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Estimating the Physical Demand of Waterproofing Worker

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Abstract: Scientific methods that measure the physical demand requirements of a construction operation have not been arrived at maturity in construction community. It is attributed to the difficulty involved in performing controlled experiments on the operation and its' volatile jobsite environment. This paper presents a method that measures the physical demand requirement of the waterproofing activity and verifies the differences between various operations (e.g., a primer painting and a polyurethane coating) consisting of the activity. Two hypotheses, which are involved in the operations, are summarized as follows: [Hypothesis 1] when one performs the same amount of work; the one's average heart rate required for the polyurethane coating operation is higher than that required for the primer painting operation. [Hypothesis 2] when one performs the same amount of work, the one's break time required for the polyurethane coating operation is longer than that required for the primer painting operation.

Keywords: Waterproofing activity, physical demand, heartbeat ratio

I. INTRODUCTION

A. Research Background

The automation and mechanization of construction equipments and methods contributes improving the job-site health and accident issues in the construction industry. However, musculoskeletal diseases are major issue involved in workers' health and accident (Woo et al., 2001). Worker's postures vary according to the type of tasks, even if a same operation is performed at a construction site (Kim & Kim, 2010). Because the components of a building are broken down into slabs, walls, columns and ceilings, the worker of different trade has to work in a squatted sitting position or imbalanced standing position for a long time in many cases. The musculoskeletal disorders (MSDs) are caused by the workloads aggravated with the postures and muscle fatigue exceeding the physical capability of the workers (Woo et al., 2001). However, it is not easy to identify hazardous factors causing MSDs due to the dynamic construction work environments and non-standardized work procedures (Lee et al, 2010). In addition, the diversity of specialty contractors in a construction project makes it difficult to standardize a consistent safety and health management (Chang et al., 2009). Roja et al. (2006) claims that it is not easy to diagnose and treat MSDs. However, if one can objectively measure the physical phenomenon of workers, the MSDs can be prevented. Chang et al. (2009) and Kim et al. (2013) mentions that the systematic application of ergonomics (i.e., physiological response measurement) is important to the construction workers' safety and health administration and different work engagement and labor intensity need to be considered depending on workers. According to Kilbom (2000), repetitive work with hand tools is the main cause of MSDs.

Construction activity involves a variety of precedence activities, depends on hand tools highly, and requires frequently performing the operations in unsafe postures. However, the method to measure and evaluate the physical demand at an operation level is still lacking. That is why the operating factor of construction laborers has been assigned with the fixed value without considering the difference of the physiological demands. This study proposes a method to measure and evaluate the physical demand requirement of a waterproofing activity. It provides a systematic framework to manage construction workers' safety and health relative to the physical demand.

B. Research Scope

It should be noted that this study was adapted from Lim et al(2015)'s research. The physical demand requirement of the waterproofing workers, who are hired for the polyurethane construction method, was measured. The polyurethane based waterproofing activity has the linearity of the movement path, and consists of highly repetitive working motions. It was easy to identify the postures and hand tools of the skilled workers engaged in the construction method.

Tasks consisting of the waterproofing activity are as follows: (1) surface grinding, (2) primer painting, and (3) polyurethane coating. This study investigates the two tasks, "(2) primer painting" and "(3) polyurethane coating", except for "(1) surface grinding". Since the electromagnetic waves generated from electric grinder causes the malfunction of heart beat measurement device

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(RS400 POLAR), the task 1 was excluded from the experiment despite the highest physical demand estimation.

This study was performed as follows: first, the existing methods which evaluate the workers' physical workload were investigated; second, the hypotheses relative to physical demands were established and verified.

II. Literature Review

The measurement of the laborers' workload has been a research agenda in construction sector as follows: Kim (2012) proposes a system that evaluates motion and MSDs of carpenters. Vi (2003) compares biomechanical stresses between the conventional manual strapping and automatic strapping to fix reinforcement bars. Roja et al. (2006) measures the heart rate and electromyogram of workers targeted for road paving and maintenance operations and analyzed the fatigue of the musculoskeletal system. Bates & Schneider (2008) measures the physiological phenomena (for example, temperature of body, water intake, and heart rate) of workers in hot weather. Chang et al. (2009) compares the variance of heart rate and fatigue symptoms targeting employees engaged in various trades (i.e., false workers, steel workers, form workers, concrete workers, electricians, and plumbers). Min et al. (2010) measures the amount of activation of the back muscles by using electromyogram (EMG) sensors and analyzes the influence of back pain by targeting scaffolding activity causing frequent fall accidents. Lee et al. (2010) develops a self-assessment checklist for workers so that they can understand the risks of MSDs. Kim et al. (2013) presents a management framework for the prevention of MSDs by utilizing the kinetic technology for recognizing the movement of the workers in real time. Indeed, several researchers have pursued to measure objectively the physical workload and to estimate MSDs in recent years.

III. Empirical Study

Construction activities are carried out by three male students who were similar to physical conditions and did not experience a musculoskeletal disorder in the past. Since the sample size is only 3 for each task, the hypothesis test procedure for small sample size (below 30 or so) is carried out by using the t-distribution instead of the Z-distribution.

The degree of fatigue accrued to the body of laborers has a positive correlation with the amount of energy consumption and a negative correlation with the operating factor associated with break and/or idle times. Change of heart rate is one of the indicators representing the physiological demand accrued to the workers. This study estimates the physical workload demanded to a worker who is involved in a type of task (refer to Figure I) by measuring heartbeat ratio. The research hypotheses are as follows:

[H1] When one performs the same amount of work; the one's average heart rate required for the polyurethane coating operation is higher than that required for the primer painting operation.

[H2] When one performs the same amount of work, the one's break time required for the polyurethane coating operation is longer than that required for the primer painting operation.

FIGURE I.
PRIMER PAINTING (L) AND POLYURETHANE PAINTING (R)

The hypothesis 1 (H1) was carried out in a one-tailed significance level of 10%. It was confirmed that the average heat rates of the subjects (HRrest) in rest before they participate the experiment were significantly different from those in working. In order to separate the differences attributed to the individuals' personal heart performance, the measured heart rate were normalized by the following equation.

$$\Delta HR = HR_{work} - HR_{rest} \quad \text{Eq. 1}$$

Table I shows the statistics of heart ratios depending on individual task. Because the t-value 4.10 is higher than the threshold 1.95, null hypothesis (H0: $\mu 1 = \mu 2$) is rejected. It confirms that the physical demand of polyurethane painting operation is relatively higher than that of primer painting operation.

TABLE I.
STATISTICS FOR THE HEART RATE VARIATIONS

Classification	No. of sample	Average	Standard deviation
Primer painting	3	22.5	2.9
Polyurethane coating	3	34.3	5.5
t-vale=4.10, threshold=1.95			

The hypothesis 2 (H2) was carried out in a one-tailed significance level of 10%. After the primer painting and polyurethane coating end, the average times to return to normal heart ratio are 131sec and 187sec, respectively.

Table II shows the statistics of the recovery times of heart ratios depending on individual operations. As the t-value 2.65 is higher than the threshold 1.94, the recovery time of the polyurethane coating operation is relatively longer than that of the primer painting operation.

TABLE II.
STATISTICS FOR THE RECOVERY TIMES

Classification	No. of sample	Average	Standard deviation
Primer painting	3	131	13.0
Polyurethane coating	3	187	49.5
t-vale=2.65, threshold=1.94			

IV. CONCLUSION

This study proposes the method to measure laborers' physical workloads, to preprocess the heartbeat ratio data and to evaluate the work related implications. It was confirmed that the workload of the primer painting operation and that of the polyurethane coating operation involved in a waterproofing activity are significantly different. The empirical experiment shows that the polyurethane coating operation is statistically more intense than the primer painting operation, and the recovery time of the polyurethane coating is relatively longer than that of the primer painting.

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REFERENCES

[1] G.P. Bates, J. Schneider, "Hydration status and physiological workload of UAE construction workers: A prospective longitudinal observational study", *Journal of Occupational Medicine and Toxicology*, vol. 3, no. 21, pp. 4-5, 2008.
[2] F. L. Chang, Y.M. Sun, K.H. Chuang, and D.J. Hsu, "Work fatigue and physiological symptoms in different occupations of high-elevation construction workers", *Applied ergonomics*, vol. 40, no. 4, pp. 591-596, 2009.
[3] Å. Kilbom, "Repetitive work of the upper extremity: part II—the scientific basis (knowledge base) for the guide", Elsevier Ergonomics Book Series, vol. 1, pp. 151-178, 2000.
[4] K.T. Kim, C.H. Kim, "Questionnaire study on the current status of the construction labor force", Proceedings of the Korea Institute of Building Construction, vol. 10, no. 1, pp. 95-97, 2010.
[5] K.T. Kim, "Development of an apparatus to measure musculoskeletal load for construction workers using accelerometers", *Journal of the Architectural Institute of Korea*, vol. 28, no. 1, pp. 167-174, 2012.
[6] T.H. Kim, M.S. Park, H.S. Lee, and K.S. Song, "Ergonomics Analysis for Construction Workers to Reduce Recurring Work-Related Musculoskeletal Disorder", Proceedings of Architectural Institute of Korea, vol. 33, no. 1, pp. 551-552, 2013.
[7] Y.K. Lee, H.S. Park, and J.K. Park, "Development of a self-administered checklist for evaluation of the musculoskeletal disorders risk factors in construction industry", *Journal of the Ergonomics Society of Korea*, vol. 29, no. 5, pp. 811-818, 2010.
[8] P. Vi, "Reducing risk of musculoskeletal disorders through the use of rebar-tying machines", *Applied Occupational and Environmental hygiene*, vol. 18, no. 9, pp. 649-654, 2003.
[9] D.P. Woo, S.D. Lee, and D.J. Lee, "A study on physical work capacity and rest allowance for Korean", *Journal of the Ergonomics Society of Korea*, vol. 20, no. 3, pp. 37-46, 2001.
[10] Z. Roja, V. Kalkis, A. Vain, H. Kalkis, and M. Eglite, "Assessment of skeletal muscle fatigue of road maintenance workers based on heart rate monitoring and myotonometry" *Journal of Occupational Medicine and Toxicology*, vol. 1, no. 20, pp. 1-9, 2006.
[11] T.K. Lim, S.M. Park and D.E. Lee, "Assessment for the Physiological Workload of Warterproof Workers" *Journal of the Architectural Institute of Korea*, vol. 31, no. 6, pp. 33-41, 2015.