International Journal of Industrial Ergonomics 56 (2016) 59–68

Contents lists available at ScienceDirect

International Journal of Industrial Ergonomics

journal homepage: www.elsevier.com/locate/ergon

The relationship between work productivity and acute responses at different levels of production standard times

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ARTICLE INFO

Article history:
Received 9 December 2014
Received in revised form
10 August 2016
Accepted 24 September 2016
Available online 2 October 2016

Keywords:
Work productivity
Acute response
Muscle activity
Work-related musculoskeletal disorders

ABSTRACT

Work productivity is typically associated with production standard times. Harder production standards generally result in higher work productivity. However, the tasks become more repetitive in harder production standard time and workers may be exposed to higher rates of acute responses which will lead to higher risks of contracting work-related musculoskeletal disorders (WMSDs). Hence, this paper seeks to investigate the relationship between work productivity and acute responses at different levels of production standard times. Twenty industrial workers performed repetitive tasks at three different levels of production standard time (PS), corresponding to “normal (PSN)”, “hard (PSH)” and “very hard (PSVH)”. The work productivity and muscle activity were recorded along these experimental tasks. The work productivity target was not attainable for hard and very hard production standard times. This can be attributed to the manifestations of acute responses (muscle activity, muscle fatigue, and perceived muscle fatigue), which increases as the production standard time becomes harder. There is a strong correlation between muscle activity, perceived muscle fatigue and work productivity at different levels of production standard time. The relationship among these variables is found to be significantly linear ($R = 0.784$, $p < 0.01$). The findings of this study are indeed beneficial to assess the existing work productivity of workers and serves as a reference for future work productivity planning in order to minimize the risk of contracting WMSDs.

1. Introduction

Work productivity is a determinant factor in the manufacturing industry, it is measured periodically in order to monitor workers' performance, which in turn, reflects the performance of the organization. Work productivity is crucial in the assembly line since the process directly involves workers, manual handling and repetitive tasks. In addition, most of the tasks in the manufacturing industry are repetitive and previous studies have shown that repetitive tasks are associated with WMSDs (Escorpizo and Moore, 2007; Nordander et al., 2009; You and Kwon, 2005). Therefore, work productivity planning should be done in advance in scenarios involving high repetition of task in order to sustain a good work productivity level whilst minimizing the risks of developing WMSDs.

The current trend in industrial tasks is moving towards more time-intensive production with standardized, short cycle time (Neumann et al., 2002) and limited completion time (Wartenberg et al., 2004) since the aim of the manufacturing industry is to attain a high work productivity levels. Process standard time, such as work pace or duty cycle time for a particular task is determined by a process engineer based on task time analysis. Furthermore, the workplace is not chosen by the worker and it is obligatory for a worker to follow a predetermined task time (Sundelin and Hagberg, 1992). Hence, the worker's capacity and productivity state are often overestimated during the planning stage.

The work productivity target is set based on a specific production standard time and therefore, work productivity can be evaluated directly through the number of products produced per day or per hour. The value of productivity loss can be calculated directly if the workers do not perform well according to predetermined standards. Such work productivity assessment and monitoring method is applied specifically for assembly workers (Escorpizo,

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http://dx.doi.org/10.1016/j.ergon.2016.09.009
0169-8141/

2008). However, the work productivity assessment method is insufficient when it comes to identifying work productivity due to the functional incapacity of workers (Allesina et al., 2010). In addition, the worker's capacity is typically underrated due to the constant drive for organizations to achieve high work productivity (Escorpizo, 2008). Thus, workers may be exposed to a higher risk of contracting WMSDs while carrying out tasks during high work productivity targets or hard production standard times. It is therefore imperative that work productivity assessment is evaluated based on multiple perspectives, and several ergonomics assessment should be contemplated during the initial stage of work productivity planning.

The combination of ergonomics and assembly engineering is vital to ensure that the work productivity targets assigned to workers are within their capacity without causing adverse health effects, in particular, WMSDs. The performance or personal capacity of each individual worker is critical since it affects the overall productivity of workers. Previous studies have shown that workers who work beyond their capacity levels result in work productivity loss (Finneran & O'Sullivan, 2010). Work productivity loss is not only characterized by time losses, but also the functional incapacity of workers. In such cases, the workers are present for work, but they are functionally limited due to WMSD-related pain or discomfort (Finneran & O'Sullivan, 2010).

Work productivity is one of the measures which have been commonly investigated in various studies related to musculoskeletal disorders. However, studies that focus on work productivity and musculoskeletal disorders (MSDs) among industrial workers are rather sparse, whereas the number of MSD cases increases each year (SOCSO, 2011).

Musculoskeletal disorders refer to conditions which involve muscles, nerves, tendons and other soft tissues (NIOSH, 1997). In general, WMSDs develop over time (Putz-Anderson, 1988) and therefore the peak and cumulative musculoskeletal discomfort experienced by workers may be used to predict future musculoskeletal pain (Hamberg-van Reenen et al., 2008). Previous studies have shown that exposure to short-term responses (acute responses) indicates the development of WMSD risks in the short term (Westgaard and Winkel, 1996).

Most of the studies on work productivity and acute responses are conducted independently (Alavinia and Burdoff, 2009; Lerner et al., 2003; Resnick and Zanotti, 1997; Shikdar and Das, 2003; Van den Heuvel et al., 2010) and there is a lack of studies which focuses on the relationship between work productivity and acute responses as well as the relationship between work productivity and WMSD risks (Conway and Svenson, 2001; Finneran & O'Sullivan, 2010). Knowledge on the relationships will indeed be beneficial as it forms a groundwork to develop a model to assess work productivity at different levels of production standard time and serves as a reference for industries to design tasks which will optimize and sustain work productivity while minimizing the risk of contracting WMSDs among workers.

2. Methodology

2.1. Acute response variables

The acute responses involved depend on the tasks executed. Performing industrial repetitive tasks involve muscle activity and thus muscle fatigue occurs when the muscle fails to maintain the required force or the desired work output level. The accumulation of muscle fatigue causes functional disability, which later develops into WMSDs (Ma et al., 2009) as a long term effect. Therefore, in relation to repetitive tasks, the acute response variables being investigated are muscle activity, muscle fatigue and perceived muscle fatigue.

2.2. Subjects

A total of 20 subjects were recruited for the series of experimental tasks, comprising 10 male and 10 female industrial workers. The subjects were between the ages of 22 and 45. All the subjects had no previous history of musculoskeletal injuries. The subjects gave their written consent prior to the start of the study. The study was approved by the local Ethics Committee. The descriptive data of the subjects are given in Table 1.

2.3. Tasks and muscles involved

The tasks involved repetitive assembly actions, similar to the actual industrial assembly task. The subjects were given two types of component, plastic clips and plastic foam rings. These components were placed into a polybox and plastic container, respectively. The subjects were instructed to assemble the ring foam onto the plastic clip using a simple jig, which pushes the foam onto the clip, as shown in Fig. 1.

The task is categorized as light assembly task with high repetition. The muscles involved were identified based on the task executed. The involved muscles are identified from consultation with an anatomist. The muscles which are the focus of this study are the forearm muscles, as listed follows:

i Right and Left Flexor Carpi Radialis (FCRR, FCRL)
ii Right and Left Extensor Carpi Radialis (ECRR, ECRL)

According to Milerad and Ericson (1994), the extensor muscles are one of the most active muscle groups and these muscles have been the focus of several studies related to repetitive tasks (Bosch et al., 2011; Mananas et al., 2005; Nag et al., 2009; Rietveld et al., 2007). The flexor muscles are one of the forearm muscle groups which have been investigated among subjects while carrying out assembly tasks (Finneran & O'Sullivan, 2013; Gooyers and Stevenson, 2012; Nag et al., 2009).

The muscle activity was recorded using surface electromyography (EMG). EMG is an experimental technique concerned with recording and analysis of myoelectric signals (Konrad, 2005). EMG detects myoelectric signals generated by muscle cells when these cells contract and at rest, and the signals are recorded using the instrument's reading software.

2.4. Production standard times

The levels of production standard time (PS) used in the experimental tasks were listed as follows:-

1 Normal production standard time (PSN)
2 Hard production standard time (PSH)
3 Very hard production standard time (PSVH)

Normal production standard time was based on the 100% normal standard time. A hard production standard (PSH) time was

Table 1
Descriptive data of the subjects.

	Age (Year)		Weight (kg)		Stature (cm)	
	Male	Female	Male	Female	Male	Female
Mean	31.90	30.10	71.4	54.9	168.7	152.6
Standard deviation	8.98	6.98	9.15	5.79	5.68	8.78