The Variation of Work Productivity and Muscle Activities at Different Levels of Production Target

Nurhayati Mohd Nur1, Siti Zawiah Md Dawal2, Mahidzl Dahari2 and Nurul Zuhairah Mahmud Zuhudi1

1Aerospace Department, Universiti Kuala Lumpur, Malaysian Institute of Aviation Technology, Jenderam Hulu, 43800 Dengkil, Selangor, Malaysia
2Department of Mechanical Engineering University of Malaya, Lembah Pantai, 50603 Kuala Lumpur, Malaysia

Abstract. This paper aims to investigate the variation of work productivity and muscle activities among workers performing industrial repetitive tasks at four different levels of production target. The work productivity and muscle activities data were recorded from twenty workers at four levels of production target corresponding to ‘participative (PS1)’, ‘normal (PS2)’, ‘high (PS3)’ and ‘very high (PS4)’. The results showed that worker productivity was found to increase at higher production target and there was a significant change ($p < 0.005$) in work productivity across the four different production targets. The muscle activities were found to increase at higher production target and correspond to more discomfort and a higher rate of muscle fatigue. The results indicated that working with a higher production target results in higher worker productivity, but could lead to higher risk of WMSDs.

1. Introduction

A number of quality management systems (QMS) applied and implemented in the manufacturing industries such as ISO 9001, ISO/TS 16949 and AS 9000. It is clearly stated in all the QMS to measure customer’s satisfaction. One of the elements in the customer’s satisfaction measurement is on time delivery. There are many improvement activities implemented by the industry in order to achieve the target such as KAIZEN, lean manufacturing and JIT (just in time). The improvement activities are well known in the industry and remarkable as appropriate tools to satisfy the customer and achieve high productivity. Instead of fulfilling QMS requirements and satisfy customers, manufacturing industry also tends to set high production target to get higher returns on their investments [1]. High production targets produce higher work productivity compared to low targets [2], but the effect on the worker’s safety and health is unknown.

Productivity is related to the ability of the individual to produce. Thus, work productivity is referred as the ability of the workers to produce or deliver products that are expected from their jobs [3]. In the industrial-repetitive task, productivity is measured through observed work productivity (OWP) [3]. The OWP measure was based on the production target [4, 5]. The production target is obtained from the production standard time of the tasks. The standard time is inherently linked to the frequency of repetitive movements [6]. In the industrial-repetitive task, the workplace is not self-chosen, and the worker must follow a specified production standard time [7]. Work productivity is important to achieve customer’s satisfaction, higher returns, more profits and more business opportunity. Therefore, it is frequently viewed from economic perspectives while the workers' role and workers' productivity state at any specific time is often underrated [3]. A few studies found that workers performing industrial-repetitive tasks are exposed to the risk of work-related musculoskeletal
disorders (WMSDs) [8, 9]. WMSDs is caused by the accumulation of muscle fatigue [10] and it has a great impact on task performance [11].

Social Security Organization (SOCSO) reported that WMSDs cases are increasing every year [12]. The compensation cost paid due to this disease is also higher compared to other industrial diseases [13, 14]. WMSDs represents approximately one-third of workers’ compensation costs in the Malaysian private industry [15]. Workers performing industrial-repetitive tasks may expose to the WMSDs risks. In addition, a high intention of the industry to achieve high production targets may provide an opportunity for the increase of the WMSDs cases reported. However, a study on the variation of work productivity, muscle activities and WMSDs risks at different levels of production target is still scarce. Therefore, it is timely to investigate the relationship and find ways to optimize work productivity with minimum risk of WMSDs.

2. Methodology

2.1 Experimental Task

An experimental task is conducted to collect data on the work productivity and muscle activities at different levels of production target. The task selected is an industry based, repetitive and involved upper limb muscles.

2.2 Subjects

Twenty healthy subjects, 10 females and 10 males were involved in this study. The subjects were between the ages of 22 and 45. All subjects were right-handed dominance and have no previous history of musculoskeletal injuries.

2.3 Production Target

The experimental tasks were performed in four levels of production target. The targets are participative target (PS1) which is referred to participative standard time, normal target (PS2) (referred to 100% normal standard time), high production target (PS3) (referred to 126% normal standard time) and very high production target (referred to 140% normal standard time). A high production target which is equivalent to 126% of the normal standard time is a realistic work pace in the manufacturing industry [16]. A very high production target is 140% of the normal standard time [2]. In the participative production target, no standard time is given to the subjects. They are allowed to perform the task at their own pace.

2.4 Experimental Task Procedure

Before the experimental task, the data on weight and height of the subject are recorded. Surface Electromyography (sEMG) was used to measure forearm muscles activity throughout the experiment. The surface electrodes were placed over the belly of the following muscles bilaterally [17]:-

1. Flexor Carpi Radialis – Left and Right
2. Extensor Carpi Radialis – Left and Right

The surface electrodes and lead electrode cable which are placed on the belly of the muscles are connected to the Noraxon Telemomyo 2400 (Noraxon, INC USA), using small signal transmitters carried on a belt by the subjects. Muscles activity signals picked up by the electrodes were transmitted telemetrically to a receiver, which was connected to a computer. The task involved repetitive assembly actions similar to actual industrial assembly task. The task is a process of assembling foam ring to the plastic clip as presented in figure 1. The subjects performed the repetitive task for 1 hour for each production target.
3. Results

3.1 Work Productivity
The result of mean work productivity at four levels of production target is shown in table 1. The work productivity was found to increase at higher production target. A one-way repeated measures ANOVA was conducted to compare the average of work productivity with production targets (PS1, PS2, PS3 and PS4). There was a significant effect of production targets on the work productivity (Wilk’s Lambda=0.188, F(3,17)=24.51, p < 0.0005, multivariate partial eta squared = 0.812).

| Production Target | Work productivity (mean) |
|-------------------|--------------------------|
| PS1               | 774                      |
| PS2               | 851                      |
| PS3               | 890                      |
| PS4               | 928                      |

3.2 Muscle Activities
In this study, the root mean square (RMS) value of the EMG data was analysed. The mean and standard deviation of the normalized RMS for all muscles is presented in table 2. The mean values of normalized RMS represent muscle activities in the study.

| Production Target | FCRR Mean (Standard Deviation) | FCRL Mean (Standard Deviation) | ECRR Mean (Standard Deviation) | ECRL Mean (Standard Deviation) |
|-------------------|--------------------------------|--------------------------------|--------------------------------|--------------------------------|
| PS1               | 8.319 (1.824)                  | 10.311 (2.825)                 | 10.107 (2.811)                 | 10.248 (3.349)                 |
| PS2               | 8.824 (1.827)                  | 11.010 (2.809)                 | 10.377 (2.344)                 | 11.409 (3.416)                 |
| PS3               | 9.596 (2.257)                  | 11.890 (2.496)                 | 11.035 (2.552)                 | 11.974 (3.431)                 |
| PS4               | 9.925 (2.402)                  | 12.475 (2.921)                 | 11.904 (3.154)                 | 12.702 (3.486)                 |

The RMS values were found to increase at higher production targets. The very high production target (PS4) showed the highest value of RMS for all muscles. The highest RMS was found at Extensor Carpi Radialis-Left (ECRL). A repeated measures ANOVA results were summarized in table 3 and it can be seen that there was a significant effect of productivity targets on the muscle activities for all muscles (P < 0.05).

| Muscle | Wilk’s Lambda | F     | P     | Partial Eta Squared |
|--------|---------------|-------|-------|---------------------|
| FCRR   | 0.478         | 6.179 | 0.005 | 0.522               |
| FCRL   | 0.410         | 8.142 | 0.001 | 0.590               |
| ECRR   | 0.420         | 7.819 | 0.002 | 0.580               |
| ECRL   | 0.222         | 19.830| 0.000 | 0.778               |
The muscle fatigue rate for all muscles was summarized in table 4. Muscle fatigue rate is found higher at higher production target.

| Production Target | Muscle Fatigue Rate |
|-------------------|---------------------|
|                   | FCRR    | FCRL    | ECRR    | ECRL    |
| PS1               | 0.044   | 0.082   | 0.083   | 0.053   |
| PS2               | 0.045   | 0.084   | 0.088   | 0.059   |
| PS3               | 0.046   | 0.086   | 0.092   | 0.105   |
| PS4               | 0.050   | 0.096   | 0.103   | 0.115   |

4. Discussion
The aim of this study is to investigate the variation of work productivity and muscle activities while performing industrial repetitive tasks at different levels of production targets. This study was conducted in the ergonomics laboratory under a controlled environment. The subjects were industrial workers and performing the industrial repetitive task. The work productivity and muscle activities of the workers were recorded during the experimental tasks. The results showed that worker productivity was found to increase at higher production targets. The results are aligned with the findings of a previous study [2]. The results also showed that the workers work harder in order to achieve the higher output.

In participative production target, no production target is assigned to the workers and they are free to decide their work productivity. The results showed that they are able to achieve work productivity with 5% higher compared to the normal target. In addition, the work productivity for the normal target is found 18% higher than expected. However, the workers are not able to achieve the target for higher production target (126% and 140% normal standard), even though the results are higher than the normal production target. Based on the ANOVA result, there is a significant effect (p < 0.005) of production target to work productivity and the result suggests that there was a change in work productivity across the four different production targets.

The muscle activities for all muscles were found to increase at higher production target and the muscles are most active at very high production target, followed by high and normal production target. The lowest muscle activities are found in participative production target. It can be observed that there was a steady increase in the muscle activities while the production target is higher and showed that there is a significant difference (p < 0.05) in the muscle activities across the four production target.

Further analysis of the muscle activities over time for all muscles involved was found to increase over time at four levels of production target. All muscles gave the positive slope of muscle activities and indicate the sign of muscle fatigue. The higher muscle activities should correspond to more discomfort [18] and a higher rate of muscle fatigue. The most active muscle in this study is left Extensor Carpi Radialis (ECRL) followed by left Flexor Carpi Radialis (FCRL), right Extensor Carpi Radialis (ECRR) and right Flexor Carpi Radialis (FCRR). The results showed that the left muscles are more active compared to the right muscles. The reason for this is due to the task performed required more left muscles movement compared to the right muscles.

The overall results indicated that WMSDs risk is higher in higher production target and workers tend to slow down due to WMSDs risks which then results to lower productivity. The result is consistent with the findings of a previous study [19]. The results provide a significant reference to the industries where industrial engineers and managers should more concern with the production target assigned and the risks of WMSDs to the workers.

5. Conclusion
In conclusion, work productivity was found to increase at higher production target and there was a significant change in work productivity across the four different production targets. However, the muscle activities were found to increase at higher production target and correspond to more discomfort and a higher rate of muscle fatigue. The results indicated that working with a higher production target
results in higher worker productivity, but could lead to higher risk of WMSDs. The results can be used as a reference in work productivity planning to optimize work productivity with minimum risk of WMSDs to the workers.

6. References

[1] Erik B 2005 Opt. Mag 4(5) 27-35.
[2] Shikdar A and Das B 2003 Ergonom. 46 466–81.
[3] Escorpizo R 2008 Int. J. Ind. Ergon. 38 291–7.
[4] Burton W N, Conti D J, Chen C Y, Shultz A B and Edington D W 1999 J. Occup. Environ. Med. 41 863–77.
[5] Lerner D, Amick B C, Lee J C, Rooney T, Rogers W H and Chang H 2003 Med. Care 41 649–59.
[6] Andersen J H, Kaergaard A, Mikkelsen S, Jensen U F, Frost P, Bonde J P, Fallentin N and Thomsen J F 2003 Occup. Environ. Med. 60 649–54.
[7] Sundelin G and Hagberg M 1992 Scand. J. Work Environ. Health 18 262–8.
[8] Moore A and Wells R 2005 Ergonom. 48 859–73.
[9] Chung M K, Lee I and Kee D 2005 Ergonom. 48 331–41.
[10] Ma L, Chablat D, Benni F, Zhang W 2009 Int. J. Ind. Ergon. 39 211–20.
[11] Joana S, Joao S B, Pedro R R M, Alberto S M, Rubmin S and Mario A P V 2016 Int. J. Ind. Ergon. 52 78-91.
[12] SOCSO 2014 Social Security Organisation (SOCSO)Annual Report 2014.
[13] Joseph B, Naveen B, Suguna A and Surekha A 2016 J. Health Manag. 18 545–54.
[14] SOCSO 2011 Social Security Organisation (SOCSO)Annual Report 2011
[15] Mohamed Azman A M 2007 Occupational disease in Asian countries World Soc. Secur. Forum, Moscow.
[16] Bosch T, Mathiassen S E, Visser B, de Looze M P and van Dieën J H 2011 Ergonom. 54 154–68.
[17] Lehman K R, Psihogiost. J P and Meulenbroek R G J 2001 Ergonom. 44 719–38.
[18] Kuijt-Evers L F M, Bosch T, Huysmans M A, de Looze M P, Vink P 2007 Appl. Ergon. 38 643–54.
[19] Resnick M L and Zanotti A 1997 Comput. Ind. Eng. 33 185–88.