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THE EFFECT OF MATERIAL CONVEYANCES ON WORKLOAD, MUSCULOSKELETAL DISORDERS, PRODUCTIVITY AND PERFORMANCE IN THE PROCESS OF PLATE CUTTING

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Abstract. The use of material conveyances that are not in accordance with the concept of ergonomics harm the human body. Repair of work brushes by applying ergonomics to material conveyances can reduce the risk category. The purpose of this study was to determine the effect of material conveyance on reducing workload, musculoskeletal disorders, increasing productivity and performance. The study was conducted using the same subject design method with a sample of 16 workers. The data were analyzed by paired t-test with a significant level of $p<0.05$. The results of the analysis showed that the PO workload data was 104.4 beats per minute, P1 was 93.5 beats per minute there was a decrease of 10.9 beats per minute or 10.4%, PO musculoskeletal complaints were 80.1 scores, P1 was 70.0 the scores were decreased by 10.1 or 12.6%, PO productivity of 0.201, P1 of 0.355, an increase of 0.154 or 43.4%. The conclusion is that the use of material conveyances means a decrease in workload, musculoskeletal disorders, an increase in productivity and performance. It is recommended to workers to use material conveyances equipment in carrying out transport and material transport activities.

Keywords: ergonomic, material conveyance, plate cutting process.

1. INTRODUCTION

Material conveyance is a tool used to carry out the work of lifting and transporting materials carried out by workers to move loads from an origin location to a destination location [1]. The materials conveyance used manually. The reason for using it manually with human labor in this material transfer activity is because there are several advantages that can be obtained, namely more flexibility in moving materials at irregular work sites, cheaper and easier to do for light loads.

The activity of lifting and transporting the eser plate is carried out by four workers without using a load carrying tool, carried out not ergonomically, namely with an unnatural attitude or an attitude of forced labor. This condition can increase the workload, cause various disorders in the musculoskeletal system, quickly cause fatigue and be followed by a decrease in productivity [2].

The process of lifting and transporting the eser plate needs to be improved with the following provisions: (1) the load that is lifted and transported for men is 20 kg, while for women 15 kg, (2) the method of lifting and transporting needs to be done correctly, for example both hands, arms, and the whole body plays a role, (3) both shoulders and body are burdened evenly [1].

Every effort to repair a work station should be simple, inexpensive, can and easy to do, can reduce workload, musculoskeletal disorders and increase productivity [3][4]. Especially regarding human resources (workers) must be empowered as optimally as possible, to achieve this goal, every worker must be provided with comfortable, safe, efficient work facilities. Work facilities include: work station facilities and work facilities, work

environment, and work organization that must be in accordance with the abilities, abilities and limits of workers with the hope of achieving the highest productivity [5][6].

Starting from these problems, improvements were made to the lifting and transporting process of the eser plate, in an effort to overcome the problems that arise, namely by using material conveyance, with the hope that the workload, musculoskeletal disorders can be reduced, so productivity and performance can be increased.

The problem that focuses on research on the plate positioning device, with indicators in the form of workload, musculoskeletal disorders, productivity and performance in lifting and transporting plates, the following problems can be described: (a) whether the use of material conveyances in lifting and transporting eser plates can reduce the workload on workers, (b) whether the use of material conveyances in lifting and transporting eser plates can reduce musculoskeletal disorders in workers, (c) whether the use of material conveyances in lifting and transporting eser plates can increase the productivity and performance of workers.

The general objective to be achieved in this study is to determine the means of conveying materials in lifting and transporting eser plates to decrease workload, musculoskeletal complaints and increase productivity and worker performance. The specific objectives to be achieved in the research are as follows: (a) knowing the use of conveying materials in lifting and transporting activities can be a workload on workers, (b) knowing that the use of conveying materials in lifting and transporting activities can decrease workload on workers, (c) knowing the use of material conveyances in lifting and transporting activities can increase worker productivity and performance. The practical function expected in this study are: (a) useful for researchers using the means of transporting materials to refer to the ergonomic aspects, (b) beneficial for workers in the use of material conveyances in lifting and transporting activities so that it refers to the ergonomic aspect. The theoretical functions expected in this study are: (a) the results of this study are expected to contribute ideas in the development of science and technology related to ergonomics, (b) the results of this study are expected to be used as a reference by other researchers in conducting similar research, (c) the results of this study are expected to be a reference for workers in lifting and transporting activities to reduce fatigue, and disorders of musculoskeletal.

2. METHODS

2.1 Research Design

This research is an experimental study using the same subject design method. In this study, a washing out is needed which is useful for eliminating the effects of previous treatments so as not to leave an effect or response (residual effect), [4]. The design of this research can be seen in Figure 1.

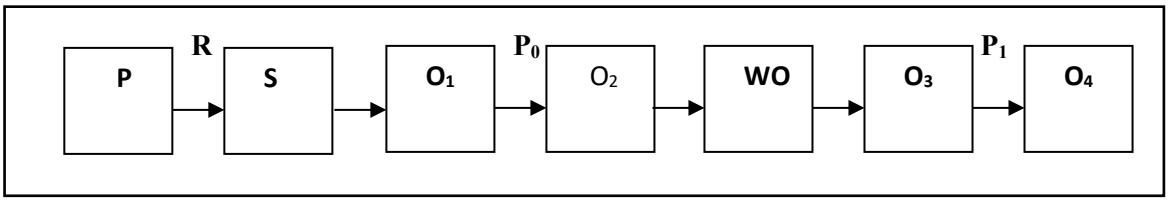

Figure 1. Treatment by Subjects Design

Description:
P : Population
R : Randomization
S : Samples that meet the inclusion criteria
P_0 : Treatment without material conveyance
P_1 : Treatment without material conveyance
O_1 : Initial observation of treatment without material conveyance
O_2 : Final observation of treatment without material conveyance
O_3 : Initial observation of treatment with material conveyance
O_4 : Final observation of treatment without material conveyance
WO : Wash out to remove the carry over effects given for one day

The research was carried out at Politeknik Negeri Bali Mechanical Technology Workshop. The research was conducted in June 2021. The scope of this research is in the field of Work Physiology Ergonomics which is focused on workload, musculoskeletal disorders, productivity, and performance, on lifting and carrying activities of eser plates.

2.2 Sampling Technique

The sampling technique for this study was random sampling [7]. The total population of lifting and transporting large plates that enter the inclusion criteria is 28 people. The 28 people in charge of lifting and transporting the eser plate were carried out by simple randomization using a random number table so that 16 people were obtained as research samples.

2.3 Research Instrument

The instruments or measuring instruments used in this study are as follows:

a. Stop Watch brand Casio made in Japan is used to record the time and count the pulse.
b. Super brand anthropometry Made in Japan to measure the anthropometry of the worker's body.
c. Kodak digital camera made in Japan to document the work attitude.
d. The Nordic Body Map questionnaire with four Likert scales was used to interpret the musculoskeletal disorders
e. The Detecto Medic Scale brand made in Japan is used to measure body weight.

2.4 Research Procedure

To avoid errors in data collection, research procedures were made, namely making a schedule for giving treatment and taking data, which can be shown in Table 1.

Table 1. Schedule of Treatment

Period I.		Period II.	
Day	Subject	Day	Subject
1	Treatment before using material conveyance on lifting and transporting plates of eser (PO)	1	Rest (16 people did not do the treatment)
2	WO	3	Treatment after using material conveyance on lifting and transporting eser plates (P1)

Description:
PO : Treatment without material conveyance on lifting and transporting eser plates.
WO : Washing Out.
P1 : Treatment with material conveyance on lifting and transporting eser plates.

2.5 Data Analysis

The steps of data analysis are as follows:

a. The data that has been obtained is then processed and analyzed with the help of the SPSS (Statistical Package for The Social Science) version 15.00 program. Statistical tests are determined with the following stages:
b. Descriptive analysis in order to obtain the mean, standard deviation, and range of the research variables.
c. Significance test to determine the difference in the mean of the control (PO) and treatment (P1) groups with the t test paired if the data is normally distributed with a significance level of 5% ($\alpha = 0.05$).
d. Abnormal data were tested by nonparametric statistical tests, namely the Wilcoxon test.

3. RESULTS AND DISCUSSION

3.1 Test Data

The number of workers who were the subjects in this study were 16 men, with two types of treatment in the lifting and transporting activities of the eser plate, namely before using the material conveyance and after using the material conveyance. Subject characteristics included age, height, weight, and body mass index (BMI). The average characteristics of the subjects can be shown in Table 2.

Table 2 Subject Characteristics

Variable	Mean	Standard Deviation	Range
Age	18,8	0,9	18,0 – 20.,0
Weight (kg)	57,0	2,4	55,0 – 65,5
Height (cm)	165,6	1,0	163,0 – 167,0
Body mass index	20,8	0,8	20,2 – 23,6

In Table 2 it can be seen that the average age of the subjects in this study was 18.8 ± 0.9 years. Age, weight, and height are included in the normal category, while the body mass index is in the normal category.

a. Subject Anthropometry Data

Subject anthropometry measured in this study included eye height, shoulder height, elbow height, and waist height. The subject's anthropometric measurements are related to the means of transporting materials. Subject anthropometric data can be shown in Table 3.

Table 3. Subject Anthropometry Data

Variable	5th Percentile	95th Persentile	Mean	Standart Deviation
Height	164,5	167,0	165,8	0,8
Eye Height	154,5	157,0	155,8	0,9
Shoulder Height	136,5	139,5	137,8	0,8
Elbow Height	83,5	86,0	83,8	0,8
Waist Height	95,0	98,0	95,9	1,3

In Table 3 it can be seen that the average standing elbow height of the subjects in this study was 83.8 ± 0.8 cm, the 5th percentile of elbow height was 83.5 cm, used as the basis for calculating the handle of the material conveyance.

Manuaba [8] state for manual work that requires space for tools and materials with a workbench surface height of 10 to 20 below elbow height in a standing position. Can be shown in the picture of the means of materials conveyance Figure 3, Picture before treatment (PO) Figure 4, Picture after treatment (P1) Figure 5.

Figure 3. Materials Conveyance

Figure 4. Before Treatment (PO)

Figure 5. After Treatment (P1)

b. Workload

The workload is calculated based on the difference between the pulse at work and the resting pulse. The pulse rate at work is measured immediately after completing the work, while the resting pulse rate is calculated before starting the work. The data obtained were analyzed for significance by using the paired t-test. The difference in the average workload in the treatment before using the material conveyance (PO) and after using the material conveyance (P1). The results of the analysis of significance with the paired t-test can be shown in Table 3.

Table 3. t-test – Paired Average Subject Workload between Treatments

Subject Group	N	Average Working Pulse (dpm)	Standard Deviation	Mean Difference	t	p
PO	16	104,4	4,5	10,9	8,117	0,000
P1	16	93,5	4,2			

The analysis of significance in table 3.2 using the t - paired test showed significantly different results ($p< 0.05$) with $t = 8.117$ and $p = 0.000$. This means that the use of materials conveyances in lifting and transporting plates can reduce the workload on workers.

c. Musculoskeletal disorders

The average value of musculoskeletal disorders was calculated based on the value of disorders after lifting and transporting the eser plate minus the disorders value before lifting and carrying the eser plate for each treatment. The data obtained were analyzed for significance by using the t-paired test. The difference in the mean of musculoskeletal disorders in the treatment before the use of materials conveyances (PO) and after the use of materials conveyances (P1). The results of the analysis of significance with the t - paired test can be shown in Table 4.

Table 4 Paired t-test Mean differences in Musculoskeletal Disorders Subjects between treatments

Subject Group	N	Mean Musculoskeletal Disorders Score	Standart Deviation	Mean Difference	t	p
PO	16	80,09	1,74	-10,08	-15,428	0,000
P1	16	70,01	1,99			

Table 3.3 shows that with the paired t-test analysis the results were significantly different ($p<0.05$) with $t = -15.428$ and $p = 0.000$. This shows that there is a difference between P0 and P1. Therefore, it can be stated that the use of material conveyances in lifting and carrying eser plates can reduce musculoskeletal disorders in workers.

a. Eser Plate Cutting Production

The production of eser plate cutting is carried out on a plate cutting machine, namely; cutting the eser plate before using the material conveyances (PO), and cutting the eser plate after using the material conveyance (P1). Cutting production data is calculated in one working hour with the same accuracy between (PO) and (P1). The

production results between P0 and P1 were carried out by using the t-paired test, the results of the analysis of significance can be shown in table 5.

Table 5. T-test – Paired Average Production

Subject Group	N	Average Production (cuts/hour)	Standart Devation	Mean Difference	t	p
PO	16	20,96	3,23			
				- 12,13	-5,597	0,000
P1	16	33,09	9,95			

From table 3.4, the analysis of significance with the t-paired test shows that there is a significant difference in production results between PO and P1 with p <0.05 and t = - 5.597 and p = 0.000. This means that the use of material conveyances can increase production, as shown in Figure 3.

Work productivity is the ratio between the average production yield of cutting plates per hour and workload for each treatment. The analysis of the significance of the productivity results between PO and P1 was carried out using the paired t test, which can be shown in Table 6.

Table 6. t-paired test of work productivity mean

Subject Group	N	Average Productivity	Standart Deviation	Mean Difference	t	p
PO	16	0,201	0,031			
				-0,154	*-6,542*	0,000
P1	16	0,355	0,109			

Table 6 shows that there is a significant difference (p <0.05) with t = -6.542 and p = 0.000 on work productivity between PO and P1. This means that it shows that the use of material conveyances can increase work productivity.

3.2 DISCUSSION

a. Subject Conditions

The subjects in this study were male workers whose characteristics discussed were age, weight, height and body mass index. The age of the subjects in this study was between 18 – 20 years with a mean of 18.8 ± 0.9 years. In this age range the subject can perform activities with optimal physical strength. A person's physical capacity is directly proportional to some extent with age, and reaches its peak at the age of 25 years (Manuaba, 1990). The average body weight of the subjects was 57.0 ± 2.4 kg, while the average height of the subjects was 165.6 ± 1.0 cm, and the average body mass index was 20.8 ± 0.8 years. Adiputra [9] stated the ideal body weight with the formula height minus 100 ± (reduction multiplied by 10%). The normal body mass index (BMI) for Indonesians is 18-25 [3].

Anthropometric data of the subjects as shown in table 3.2 shows that the average standing elbow height of the subjects in this study was 83.8 ± 0.8 cm. This elbow height is used as the basis for making material conveyances for lifting and transporting large plates. The height of the material conveyances must be below the subject's elbow height of 10 cm, adjusted to the size of the eser plate cutting machine, namely; machine table height 90 cm, width 60 cm, length 240 cm.

b. Workload

In this study, ergonomic intervention was carried out on the lifting and transporting activities of the eser plate using a materialconveyances, in fact a significant difference (p <0.05) was obtained compared to before using a materials conveyance on the workload of workers. The results of the analysis show that before using the material conveyance (PO) the average worker load is 104.4 beats per minute, while after using the material conveyance (P1) it is 93.5 beats per minute. This means that there is a decrease of 10.9 beats per minute or a decrease of 10.4%. According to Grandjean [2] and Adiputra [1], the working pulse is between 100 – 125 beats per minute, including the moderate category. So the work pulse before using the material conveyance is in the medium category, while after the ergonomic intervention using the material conveyance is included in the light category.

c. Musculoskeletal Disorders

Musculoskeletal disorders experienced by workers often occur in the upper and lower neck, back, waist, both upper arms, as well as both knees and calves. Unnatural work attitudes or forced attitudes experienced by workers cause reactions in the form of complaints in the musculoskeletal system [10][11]. The results of the analysis showed that after using the material conveyance there was a significant difference (p <0.05) and a decrease

in musculoskeletal disorders from an average score of 80.1 to 70.0. This means that it experienced a large decrease of 10.1 or 12.6%.

d. Work productivity

The occurrence of a decrease in workload and a decrease in musculoskeletal disorders in lifting and transport activities directly increases work productivity. The analysis shows that productivity before treatment (PO) is 0.201 while after treatment (P1) is 0.355. This means an increase of 0.154 or 43.4%. Ergonomic intervention on equipment that is suitable for anthropometry will be able to reduce workload, and musculoskeletal disorders and can increase work productivity [12] [13]. A decrease in workload, and musculoskeletal disorders, as well as an increase in work productivity can increase work time efficiency. The increase in productivity also means an increase in the work efficiency [14][15].

4. CONCLUSION

4.1 Conclusion

Starting from the results of the analysis and discussion, it can be concluded as follows:

a. Material conveyance in lifting and transporting large plates can reduce workload workers in plate cutting.
b. Material conveyance in lifting and transporting ice plates can reduce worker musculoskeletal disorders in the plate cutting process.
c. Material conveyance in lifting and transporting eser plates can increase worker productivity and performance in the plate cutting process.

4.2 Suggestions

a. To workers in carrying out lifting and transporting eser plates using material conveyance avoid musculoskeletal disorders.
b. To the policy makers to pay attention to the condition of the tools and facilities in order to increase productivity and performance.

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