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RESEARCH ARTICLE

The Study of Human Physiological Aspect; The Implementation of Clean Production Technology Through Participatory Ergonomic Decreases Workers' Musculoskeletal Disorders

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Abstract

Metal manufacturing industries in Bali are spread in Klungkung Regency, Bali. The position of the metal manufacturing industries is in buffer sector of Bali tourism development, so that the stability of sales and production in each period continues to increase. Demand for product quality assurance is carrying out by exporters, including guaranteeing environmentally friendly process. There are many high-quality products are rejected in international market due to the fact that metal manufacturing industries have not considered human and environmental factors (eco-labeling) in their production activity. Companies are switched from Industrial Systems Type I to Closed Loop Industrial System. Various environmental management and industrial management approaches have been carried out, but the current literature review has not reached human physiological aspect. This research is experimental research using treatment by subject design. The result shows that the implementation of clean production technology through participatory ergonomic is able to increase work performance, in the form of the decrease of musculoskeletal disorders as much as 34.66%.

Keywords: Physiological, Musculoskeletal disorders, Metal industry.

Introduction

Work activity may influence physiological burden. The heavier the physical burden, the heavier the body metabolism burden will be. Therefore, every single activity needs to pay attention to human ability, skill, and limitation due to its effect to the increase of workers' work performance. The increase of work performance can be carried out if the condition of work environment is optimal, as the condition in metal manufacturing industries. Klungkung-Bali is famous for its tourist village with the main object of metal industry center. The majority of local people have the skills to process material derived from metal.

The products are religious ceremonial equipment like *bokor*, *sangku*, *wanci*, pagut umbrella, or other equipment such as gong and lampshade. Based on the result of processing survey data of period quarter IV of 2014, the growth of metal manufacturing industries is 15.39%. Metal manufacturing industries market, besides tourists visiting Bali, is Europe and Australia. Thus, metal manufacturing industries will not be disappeared because such industries are able to provide essential contribution in order to enrich and to preserve the nation's culture, especially in Bali. Metal processing has a philosophical meaning, that is, the expression of the existing cultural creativity of the community as an Archipelago cultural heritage. In the process of metal production, it is found a work attitude of printing steel that is not ergonomic, an attitude of work labor, and work organization on the use of tools that has not been arranged properly, leading to the occurrence of potential injury on muscles and skeleton of workers' body.

Thus, it is important to evaluate work attitude to reduce musculoskeletal disorders. Other implication if such work activities do not meet solution is musculoskeletal disorders. Musculoskeletal disorders that keep occurring in certain part of the body will result in other disorders like fatigue. Fatigue

commonly attacks the central or peripheral nervous system, which is muscles contracting [1], body immune, and decreased work concentration [2]. The physical fatigue is caused by physiological change seen in unstable mental condition [3]. The result of the fatigue is the decrease of work capacity and body's resistance [4], so that the workers are not able to bear work burden [5].

Problems that currently occur in metal manufacturing industries have been solved approaches. with several namelv the implementation of environmental management and security management. However, those approaches only take a look at process aspects and products, not consider the workers performance as a part of wokers' improvement. physiological condition Therefore, it is necessary to conduct a with participatory research ergonomics approach. Generally, ergonomic model can be carried out through conceptual and curative approach [6].

Commonly, the condition of the existing metal manufacturing industries currently are still lacking of technology and human resources. Thus, it is important to hold a research by looking at the whole problem (holistic-participative) which can result comprehensive conclusion, such as workers of metal manufacturing industries are considered as 'human capital' who need to get much attention (to be treated like a human). Performance increases along with the increasing company's profit.

Table 1. Subject abaractoristics (n=67)

Research Design

This research is experimental research with treatment by subject design. The subjects are selected from thepopulation through Random Sampling.

Research Object

The object of this research is workers of manufacturing industries metal in Klungkung, Tihingan village, Bali, with activity criteria (task): a) preparation of metal material process; b) metal material processing (casting or forging); c) product finishing process. Data collected is the record of work attitude or effective and ineffective movement, work environmental condition, the use of muscle and skeleton of the workers' body.

Population

Targeted population of this research is all industries of Gamelan Craftsmen Group "Labda Karya" of Tihingan village. Banjarangkan district, Klungkung Regency. There are 59 business units consisting of 223 people. Reachable population is 17 business units or equals to 67 workers.

Result and Discussion

Subject Characteristic Data

Subject characteristics include age, weight, height, work experience, and BMI which completely can be seen in the following Table 1.

Information	Mean	Standard Deviation
Age (yr)	48.82	9.52
Weight (kg)	62.44	8.24
Height (cm)	166.25	5.15
Work Experience (yr)	20.18	9.77
BMI (kg/m ²)	22.60	2.830

The average age of the population can be seen from the muscle strength that has decreased because the recommended optimum muscle strength to be able to work is around the age of 20 to 30 years [7], while according to [8], it is stated that physical strength will start to decrease in the age of 39 years. This statement is in line with [9] clarifying that physical capacity is proportional to the age of a person up to the peak of 25 years old. Meanwhile, according to [10, 5], it is stated that the peak of muscle strength is in the age of 25 to 35 years. Workers of the industries have experience decreasing muscle strength, but the standard deviation is in 9.52, meaning that the workers are below 25 years old, and they are included in productive stillworkers. However, the average BMI value is in ideal category, but there is 9.09% above the average and 1.82 below the ideal age. It happens probably due to inheritance or hereditary factor. The average work experience 20.18 years, but there is quite high variation, that is, the amount of standard deviation reaches 9.77 meaning that there is work experience below 15 years. The implementation of clean production

technology is generally carried out with the initial stage of minimizing risk on the human and surrounding environment, that is known as 5R [11,12], including Elimination, Reduce, Reuse, Recycle, Recovery, according to United Nations Environment Program (UNEP).

Ergonomic participatory approach is conducted by assembling workers and employer to find out the solution of some proposed alternatives. This participatory process is expected to meet the need of the industries which is the solution of the problem [13, 14]. Generally, the benefits for the increase of performance are security, comfort, health, effectiveness, efficiency, and productivity [15]. Some similar studies conducted by the previous researches, such as [16, 17].

A research related to ergonomic takes the research subjects of workers in printing sector of metal casting industries in Ceper, Klaten. The report of the result shows: (a) increased workers' performance in the form of decreased work burden, decreased musculoskeletal disorders, decreased fatigue, decreased work boredom, increased work satisfaction, and increased peripheral oxygen saturation; (b) increased company's environmental quality in the form of a decrease in total indoor suspended dust, decreased inhaled dust, decreased skin surface temperature, and (c) increased value added of waste. In addition the to of implementation Clean Production Technology, [16]makes а Right Use Technology product, that is, Liquid Steel

Manual Transportation (Ladle-Kowi) with Capacity of 50 kg. Some researches of Clean Production Technology using metal industry as the object have been found that on some previous researches, such as a research about Ergonomic Approach Analysis [18], the result is used as the base of identification and improvement of the work condition on metal casting industry with induction kitchen system; a case study in PT. Adi Logam Jaya Ceper Klaten.

A research on Hazard and risk valuation in metal casting industry with induction furnace system [19] has a result that is used as the base of determining initial work improvement. In accordance with other researches on work fatigue, work boredom, and work satisfaction [20], the result of this research is used as the base of the recommendation on worker's physiological improvement in metal industries as well as work burden evaluation and workers' musculoskeletal disorders in metal casting company with induction kitchen system [21].

The result is used as the base of work condition improvement. From all literatures above, it can be concluded that ergonomic study may complete and increase the industry's problem solving. Participatory ergonomic approach considers local culture as well as provides unique process carried out workers in metal manufacturing bv industries. The implementation of Clean Production Technology makes other similar companies be a model in order to increase workers' performance in the form of the decrease of musculoskeletal disorders in Metal Manufacturing Industries.

N		Very	Painless	Rather Painful	Painful	Very Painful
NO	Part of the Body	Painless (%)	(%)	(%)	(%)	(%)
1	Pain/Stiffness in the upper neck	14.55	69.09	3.64	7.27	1.82
2	Pain/Stiffness in the lower neck	10.91	72.73	3.64	7.27	3.64
3	Pain in the left shoulder	20.00	74.55	3.64	1.82	1.82
4	Pain in the right shoulder	16.36	74.55	3.64	3.64	5.45
5	Pain in the left upper arm	14.55	80.00	3.64	1.82	-
6	Back pain	16.36	69.09	3.64	5.45	5.45
7	Pain in the right upper arm	20.00	69.09	3.64	3.64	3.64
8	Pain in the waist	12.73	60.00	3.64	7.27	18.18
9	Pain in the buttocks	14.55	67.27	3.64	9.09	5.45
10	Pain in the butt	16.36	81.82	3.64	-	-
11	Pain on the left elbow	16.36	78.18	3.64	5.45	-
12	Pain on the right elbow	16.36	72.73	3.64	5.45	5.45
13	Pain in the left lower arm	16.36	58.18	3.64	12.73	12.73
14	Pain in the right lower arm	16.36	67.27	3.64	10.91	5.45
15	Pain in the left wrist	16.36	80.00	3.64	1.82	1.82
16	Pain in the right wrist	16.36	80.00	3.64	-	3.64
17	Pain in the left hand	16.36	78.18	3.64	-	5.45
18	Pain in the right hand	16.36	76.36	3.64	1.82	5.45
19	Pain in the left thigh	16.36	81.82	3.64	1.82	-

 Table 2: Musculoskeletal Disorders Pretest (n=67 people)

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20	Pain in the right thigh	16.36	81.82	3.64	1.82	-
21	Pain in the left knee	16.36	81.82	3.64	1.82	-
22	Pain in the right knee	16.36	81.82	3.64	1.82	-
23	Pain in the left calf	16.36	80.00	3.64	3.64	-
24	Pain in the right calf	16.36	80.00	3.64	3.64	-
25	Pain in the left ankle	16.36	83.64	3.64	-	-
26	Pain in the right ankle	16.36	83.64	3.64	-	-
27	Pain in the left leg	16.36	81.82	3.64	-	1.82
28	Pain in the right leg	16.36	81.82	3.64	-	1.82

Musculoskeletal disorders can occur in certain part of the body. One worker may experience different musculoskeletal disorders from other workers. However, because their work behavior is almost the same, it can be temporarily concluded that musculoskeletal disorders will have the same effect to one worker as well as other workers. Physical factors influence the level of musculoskeletal disorders.

Part of the body that receives bigger force than other part of the body will get high possibility of musculoskeletal disorders, as well as other part of the body. The flow of musculoskeletal disorders is caused by human muscle power during working which will experience static muscle contraction, and blood vessel is suppressed from muscle tissue. As a result, this condition will inhibit blood circulation to muscle tissue [10]. Musculoskeletal disorders are the level of disorders in the muscle and bone system, including the joints and soft tissue caused by work and work environment [4].

Meanwhile, fatigue is a condition of efficiency loss and decreased work capacity and body immune. Therefore, fatigue and musculoskeletal disorders are different although we feel them the same, that is, inside our body. Fatigue results in a decreased performance [22, 23].

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No	Bagian tubuh Very Painless Painless Rath		Rather Painful	Painful	Very Painful	
NO	Bagian tubun	(%)	(%)	(%)	(%)	(%)
1	Pain/Stiffness in the upper	50.91	47.27	1.82	-	1.82
	neck					
2	Pain/Stiffness in the lower	54.55	45.45	1.82	-	-
	neck					
3	Pain in the left shoulder	52.73	45.45	1.82	-	1.82
4	Pain in the right shoulder	56.36	43.64	1.82	-	-
5	Pain in the left upper arm	54.55	45.45	1.82	-	-
6	Back pain	60.00	40.00	1.82	-	-
7	Pain in the right upper	54.55	43.64	1.82	1.82	-
	arm					
8	Pain in the waist	47.27	49.09	1.82	1.82	1.82
9	Pain in the buttocks	50.91	45.45	1.82	1.82	1.82
10	Pain in the butt	52.73	45.45	1.82	1.82	-
11	Pain on the left elbow	54.55	43.64	1.82	1.82	-
12	Pain on the right elbow	52.73	45.45	1.82	1.82	-
13	Pain in the left lower arm	50.91	45.45	1.82	-	-
14	Pain in the right lower arm	50.91	45.45	1.82	-	-
15	Pain in the left wrist	50.91	49.09	1.82	-	-
16	Pain in the right wrist	50.91	49.09	1.82	-	-
17	Pain in the left hand	50.91	49.09	1.82	-	-
18	Pain in the right hand	50.91	49.09	1.82	-	-
19	Pain in the left thigh	50.91	49.09	1.82	-	-
20	Pain in the right thigh	50.91	49.09	1.82	-	-
21	Pain in the left knee	50.91	49.09	1.82	-	-
22	Pain in the right knee	50.91	49.09	1.82	-	-
23	Pain in the left calf	50.91	49.09	1.82	-	-
24	Pain in the right calf	50.91	49.09	1.82	-	-
25	Pain in the left ankle	50.91	49.09	1.82	-	-
26	Pain in the right ankle	50.91	49.09	1.82	-	-
27	Pain in the left leg	50.91	49.09	1.82	-	-
28	Pain in the right leg	50.91	49.09	1.82	-	-

Musculoskeletal disorders felt before improvement or the implementation of clean production technology orient in participatory ergonomic which is able to decrease musculoskeletal disorders. Thus, it indirectly gives contribution to the increase of workers performance in metal manufacturing industries. Table 4: Data Recapitulation of Musculoskeletal Disorders and Fatigue

	Pre-Test Po		Post-	Test	
Туре	R	SB	R	SB	P (%)
Musculoskeletal Disorders	56.49	8.92	41.95	13.51	34.66

R= Mean; SB= Standard Deviation; P=Change (%)

Problem in musculoskeletal system is caused by some factors, namely a) insufficient work place, b) repetitive activities, c) equipment design that is not suitable for the user, inefficient work organization, d) irregular break time, e) unnatural work behavior [24]. These disorders can be overcome by improving work tools, work system, break time management or work organization [25]. The development of industry which does not pay attention to work environment and work tools will result in the occurrence of workers' musculoskeletal disorders [26, 27].

Unnatural and repetitive work behavior may increase the risk of cumulative trauma [28, 29] and the risk of accident with various cumulative problems on the muscle [30]. A common method of evaluating skeleton muscle disorders subjectively is questionnaires *Nordic* Body Map with rank [31]. The structure of questionnaire *Nordic*

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Body Map (NBM) is divided into three parts: a) truncus muscles: upper neck, lower neck, back, waist, buttocks, butt, b) upper extremities muscles: left shoulder, right shoulder, left and right upper arm, left and right elbows, left and right forearms, left and right wrists, left and right hands, c) lower extremity muscles (lower extremity): left and right thighs, left and right knees, left and right legs.

Conclusion

The decrease of workers' musculoskeletal disorders is 34.66%, which means that the implementation of clean production technology is able to increase workers performance in Tihingan, consisting of 223 people. It is seen in the decrease of musculoskeletal disorders from the average of 56.49±8.92 into 41.51±34.66 or the change is 34.66%.

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