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Work Posture Improvement Using Ergonomic Approach Decreases Subjective Disorders of Perapen Workers on the Process of *Nguwad Gamelan* in Bali

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Abstract

The process of nguwad trompong is still considered as a heavy task for workers because it is still done using ember of the perapen (fireplace) that is exposed in open and unnatural work posture such as bending work posture. Moreover, the heat of the perapen furnace makes the work heavier for the nguwad workers which can make them tired easily and cause musculoskeletal disorders or known as subjective disorders. Thus, an experimental research was conducted using treatment by subject design toward 12 gamelan workers in Klungkung Bali. The intervention was done by improving the workstation so that the bending work posture of the prapen workers was changed into sat naturally and the bending-while-standing work posture of the smiths was changed into straighter standing work posture. Musculoskeletal disorders were measured using NIOSH Nordic Body Map Subjective Filling. The general fatigue was measured using 30 Items Self-Rating Questionnaire Industrial Fatigue Research Committee from Japan Association of Industrial Health. The data were analyzed descriptively and inferentially on the level of significance $\alpha = 0.05$. The result showed that there was a decrease of workload by 4.2%, musculoskeletal disorders decreased by 27.1% and fatigue, in general, decreased 33.7%. Thus it can be concluded that the improvement of work posture using the ergonomic approach decreases the subjective disorders of the perapen workers on the process of nguwad.

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1. Introduction

Gamelan has a meaning and a very important role for Balinese as a means of customary and religious ceremonies. Gamelan can also be used as a means of entertainment or for competition such as gong kebyar festival and bleganjur competition. Other than Bali, Gamelan is also famous in Java, Madura, and Lombok. A set of Balinese gamelan usually consists of various instruments which are played using different methods according to each tone. Each classification of gamelan type is different in form, characteristic, material type, complimentary instrument type, and is differentiated based on properties and characteristics of the instrument (Astrand and Rodahl, 1997). Trompong is one of the important instruments of Balinese gamelan which is included in the hit-to-play instrument category that often called as babonangan that uses pencon (in Balinese: moncol). Some hit-to-play instruments in Balinese gamelan that use pencon are reong, kajar, kempli, kempur, and gong. According to Sukerta (Chavalitsakulchai and Shahnavaz, 1991) trompong is one of the tungguhan pedandan category in gong kebyar which more emphasizes on melody, that is; to play the part of gending kawitan (in Central Java it is called buka), as gending connector, and to execute gending using tabuhan pattern that employs various variation or wilet.

The process of making gamelan instruments that uses pencon consists the process of nglebur (the process of melting and molding the materials); nguwad (the process of forging trompong); ngicep and moncolin (the process of shaping the edge and front side of trompong or pencon's part); ngerinda and ngikir (the process of smoothing the surface); manggur (The process of grinding or removing certain part of the surface in order to produce the appropriate tone); and the last one is metuding (the process of harmonizing the tone of a set trompong started from low tone trompong to high tone trompong). The process of nguwad gamelan instruments that uses pencon is different from the process of nguwad gamelan instruments in form of bilah. The process of nguwad gamelan instruments that uses pencon has to be done by four or five workers or more than one person, in which a person as a perapen whose task is heating the work until it achieves certain temperature degree, a person as a jepit whose task is holding, rotating and directing the work when the work is being forged and three persons as nguwad who take turn forging the work.

The process of nguwad trompong is still considered as a heavy task for the workers because it is still done using ember of the perapen that is exposed in open and traditional work posture (has not adjusted to the natural work posture). Unnatural work posture easily causes the increase of musculoskeletal disorders and fatigue of the workers. The work posture of this perapen worker was sitting on the production floor on a seat about 10 cm in height thus his work posture was like squatting work posture in front of perapen with both hands holding a holder tool called culik (culik: Balinese, a holder tool to hold the work in form of iron handle equipped with a holder made of wood which has approximate length of 60 cm which is used to rotate and turn the work in fire). The manually and repeatedly work on a hot work condition was one of many factors that potentially increases physical workload and work accidents that can cause work injury (musculoskeletal disorders and fatigue) (Grantham, 1992). One form of protection efforts for the operator from the danger and the risk at work is by improving the work condition by the intervention of ergonomic which is based on fitting the task to the man principle.

The work posture that is not too comfortable and a repetitive work that is experienced by perapen workers on nguwad process can increase the risk of cumulative trauma disorders (Hendra, 2003; Humantech, 2006), and can increase the risk of accidents and various cumulative disorders on muscles (Indra Sadguna, 2009). Nguwad work uses more muscle strength thus during working or on the static muscle contraction, the blood vessel is pressed by the pressure from the muscle tissue. This condition will hamper blood circulation to the muscle tissue (Indra Sadguna, 2009). The use of unnatural work posture on nguwad process such as sitting using squatting work posture, the excessive use of muscle when using tools, working while breathing the dust particles will cause pain on the certain part of the body (Inzumi, 2008; Kee and Karwowski, 2007).

The unergonomic work posture of the perapen workers impacts on the presence of work boredom such as the workers feel that the work that supposes to be light become heavy, there is no work motivation, there are unnecessary movements that are not effective and cause work mistake, there is break time stealing that cause the longer production completion time. If these conditions continue to be neglected then on a certain period of time, the workers will experience work boredom and decrease on work satisfaction because of the increase of fatigue and musculoskeletal disorders (MSDs) which in the end cause longer product completion time.

A study that was conducted on 482 workers in 12 regencies/cities in Indonesia stated that injury that generally found in the work field was musculoskeletal disorders (MSDs) that scored 16%. MSDs are one of many injuries caused by incorrect position or work posture. Hendra's research in Kroemer and Grandjean (2009) showed that the most MSDs disorders caused by unergonomic work posture came from the oil palm workers on their neck and lower

back which were felt by 98 workers. Sutajaya (2007) in his research stated that there were musculoskeletal disorders caused by unnatural work posture as big as 64% of total workers of batako in Gianyar Bali. At first, MSDs causes pain, numbness, tingling, swelling, stiffness, trembling, sleeping disorders, and burnt feeling (Manuaba, 2003). Body parts that mostly being complained were on neck muscle, shoulders, arms, hands, back, waist, and lower part muscles as stated by Attwood *et al.,* in Miftah (2012). MSDs are the disorders of normal function of muscles, tendons, nerves, blood vessels, bone and ligaments that are caused by a change of structure or musculoskeletal system in short or long time (Manuaba, 2000). The work processes of perapen workers on nguwad cover the process of heating the materials and holding and rotating materials that are being forged by nguwad workers in which they use unergonomic work posture. This condition has a big risk of being exposed to MSDs. Based on the previous study using questionnaire of Nordic Body Map (NBM) Test toward 10 perapen workers on the process of nguwad gamelan in Tihinga village, it was found that 100% respondents had disorders on musculoskeletal parts after working. Most of the disorders were felt on the right shoulder and right hand which was experienced by 8 persons (80%), followed by disorders on upper neck, back, and waist which was experienced by 7 persons (70%), the third disorders were on back and lower foot which was experienced by 6 persons (60%), and also the fewest disorders that were less felt were on hands which were experienced by 3 persons (30%). Parts of the body that felt the pain most were back and waist. All respondents admitted that the pain and stiffness that they felt were varied.

To give solution toward the above problem, an improvement based on the ergonomic approach toward work posture was conducted to decrease subjective disorders of perapen workers in the process of nguwad gamelan in Bali.

2. Materials and Methods

Gamelan workers on the process of nguwad in Tihingan Village who met the inclusion criteria and were simply chosen randomly. The intervention was done by improving the workstation so that the bending work posture of the prapen workers was changed into sat naturally and the bending-while-standing work posture of the smiths was changed into straighter standing work posture. Musculoskeletal disorders were measured using NIOSH Nordic Body Map Subjective Filling, fatigue was measured using 30 Items Self-Rating Questionnaire Industrial Fatigue Research Committee from Japan Association of Industrial Health, pulse was measured using stopwatch with palpation method, and work tools were measured using the metal meter. The data of measurement results were descriptively and inferentially analyzed. Data normality was tested using Shapiro-Wilk test, the effects of treatment toward musculoskeletal disorders and fatigue were tested using t-pair test if they were normally distributed if the data were not normally distributed, Wilcoxon test was used. The analysis was done on the level of significance $\alpha = 0.05$.

3. Results and Discussions

3.1 Subjects Characteristics

The result of the research subjects' measurements of 12 person samples in this research is shown in table 1 below.

Table 1
The result of research subjects analysis

Variable	N	Mean	S D	*Range*
Subjects' age (years)	12	34.39	9.62	21.00-53.00
Body weight (kg)	12	59.34	8.13	46.00-76.50
Body height (m)	12	1.63	0.05	1.48-1.75
Body mass index	12	22.28	2.69	17.24-28.39
Hb (g %)	12	14.81	1.18	12.40-16.70
Working experience (years)	12	11.81	6.15	1.00-27.00

* N : Total subjects

SD : Standard deviation

While the comparison between subjects' BMI and ideal BMI based on age is shown in table 2.

Table 2
Workers' BMI (research subjects)

Age (years)	Ideal BMI	Workers' BMI	Categories			Total
			Under	Average	Over	
19-24	19-24	17.24-23.02	2	1	0	3
25-34	20-25	17.60-24.81	2	4	0	6
35-44	21-26	17.42-25.39	1	1	0	2
45-54	22-27	20.14-25.08	0	1		1
		Total	5	7	0	12
		Percentage (%)	41.6	58.4	0	100

NIOSH in Saputra Oesman (2010) stated that BMI that higher than 29 kg/m^2 (obese) had a risk of being exposed to musculoskeletal disorder 250% higher compared to someone who had BMI less than 20 kg/m2 (thin).

3.2 Workers' Anthropometry

The result of anthropometry measurement data of 12 gamelan workers in Tihingan Village Klungkung Regency is shown in table 3 below.

Table 3
The Result of Workers' Anthropometry Measurement Data

No	Name of Measurement	Percentile		
		5 % tile	50% tile	95% tile
1	Standing height	162.20	165.30	177.00
2	Standing shoulder height	135.10	139.40	150.20
3	Standing elbow height	95.10	104.65	116.50
4	Sitting height	84.00	86.95	93.00
5	Sitting shoulder height	57.80	61.90	68.80
6	Sitting elbow height	19.70	24.65	28.20
7	Sitting knee height	46.80	49.60	52.90
8	Sitting popliteal height	40.30	42.35	44.20
9	Waist width	31.70	35.65	39.00
10	Foot length	23.50	24.50	26.70
11	Foot width	7.10	8.50	11.00
12	Front reach	68.50	72.65	74.30

*Unit in cm

By using the gamelan workers body size, the accordance between body size and the seat will make the ability of the workers at work approach optimum measurement. The anthropometry data were used to get an accordance between workers' body size with their workstation. According to Tarwaka (2011), a design that involved space dimension used big percentile of 90 and 99 and a design that involved scope used small percentile of 2 to 10. The design of percentile is not absolute but it depends on the situation and works condition (Indra Sadguna, 2009).

3.3 Workplace Microclimate Condition

The microclimate condition of the workplace is shown in Table 4 below.

Table 4
Workplace Microclimate Condition

Microclimate	N	Measurement Result	
		Mean	SD
Wet-bulb temperature (°C)	3	27.55	0.14
Dry-bulb temperature (°C)	3	31.06	0.82
WBGT (°C)	3	29.17	0.17
Relative humidity (%)	3	76.72	1.97
Wind velocity (m/s)	3	1.04	0.20
Noise (dB A)	3	92.92	0.78

*N : Total measurement
SD : Standard Deviation

Work environment condition greatly affects a person's performance directly and indirectly (Pande Made Sukerta, 2009; Saputra, 2003; Sutajaya, 2007). Microclimate condition, noise, vibration, lighting, and air quality that exceed the recommended threshold score or standard can weaken body function, decrease performance, and in the end decrease work productivity. According to Minister of Manpower and Transmigration Regulation No. 13/MEN/X/2011 about physical factor threshold score in the workplace for medium workload, the threshold work climate score with WBGT is not allowed over 28°C. Hot temperature can decrease work presentation and health of a person because of heat stroke that can lead to death (Indra Sadguna, 2009).

3.4 Work Posture Improvement

Work posture of the workers on *nguwad terompong* was vary depending on the work demand of the workers. The work posture of the *prapen* workers was sitting on *dingklik* that had height around 15 cm (Picture 1a) and *jepit* worker sat next to the furnace facing the *nguwad* worker who also sat on *dingklik* that had height around 15 cm (Picture 1b).

Picture 1. Work posture of *prapen* worker

This work posture was unnatural and it created a problem. This work posture improvement covered the process of making foot hole for perapen workers so that the feet work posture that was bent was improved into better work posture by using sitting work posture where the feet were bent 90° toward tight (sit naturally) as seen on Picture 1c.

3.5 Workload

The workload was measured based on the pulse of the workers. The worker's pulse is shown in Table 5 below.

Table 5
Pulse and Cardio Vascular Load (CVL) of the Workers

Variable	N	Without Treatment (P0)		With Treatment (P1)		t	p
		Mean	SD	Mean	SD		
Resting pulse beat (bpm)	6	73.73	1.54	73.30	1.44	1.15	0.258
Working pulse beat (bpm)	6	126.87	0.19	121.59	0.13	53.15	0.000
Work pulse (bpm)	6	52.08	1.22	43.35	0.88	30.97	0.000
% CVL	6	49.37	1.75	42.78	1.64	52.87	0.000

*N : Total Group
SB : Standard Deviation

Based on Table 5. There was a significant difference between P0 and P1 on working pulse and % CVL (cardiovascular load) with the score of $p < 0.05$. The decrease of working pulse or workload from 126.87 beats/minute into 121.59 beats/minute or decrease by 4.2%.

3.6 Subjective Disorders

Subjective disorders of the workers based on musculoskeletal disorders and fatigue which were taken before the work started and after the work done on both treatments. The analysis result of the *Wilcoxon test* showed that the mean score of subjective disorders before starting the work on both treatments was no significant difference ($p>0.05$). This analysis result proved that subjects condition before starting the work on both treatments was the same.

After the subjects did the work, the subjective disorders score was recalculated. The result of the *Wilcoxon test* showed that subjective disorders of both treatments significant difference ($p<0.05$). This analysis proved that the treatment (P1) had given effect toward the decrease of subjective disorders. The analysis result is shown in Table 6.

Table 6
Analysis Result of Workers' Subjective Disorders

Subjective Disorders	N	Without Treatment (P0)		With Treatment (P1)		z	p
		Mean	SD	Mean	SD		
Fatigue before work	6	30.25	0.46	30.17	0.32	-0.405	0.686
Fatigue after work	6	52.79	2.82	38.51	1.29	-2.201	0.028
Increase of fatigue	6	22.54	2.07	8.35	0.42	-2.201	0.028
Musculoskeletal disorders before work	6	28.48	0.60	28.24	0.37	-1.461	0.144
Musculoskeletal disorders after work	6	58.44	3.70	38.74	1.51	-2.201	0.028
Increase of musculoskeletal disorders	6	29.96	3.02	10.50	0.82	-2.201	0.028

Based on Table 6, It was achieved not a significant difference between P0 and P1 on fatigue and musculoskeletal disorders before work ($p>0.05$). This showed that the starting condition of the workers before work was the same. On fatigue and musculoskeletal disorders after work, it was achieved significant difference between P0 and P1 ($p<0.05$). The score of P0 fatigue after work was 52.79 while P1 was 38.51 or decreased 27.1%. While the score of P0 musculoskeletal disorders was 58.44 and P1 was 38.74 or decreased 33.7%. Thus, it could be justified that the ergonomic intervention on this work posture was able to decrease subjective disorders of gamelan workers.

4. Conclusion

The conclusions of this research results are as follow.

a) The improvement of work posture by using ergonomic approach decreased the workload of perapen workers on the process of nguwad gamelan in Bali.
b) The improvement of work posture by using ergonomic approach decreased subjective disorders of perapen workers on the process of nguwad gamelan in Bali.

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The author(s) have a responsibility for the conception and design of the study. The author(s) have approved the final article.

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