Ergonomic Work Station Design to Improve Workload Quality and Productivity of the Craftsmen

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Abstract. This study is a research on ergonomics field, especially for ergonomics work station. This research begins with direct observation on the work process of carving craft. In addition to the aspect of occupational health, the stages of the process are also subject matter in the effort to solve the research problem. In accordance with the master plan of research of Bali State Polytechnic, problem solving will be focused on human aspect and utilization of appropriate technology, so that will get the work process ENASEP (effective, convenient, safe, healthy, efficient and productive) Technical easy to work, economical, ergonomic, energy saving, environmentally friendly and in accordance with the trend of the era. The method to be used in this research is experimental with the same subject design. Involves 9 samples who perform activities on conditions before and after treatment. Data on environmental conditions were analyzed by Mann-Whitney test. Data on work productivity and workload were tested with two pair sample t-test at a significance level of 5%. The results showed that by utilizing ergonomic work stations, occupational health indicators such as workload showed better signs, indicated by decreased the workload. In addition to occupational health, productivity indicators also increased significantly.

1. Introduction
The development of sculpture in the homeland shows a very encouraging development. Signs of progress in the field of carving art is marked by the increasing number of carving artwork adorn every corner of the road in the homeland, including the grand stand of Garuda Wisnu Kencana (GWK). The construction of several galleries and museums that specifically display the works of the sculptors also have an important role of the development of the art of sculpture. Various masterpieces have been born from the art of sculpture. In Bali the works of carved artists adorn almost all the holy places, cultivate a positive aura and facilitate the Hindu people connected with his God.

Epstein and Moran [1] provides an explanation that supports the above statement, that fatigue, pain and even increased heart rate have a strong correlation with the work environment. A hot working environment can cause heat stress that spur the heart rate. Under normal conditions our heart will be pulsed 60 times per minute, but if the range is up to 125 - 150 beats/min, which includes weight classification, it can cause various health effects [2,3]. In line with the research [4], also prove in his analysis that humans can be very productive if always in a fit state. Fit conditions are characterized by low levels of workload during on-the-job activity. Workload can be reduced and even eliminated if humans in the move can still be in a natural position. Hignett et.al. [5] found a surefire way to reduce pain in skeletal muscle while working, that the size of the human body wearing a tool used to design the size of the work table and chairs, so that the worker's body position during the move permanent in...
a natural or scientific position. The results of this study are in line with the results of analysis the research [6] which passes a survey on industrial workforce in North India, which results in the conclusion that anthropometric workpiece positions can eliminate work-related pain. By the various problems above, in the realm of art carving also experienced the same thing.

Carving art craft is much favored and in demand by foreign and domestic tourists so managed as a small or medium industries depending on the amount of capital and labor used. Carved art craft products many kinds ranging from eye cendra to carvings for buildings typical of Bali. Some of the problems associated with occupational health are workload. The method used to determine the amount of workload, one of them by calculating the pulse of work with the method of 10 pulses, while the measurement of resting pulse rate method 15 seconds [7].

Carrivick et.al. [8] explains that working anywhere is inseparable from the workload, because in the process of working activity requires muscle and mental work simultaneously shown through the fatigue marked by the change in the frequency of the pulse. A pulse per minute describes the work of the heart in pumping blood into and out of the heart organ. The greater the frequency of heart rate per minute means the higher the body activity that causes increased body metabolism. Furthermore the research [9] says that according to the rules of ergonomics, every burden received by the body must be balanced with the physical and cognitive abilities as well as the limitations of the body that accepts the burden. The human body's ability to accept loads varies greatly, depending on skill level, fitness, nutritional intake, gender, age and body anthropometry. The light weight of an activity can be seen from the need for oxygen, the capacity of pulmonary ventilation, changes in core body temperature, energy requirements and the production of sweat or weight changes. Heart rate is a good estimator of metabolic rate, except in the emotional state and vasodilation (widening of blood vessels) [10, 11].

The weight category of workload is based on metabolism, respiration, body temperature and heart rate. The second problem related to occupational health is musculoskeletal disorders. Art workers in the move will experience physiological changes as a result of accumulation of external and internal loads. Internal burdens such as body weight, mental burden and health impairment also collectively affect workers, all of which can cause stress [13]. Stress received by the body is actively anticipated in the form of work and passive system efficiency in the form of physiological reactions known as adaptive responses. According to the research [14,1], in conclusion his research, that physiological changes aims to maintain cell metabolism in the optimal state. To achieve this necessary intake of oxygen and food substances continuously. In addition, muscle contraction and relaxation should be regular. When the energy supply is limited and the flow of oxygen and nutrients is disrupted then the cell metabolism will be disrupted thus accelerating the onset of musculoskeletal disorders. Workers who use workstations and workplaces that have dimensions that are less suited to the anthropometry of the worker will cause less unnatural movements and work attitudes, so musculoskeletal disorders will occur earlier and more severe. The musculoskeletal system is a muscular system attached to the bone composed of cross-shaped muscle fiber of voluntary movement [8].

The third problem related to occupational health is fatigue. Fatigue consists of muscle fatigue and general fatigue. Muscle fatigue is a very painful symptom of pain when muscles suffer from excessive stress, while general fatigue is a stage marked by a decrease in readiness to use energy. Research conducted by [5] and [9] suggest general symptoms of fatigue can start from very mild to exhausting feelings. Subjective fatigue usually occurs at the end of working hours, if the average workload exceeds 30% - 40% of the maximum aerobic power. Fatigue usually indicates the different conditions of each individual, but it all leads to loss of efficiency and decreased work capacity and body resistance. Grandjean [15] and Bubb [3] indicate fatigue in general is a condition that is reflected in symptoms of psychological changes in inaction of motor activity and respiration, the presence of pain, weight on the eyeballs, attenuation of motivation, decreased activity that will affect physical and mental activity.
One obvious effect of fatigue is reduced alertness [16, 17]. A person will not be able to concentrate continuously for mental activity. After experiencing tension during a certain period, there will be a disturbance in perception, and the speed of the reaction becomes slow. To overcome this interference need to be refreshed outside of pressure [13]. Refreshes occur mainly during night time sleep or rest periods and during work breaks.

2. Methodology
To know the impact of treatment/intervention on subject conditions will be done experimental research with the same subject design (Treatment by subjects design). Based on the design, the measurement is done twice before and after the implementation of work station and ergonomic environment. The tools used to retrieve data consist of: Japanese olympus FE-15 digital camera for documentation, table of psychrometry to determine relative humidity by % unit, stop watch - British-made diamond brand with seconds units, used for recording the time of the pulse, as well as the working time of the subject, sound level meter, lux meter, black globe thermometer, sling thermometer, Anemometer, super Japanese anthropometer tool made in Japan with 0.1 cm accuracy, which is used to measure the anthropometry of the subject. Data were collected from samples at industrial centers of carving stations in Tangkub Village and Kapal Village, namely Ud. P. Jatayu, Ud. Rinna Dewata Sari, Ud. Agus. Selected samples were collected in Ud. Agus for treatment. The object of research is work station and work environment of Bali carving artisans. Health work and productivity data were collected using stop watch. Officers involved to observe are ergonomics (masters or ergonomics doctors) and doctors who master palpation techniques (holding and counting pulse on the wrist). The environmental conditions will be observed with sound level meter, lux meter (for measuring the intensity of light), sling thermometer (measuring wet temperature and dry temperature), black globe thermometer (measuring radian temperature) and anemometer (to measure wind speed).

3. Results and discussion
Characteristics of subjects including age, weight, height, work experience, resting pulse and body mass index (BMI) are presented in Table 1.

| No. | Description                  | Average | Standard of Deviation | Range  |
|-----|------------------------------|---------|-----------------------|--------|
| 1   | Age (year)                   | 37.72   | 4.72                  | 30 – 51|
| 2   | Weight (kg)                  | 60.56   | 6.22                  | 49 – 71|
| 3   | Height (cm)                  | 167.61  | 4.12                  | 150 – 171|
| 4   | Work experience (year)       | 11.31   | 4.91                  | 10 – 20|
| 5   | Resting pulse Period I (bpm) | 84.31   | 3.92                  | 77.33 – 90.67|
| 6   | Resting pulse Period II (bpm)| 78.02   | 4.53                  | 69.33 – 85.33|
| 7   | Body mass index (BMI)        | 21.67   | 3.37                  | 18.34 – 24.89| (kg/m²)

Description : bpm = beats per minute.

Most of the subjects of research are educated at Senior high school level (44.44%), while those with elementary and college education are 33.33% and 22.22% respectively. Subjects totaling 9 people are all male and are employees at UD. Jatayu, CV. Rinna and UD. Agus. The life span of the subject is 30 s.d. 51 years, average 37.72 ± 4.72. Subject weight ranges from 49 s.d. 71 kg with mean of 60.56 ± 6.22 kg. The subject's height is in the range of 150 s.d. 171 cm with mean of 167.61 ± 4.12 cm. The work experience of the subject as a farmer ranged from 10 s.d. 20 years with an average of 11.31 ± 4.91 years. Work experience related to the ability of adaptation and freshness level of craftsmen. The resting pulse can also show the degree of physical fitness of a person, the lower the resting pulse of a person the better the physical fitness. In this study the subjects’ pulse rate ranged from 77.33 s.d. 90.67 beats per minute (bpm) with an average of 84.31 ± 2.92 bpm before the ergonomic
implementation (study period I) and between 69.33 s.d. 85.33 bpm with a mean of 78.02 ± 4.53 bpm after the implementation of ergonomics (research period II). The resting pulse in period I and period II is still in the range of 69.33 bpm s.d. 90.67 bpm, which shows the physical condition of the subject in good health, because the workload is very light to light category.

Prior to the conduct of the study all the population received medical examinations from the Doctors. Out of 45 people, 9 of them were selected. From the results of the examination which includes blood pressure measurement, sugar levels in time and pulse have obtained health status of the sample, which is healthy. The result of normality test to the environmental condition data, both for the working environment condition during period I and period II shows that normal distribution data is light intensity data, while dry temperature data, wet temperature, humidity, ball temperature, wind speed, noise and WBGT index not normally distributed. If one of the data is not normal then the test using non-parametric test equipment. Thus the data were tested by Mann-Whitney test. The results of data analysis of environmental conditions in the workshop of the crafters can be seen in Table 2.

Table 2. Environment conditions

| Variable                  | Period I       | Period II      | Value  | Value  |
|---------------------------|----------------|----------------|--------|--------|
|                           | Average SD    | Average SD    | Z      | p      |
| Dry temperature (°C)      | 27.64 ± 0.82  | 27.61 ± 1.14  | -1.721 | 0.068  |
| Wet temperature (°C)      | 24.11 ± 1.14  | 23.97 ± 1.21  | -1.227 | 0.221  |
| Relative humidity (%)     | 76.18 ± 4.61  | 76.22 ± 4.67  | -0.739 | 0.461  |
| WBGT index (°C)           | 25.17 ± 1.11  | 25.12 ± 1.10  | -1.366 | 0.171  |
| Wind speed (m/dt)         | 11.15 ± 3.02  | 11.07 ± 2.82  | -1.112 | 0.487  |
| Light Intensity (lux)     | 190.00 ± 4.71 | 193.00 ± 6.89 | -0.043 | 0.965  |
| Ball temperature (°C)     | 29.77 ± 0.82  | 29.31 ± 0.96  | -1.396 | 0.164  |
| Noise (dBA)               | 74.337 ± 6.53 | 74.61 ± 6.91  | -0.313 | 0.754  |

Environmental conditions consisting of dry temperature, wet temperature, relative humidity, wind speed, light intensity, ball temperature and noise also greatly affect the subject condition. The data of light intensity, wind speed and noise are measured at five points and at different times. The result of data analysis shows that environmental condition seen from dry temperature, wet temperature, ball temperature, relative humidity, wind speed, light intensity and noise period I and in period II is no difference. It is said that because all values $p > 0.05$ or it can be said that: (a) the average of dry temperature in the study period I is not significantly different with the average of dry temperature at the time of observation period II; (B) the average of wet temperature at observation period I was not significantly different with mean wet temperature of period II; (C) the average of sphere temperature at observation period I was not significantly different with mean of ball temperature of period II; (D) the relative humidity average at observation period I was not significantly different with the mean of relative humidity during observation period II; (E) the average of wind velocity in observation of period I is not significantly different with mean of wind velocity of period II, and (f) average of noise, WBGT and light intensity at observation period I is not significantly different with mean of noise, WBGT and light intensity of period II.

To know the suitability between the tools used by artisans done anthropometry measurement. The size obtained should be in accordance with the size of the body and comfortable to use by crafters. Anthropometric data is very important for the designers of the tool to get the most appropriate size. The more samples involved the better, even in developed countries already available anthropometry data that represent the population of the country. Data obtained by: (1) all subjects measured; (2) anthropometric data of all subjects is taken average and its standard intersection (3) the average value of the subject then searched the percentile value with SPSS. From anthropometry data then desk and chair work in design. The height of the table uses a high reference point 95th elbow, so the table height is determined 71.7 cm. Table length uses a 95th percentile shoulder width of 95, which is 49 cm, so the length of the table is made 100 cm. Table width is determined using 95th percentile hand coverage range, so it is made 69 cm.
Work productivity is the comparison between the average work that can be completed/working day with workload (work pulse) multiplied working time. The results of normality test data for work productivity can be seen in table 3.

| No. | Description                      | Nilai Z | Df | Nilai p |
|-----|----------------------------------|---------|----|---------|
| 1   | Work Productivity of Period I    | 0.895   | 9  | 0.068   |
| 2   | Work Productivity of Period II   | 0.951   | 9  | 0.703   |

It can be seen that Z value of work productivity in period I is 0.895 with p value = 0.068, likewise in period II is 0.951 with value p = 0.703. It turns out p value> 0.05, so it can be concluded both data is normally distributed. Productivity is said to increase if the output increases at the same time. Increased productivity of the craftsmen carving is marked by the increasing number of carved objects that can be completed by a carving artist by utilizing the same workmanship time. Since the data is normally distributed, the mean difference test uses t-paired. Test results can be seen in Table 4.

| No. | Variable                   | Period I | Period II | Value | Value |
|-----|----------------------------|----------|-----------|-------|-------|
|     | Average                   | SD       | Average   | SD    | T     | p     |
| 1   | Work Productivity         | 5.54     | 0.80      | 10.61 | 0.84  | -18.984 | 0.0001 |

Workload is the number of heart beats per minute after the activity is reduced heart rate before the activity. The pulse measurement is as follows.

| No. | Description                   | Value | Df | Value |
|-----|--------------------------------|-------|----|-------|
| 1   | Rest heart rate (RHR) Period I | 0.878 | 9  | 0.054 |
| 2   | Rest heart rate (RHR) Period II| 0.918 | 9  | 0.163 |
| 3   | Work heart rate (WHR) Period I | 0.968 | 9  | 0.784 |
| 4   | Work heart rate (WHR) Period II| 0.961 | 9  | 0.663 |

Because the data is normally distributed, then tested with parametric test in the form of t-paired test. The results of the analysis can be seen in Table 6.

| No. | Variable                   | Period I | Period II | Value | Value |
|-----|----------------------------|----------|-----------|-------|-------|
| 1   | Rest heart rate (RHR) (bpm) | 81.31    | 3.40      | 78.13 | 4.92  | 1.837 | 0.086 |
| 2   | Work heart rate (WHR) (bpm) | 132.56   | 2.80      | 107.81| 5.92  | 13.237| 0.0001|

From Table 6, the mean of heart rate before activity in period I was 81.31 ± 3.40 and the mean of heart rate before activity in period II was 78.13 ± 4.92 with value Z 0.878 and p value> 0.054. This value indicates that the data do not differ significantly between period I and period II. That means the initial condition of the subject is seen from its heart rate under the same conditions. After the activity, the
The mean of heart rate in period I was 132.56 ± 2.80 and the mean of heart rate at period II was 107.81 ± 5.92 with value Z 0.968 and p value = 0.0001. Thus it can be said heart rate after the activity is significantly different (p <0.05) between period I and period II.

4. Conclusion
Based on the previous discussion can be concluded some of the essence of research to answer the existing problems, as follows. By utilizing the appropriate technology, the ergonomic work station obtained a 47.79% increase in productivity. The productivity of crafters in the period I was 5.54 ± 0.80 and in the second period of 10.61 ± 0.84. This increase in productivity is characterized by an increase in the number of products produced at the same time.

The amount of workload depends on the size of the heart rate in units of beats per minute (bpm). Working pulse in period I was 129.67 ± 2.81 bpm and work pulse in period II was 104.23 ± 5.93 bpm, or decreased 19.62%. The pulse rate in period I was still in the category of heavy workload, while in period II included the medium workload. It should gradually begin to be considered for the work station to be moved on. Utilization of appropriate technology is one of the solutions offered [18]. Held a paradigm shift from conventional work stations working on the floor without regard to health change. Craftsmen are encouraged to start using tables and chairs to increase productivity and reduce workload.

Wind speed should be made not too tight and not too stagnant. With a blow of ± 4 m/min, the natural wind will be able to keep the worker's physical condition in shape throughout the day. Artificial lighting or lamp use should be able to make the worker work hard. With a light intensity of 300 lux or more can prevent art workers from accidents due to work or errors in determining size of chisel [19]. Air humidity should be maintained in the range of 70% to 76% to allow perspiration to escape from the skin pores [20]. Noise should be avoided for carving workers because it can affect concentration and accelerate psychological fatigue. Air temperature will be better if it can be maintained in the range of 24°C Celsius to 28°C Celsius for better working comfort and worker satisfaction can be maintained [21].

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References
[1] Epstein Y and Moran D S 2006 Thermal Comport and the Heat Stress Indices. Industrial Health Journal. 44 (1) 388-98.
[2] Christensen E H 1991 Physiology of Work. In : Parmeggiani, L. Editor. Encyclopaedia of Occupational Health and Safety, 3rd (revised) Ed. (Genewa : ILO) pp 1698-1700.
[3] Bubb H 2013 A Consideration of the Nature of Work and the Consequences for the Human Oriented Design of Production and Products Journal of Applied Ergonomics. 37 (4) 401-7.
[4] Erensal Y C and Albayrak E 2007 The Impact of Micro dan Macroergonomics Considerations on Appropriate Technology Transfer Decisions in Developing Countries : The Case of Turkey. Journal of Human Factors and Ergonomics in Manufacturing. 17 (1) 1-19.
[5] Hignett S, Wilson J R dan Morris W 2005 Finding Ergonomic Solutions – Participatory Approaches. Occupational Medicine Journal. 55 200-7.
[6] Chandna P, Deswal S dan Chandra A 2010 An anthropometric survey of Industrial Workers of the Northern Region of India. International Journal of Industrial and Systems Engineering. 6 (1) 110-28.
[7] Habibi E and Soury S 2015 ‘The effect of three ergonomics interventions on body posture and musculoskeletal disorders among stuff of Isfahan Province Gas Company’, Journal of Education and Health Promotion, 4.
[8] Carrivick P J W, Andy H, Lee and Kelvin K W Yau 2002 Effectiveness of a Participatory Workplace Risk Assessment Team in Reducing the Risk and Severity of Musculoskeletal
Injury: *Journal of Occupational Health*. **44**. No. 4. July. 2002.: Japan Society for Occupational Health.

[9] Chaff'm D B 1974 Human strength capability and low back pain, *Journal of Occupational medicine*, **9**, 248-254.

[10] Alamgir H, Li O W, Yu S, Gorman E, Fast C and Kidd C 2008 Evaluation of Ceiling Lifts: Transfer Time, Patient Comfort, and Staff Perceptions, *Journal of Injury,** 40** (2009) 987 – 992.

[11] Nishanth R, Muthukumar M V and Arivanantham A 2015 ‘Ergonomic Workplace Evaluation or Assessing Occupational Risks in Multistage Pump Assembly’, *International Journal of Computer Applications*, **113**.

[12] McCann M 2010 Hazards in cottage industries in developing countries, *American Journal of Industrial medicine*, **30** 125-129.

[13] Eastman K 1983 *Ergonomics Design for People of Work* (New York : Van Nostrand Renhold) pp 133-137

[14] Mitchell K S 2013 Optimising Business Performance through Innovative Workplace Strategies, *Journal of Facilities Management*, **20** 258-276.

[15] Grandjean E 2000 *Fitting the Task To The Man*. A Textbook of Occupational of Ergonomics. 4th Ed. (London : Taylor & Francis).

[16] Chung M K and Choi K I 1997 Ergonomic analysis of musculoskeletal discomfts among conventional VDT operators. *Journal of Computers and industrial engineering*. **33** 521-524. Available from http://www.postech.ac.kr /ie/huma/html/journal/Inter-J.htm. Accessed August 28, 2017.

[17] Chan A D C and Fishbein J 2009 A Global Engineer for the Global Community. *The Journal of Policy Engagement*, **1** (2) 4-9.

[18] Dutta T, Holliday P J, Gorski S M, Baharvandy M S and Fernie G R 2011 ‘A Biomechanical Assessment of Floor and Overhead Lifts Using One or Two Caregivers for Patient Transfer’, *Journal of Applied Ergonomics*, **43** 521 – 531.

[19] Pandit S, Kumar P and Chakrabarti D C 2013 *Ergonomic problems prevalent in handloom units of North East*, *International of Scientific and Research Publications*, **3** (1) (2013) 1-7.

[20] IK Widana 2012 *Redesigning Tractors for increased productivity in the Agricultural Sector in Indonesia*. Ergonomics In Asia: Development, Opportunities and Challeges (London : Taylor & Francis).

[21] Parasuraman A., Zeithaml V A and Berry L L 1988 *Servqual*: A Multi-item Scale for Measuring Consumer Perceptions of Service Quality. *Journal of Retailing*, **64** (1) (1988) 12-40.