Workload measurement of batik workers at UKM batik jumputan Yogyakarta using RULA and NASA-TLX

R Widiastuti[1], E Nurhayati[1], D P Wardani[1] and E Sutanta[2]

[1] Department of Industrial Engineering, Universitas Sarjanawiyata Tamansiswa Miliran street #16, Yogyakarta, Indonesia
[2] Department of Informatics Engineering, Institut Sains & Teknologi AKPRIND Yogyakarta Kalisahak street #28, Yogyakarta, Indonesia

E-mail: dias.rw@ustjoga.ac.id

Abstract. A workload that exceeds the ability of workers or vice versa can cause a problem for workers. In this paper, we present a measurement of the physical and mental workload of workers at UKM Batik Jumputan Ibu Sejahtera Yogyakarta, and it has a purpose to find problems that occur so that recommendation for further improvement and problem-solving can be proposed. The physical workload measured by using RULA (Rapid Upper Limb Assessment) method, while the mental workload is measured by using NASA-TLX (NASA *Task Load Index*). This study succeeded in revealing the problems occur on workers such as there are differences in the level of worker risk which is caused by differences in age and differences in worker perceptions towards the dimensions of workload, and some workers experience high or very high levels of risk which is caused by improper work postures. Recommendations that can be done to solve the case are adding or replacing workers, increasing the workability of workers, adding work aids, changing work methods, and increasing workers' understanding so that they can fill out questionnaires accurately.

1. Introduction

The workload of worker is one of the important factors in a work activity, so the measurement of workload is essential in a work environment. The term workload has been defined in several ways, one of which is a difference between the ability or capacity of workers compared to the demands of work to be carried out [1]. The workload includes 2 types, namely, physical and mental [2]. Excessive physical and/or mental workload can cause disorder, which is caused by improper work postures. This study aims to find out the physical and mental workload of the workers so that the recommendations for improving work procedures are known.

Several methods can be used to solve the problem of physical workload (work posture); one of them is RULA (Rapid Upper Limb Assessment). RULA is a method for assessing the posture, style, and movement of a work activity which is related to the use of the upper limb [3]. Measurement of differences in mental workload experienced by workers can also be done using various methods, both subjective and objective. However, objective measurement rarely used because they require expensive costs and considered not comparable to the results that are not necessarily accurate. Therefore, other alternatives have been developed by measuring and using subjective methods. The workload measurement method that is popularly used is NASA-TLX method (NASA *Task Load Index*). This method was developed by Sandra G. Hart (from Aerospace Human Factors Research Division, NASA-Ames Research Center, Moffett Field, California) and Lowell E. Staveland (from San Jose State University) in 1988 [4-5]. Originally, NASA-TLX consisted of two parts: the total workload that is divided into six subjective subscales that are represented on a single page, serving as one part of the questionnaire of mental demand, physical demand, temporal demand, performance, effort, and frustration level [4]. There is a description for each of these subscales that the subject should read before rating. They are rated *for each task* within a 100-points range with 5-point steps. These ratings then combined to the task load index. Each description has provided a description to help respondents in answering more accurately [6].

Research and measurement of workload is a topic that attracts the attention of many researchers. Several studies that correlate with this topic founded in [7-24]. Theoretically, the workload consists of physical and mental workload [1]. Measurement and analysis of physical and mental workload can be done by using different methods, including RULA and NASA-TLX. Research using the RULA method was found, among others to an investigation of work-related upper limb disorders [25], combined RULA and fuzzy logic for assessing the risk of working [26]. Method of RULA has also been developed for real-time evaluation by [27], while the research of [28] adapted for the need on cross-cultural analysis of biomechanical exposure and tested the measurement properties of RULA and Strain Index (SI) in Brazilian-Portuguese countries. The application of NASA-TLX method to the measurement or analysis of workload found in the publication of several research results, including found in [2, 11, 12, 14-19, 21, 22, 29-32]. Measurements of workload by using NASA-TLX method are generally carried out by using a questionnaire that serves to collect data on workload needs on workers' mental activities. The use of the questionnaire on workload measurement found in [9], [33], [14], [34], and [24]. The focus of our research is to measure physical workload by using RULA method and measure mental workload by using NASA-TLX method, especially for batik workers at UKM Batik Jumputan Ibu Sejahtera Yogyakarta.

2. Materials and methods

The data used in this study include workers, work posture, and NASA-TLX questionnaire. The study conducted at 5 work stations, each station consisting of 2 workers, with ages in the range of 32-64 years. Work station and worker data on the research object shown in Table 1.

Table 1. Work stations and workers

Work Station	Worker	Sex	Age (Years)
1. Pattern making	Worker #1	Female	45
	Worker #2	Female	45
2. Tying dye fabric	Worker #3	Female	32
	Worker #4	Female	43
3. Coloring	Worker #5	Female	36
	Worker #6	Male	64
4. Drying	Worker #7	Female	32
	Worker #8	Female	33
5. Finishing	Worker #9	Female	42
	Worker #10	Female	56

Physical workload needs are measured based on the image of work posture on each work station. The physical workload data obtained were tested by using the test of adequacy, uniformity, and normality of the data. Furthermore, the determination of physical workload requirements is calculated by using RULA method with the help of Ergofellow software. Mental workload data was collected by using the NASA-TLX questionnaire to capture the workload needs of workers' mental activities. Mental workload needs consist of 6 activities, namely thinking, deciding, counting, seeing, remembering, and looking for. The questionnaire consisted of 6 questions which were filled out by respondents, and they are all the workers in a total of 10 people. Respondents filled out the questionnaire by selecting a value that shows the mental workload needs score with an interval of 0-100 values. The result of the questionnaire entries is then used to determine the value of mental workload based on indicators of time, performance, effort, and facilities. Mental workload data from questionnaire result were tested by using test correlation person with the help of Minitab software 18. The need for mental workload was calculated using NASA-TLX method. The procedure for measuring mental workload by using NASA-TLX method is weighting, rating, calculating product value, calculating Weighted Workload (WWL), calculating WWL average, and interpreting the score calculated. Calculation of product value done using formula (1), WWL is calculated using formula (2), and the score or mean value of WWL is calculated by using formula (3) [32].

$$Product = Rating * Weight\ Factor \tag{1}$$

$$WWL = \Sigma Product \tag{2}$$

$$Score = (\Sigma(WeightxRating))/15 \tag{3}$$

3. Results and discussion

In our study, the analysis of physical workload was carried out based on work postures in 5 parts, such as the neck, upper arm, lower arm, wrist, and wrist twist. The result of the work posture analysis is in the form of movement angles in each part of the body of the worker. Pictures of work postures for each work station are shown in Figure 1 through Figure 5. The movement angles in the work posture image are scored according to RULA standard, which is then used as a basis for calculating physical workload.

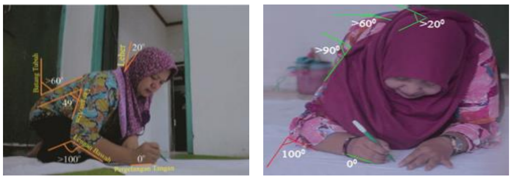

Figure 1: Work posture at work station 1

Figure 2: Work posture at work station 2

Figure 3: Work posture at work station 3

Figure 4: Work posture at work station 4

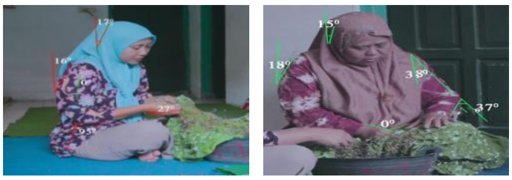

Figure 5: Work posture at work station 5

The result of normality test on work posture test obtained the following values, they are such as the amount of research data is 10, the average of work posture data is 5.3, the standard deviation is 1.160, of KS (Kolmogorov-Smirnov) value is 0.202, and P-value is 0.150. By using an accuracy level of 95%, the result of the normality test included as usual if 0.05 <KS <1.50. The result data of the normality test obtained P-value of 0.150, and it means that the data is reasonable, and there is no need to improve data. The result of homogenous data test obtained an average value of 5.3, UCL (Upper Control Limit) value of 8.78, LCL (Lower Control Limit) value of 1.82, and all work posture data are between UCL and LCL, and this means that the data is already in normal condition. The sample used in this study is 10. The result of the data adequacy test by using Slovin's formula obtained a value of sample (n) of 9.75, and it means that the sample used is sufficient because there are more than the number of samples that should be used. Furthermore, the calculation of workers' physical workload, risk level, and required actions are shown in Table 2.

Based on our study, it can be known that the highest physical workload score is 7 which is experienced by 2 workers at the drying work station with a high-risk level, and it needs further action at present. Addition, there are 5 workers who experienced workload with moderate risk level, and further action is needed shortly. The remaining of the result is 3 workers involved in a small physical workload with a score of 4, occurring at finishing work stations with a small level of risk, and further actions can be carried out in the future.

The result of the physical workload analysis (Table 2) indicates that there is a problem that occurs at the work station on the stage of coloring, and there are different risk levels for the two workers. This condition is characterized by differences in the age of workers resulting in differences in workers' abilities. Improvement recommendations for staining work stations are to improve work capacity of workers 6. The result of the analysis of physical workload also indicates a problem at the drying station, and both workers are at a high-risk level. This condition can occur due to improper work posture, and it called a bending position (Figure 4) in the drying activity. Recommendation for improvements that can be given is by adding tools and changing work methods. The tools added can be in the form of a drying rack and/or a drying rope while changes in work methods can be done by moving the drying place from the floor to the drying rack and/or drying rope so that the workers do not need to bend when doing drying activities.

Table 2. The physical workload for each work station uses the RULA

Work Station	Worker	Age (Years)	Score	Risk Level	Action
1. Pattern making	Worker #1	45	5	Medium	Shortly
	Worker #2	45	6	Medium	Shortly
2. Tying dye fabric	Worker #3	32	5	Medium	Shortly
	Worker #4	43	5	Medium	Shortly
3. Coloring	Worker #5	36	4	Low	Next time to come
	Worker #6	64	6	Medium	Shortly
4. Drying	Worker #7	32	7	High	At present
	Worker #8	33	7	High	At present
5. Finishing	Worker #9	42	4	Low	Shortly
	Worker #10	56	4	Low	Shortly

The mental workload analysis is based on the questionnaire to determine workload scores calculated by using NASA-TLX method. The mental workload scores of the workers and the workload categories obtained are shown in Table 3. By using the same methods as testing work posture data, it is known that mental workload data is included as normal, all data are in homogenous condition, and they are enough to be used and analyzed in the next step. Based on the result of experiments, it can be known that the highest mental workload score occurs in 2 workers at the coloring station with a score of 82.7 with a very high category, and the lowest score at 33.0 at the finishing work station. Three workers experienced a high mental workload spread across 3 different work stations, such as picking, coloring, and drying. The mental workload is being experienced by 6 workers spread across 4 work stations, including such as in pattern making, picking, drying, and finishing. The result of mental workload analysis (Table 3) indicates that there are problems occur in the work station of picking, coloring, and drying, the cases are such as there are differences in the level of risk and there are 2 workers have a high risk. Based on the questionnaire data, it is known that these conditions occur due to differences in workers' perceptions of the dimensions (weights and ratings) of the mental workload. The recommended further improvement for this problem is to ensure workers understand the questionnaire contents so that they can fill accurately, such as adding descriptions to the questionnaire [6]. The result of the mental workload analysis in this study also indicates a problem with the drying work station, and in which the worker 6 has a very high level of risk. Based on the questionnaire data, it is known that these conditions occur due to "very high levels of frustration" and "performance", each worth 90. It is recommended to add workers or replace workers 6 with workers who have ability according to job demands.

Table 3. The mental workload for each work station uses the NASA-TLX

Work Station	Worker	Age (Years)	Score	Category
1. Pattern making	Worker #1	45	47.0	Medium
	Worker #2	45	48.3	Medium
2. Tying dye fabric	Worker #3	32	52.7	High
	Worker #4	43	48.3	Medium
3. Coloring	Worker #5	36	76.0	High
	Worker #6	64	82.7	Very high
4. Drying	Worker #7	32	59.0	High
	Worker #8	33	40.3	Medium
5. Finishing	Worker #9	42	33.0	Medium
	Worker #10	56	33.3	Medium

Our study indicate that the highest physical workload occurs in male workers, this is in contradiction with Darvishi and Meimanatabadi [14] which states that the maximum physical workload occurs in female workers. This difference in results occurs because in this study male workers have the oldest age with a significant age difference. Meanwhile, the mental workload are in accordance with Gary et.al. [10] where the highest mental load occurs due to the amount of work activity.

4. Conclusion

The result of the workload measurements at UKM Batik Jumputan Ibu Sejahtera Yogyakarta shows that the highest physical workload of workers occurs at the drying work station with a score of 7, while the highest mental workload occurs at the coloring station with a score of 82.7. Problems that occur in workers are different levels of risk caused by differences in age and differences in workers' perceptions of the dimensions of workload, and some workers experienced high or very high levels of risk as a result of improper work postures. Recommendations needed for repairs are adding or replacing workers, increasing the work capacity of workers, adding work aids, changing work methods, and increasing workers' understanding so that questionnaires more accurate. Subsequent research is conducted to analyze the effect of work equipment ergonomics on the occurrence of disorder and the design of work aids that are appropriate to work requirements.

5. References

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