significant difference between before and after work quality improvement.

Workload

The average resting pulse rate before treatment was 79.14 ± 2.08 pulses/ minute and after treatment 78.48 ± 3.01 pulses/ minute with a range of 69.25 pulses/ minute to 85.77 pulses/ minute, so the average resting pulse rate was 78.81 ± 2.65 pulses/ minute. The resting pulse rate before and after work quality improvement was not quite different. The average resting pulse rate of porters of Badung market is not quite different from that in the study by Adiputra (2008) on the work load in preparing land for cultivation on the field using hoes with four forks and one fork, which resulted in resting pulse rate of 77.31 ± 7.71 and 77.31 ± 7.71, respectively.

Based on the t test, the avera ge resting pulse rate before and after treatment was not different signify cantly at a probability of 0.14 ($p > 0.05$). The result of measurement showed the average working pulse rate before treatment was 150.61 ± 1.06 pulses/ minute and after treatment 119.51 ± 1.39 pulses/ minute. It shows that after the improvement of work quality, working pulse decreased to 31.09 pulse/minute or by 20.64 %.

The result of t test on working pulse rate showed that the average working pulse rate before and after treatment was different significantly, at a probability score 0.00 ($p < 0.05$), indicating work load of porters before and after treatment differed significantly. According to Adiputra (2002), the greater body activities cause greater metabolism of the body, so oxygen needs become greater and pulse rate increases.

Productivity

Work productivity measured in this study was based on partial productivity calculation, in which output was mass number average carried at a single evening. Input was workload average taken by the porter during working hours. In this matter workload was equal to the average working pulse rate. The result sho wed that average score of produc tivity before improvement was 1.78 x 10^{-2} ± 0.01 x 10^{-2} and after improvement was 2.24 x 10^{-2} ± 0.03 x 10^{-2} with average difference 0.04 x 10^{-1}. The result of t-test indicated probability of 0.00 ($p < 0.05$), which means there was a significant change before and after improvement. Productivity increased to 26.04 % after improvement on work quality. Overall, increase of work produc tivity was enhanced by decrease in musculoskeletal complaints by 29.99 %, reduction of fatigue by 34.97 %, and decrease in workload by 42.58 %, which all resulted after impro vement.

The data showed that frequency of porting activity done by a single porter before improvement was 16 times with 29.21 kilograms of load for each activity that made a total weight of 963.77 kilograms. The data indicated that the total weight carried by each porter every evening was about the same.

CONCLUSION

Based on the study results, it can be concluded that:

Work quality improvement by applying ergonomic approach can decrease musculoskeletal complaints of traditional porters at Badung market by 29.99 %.

Work quality improvement by applying ergonomic approach can decrease level of fatigue of traditi onal porters at Badung market by 34.97%.

Work quality improvement by applying ergonomic approach can reduce workload of traditional porters at Badung market by 42.59%.

Work quality improvement by applying ergonomic approach can increase work productivity of tradi tional porters at Badung market in 26.04 %.

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