The Risk of Physical Fatigue At Different Level of Posture and Repetition During Manual Handling Task in Aerospace Manufacturing Industry

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***Abstract:** This paper aims toinvestigatethe risk of physical fatigue at different levels of posture and repetition during manual handling task. Ten subjects with nohistoryof musculoskeletal disorders performed manual handling tasks at three levels of posture and two levels of repetition. The task completion time is recorded during the experimental task and the subjects rated their perceived discomfort level after the task completion. The results indicated that the lower posture of hand at higher repetition resulted in higher perceived discomfort level that leads to higher risk of physical fatigue. The higher repetition requires higher rest time for recovery and required lengthy completion time. The findings of this study served as a reference to the manufacturing industry in manual handling task design and planning to mitigate issues related to work-related physical fatigue at different levels of posture and repetition that could lead to the risk of work-related musculoskeletal disorders (WMSDs).*

I. INTRODUCTION

Ergonomics is defined as the science that addresses human performance factors and related to the job, the workplace, tools, and the environment (McColley, 2016). Ergonomics is important to reduce stress, eliminate injuries and disorders associated with the overuse of muscles, bad posture, and repetitive tasks. This is accomplished by designing tasks, workspaces, controls, displays, tools, lighting, and equipment to fit the employee´s physical capabilities and limitations (Frieden, 2013).Ergonomics is the practice and research of the interaction between the human and the physical environment with the goal of optimizing human well-being and overall system performance (Dennerlein, 2016).

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It aims to create safe, comfortable and productive workspaces and applies scientific information about human cognition and behaviour to support the design of products and systems that enhance human well-being and performance (Maureen et al., 2015).

Ergonomic risk factors are the aspects of a job or task that impose biomechanical stress on the worker. Ergonomic risk factors are the synergistic elements of musculoskeletal disorders (MSD)risks(McColley, 2016). When workers doing manual handling task that is beyond their body capabilities and limitations, it will lead to the musculoskeletal system at risk (Middlesworth, 2015).

Working in the environments which are not or fewer ergonomics such as awkward posture, excess load or force and highly repetition may lead to the risk of work-related musculoskeletal disorders (WMSDs). WMSDs is resultant from working which may involve damage to the muscles, nerves, ligaments, joints, cartilage, and spinal discs. Mitigation of WMSDs is important because they are prevalent and costly (Salas et al., 2016). The types of WMSDs injuries included shoulder pain, back pain, carpal tunnel syndrome, epicondylitis, tension neck syndrome, and hand-arm vibration syndrome.

Work-related physical, psychosocial, and ergonomic factors are considered to contribute to the development of WMSDs such as shoulder complaints (Kanlayanaphotporn, 2014). According to the Kumar et al. (2015) manual material handling (MMH) task is considered to be an extremely risky work system as it may be associated with frequent occurring of work-related injuries to the concerned workers.

WMSDs are a major cause of suffering and disability among working-age adults (Madan, 2015). A number of work-related regional musculoskeletal syndromes include disorders of the neck, shoulder, elbow, hand and wrist and lower back (Panush, 2016). On top of that, musculoskeletal disorders (MSDs) are the non-traumatic soft tissue disorders that are caused and/or exacerbated by workplace exertions. These disorders require more days away from work than any other group of occupational diseases (Nimbarte, 2014).WMSDs problem represents a significant threat to employees' health and wellbeing across a wide range of industries and occupations (Joseph et al., 2016).

There are many factors that lead to WMSDs during a physical working task which are force, posture, and repetition. These have each been associated with increased operator discomfort in industry. Ergonomic interventions reducing the effects of these risk factors have been demonstrated to lower discomfort and at the same time increase productivity (Finneran& O'Sullivan, 2010).

The combinations of force, repetition, and postural work were found to have a positive relationship with WMSDs (Choobineh et al., 2007; Finneran& O'Sullivan, 2010).Best working performance becoming the target for every employee to reduce and prevent injuries during working. Thus, it is very important to investigate and analyse the effect of force, posture and repetition in order to provide ergonomics task and workstation that could minimize the discomfort level and at the same time reducing the risk of contracting WMSDs among workers.

II. METHODOLOGY

Experimental Task

An experimental task is conducted to collect data at different levels of posture and repetition. The taskselected is similar to aircraft's parts assembly process (installation of aircraft panel), which is categorised as repetitive task and also related to hand and shouldermovement.The subjects need to assemble the sheet metal panel on the provided structure using 4mm screw. The external force in the experimental task is constant whereby all subjects used the same type of tool (cordless drill) with a mass of 1.5kg. The level of posture and repetition is showed in Table 1 and in total there are six experiments are carried out at different levels of posture and repetition as stated in Table 2.

Table. 1 Level of Posture and Repetition

Level	Hand Posture	Repetition
1	45^o(hand up)	5
2	0^o	10
3	-45^o(hand down)	

Table. 2 No. of Experiment Involved

Experiment	Posture	Repetition
1	45^o	5 screws(R1)
2	45^o	10screws (R2)
3	0^o	5 screws (R1)
4	0^o	10 screws (R2)
5	-45^o	5 screws (R1)
6	-45^o	10 screws (R2)

Subjects

There are ten subjects involved in this study and all subjects were interviewed to ensure they had no history of MSDs.

Discomfort Level

The Borg Rating of Perceived Exertion (RPE) will be used to measure the discomfort level experienced by the subjects during the experimental task. The Borg's scale is shown in Table 3.

Table. 3 Borg's Scale

The Borg General Scale		
0	---	nothing at all
0.5	---	extremely weak (just
1	---	very weak
2	---	weak
3	---	moderate
4	---	somewhat strong
5	---	strong
6	---	
7	---	very strong
8	---	
9	---	
10	---	extremely strong

Experimental Task Procedure

The experimental tasks have been operated in a suitable area with adequate space and sufficient light. Before the commencement of the task, the tool and materials were prepared in a proper position for easy reachability of the subjects during the experimental task. Before the experiment, the subjects were briefed on the procedure to ensure they are fully understood on the task procedure and process.The subjects will be given time for training and familiarization before the experimental task begins.

All subject should perform six experiments with different level of posture and repetition as stated in Table 2. Task completion time has been recorded for each experiment counted from the installation of the first screw until the last screw.The three different levels of hand posture can be seen in Figure1.

Fig. 1 Three levels of posture - Level 1 (45^o), Level 2 (0^o) and Level 3 (-45^o)

Data Analysis

The data collectedfrom the experimental task werecompiled and analysed. The data are presented in terms of the completion time, average completion time, the perceived discomfort level and the average perceived discomfort level.

III. RESULTS

Task Completion Time The result of completion time is presented in Table 3.

Table. 3 Task Completion Time

Subjects	Task Completion Time					
	45 deg x R1	45 deg x R2	0 deg x R1	0 deg x R2	-45 deg x R1	-45 deg x R2
1	60 s	110 s	58 s	99 s	53 s	109 s
2	68 s	97 s	55 s	121 s	51 s	120 m
3	51 s	90 s	56 s	110 s	54 s	110 s
4	48 s	76 s	56 s	123 s	76 s	120 m
5	43 s	77 s	56 s	119 s	52 s	85 s
6	43 s	90 s	50 s	107 s	55 s	92 s
7	56 s	93 s	63 s	121 s	76 s	115 s
8	44 s	86 s	34 s	82 s	35 s	75 s
9	40 s	76 s	35 s	77 s	40 s	84 s
10	46 s	74 s	52 s	87 s	40 s	92 s
Average	50 s	93 s	52 s	110 s	53 s	104 s

Perceived Discomfort Level at Different Level of Posture and Repetition

The results of perceived discomfort rating from scale 0 to 10 at the posture of 45 degrees, 0 degrees and -45 degrees with two different levels of repetition is presented in Table 4.

Table. 4 Perceived Discomfort Rating

Subjects	Perceived Discomfort Rating					
	45 deg x R1	45 deg x R2	0 deg x R1	0 deg x R2	45 deg x R1	45 deg x R2
1	3	7	5	8	6	9
2	5	7	7	10	9	10
3	3	3	4	7	5	10
4	2	4	5	6	10	7
5	3	4	4	5	4	2
6	2	5	4	7	6	8
7	3	3	5	7	6	8
8	3	6	2	4	5	10
9	3	5	3	6	5	9
10	2	6	2	7	4	7
Average	3	5	4	7	6	8

IV. DISCUSSION

The aim of this study is to investigate the risk of physical fatigue at a different level of posture, and repetition while performing manual handling task at constant external force. This study has been conducted in the ergonomics laboratory under controlled environment. Ten subjects involved in this study and they performed manual handling tasks similar to aircraft manufacturing process during the experiment.The experimental task for this study has been performed by simulating the assembly of aircraft's panel. The experimental task was successfully performed by 10 male subjects and each subject has completed 6 experiments at different level of posture and repetition. The level of posturesusedis45 degree, 0 degree and -45 degree. Meanwhile, the level of repetition is divided into R1 (5 screws stallation/repetition) and R2 with 10 screws installation/repetition.

The completion time was recorded during the experimental tasks and Borg's scale has

been used to rate the perceived discomfort level.

The task completion time is taken when the subject starts to drill the first screw by using cordless drill and time is stopped when the last screw is fully assembled. Since in R1, less number of screws need to be assembled, the task completion time for R1 is lesser compared to the task of completion time of R2. All subjects took lesser time to complete low-level repetition (R1) in all different posture than high-level repetition (R2).It can be seen that at the low level of repetition R1 at the posture of 0 degree (52 s) is slightly higher than 45 degree (50 s). However, at posture -45 degree (53 s) is the highest average task completion time. In addition, for a high level of repetition R2, lesser average time at the posture of 45 degrees (93 s) and 0 degrees (110 s) was the higher average task completion time. The results indicated that the subjects took longer time and tend to slow down in higher repetition due to WMSD's (Santos et al., 2014).In this study, the muscles along the forearm until shoulder are involved. At a high-level of repetition, the neutral position of hand was the higher time taken to complete the task compared to awkward posture of 45 degree and -45 degree.

Meanwhile, the perceived discomfort of the subject's hand at a low level of repetition R1 is lower than a high level of repetition R2. However, the posture of -45 degree for low-level repetition also shows the result of high scale perceived discomfort compared to others posture for high-level repetition. It can be seen that posture of -45 degree at both levels of repetition are the highest instead of other postures.The perceived discomfort of subject's hand at a low level of repetition R1 is lower than a high level of repetition R2. However, the posture of -45 degree for low-level repetition also shows the result of high scale perceived discomfort compared to others posture for high-level repetition. The posture of -45 degree was the highest rate perceived discomfort where it was most discomfort for the hand during manual handling task while standing. Therefore, the experiments show that manual handling task was most difficult and high-risk factors were at the lower level position for both levels of repetition.

The higher repetition required higher recovery time, and more time required to complete the task. The workers will endure a certain level of fatigue to protect their output level by investing more resources and working harder. This behavior will continue until fatigue peaks and the worker unable to perform work at the same level. The result is aligned with previous study that workers discomfort effects due to awkward posture and high repetitive tasks which thenaffect the work productivity (Finneran& Sullivan, 2010).The overall results indicated that awkward posture of hand at higher repetition resulted in higher perceived discomfort level. The higher repetition requires increasing rest time for recovery and more time required to complete the task, leads to physical fatigue and the risk of contracting WMSDs.

V. CONCLUSION

In conclusion, it can be revealed that the awkward posture with high repetition will lead to higher discomfort level and has a higher chance ofWMSDsrisks.The awkward postures have made the task more difficult and affected the work's progress in terms of completion time and increasing the discomfort level. The result of this study is useful as a guideline to the aerospace manufacturing industry to minimize, overcome and eradicate the risk of physical fatigue among their workers and optimize worker productivity

REFERENCES

1. Choobineh, A., Tabatabei, S.H., Tozihan, M.H., and Ghadami, F. (2007). Musculoskeletal problems among workers of an Iranian communication company. Indian Journal of Occupational and Environment Medicine, 11(1), 32–36.
2. Dennerlein, J. T. (2016). Ergonomics and Musculoskeletal Issues. *International Encyclopedia of Public Health*, *2*, 577–584.
3. Finneran, A., & Sullivan, L. O. (2010). International Journal of Industrial Ergonomics Force , posture and repetition induced discomfort as a mediator in self-paced cycle time. *International Journal of Industrial Ergonomics*, *40*(3), 257–266. https://doi.org/10.1016/j.ergon.2010.01
4. Frieden, T. (2013). Ergonomics And Musculoskeletal Disorders. Retrieved November 17, 2016, from http://www.cdc.gov/niosh/topics/ergonomics/
5. Joseph, B., Naveen, B., Suguna, A., Surekha, A. (2016). Prevalence, Pattern and Factors Associated with Work-related Musculoskeletal Disorders (WRMD) among Housekeeping Workers in a Private Tertial Care Hospital in Bangalore. Journal of Health Management, 18(4), 545–554.
6. Kanlayanaphotporn, R. (2014). Changes in sitting posture affect shoulder range of motion. *Journal of Bodywork and Movement Therapies*, *18*(2), 239–243. https://doi.org/10.1016/j.jbmt.2013.09.008
7. Kumar, P., Parida, R., & Saha, E. (2015). Status survey of occupational risk factors of manual material handling tasks at a construction site in India. *Procedia Manufacturing*, *3*(Ahfe), 6579–6586. https://doi.org/10.1016/j.promfg.2015.07.279
8. Madan, I., & Grime, P. R. (2015). The management of musculoskeletal disorders in the workplace. *Best Practice and Research: Clinical Rheumatology*, *29*(3), 345–355. https://doi.org/10.1016/j.berh.2015.03.002
9. McColley, R. (2016). Force. Retrieved January 1, 2016, from http://www.ehs.iastate.edu/occupational/ergonomics/force
10. Maureen Hassall, Tania XiaoPenelope Sanderson, A. N. (2015). International Encyclopedia of the Social & Behavioral Sciences. *Human Factors and Ergonomics*, *2*, 297–305.
11. Nimbarte, A. D. (2014). Risk of neck musculoskeletal disorders among males and females in lifting exertions. *International Journal of Industrial Ergonomics*, *44*(2), 253–259. https://doi.org/10.1016/j.ergon.2013.01.007
12. Panush, R. S. (2016). Occupational and Recreational Musculoskeletal Disorders. *Kelley and Firestein's Textbook of Rheumatology*, *1*, Kelley and Firestein's Textbook of Rheumatology.
13. Salas, E. A., Vi, P., Reider, V. L., & Moore, A. E. (2016). Factors affecting the risk of developing lower back musculoskeletal disorders (MSDs) in experienced and inexperienced roadworkers. *Applied Ergonomics*, *52*, 62–68. https://doi.org/10.1016/j.apergo.2015.06.016