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Design of ergonomic work facilities on assembly station of mozaic stone for increasing work productivity

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Abstract

This research aims to improve work facilities' designs ergonomically on the assembly station with the goal of increasing work productivity using an anthropometry database approach. One of the production processes in small and medium enterprises was the stone assembly. The stone assembly was conducted by an operator who sits on a small bench and uses a box-shaped can as a table. The operator worked in a bent position, head bowed and both legs folded. According to Standardised Nordic Questionnaires, the worker suffered from pain in the neck, shoulders, elbows, wrists, back, buttocks, and knees, negatively affecting their work productivity. This research applied the Rapid Upper Limb Assessment (RULA) method to assess the postures of the worker's upper limb during working h. The concept of ergonomics was used for the designing of work facilities. The anthropometric data was taken as reference for the dimension of assembly work facilities design which matched the body dimension of the worker. In terms of RULA score, both proposed layouts (score 4) indicated an improvement compared to the initial layout (score 7). Regarding the standard time, both of those layouts showed a decrease in the standard time of 40% and 44%, respectively when compared to the initial condition. Related to the standard output, it indicated that there was an increase of 200% in terms of productivity when compared to the initial condition. Furthermore, there was a decrease at the level of uncomfortable from 80% to 30%. The second proposed layout alternative recommended a better improvement than the first one.

Keywords: Ergonomics, Work facilities, Productivity, RULA

1. Introduction

Indonesia is a developing country that is growing rapidly, and a plethora of industries are growing with it including both large scale and small and medium (SMEs) enterprises. The Indonesian government has focused on SMEs since recognizing the important role they play as the backbone of the Indonesian economy, where approximately 99.9% of industry was SMEs. They contributed up to 57.9% to Indonesia's GDP and employ up to 97.2% of workers in the SMEs sector [1]. The increase in the number of SMEs led to an increase in the number of accident and incidents on those SMEs. Some previous research studied the most common injuries that happened in SMEs workplaces. Contorting the body into awkward postures while working (e.g., bending or twisting) caused by positioning tools lower than the position of the hands was frequently reported to lead to back pain [2]. Other research reported that uncomfortable working positions, such as knees bent due to the operator sitting on a small bench [3], prolonged elbow folding [3], and back bending due to the workpiece being located at a lower position than worker's hand [3] were problems as well. The main cause of all those incidents and accidents was the existence of the dimensional gap in the man-machine system while working [2]. This influenced well-being [2], health [4], comfort [5], the safety of the workers [4] and worker productivity [6].

In Indonesia, one of the SMEs that encountered a serious problem with the dimensional gap in the human-machine system was the industry of natural stone handicrafts. The typical processes for this industry included raw material cutting process, smoothing process, sorting process, assembly process, and finishing process. The dimensional mismatch could be found on the assembly process. The assembly activity involved an awkward position in which the operator worked in a sitting position on a small bench and used a box-shaped can as the table as shown in Figure 1(A). It caused the worker to work with their body in a bent position, head bowed and both legs folded as could be seen in Figure 1(B). According to Standardised Nordic Questionnaires (SNQ), the worker suffered from pain in the neck, shoulders, elbows, wrists, back, buttocks and knees, therefore affecting work productivity.

Figure 1 The initial assembly work station: (A) the initial layout work station; (B) the initial operator's work position (Courtesy: Denta Stone, 2015).

According to the unergonomic conclusions drawn on natural stone SMEs, redesigning the workplace to fit the anthropometry of the worker is needed to provide a safer and more comfortable work environment. This means that the availability of the anthropometry database is very important. Anthropometry is defined as the human sciences regarding body measurements: principally focusing on body size, shape, strength and working capacity measurements [7]. In SMEs, the significance of anthropometry data fitting to labor is required in the work environment, with tools and machines designed to enhance comfort, safety, well-being, and health.

This research aimed to improve the design of work facilities ergonomically on the assembly station of mozaic stone for increasing the work productivity using the anthropometry database approach. The measurement of anthropometric data of Indonesian workers was conducted in this study due to the need for the dimensional match in the man-machine system.

2. Materials and methods

2.1. Participants

Thirty females consisting of 5 female operators and 25 Indonesian females were recruited to participate in this study. The additional 25 participants were chosen for their gender and age, as they were of the same age range as the actual operators.

2.2. Measurement of anthropometry dimension

There were 7 body dimensions used in this research. They were shoulder-grip length (SG), popliteal height (PH), buttock-popliteal length (BP), hip breath (HB), span (SP), sitting elbow height (SE) and sitting shoulder height (SS). The measurement methods of those dimensions could be seen in Table 1.

Table 1 Anthropometry Dimension Measurement Methods [7].

Dimension	Measurement method
SG	Distance from the acromion to the center of an object gripped in the hand, with the elbow and wrist straight (Figure 2A).
PH	Vertical distance from the floor to the popliteal angle at the underside of the knee where the tendon of the biceps femoris muscle inserts into the lower leg (Figure 2B).
BP	Horizontal distance from the back of the uncompressed buttocks to the popliteal angle, at the back of the knee, where the back of the lower legs meet the underside of the thigh (Figure 2C).
HB	Maximum horizontal distance across the hips in the sitting position (Figure 2D).
SP	The maximum horizontal distance between the fingertips when both arms are stretched out sideways (Figure 2E).
SE	Vertical distance from the seat surface to the underside of the elbow (Figure 2F).
SS	Vertical distance from the seat surface to the acromion (i.e. the bony point of the shoulder) (Figure 2G).

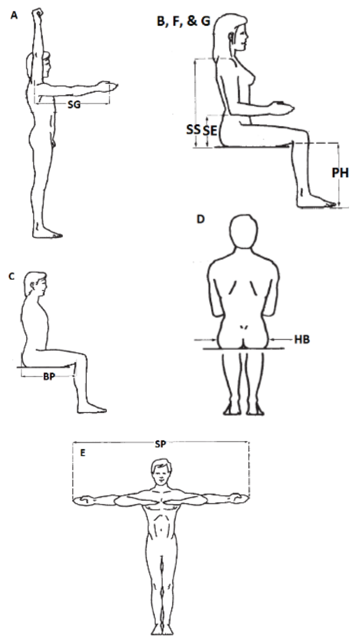

Figure 2 Anthropometry dimension.

2.3. Data collection

The prevalence of musculoskeletal symptoms and the identification of affected body parts were investigated using the Standardised Nordic Questionnaire (SNQ) [8] which was modified to the Indonesian version. The anthropometry dimension data was collected by conducting a direct measurement of all participants using tape measure gauges and an anthropometry chair. The ergonomic positioning data was measured using The Rapid Upper Limb Assessment (RULA) method [9].

RULA is an employee assessment worksheet that assesses postures of neck, trunk, and upper limb loading [10]. RULA was designed for use by researchers without any previous ergonomic training or knowledge. It requires no additional tools, and it involves minimal disruption to those being studied. This survey involved 15 steps, each of which measured the angles of specific body parts while the subject was in the measured posture: upper arm, lower arm, wrist, neck, trunk, and legs. For example, for the ''upper arm'' score, 1 point was added if the arm was in extension or flexion <20˚ from the torso; 2 points were added if the arm was in extension >20˚ or in flexion from 20˚ to 45˚; 3 points were added if the arm was in flexion between 45˚ and 90˚; and 4 points were added for flexion > 90˚. One more point was added if the arm was abducted or the shoulder was raised, and 1 point was deducted if the arm was supported. In addition to the body part scores, points were added if the posture was held for >10 min, was repeated 4 times in a min, or involved a load >4.4 lb. The individual joint scores were then combined through a table to yield a total score of 1 to 7.

The RULA score was meant as a screening tool to determine which postures required further investigation about their ergonomic consequences. Therefore, it was meant solely as a means to guide further study, rather than a definitive tool for assessment. A higher score indicated an ergonomically unfavorable posture that might lead to the development of MSDs. Specifically, a score of 1 or 2 indicated acceptable posture if not held for long periods; 3 or 4 signals that further investigation was required and change might be needed; 5 or 6 meant that investigation and change were required soon; and 7 alerted the need for immediate investigation and change to prevent upper limb MSDs [11].

2.4. Experimental procedure

Thirty females consisting of 5 female operators and 25 Indonesian females were recruited to participate in this study. All subjects had their anthropometry dimensions measured using anthropometric measuring tape and an anthropometric seat based on the measuring methods showed in Table 1. This anthropometry data was then used to design new work facilities using SolidWorks software. Then, the real 5 operators were instructed to perform their job using the current work facility layout while the observed time data were recorded using stopwatch. After finishing the instruction, the subjects were given a Standardised Nordic Questionnaires (SNQ) to assess their perceived discomfort. On monitoring conditions post-design, the same operators were instructed to do the same task using the new work facility design while the observed time data were recorded and the perceived discomfort was evaluated using Standardised Nordic Questionnaires (SNQ).

2.5. Statistical analysis

The raw data collected was input into the excel sheet and was imported into SPSS software for the descriptive statistical analysis. The Shapiro-Wilk test (p>0.05) was performed to check the normality of the data.

3. Results

3.1. Anthropometric body dimensions

Table 2 shows the descriptive statistics of the obtained measurements of the body dimensions of the subjects.

Table 2 Anthropometric body dimensions of operator (all dimensions in cm).

No	Body dimension	Min	Max	Mean	SD	Percentile		
						5th	50th	95th
1	SG	63.40	69.00	66.21	1.67	64.46	66.21	68.95
2	PH	37.70	41.00	39.27	1.10	37.71	39.15	41.00
3	BP	39.50	43.60	41.51	1.09	39.70	41.51	43.29
4	HB	32.50	37.00	34.71	1.25	32.65	34.71	36.75
5	SP	148.00	154.00	151.04	1.64	148.35	151.04	153.74
6	SE	21.50	27.20	24.63	1.81	21.59	25.00	27.14
7	SS	52.00	58.20	55.06	1.61	52.40	55.06	57.70

In order to ensure that the anthropometry data came from a normal distribution, a normality test using the Shapiro-Wilk test was performed. Table 3 displays the normality test results of the anthropometry data. Based on Table 3, it may be concluded that all anthropometry data came from a normal distribution since the p-value for all data is greater than 0.05 (α-value).

Table 3 The normality test using The Shapiro-Wilk test.

	SG	PH	BP	HB	SP	SE	SS
p-value	0.185	0.060	0.148	0.109	0.060	0.057	0.463

The next statistical analysis for the anthropometry data was a data adequacy test. To ensure that the data was enough to perform further analysis, a data adequacy test for the anthropometry data was conducted. Table 4 shows the results of the adequacy test for the anthropometry data. It was taken at the confidence level of 95% (confidence level index = 2) and error level of 5% for conducting the adequacy test using the following formula:

$$N' = \left(\frac{{}^{k}/{}_{s} \sqrt{N \sum X^2 - (\sum X)^2}}{\sum X} \right)^2 \quad (1)$$

with N’ = number of theoretical data
N = number of observational data
k = confidence level index
= 2 at confidence level of 95%
s = error level of 5%

It can be seen in Table 4 that all of the anthropometry data had sufficient numbers in this study since the value of N’ is less than N.

Table 4 The adequacy test for anthropometry data.

No	Body dimension	N’	N	Remark
1	SG	0.98	30	Adequate
2	PH	1.20	20	Adequate
3	BP	1.06	30	Adequate
4	HB	1.99	30	Adequate
5	SP	0.18	30	Adequate
6	SE	8.27	25	Adequate
7	SS	1.33	30	Adequate

N = number of observation data; N’ = number of theoretical data.

3.2. Standard time determination

Statistical analysis of the observed time data was conducted using a data uniformity test, followed by a data adequacy test. To ensure that there were no extreme data among the observed time data set, it was required to perform a data uniformity test. The data uniformity test results for the observed time data could be seen in Figure 3.

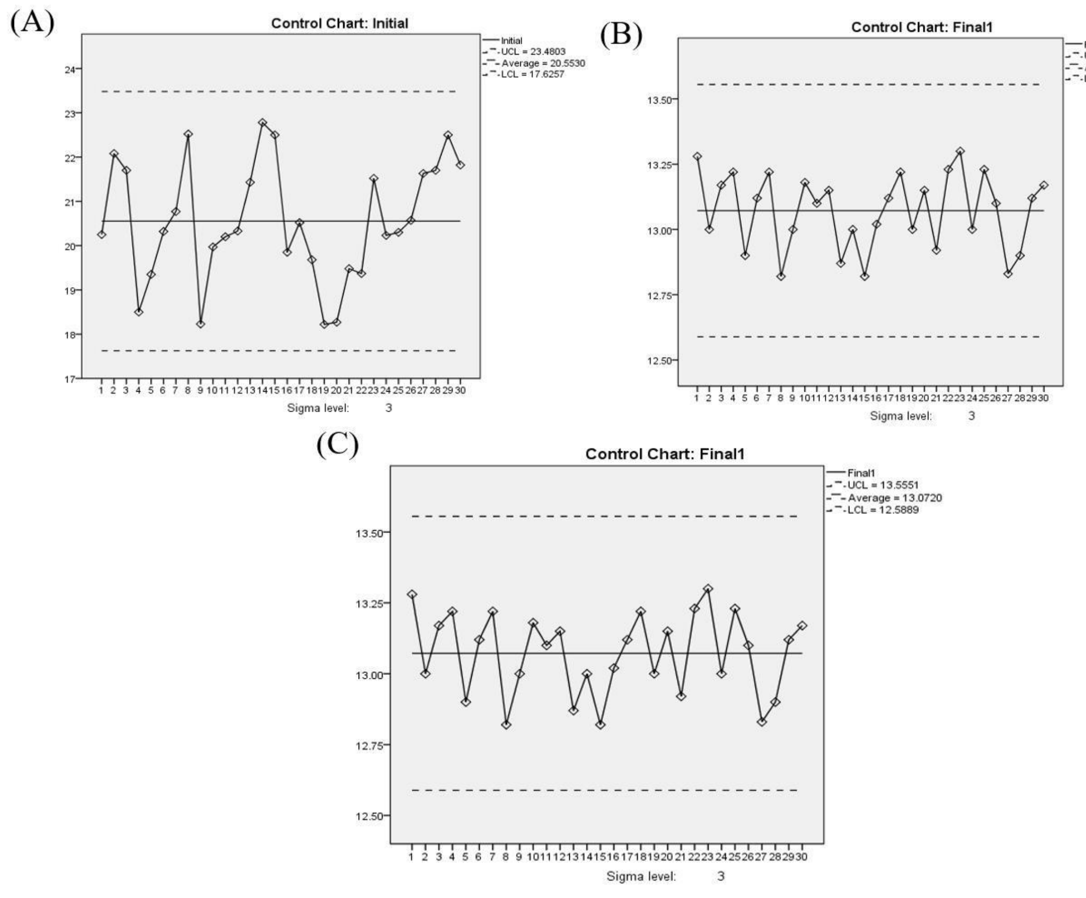

Figure 3 The data uniformity test results for the observed time data (A) initial condition, (B) final condition of 1st layout, (C) final condition of 2nd layout. All dimensions were measured in min.

All data of observed time were located between the upper control limit (UCL) and the lower control limit (LCL). It could be concluded that all those data were uniform. Then, a data adequacy test for the observed time data was conducted. Table 5 shows the results of the adequacy test for observed time data. A confidence level of 95% (confidence level index = 2) and error level of 5% were found for conducting the adequacy test. It can be seen in Table 5 that all observed time data has sufficient numbers in this study since the value of N' is less than N.

Table 5 The adequacy test for observed time data.

No	Condition	N'	N	Remark
1	Initial	6.60	30	Adequate
2	Final of 1st layout	0.19	30	Adequate
3	Final of 2nd layout	0.09	30	Adequate

N = number of observation data; N' = number of theoretical data.

These observed times were adjusted by a rating factor so that a qualified operator working at a normal pace could easily do the work in the specified time. This corrected time was called the normal time. Allowances for personal time, fatigue, and delay, were added to this normal time, resulting in the standard time for the task. The Westinghouse method was used as the performance rating system. The determination of performance rating factors refer to Barnes [12]. In order to determine the allowances of the operator, the recommendations of the International Labor Organization (ILO) were followed [13]. The performance rating factors and allowances for this study can be seen in Table 6 and Table 7, respectively.

Table 6 The performance rating factors for this study.

Factors	Initial condition	Final condition (both 1st and 2nd layout)
Skill	+0.03	+0.03
Effort	+0.02	+0.02
Condition	+0.00	+0.00
Consistency	+0.01	+0.01
Total	+0.06	+0.06
Performance rating (p)	1 + 0.06 = 1.06	1 + 0.06 = 1.06

Table 7 The allowances for this study.

Variables	Initial condition (%)	Final condition (both 1st and 2nd layout) (%)
Personal allowances	5	5
Standing allowance	2	2
Atmospheric condition	3	2.5
Close attention	3	3
Abnormal position allowance	5	1
Muscular energy	6.1	6.1
Bad light	2	2
Noise level	0	0
Mental strain	1	1
Monotony	1	1
Tediousness	2	2
Total allowances	30.1	25.6

The standard time for the task could be calculated using the formulas shown in Table 8.

Table 8 The standard time calculation.

Dimension	Formula	Initial condition	1st final condition	2nd final condition
Cycle time	$\frac{\sum \text{Observed time}}{N}$	20.55 min	13.07 min	12.32 min
Normal time	Cycle time x p	21.79 min	13.86 min	13.06 min
Standard time	Normal time x $\left(\frac{100\%}{100\% - \text{allowances (\%)}}\right)$	31.17 min	18.62 min	17.56 min

p = performance rating.

3.3. Discomfort perceived

Table 9 shows the comparison of pain in various body parts of the worker between pre and post designing conditions.

Table 9 Comparison of discomfort perceived.

No	Part of body	Pre-designing condition		Post-designing condition	
		Comfort	Discomfort	Comfort	Discomfort
1	Neck		√	√	
2	Shoulder		√	√	
3	Elbow		√		√
4	Wrist		√		√
5	Upper back		√	√	
6	lower back		√		√
7	Buttock		√	√	
8	Hip/thigh	√		√	
9	Knee		√	√	
10	Ankle	√		√	

3.4. RULA assessment

The comparison between the initial and final RULA assessment can be seen in Table 10.

Table 10 The comparison between initial and final RULA assessment.

	Initial condition		Final condition	
	Score	Remark	Score	Remark
Body posture part A : arm and wrist analysis				
Upper arm	3	Makes angle of 60˚	2	Makes angle of 35˚
Upper arm adjustment	0	-	0	-
Lower arm	2	Makes angle of 130˚	2	Makes angle of 115˚
Lower arm adjustment	0	-	0	
Wrist	3	Makes angle of 30˚	3	Makes angle of 28˚
Wrist twist	1	Twisted in mid-range	1	Twisted in mid-range
Muscle arm	1	Repeated more than 4X/min	0	Repeated less than 4X/min
Force load	0	Load < 4.4 lbs (0.33 lbs)	0	Load < 4.4 lbs (0.33 lbs)
Total score A	5		3	
Body posture part B : neck, trunk and leg analysis				
Neck	3	Makes angle of 40˚	2	Makes angle of 15˚
Neck adjustment	2	Neck is side bending	0	Good position
Trunk	3	Makes angle of 45˚	2	Makes angle of 20˚
Trunk adjustment	2	Twisted and side bending	1	Twisted or side bending
Legs	2	Not supported	1	Supported
Upper body muscle	1	Repeated more than 4X/min	0	Repeated less than 4X/min
Force load	0	Load < 4.4 lbs (0.33 lbs)	0	Load < 4.4 lbs (0.33 lbs)
Total score B	9		4	
Final score	7		4	

3.5. *Proposed solution*

The recommendations for work facility feature dimensions for the worker can be seen in Table 11.

Table 11 The recommendation work facility feature dimensions.

Features	Anthropometric measurements	Design dimensions (cm)	Determinants
Work table height	PH and SE	59	5% le of PH + 5% le of SE
Work table length	SP	148	5% le of SP
Work table width	SG	63	5% le of SG
Seat surface height	PH	37	5% le of PH
Seat length	BP	41	50% le of BP
Seat width	HB	37	95% le of HB
Backrest height	SS	55	50% le of SS

The anthropometric created a prototype of work facilities with the proposed dimensions as can be seen in Figure 4. It should be tested in the user population before making a final design recommendation. Solid Works software was used in this research for designing work facilities.

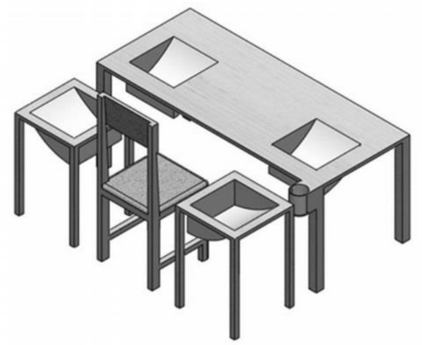

Figure 4 Proposed work facilities.

This research developed two potential scenarios for the layout of work facilities. The purpose was to compare the two and figure out which is the most functional work facilities layout. The two layouts can be seen in Figure 4. The difference between the first layout and the second layout is the location of the container of raw materials (small and large sized stone) and assembled products. On the first layout, the container of pre and post assembly mall are located on the right and left side of the operator's chair, respectively. Whereas, the container of big and small sized stones is on the right and left side on the table area, respectively (Figure 5A). The work operator's position using the first layout can be seen in Figure 6. In the second layout, the container of large and small sized stones is located on the right and left side of the operator's chair, respectively. Whereas, the container of pre and post assembly mall are in the right and left side on the table area, respectively (Figure 5B). The work operator's position using the second layout can be seen in Figure 7.

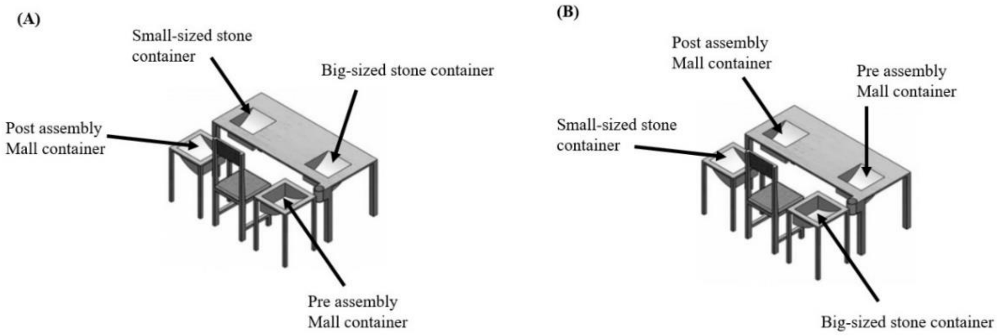

Figure 5 Work facilities layout (A) the first layout and (B) the second layout.

Figure 6 Work operator’s position using first layout (A) right view, (B) left view and (C) front view (Courtesy: Denta Stone, 2015).

Figure 7 Work operator’s position using second layout (A) right view, (B) left view and (C) front view (Courtesy: Denta Stone, 2015).

3.6. Productivity determination

The standard time is used as the basis for the work productivity calculation using the following formula.

$$\text{Standard output} = \frac{1}{\text{standard time}} \quad (2)$$

Then, referred to (2), the standard output for initial, 1st final condition and 2nd final condition were 1 unit/h, 3 unit/h and 3 unit/h, respectively.

4. Discussion

Table 8 shows the comparison of standard time between initial, first proposed layout, and second proposed layout. This study compared the standard time for each condition. The performance rating and allowance values determination needed for standard time calculation referred to the research of [3]. The standard times were 31.17 min/unit, 18.62 min/unit, and 17.56 min/unit for initial condition, first proposed layout condition and second proposed layout condition, respectively. Both of those layouts contributed to a decrease in the standard time of 40% and 44% respectively when compared to the initial condition.

Table 9 gives information about the level of discomfort that was perceived by the worker. The worker felt discomfort on 8 body parts and 3 body parts of the 10 total body parts for pre-designing and post-designing condition, respectively. This indicates that there was a reduction in the term of discomfort perceived at a level of 50% between initial and final conditions. Many previous studies also reported that the improvement of work facility layout could reduce the level of discomfort perceived in any production processes [3].

The operator still perceived pain in 3 body parts after using a new work facility layout, namely elbow, wrist, and lower back pain. These findings were well-matched with the RULA assessment result for the final condition displayed in Table 10. Elbow being categorized as part of the lower arm body. According to Table 10, the lower arm on the final condition made an angle of 115 degrees, resulting in a RULA assessment score of 2. It indicated that the posture was acceptable if it was not maintained or repeated for long periods. The wrist part on the final condition made an angle of 28 degrees. This resulted in a RULA score of 3 which indicated that further investigation was needed and changes might be required. The lower back was categorized as the trunk part. The trunk on the final condition formed an angle of 20 degrees. The RULA assessment gave a score of 2, indicating that the posture was acceptable if it was not maintained or repeated for long periods. The final RULA evaluation showed a score change from 7 to 4. It indicated that the new layout design could reduce the potential occupational risk suffered by the worker, but further investigation was needed and further change might be required. This result was in accordance with previous research regarding the ergonomics evaluation using the RULA method [14].

The purpose of ergonomics is to enable a working system to function better by improving the interactions between users and machines. Better functioning can be defined more closely, for example, as more output from fewer inputs to the system (greater 'productivity') [15]. This study also calculated work productivity by using measured standard time. The work productivity calculation referred to the research of [3]. Related to the standard output, this research showed 1 units/h for initial condition and 3 units/h for both proposed layouts condition. There was an 200% increase in terms of productivity when compared to the initial condition. This result was in accordance with previous research regarding work productivity improvement [16-18].

This study still had some limitations. The first limitation is due to the fact that the RULA assessment functioned only on the new work facility design as a whole even though the new work facility design proposed two model layouts as seen on Figure 5, Figure 6, and Figure 7. It would be better if the RULA assessment applied to both first and second proposed work facility layouts. Therefore, the differences between those two proposed layouts could be investigated more significantly. The second limitation was the existence of discomfort or body pain perceived by the worker on the part of the elbow, wrist, and lower back in the post-redesigning condition. This indicates that the potential risk of injury is still a factor. Further research that could eliminate the pain perceived by the worker on the part of the elbow, wrist, and lower back is still required.

5. Conclusions

Overall, the new work facility layout has met the ergonomics requirement concept. The new work facility layout succeeded to reduce the potential risk of injury by 50% and reduce the standard time by 40% (first proposed layout alternative) and 44% (second proposed layout alternative) and also increased work productivity by 200% both for the first and second proposed layout alternative. According to the standard time and work productivity measurements, the second proposed layout alternative recommended a better improvement compared to the first one.

6. References

[1] Declaration of HumanEntrepreneurship in Jakarta, Indonesia [Internet]. International Council for Small Business. 2015 [cited 2018 May 7]. Available from: https://icsb.org/declaration-of-humanentrepreneurship -in-jakarta-indonesia/

[2] Sutalaksana IZ, Widyanti A. Anthropometry approach in workplace redesign in Indonesian Sundanese roof tile industries. Int J Ind Ergon. 2016;53:299-305.

[3] Kristanto A, Fanany DF. Improvement of working position on frying pan lathing process using the ergonomics approach (A case study at WL alumunium metal casting yogyakarta). In: 3th International Conference on Green World in Business and Technology (ICGWBT). Yogyakarta, Indonesia; 2014. p. D-21.

[4] Del Prado-Lu JL. Anthropometric measurement of Filipino manufacturing workers. Int J Ind Ergon. 2007;37(6):497-503.

[5] Mokdad M, Al-Ansari M. Anthropometrics for the design of Bahraini school furniture. Int J Ind Ergon. 2009;39(5):728-735.

[6] Battini D, Faccio M, Persona A, Sgarbossa F. New methodological framework to improve productivity and ergonomics in assembly system design. Int J Ind Ergon. 2011;41(1):30-42.

[7] Pheasant S. Bodyspace Anthropometry, Ergonomics and the design of work. 2nd ed. London: Taylor & Francis; 1998.

[8] Kuorinka I, Jonsson B, Kilbom A, Vinterberg H, Biering-Sørensen F, Andersson G, et al. Standardised Nordic questionnaires for the analysis of musculoskeletal symptoms. Appl Ergon. 1987;18(3):233-237.

[9] Karwowski W. International encyclopedia of ergonomics and human factors. 2nd ed. Vol. 1. New York: Taylor & Francis; 2006.

[10] Govil N, DeMayo WM, Hirsch BE, McCall AA. Optimizing positioning for in-office otology procedures. Otolaryngol Head Neck Surg. 2017;156(1):156-160.

[11] McAtamney L, Nigel Corlett E. RULA: a survey method for the investigation of work-related upper limb disorders. Appl Ergon. 1993;24(2):91-99.

[12] Barnes RM. Motion and Time Study. 3rd ed. New York: John Wiley & Sons; 1980.

[13] Hartanti LPS. Work measurement approach to determine standard time in assembly line. Int J Manag Appl Sci. 2016;2(10 Special Issue-1):192-195.

[14] Kushwaha DK, Kane PV. Ergonomic assessment and workstation design of shipping crane cabin in steel industry. Int J Ind Ergon. 2016;52:29-39.

[15] Bridger RS. Introduction to ergonomics. New York: Taylor & Francis; 2003.

[16] Zare M, Croq M, Hossein-Arabi F, Brunet R, Roquelaure Y. Does ergonomics improve product quality and reduce costs? a review article. Hum Factors Ergon Manuf Serv Ind. 2016;26(2):205-223.

[17] Deros BM, Yusoff ARM, Ismail SJ, Daruis DDI. Optimizing workstation design for standing work system in an electronics assembly work. Iran J Public Health. 2016;45(1):17-24.

[18] Zakerian SA, Garosi E, Abdi Z, Bakhshi E, Kamrani M, Kalantari R. Studying the influence of workplace design on productivity of bank clerks. Health Saf Work. 2016;6(2):35-42.