IOP Conf. Series: Materials Science and Engineering **248** (2017) 012015 doi:10.1088/1757-899X/248/1/012015

The Mediating Effects of Muscle Activities on the Relationship of Production Standard Time and Work Productivity

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Abstract. The aim of this study is to investigate the mediation effects of muscle activities on the relationship between production standard time and work productivity. The work productivity and muscle activities data are collected from twenty workers (10 males, 10 females) while performing industrial repetitive tasks at three different levels of production standard time corresponding to "normal", "hard" and 'very hard". Mediation test was performed on the data and the results showed that muscle activities act as a mediator in the relationship between production standard time and work productivity. The result indicates the importance of assessing muscle activities in relation to work productivity at different levels of production standard time in order to optimize work productivity and reduce WMSDs risks.

1. Introduction

Work productivity can be referred as the worker's ability to produce goods that are expected from his or her job [1]. The work productivity is commonly measured based on the quantity produced per hour during specified production target in a standardized and short cycle time. With this approach, it is insufficient to identify the effect of the functional incapacity of workers associated with the work productivity [2]. Thus, workers may be exposed to a higher risk of contracting WMSDs while carrying out tasks in high work productivity targets or hard production standard times. WMSDs are recognized for their adverse impact on worker productivity and health [3, 4]. It has been suggested that work exposure such as task demands and work capacity may influence the occurrence of muscle fatigue, discomfort and injuries [5] which are associated with WMSDs. WMSDs cases are increasing every year [6] and the occurrence rate is still high. WMSDs provide a significant impact on the performance of the workers [7] and involved higher compensation cost [8]. Hard production standard time is a form of work exposure related to task demands. In general, tasks become more repetitive with hard production standard times, which will expose workers to higher muscle fatigue rate and WMSDs risks.

Muscle fatigue is related to muscle activity. Hence, muscle fatigue refers to a decline in muscle performance which is associated with intense muscle activity [9]. An increase in muscle activity signifies the development of muscle fatigue [10]. Thus, muscle fatigue is defined as the point at which the muscles are no longer able to sustain the required force or work output level [11, 12]. Muscle fatigue begins with the contraction of muscles and manifests itself eventually as a failure to proceed with the activity at the initial amount of force [12]. Muscle fatigue and muscle injury are interrelated to one another [9]. Workers with muscle fatigue may be at higher risk of developing WMSDs [13]. Based on the above argument, there is very high possibility workers are dealing with high muscle activities while performing the task with high work productivity target. However, it is unknown either muscle activities is the mediator for work productivity and it is timely to investigate the relationship.

2. Methodology

2.1 Measurement of Work Productivity and Muscle Activities
Work productivity and muscle activities data are collected from twenty workers (10 males, 10 females) while performing industrial repetitive tasks at three different levels of production standard time. The subjects were between 22 and 45 years old. The production standard times are listed as follows:

1. Normal (100% of the normal standard time)
2. Hard (126% of the normal standard time)
3. Very Hard (140% of the normal standard time)

2.2 Mediation Test
Mediation is a hypothesized causal chain in which one variable affects a second variable which in turn affects the third variable. The intervening variable (M) is the mediator and it mediates the relationship between a predictor (X) and an outcome (Y). This relationship is represented graphically in figure 1. In this study, M represents muscle activity, whereas X and Y represent production standard time and work productivity, respectively.

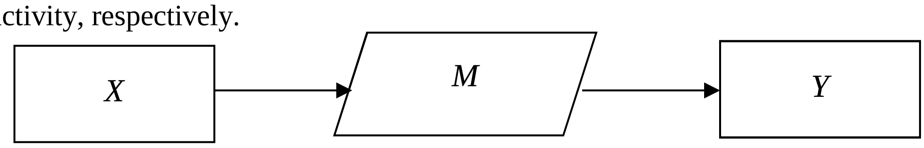

Figure 1. Graphical representation of the mediation model.

3. Results

3.1 Work Productivity and Muscle Activities
The result of mean work productivity at three levels of production standard time is shown in table 1.

Table 1. Work Productivity and Muscle Activities.

Production Standard Time	**Work Productivity (mean)**	**Muscle Activities (mean)** FCRR	FCRL	ECRR	ECRL
Normal	851	8.824(1.827)	11.010(2.809)	10.377(2.344)	11.409(3.416)
Hard	890	9.596(2.257)	11.890(2.496)	11.035(2.552)	11.974(3.431)
Very Hard	928	9.925(2.402)	12.475(2.921)	11.904(3.154)	12.702(3.486)

3.2 Mediation Analysis Results
The mediation effect of muscle activity on the work productivity is tested. The relationship between X and Y refers to the total effect of X and Y and is given by the value of c, as shown in figure 2.

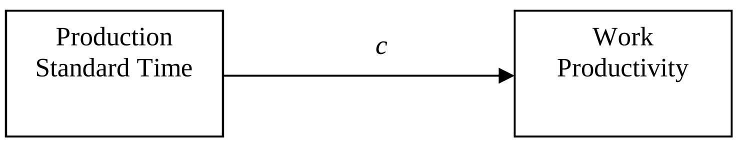

Figure 2. Total effect of X (production standard time) on Y (work productivity).

The direct effect of *X* on *Y* after controlling *M* is given by *c'*, as shown in figure 3.

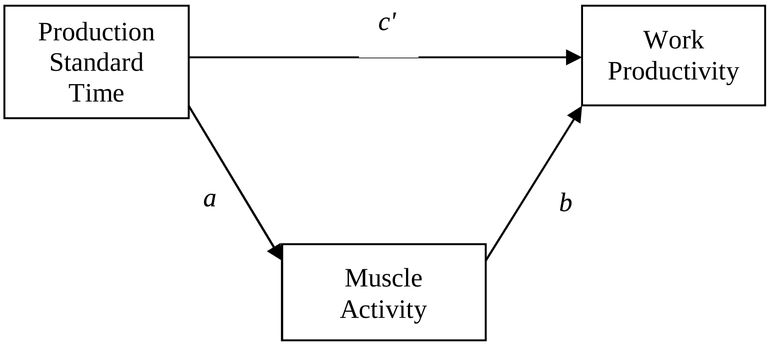

Figure 3. Direct and indirect effects of the mediation model.

Mediation analysis was carried out according to the procedure outlined by Baron and Kenny [14]. The results of the mediation analysis are summarized in table 2. It can be seen that the muscle activity acts as a mediator based on the following observations:

1. Production standard time significantly predicts work productivity
($c = 0.571$, $c \neq 0$).
2. Production standard time significantly predicts muscle activity
($a = 0.402$, $a \neq 0$).
3. Muscle activity significantly predicts work productivity while the production standard time is controlled ($b = 0.475$, $b \neq 0$).

Table 2. Summary of the mediation analysis results.

	Dependent Variable (Work Productivity)		
	Without Mediator	**With Mediator**	**Conclusion**
Production standard time	0.571	0.374	Mediation occurs
Muscle activity	-	0.475	

The unstandardized coefficient should either be zero or reduced significantly in the presence of mediation effects [14]. The results show that the value of the unstandardized coefficient decreases, which indicates the occurrence of partial mediation. However, according to Hayes [15], the terms ‘partial mediation’ and ‘full mediation’ are no longer applicable in the 21st century. The complete mediation model is shown in figure 4.

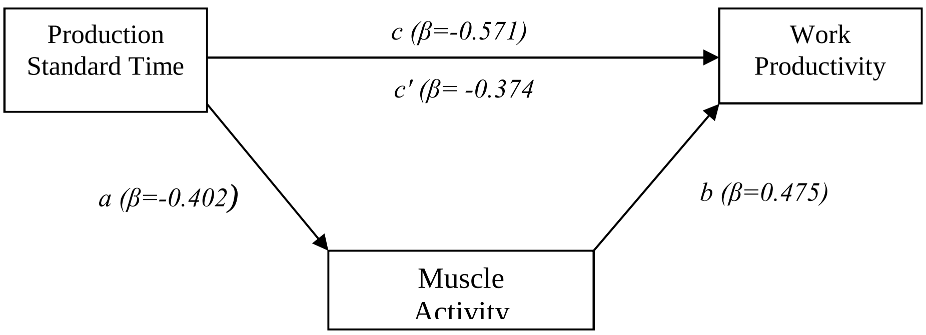

Figure 4. Complete mediation model.

The mediation model was validated using PROCESS add-on macro [16] which is available in the SPSS software and the results are summarized in table 3. The results reveal that there are no zeroes within the bias-corrected bootstrap confidence intervals, which indicates that the null hypothesis (i.e. H_0: mediation effects do not occur) can be refuted.

Table 3. Mediation results generated by PROCESS add-on macro.

Effect	Estimate	SE	t	p	Bias-Corrected Bootstrap Interval
c	0.1235	0.0242	5.0979	0.0000	(0.0139, 0.0790)
a	1.8590	0.5593	3.3236	0.0015	
b	0.0230	0.0061	3.7385	0.0004	
c'	0.0808	0.0241	3.3566	0.0014	
a*b	0.0427				

4. Discussion

Muscle activities are found to vary at different levels of production standard time. In general, muscle activities increases in harder production standard times, which reduces work productivity in terms of the percentage of normal production standard time. The increment of muscle activities over time signifies the development of muscle fatigue [17]. Muscle fatigue is an initiating factor of WMSDs [18] and it has been suggested that the accumulation of muscle fatigue causes WMSDs [12]. Previous studies suggested that WMSDs cause a reduction in work productivity [19].

The mediating test was conducted. The results show that muscle activities act as a mediator in this study. The muscle activities was used to predict work productivity while the production standard time is controlled ($\beta = 0.475$, $p < 0.05$ and $\beta = 0.374$, $p < 0.05$). The mediation test was validated using the procedure by Hayes [16]. The validation test shows that there are no zeroes within the bias-corrected bootstrap confidence intervals which indicate the presence of mediation. Hence, it is deemed necessary that the muscle activities of workers are assessed in relation to work design, particularly during the work productivity planning stage. Knowledge of the muscle activities will assist organizations to design tasks which will sustain work productivity and reduce the risk of WMSDs among workers.

5. Conclusion

In conclusion, muscle activities act as a mediator for production standard time and work productivity. The result indicates the importance of assessing muscle activities in relation to work productivity at different levels of production standard time in order to optimize work productivity and reduce WMSDs risks concurrently. A mediation model has been developed and validated. The model can also be used as a reference in other studies pertaining to muscle activities, work productivity and production standard time.

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