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THE CHANGE OF WORKING POSTURE IN *MANGGUR* DECREASES CARDIOVASCULAR LOAD AND MUSCULOSKELETAL COMPLAINTS AMONG BALINESE GAMELAN CRAFTSMEN

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Manggur, which means to plane down or sharpen, is a manual process in producing copper blades of Balinese gamelan orchestra. The craftsmen of *Manggur* work 6 to 8 hours a day, sitting on the floor with folded legs and hunched back. Because the craftsmen often complain about musculoskeletal problems after having completed a full day work, an ergonomic intervention was made by changing their usual working posture (the first working posture) into working on tables while sitting on chairs for one hour and alternately standing for half an hour (the second working posture). Treatment by subject design was applied to 22 randomly chosen craftsmen. Resting heart rate and working heart rate were measured by using a stopwatch, and the number of musculoskeletal complaints were recorded with Nordic Body Map Questionnaire. As a result, the second working posture caused significant reductions in working heart rate, work pulse (the difference between working heart rate and resting heart rate) and the number of musculoskeletal complaints. These results suggest that the change of working posture in *manggur* decreases cardiovascular load and musculoskeletal strain among Balinese gamelan craftsmen.
Key Words: *manggur;* working posture; heart rate; cardiovascular load; musculoskeletal complaints

Villagers of Tihingan, Klungkung Regency, Bali Province, who are mostly Balinese gamelan craftsmen, work in the sector of home industry. They follow the gamelan production stages starting from material melting (usually copper or tin), forging, honing, hitting, and *manggur* which literally means to plane down or sharpen, to refine their productions (Warna, 1978). All the production stages are implemented manually in which the physical workload in each stage is different from one another.

In *manggur*, craftsmen sit on the floor with folded legs and hunchbacked bodies while their arms move forward and backward to plane down gamelan blades. This working stage is interspersed with gamelan blade sound testing to have the desired sound. Their working hours are 08.00 to 15.00.

The working postures of the craftsmen in *manggur* look hardly ergonomic so that their optimal ability and effectiveness appear relatively discouraging. Manuaba (1997) has reported that these unergonomic working postures are usually found in small-scale industries including that of blacksmiths in Bali. Patrick (1998) has stated that the unnatural manual working postures can generate physical troubles to workers, specifically in their cardiovascular and musculoskeletal systems. As a consequence, workers will easily suffer from fatigue, discomfort and muscle pain. Marco et al. (1998) also has indicated similar problems faced by workers whose works involve pulling and dragging things.

To reduce the work load among Balinese gamelan craftsmen, alternative working postures, which appear more ergonomic than the traditional one, was introduced in this study, and their effects

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were evaluated by the cardiovascular responses and musculoskeletal complaints.

SUBJECTS AND METHODS

In reference to the quantitative formula (Pocock, 1986), 22 craftsmen aged 15 to 64 were chosen randomly as experimental subjects out of 80 craftsmen in Tihingan village that represents the population group. The lowest education level among the subjects was elementary school, which enabled them to fill in the questionnaire mentioned below.

Treatment by subject design was applied in the study. The ordinary working posture of sitting on the floor with folded legs without chairs nor working tables (Fig. 1), hereinafter referred to as the first working posture, was then altered into working on the tables while sitting on chairs for one hour (Fig. 2A) and alternately standing for half an hour (Fig. 2B). The latter two postures are hereinafter referred to as the second working posture.

Fig. 1. The first working posture; craftsmen sit on the floor with folded legs and hunched back.

A B

Fig. 2. The second working posture; craftsmen work on the tables while sitting on chairs for one hour (A) and alternately standing for half an hour (B).

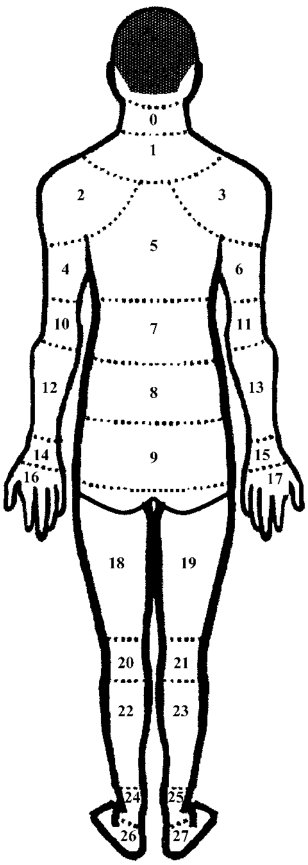
The first study was conducted on the 22 craftsmen (the subjects) who assumed the first working posture from 08.00 to 15.00, with an hour break between 11.00 and 12.00. These subjets then took three days off or washing out period. The second study was conducted on the same craftsmen who assumed the second working posture with the same working hours.

Despite the environmental conditions of the working place could not be controlled, ambient temperatures including wet-bulb globe temperature (WBGT), relative humidity, noise, and light intensity were recorded.

In this study, the workloads were evaluated by working heart rate (Grandjean, 1993) and work pulse, i.e. the difference between working heart rate and resting heart rate (Kamiel and Kitti, 1993). Resting heart rate was measured 15 minutes before working and the working heart rate was measured every 15 minutes.

Heart rate was counted based on a ten-pulse method (Andersen et al., 1978; Astrand and Rodahl, 1986). A stopwatch was used to measure the first pulse of radial artery in their wrists. Then, when the number indicates eleven, the stopwatch was paused to enable to know how many seconds required for ten pulses. An example is that if it takes 6 seconds for ten pulses, the pulse frequency will be 60/6 x 10 = 100, or if 5 seconds, it will be 600/5 = 120.

The number of musculoskeletal complaints was recorded by using the Nordic Body Map Questionnaire filled in by the craftsmen (Fig. 3). They were requested to fill up the same question-



No	Location	Grade of complaints			
0	Pain/stiff in the upper neck	A	B	C	D
1	Pain in the lower neck				
2	Pain in the left shoulder				
3	Pain in the right shoulder				
4	Pain in the left upper arm				
5	Pain in the back				
6	Pain in the right upper arm				
7	Pain in the waist				
8	Pain in the buttock				
9	Pain in the bottom				
10	Pain in the left elbow				
11	Pain in the right elbow				
12	Pain in the left lower arm				
13	Pain in the right lower arm				
14	Pain in the left wrist				
15	Pain in the right wrist				
16	Pain in the left hand				
17	Pain in the right hand				
18	Pain in the left thigh				
19	Pain in the right thigh				
20	Pain in the left knee				
21	Pain in the right knee				
22	Pain in the left calf				
23	Pain in the right calf				
24	Pain in the left ankle				
25	Pain in the right ankle				
26	Pain in the left foot				
27	Pain in the right foot				

Fig. 3. A modified Nordic Body Map Questionnaire. Craftsmen just need to tick (✓) in the columns based on what they felt in the body segment numbered in the left figure. A (equals to 1 point): no pain felt; B (2 points): moderate pain; C (3 points): pain; and D (4 points): very painful.

naire twice, one in the morning before working hours and the other in the afternoon after working hours.

Anthropometric dimensions of the craftsmen were measured according to Pheasant (1988). These measurements were required for designing ergonomic chairs and tables in order to be suited for the craftsmen's jobs and for minimizing the musculoskeletal complaints after works. For this purpose, the anthropometer set (Super, Japan) was used.

Statistical analysis using paired t test was judged significant at $p = 0.05$.

RESULTS AND DISCUSSION

The characteristics and anthropometric dimensions of the subjects in sitting and standing postures are shown in Table 1. Meanwhile, environmental conditions in *manggur* are listed in Table 2.

Based on the data in Table 1, the craftsmen have experience in *manggur* for more than 10 years, which indicates that they have mastered the required skills for *manggur*. The anthropometric dimensions of sitting and standing postures are the same as those found in the report of Indonesian Occupational Health and Hygiene Department on male workers in some industrial sectors (Manuaba, 1992).

The working environments in *manggur* were significantly differrent between the first and second working postures except the wet temperature, WBGT, and noise (Table 2). However, the difference was rather slight except for the humidity.

The working heart rate is significantly higher in the first working posture (85.8 beats per minute) than in the second working posture (79.9 beats per minute) (Table 3), although they both belong to the same low physical workload category (Grandjean, 1993). The difference of work pulse between the two working postures is 5.2 (12.9-7.7) beats, which is statistically significant ($p < 0.01$)

Table 1. Characteristics and anthropometric dimensions of subjects (n=22): Mean and standard deviation (SD).

Characteristics and dimensions	Mean	SD
Age (years)	35.5	11.3
Length of employment (years)	17.1	9.7
Height (cm)	162.0	6.6
Weight (kg)	58.6	6.3
Anthropometric dimensions in sitting posture (cm)		
Sitting height	122.5	3.5
Elbow height	22.3	2.1
Knee height	51.3	2.2
Popliteal height	41.3	1.6
Buttock-knee length	53.9	3.2
Buttock-popliteal length	43.5	2.8
Anthropometric dimensions in standing posture (cm)		
Eye height	152.2	6.7
Elbow height	99.4	5.0
Vertical grip reach	187.8	20.8
Shoulder-grip length	55.5	6.0
Shoulder width	42.3	2.1
Hip height	97.0	9.3

Table 2. Mean and SD of working environments during *manggur* in two different working postures and their statistical analysis (paired-sample *t*-test).

Variables	1st working posture		2nd working posture		Difference
	Mean	SD	Mean	SD	*(p)*
Wet temp. (℃)	29.1	0.6	29.6	1.5	>0.05
Dry temp. (℃)	32.5	0.9	30.6	1.8	<0.05
Humidity (%)	78.3	4.2	92.3	2.1	<0.05
WBGT (℃)	29.8	0.8	30.1	1.8	>0.05
Radiation temp.(℃)	31.5	1.7	30.1	2.3	<0.05
Noise (dB)	70.3	1.2	70.2	2.5	>0.05
Light intensity (lux)	422.9	56.9	427.5	75.4	<0.05

Table 3. Comparison of mean and SD of resting heart rate, working heart rate, work pulse in *manggur* between the first working posture and second working posture and their statistical analysis (paired-sample *t*-test).

Variables	N	1st working posture		2nd working posture		Difference
		Mean	SD	Mean	SD	*(p)*
Resting h. r.	22	72.9	6.9	72.2	6.4	>0.05
Working h. r.	22	85.8	5.3	79.9	4.3	<0.01
Work pulse	22	12.9	2.9	7.7	2.9	<0.01

and represents 40.3% reduction. The figure implies that the change of working posture has caused cardiovascular load to decrease. While this reduction belongs to a light category (Kamiel and Kitti, 1993), it is greater than the result reported by Sutajaya (1998). In the latter study undertaken in small-scale industries, an improvement of working conditions by changing the working postures among woodcarvers reduced the work pulse by 24.8%.

Static and constraint postures such as folded legs and hunchbacked bodies are seen in the first working posture. This sort of posture causes workers to suffer from fatigue and pain on their back and thigh, which lead to a higher heart rate and a longer resting period for recovery (Grandjean, 1993). However, the difference in the environmental conditions between the first and second postures should also be taken into account. As noted above, dry temperature, radiation temperature, and light intensity were significantly but slightly different between the postures. Given the fact that the craftsmen were well adapted to their surrounding environments, such a minor difference could have limited effects on the cardiovascular responses.

By contrast, relative humidity was substantially higher in the second working posture (92.3%) than in the first working posture (78.3%). High humidity level tends to increase heart rate during working. Because the obtained results were that the craftsmen's heart rate during the second working posture was lower than that of the first working posture, it follows that the change of working posture had a significant effect on the decrease of working heart rate.

The musculoskeletal complaints in the afternoon is significantly lower in the first posture than in the second posture (Table 4). The difference by posture in the morning-afternoon difference in musculoskeletal complaints is 3.1 (9.8-6.7) points that represent 31.6 % reduction, and is statistically significant (Table 4). The lower rate of musculoskeletal complaints in the second working posture is conceivably because this posture enables better blood circulations in the buttocks and lower extremities, and muscles in these areas are not in isometric contractions.

The reduction in complaints is not so much different from that (29.6%) reported by Sutajaya (1998) on the improvement of woodcarvers' working posture. The reduction of musculoskeletal complaints among craftsmen in *manggur* means that they can work longer and in healthier conditions.

Table 4. Mean and SD of the number of points of musculoskeletal complaints in *manggur* in the morning and afternoon, their differences between the first working posture and second working posture, and their statistical analysis (paired-sample *t*-test).

Variables	N	1st working posture		2nd working posture		Difference
		Mean	SD	Mean	SD	*(p)*
Morning	22	32.0	1.5	31.3	1.1	>0.05
Afternoon	22	41.7	2.5	38.1	1.9	<0.01
Difference	22	9.8	2.4	6.7	1.5	<0.01

CONCLUSIONS

Balinese gamelan craftsmen work 6 to 8 hours a day sitting on the floor with folded legs and hunched back. A change of working posture from the traditional one into working on tables while sitting on chairs for one hour and alternately standing for half an hour has proven to reduce the working heart rate and work pulse, suggesting a lightened cardiovascular load. The same change in working posture also reduced the number of musculoskeletal complaints. The results of this study would be a useful reference to the relevant government agencies supervising working conditions in small-scale industries employing craftsmen producing blades of Balinese gamelan orchestra.

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