REDUCTION OF LOW BACK MUSCULAR DISCOMFORT THROUGH AN APPLIED ERGONOMICS INTERVENTION PROGRAM

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Abstract. An applied ergonomics intervention program (AEIP) was conducted with male employees who work in the pressing and storage sections of a metal auto parts factory in eastern Thailand. The objective of this study was to reduce worker muscular discomfort at the low back. The study design was a participatory research approach, with quasi-experimental pretest-posttest, and with a non-equivalent control group. Thirty-five persons participated in the AEIP (AEIP group) and 17 persons did not (non-AEIP group). The AEIP was composed of three major categories: (1) top management support; (2) equipment designed for workstations and manual material handling; and (3) administrative intervention, training, and health education. Muscle activity was measured by surface electromyography of the left and right erector spinae, and multifidus muscles; and evaluated by multivariate test for dependent samples (paired observation) and for independent samples. After the AEIP, the low back muscular loads of the AEIP group was significantly reduced, while those of the non-AEIP group were not. Comparison of the means of percentage maximum voluntary contractions (% MVC) of low back muscular activity between the AEIP group and non-AEIP group indicated that the AEIP group had significantly reduced low back muscular load, with a 95% confidence level (p-value < 0.05).

INTRODUCTION

There has been an apparent increase in ergonomics-related injury cases in the industries of Thailand. The Health Insurance Office (1998) reported that in 1992 there were 6,600 cases of injury caused by manual material handling, of which 1,907 were exacerbated by unnatural working postures; and for 1997, the figures had increased to 15,406 and 4,389 cases, respectively. This increase was approximately 2.3 times over a period of six years.

The Division of Occupational Health (1998) reported that of the musculoskeletal disorders (MSDs) suffered by 2,595 workers studied in 300 factories of 48 provinces in Thailand were 78.5% for body pain, of which 52.4% was low back pain. The MSDs were higher among female workers than males. A higher MSD rate was characteristic of the older age group. Working posture was indicated as affecting MSDs the most.

Based on a study of the health and well-being of workers in a metal auto parts factory in eastern Thailand (Poosanthanasan and Lohachit, 2005), muscular discomfort of employees working in the pressing and storage sections was significantly related to the workstation and frequency; thus, regular taking of medicine to release muscular pain was evident. Work-related muscular discomfort was also found to be a significant factor influencing accidents.

An epidemiological review of the higher prevalence of low back injuries suggested that lifting an object was one of the major risk factors for low back injury (Marras, 2000). Work-related injuries described by the Workmen Compensation Fund (1998) indicated that, of 11,580 workers who suffered from low back pain caused by lifting and transferring objects, 10,134 were absent from work for not more than 3 days and the remaining 1,432 cases were absent from work for more than 3 days. This problem can also lead to other work-related problems, such as loss of work potential, work quality, and workers' quality of life.

Several studies have demonstrated the prevalence of low back pain in the workplace in developed countries (NIOSH, 1997). To prevent low back pain, ergonomic interventions have been advocated to decrease workers' exposure to risk factors (Garg and Moore, 1992; Haag, 1992; Stobbe, 1996). Among the various approaches to ergonomics, participatory ergonomics has become increasingly popular. Participatory ergonomics consists of actively involving the workers in implementing ergonomic knowledge and procedures in their own workplace, supported by their supervisors and managers, to improve their working conditions (Nagamachi, 1995). Participatory

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ergonomic interventions have been associated with a decrease in the incidence of musculoskeletal symptoms (Garg and Owen, 1992; Vink and Kompier, 1997), a decrease in work absenteeism (Lanoie and Tavenas, 1996; Moore and Garg, 1998), and an improved psychosocial work environment (Laitinen *et al*, 1998). To date, participatory ergonomics has been applied mostly to the primary prevention of back pain (Garg and Owen, 1992; Lanoie and Tavenas, 1996; Moore and Garg, 1998).

This study aimed to develop an applied ergonomics intervention program to reduce work-related low back muscular discomfort among Thai workers in the pressing and storage section of a metal auto parts factory. The primary objectives of this program were to improve the health and well-being of the workers in these sections, and to provide a safe and productive workplace to fulfill the goals and objectives of the organization successfully. In applying AEIP, the basic premise of the program was that additional job content should not exceed workers' capabilities and limitations, safety and health, or affect the company's productivity.

MATERIALS AND METHODS

Sample

The study used a participatory research approach, with quasi-experimental pretest-posttest design, and with a non-equivalent control group. Fifty-two male volunteers, aged 20 to 40 years, participated in this study. The volunteers were working in the pressing and storage sections of a metal auto parts factory in eastern Thailand. Poosanthanasarn and Lohachit (2005) studied the health and well-being of the workers in these sections and found a great impact from low back muscular discomfort.

An applied ergonomics intervention program (AEIP) was conducted with the 35 participants (hereafter referred to as the AEIP group) working in Building A. The average age of the 35 employees was 26.91 ± 5.52 years, body weight was 62.37 ± 7.36 kg, and height was 169 ± 4.92 cm. The average time working in the pressing and storage sections was 3.28 + 3.47 years.

The control group of 17 employees (hereafter referred to as the non-AEIP group) was working in Building B, which situated next to the Building A. These employees received no AEIP at all. The average age, body weight, and height of the non-AEIP group of 17 employees were 23.35 ± 2.67 years, 61.59 ± 6.15 kg, and 172.94 ± 4.80 cm, respectively. The average time in the pressing and storage sections in Building B was 1.72 ± 0.65 years.

All employees completed questionnaires about their health, muscular discomfort, environment, and work satisfaction. Based on these questionnaires, all of the employees in the AEIP group were healthy and had a history neither of back accident nor of neuropathy.

Top management support

Prior to implementation of the AEIP with the 35 AEIP employees, meetings with top managers, the head safety officer of the Human Resource Section, and the heads of the pressing and storage sections were held to obtain full support and to sustain the program. A brief description of the potential of AEIP gave equal priority to health and well-being, productivity, quality, and safety.

Engineering design

The workstations and their environments, work methods, and tool and handle designs were observed at the job site during the working hours of the pressing and storage sections in Building A. The observations included the accommodation of the employees assigned to the workstations, tools and work methods, to eliminate occupational risk factors. The static, awkward and extreme postures, repetitive movements, and excessive forces of the employees were recorded.

The anthropometry of the employees in the AEIP group was studied. The 5^{th} percentile of elbow height was utilized as the adjustment to improve the workstation and manual material handling, if necessary, for accommodating the workers' anthropometry as suggested by Sanders and McCormick (1993).

Administrative intervention, training, and health education

The administrative intervention, training, and health education program initially began with a meeting of top managers, safety officers, and the heads of the pressing and storage sections. The intervention sessions included improving work method, training in work posture, health education and training, and before-work warm-up exercise.

The health education and training sessions were provided in a classroom. The frequency of education and training was 7 times during the period from 19 July to 11 October 2003, and lasted about three hours per session. The first five training courses were provided for workers and head workers. The last two training courses were for head workers, top managers and safety officers. Each employee in the AEIP group, top managers, safety officers, and the heads of the pressing and store sections were required to attend class at least once. In addition, the employees were free to decide to attend classes as much as they wished.

The education and training sessions were the following: 1) Kiken yochi training (KYT) (Tanabae, 2000), 2) a brief lecture on the anatomy of the back with a laboratory demonstration, and 3) a demonstration and practice of low back muscular exercise, as recommended by the Ministry of Public Health (following Selger *et al*, 1998). Low back muscular exercise at home was encouraged as a self-health behavior for participants.

The KYT activity is comprised of steps of work to be done. First, all participants attended a short lecture, which demonstrated individual carelessness on the job, how the accidents occurred, and ways to avoid the accidents. The lecturer also generated employee involvement and encouraged them to participate in the safety and good-health outcomes. After the lecture, the participants were divided into small groups of four members. Each participant identified the work-related hazards found on his job site, considered together which was the most hazardous one, and then spoke loudly "zero accidents" to show their conscious intention to prevent accidents and to be safe.

The sessions for improving work methods at the workstation started in August 2003. These included arranging flexible working hours, such as night/day work rotation, and providing recreation areas near Building A. Work postures were individually observed during working hours, and any unnatural work postures found were corrected at the job site.

Before work, warm-up exercise was launched in September and ran through October 2003. The KYT activity and exercise were conducted every day in the morning, for about 5 to 10 minutes on Monday to Friday, and for 15 minutes on Saturday.

Surface electromyography

Each employee in the AEIP group was asked to perform their tasks and be evaluated for muscular activity by electromyography (EMG), using a Muscle Tester ME 3000 (Mega Electronic, Finland). The method of measurement followed Jeffery *et al* (1998). After rubbing the skin with alcohol, pairs of disposable (Ag/AgCl) surface electrodes were attached bilaterally over the erector spinae at L2-L3, and over the multifidus at L5. At the erector spinae, two electrodes were placed over the muscle mass and parallel to the spine, approximately 2 cm laterally from the midline of the back. Then, at the multifidus muscle, which is located at L5, another two electrodes were placed 2 cm laterally from the spine but lower than the erector spinae electrodes. The lower multifidus electrodes were about 1 cm apart.

The back muscular load (percentage maximum voluntary contraction, %MVC) from the left and right of the erector spinae muscles and multifidus muscles were measured 3 times on the same day by electromyography. The first measurement was before work began, at 07:30 AM The second measurement was during work, at 09:30 AM for lowering activity and 09:35 AM for lifting activity. The third measurement was at 11:30 AM for the lowering activity and 11:35 AM for lifting. The result of work measurement in the pressing and storage sections of the metal auto parts factory showed that each employee continuously lowered, lifted, or transferred objects at approximately 700 kg/hr.

In this study, the EMG measurements were on two occasions for both AEIP and non-AEIP groups. For the AEIP group, measurements were taken before the commencement of the AEIP and after being involved for four months. Those in the non-AEIP group had their muscle activities measured twice to coincide, for the purpose of comparison, with the timing of the AEIP group.

The percentage maximum voluntary contractions (%MVC) were calculated as follows (Solderberg, 1992):

$$\%MVC = \frac{\text{Test AEGM} - \text{Rest AEMG}_1}{\text{MVC AEMG} - \text{Rest AEMG}_2} \times 100$$

Where:

Test AEMG = Average EMG during the working period

Rest $AEMG_1$ = Average EMG during the rest period before working

Rest $AEMG_2$ = Average EMG during the rest period before MVC testing (Sorensen test)

MVC AEMG = Average EMG during the MVC test (Sorensen test)

For statistical analyses, comparisons of the means of %MVC for back muscular activities, in which subjects served as their own controls, were performed in the AEIP group; and in the non-AEIP group, the multivariate test was used for dependent samples (paired observation). In order to determine what effect the AEIP had on the AEIP group, comparative statistical analyses of the AEIP group and non-AEIP groups were conducted by multivariate test for independent samples.

RESULTS

Table 1 shows the anthropometric measurements of the employees in the AEIP group as values of 5, 25, 50, 75, and 95 percentiles. The 5th percentile of elbow height (97.00 ± 4.19 cm) was utilized to improve workstation and manual material handling in the pressing and storage sections of Building A (Table 1).

Six types of equipment and workstations in the pressing and storage sections of Building A needed to be designed or redesigned. After discussion and consideration with the top managers and supervisors of the pressing and storage sections, six engineering designs were built to fit the work to the employee. They were 1) altered standing bench in pressing section, 2) altered table height in pressing section, 3) designed floor surface height in storage section, 4) designed supply truck in storage section, 5) altered handling truck in pressing section, and 6) altered handling truck in storage section.

Table 2 presents the means and standard deviations of %MVC of the left and right erector spinae and multifidus muscles of the 35 employees in the AEIP group, before and after application of AEIP, and the time interval and activity. Statistical analyses by multivariate test for dependent samples (paired observations) indicated significant changes in the low back muscular loads of the AEIP group after receiving AEIP.

Table 3 shows the means and standard deviations of %MVC of the left and right erector spinae and multifidus muscles of the 17 employees in the non-AEIP group, measured on the same occasions as the AEIP group. The time of measurement, including working position and statistical analyses are also shown in Table 3. It was apparent that the non-AEIP employees had no significant changes in their low back muscular load.

Tables 4 and 5 show comparisons of the means and standard deviations of %MVC between the 35 employees in the AEIP group and the 17 employees in the non-AEIP group. Statistical analysis showed that, before the application of AEIP (Table 4), the means for %MVC of low back muscular activity of the AEIP group were not significantly different from those of the non-AEIP group. However, after the application of AEIP to the AEIP group only, the means for low back muscular activity of the AEIP group were significantly different from those of the non-AEIP group, at 95% confidence level (p-value <0.05) (Table 5).

DISCUSSION

In the AEIP group, in which the subjects served as their own controls, the activities of left and right erector spinae and multifidus muscles showed %MVC means after AEIP application that were significantly lower than before AEIP application, at over 95% confidence level (p-value <0.05) (Table 2). This evidence, therefore, demonstrated that the low back muscular load decreased after AEIP application to these employees.

In the non-AEIP group in which the subjects served as their own controls, the %MVC means of the low back muscular activity of the control group, who did not receive AEIP, were not significantly over the period of the study (Table 3). This result clearly suggested that for the employees who worked in the workplace where the AEIP was not applied, the low back muscular load of the employees was not reduced.

A comparison of the means for the %MVCs of low back muscular activities of the AEIP group with the non-AEIP group, before and after application of AEIP to the AEIP group, (Tables 4 and 5), clearly suggested that the burden of low back muscular activity was less after the employees received the AEIP.

Table 1
Anthropometric data of 35 employees in the AEIP group (cm).

	Mean	SD	Percentile				
			5	25	50	75	95
Stature	169.39	4.51	161.80	166.00	169.00	172.00	176.00
Eye height	158.02	5.30	150.00	155.00	157.00	162.00	166.00
Shoulder height	139.67	5.76	133.60	137.00	139.00	144.00	147.00
Waist height	103.42	4.57	96.80	100.80	103.00	106.00	110.00
Elbow height	104.34	4.19	97.00	101.00	105.00	107.00	111.20
Knuckle height	65.41	3.32	60.80	63.80	65.00	68.00	72.00
Knee height	49.93	2.72	44.80	49.00	50.00	51.00	54.00
Ankle height	9.52	0.50	9.00	9.00	10.00	10.00	10.00

Table 2
Comparison of the %MVC of the left and right erector spinae and multifidus muscles of 35 employees of the AEIP group.

Time	Position	Muscle	Application of AEIP	Mean	SD	Hotelling's trace[a]	p-value
9:30 AM	Lowering	Left erector spinae	Before	73.67	30.42	0.993	0.000
			After	48.71	19.68		
		Left multifidus	Before	72.94	29.52		
			After	50.08	19.90		
		Right erector spinae	Before	67.87	34.87		
			After	46.11	21.91		
		Right multifidus	Before	74.93	41.08		
			After	48.88	21.63		
9:35 AM	Lifting	Left erector spinae	Before	108.60	33.02	2.742	0.000
			After	68.21	26.75		
		Left multifidus	Before	107.26	38.54		
			After	71.40	26.58		
		Right erector spinae	Before	102.51	34.81		
			After	64.83	30.69		
		Right multifidus	Before	107.62	34.26		
			After	69.11	26.79		
11:30 AM	Lowering	Left erector spinae	Before	71.34	23.14	1.096	0.000
			After	50.27	23.92		
		Left multifidus	Before	67.16	30.28		
			After	48.64	20.94		
		Right erector spinae	Before	67.44	30.18		
			After	44.28	23.55		
		Right multifidus	Before	66.60	32.20		
			After	45.45	20.03		
11:35 AM	Lifting	Left erector spinae	Before	114.21	41.56	2.703	0.000
			After	67.16	24.14		
		Left multifidus	Before	113.50	43.54		
			After	68.57	27.82		
		Right erector spinae	Before	108.67	36.77		
			After	66.07	26.60		
		Right multifidus	Before	108.84	35.57		
			After	68.16	22.92		

[a] Multivariate test for dependent samples (paired observations).

This study supports the conclusion that there were positive results from the application of AEIP with the employees working in the pressing and storage sections of a metal auto parts factory. Ergonomic risk factors are synergistic elements to musculoskeletal disorder hazards (Reese, 2003), and excessive exposure to these risk factors can lead to MSDs (OSHA, 2003). A participatory ergonomics intervention to reduce risk factors for low-back disorders in concrete laborers had been an effective intervention (Hess *et al*, 2004) as well as in other careers (Garg and Owen, 1992; Lanoie and Tavenas, 1996; Moore and Garg, 1998). Therefore, the application of AEIP with the employees of the pressing and storage sections was an effective practice to reduce low back muscular discomfort among employees in this factory.

Table 3
Comparison of the %MVC means of the left and right erector spinae and multifidus muscles of 17 employees of the non-AEIP group.

Time	Position	Muscle	Application of AEIP	Mean	SD	Hotelling's trace[a]	p-value
9:30 AM	Lowering	Left erector spinae	Before[1]	68.51	37.11	0.380	0.344
			After[2]	73.90	22.97		
		Left multifidus	Before	57.54	26.50		
			After	75.76	39.35		
		Right erector spinae	Before	57.04	32.63		
			After	67.93	37.73		
		Right multifidus	Before	63.08	41.30		
			After	67.04	31.92		
9:35 AM	Lifting	Left erector spinae	Before	104.27	38.88	0.090	0.279
			After	104.32	19.97		
		Left multifidus	Before	121.63	40.58		
			After	129.05	40.81		
		Right erector spinae	Before	108.03	55.11		
			After	112.23	42.20		
		Right multifidus	Before	105.16	42.72		
			After	105.70	37.95		
11:30 AM	Lowering	Left erector spinae	Before	59.23	29.77	0.843	0.279
			After	69.07	22.78		
		Left multifidus	Before	46.33	22.67		
			After	64.88	24.62		
		Right erector spinae	Before	65.63	34.60		
			After	65.80	24.97		
		Right multifidus	Before	55.60	34.60		
			After	59.26	18.39		
11:35 AM	Lifting	Left erector spinae	Before	111.49	65.99	0.295	0.462
			After	109.34	38.77		
		Left multifidus	Before	108.51	46.05		
			After	126.22	51.19		
		Right erector spinae	Before	94.77	44.01		
			After	101.30	42.12		
		Right multifidus	Before	98.56	47.29		
			After	101.73	35.65		

[a] Multivariate test for dependent samples (paired observations).
[1] Measured before application of AEIP to 35 employees of AEIP group.
[2] Measured after application of AEIP to 35 employees of AEIP group.

In this study, the practical development of the AEIP was through a better understanding, participation, and appreciation of changes of the employees and administrative staff. Commitment by the management provided the organizational resources and motivating force necessary to deal effectively with ergonomics-related hazards. Hence, management's support in this study was demonstrated at all organizational levels for the program to gain credibility and corporate-wide cooperation. In addition, with a human-centered design approach - as examples, six types of engineering designs for functions and tasks that could best be done by employees were provided to them, the correction of work postures at the job site, health education and

Table 4
Comparison of the means of %MVC of erector spinae and multifidus muscles of AEIP and non-AEIP groups, before application of AEIP to 35 employees of the AEIP group.

Time	Position	Muscle	Group	Mean	SD	Hotelling's trace[a]	p-value
9:30 AM	Lowering	Left erector spinae	AEIP	73.67	30.42	0.076	0.474
			Non-AEIP	68.52	37.10		
		Left multifidus	AEIP	72.94	29.52		
			Non-AEIP	57.54	26.50		
		Right erector spinae	AEIP	67.87	34.87		
			Non-AEIP	57.04	32.63		
		Right multifidus	AEIP	74.93	41.08		
			Non-AEIP	63.80	41.30		
9:35 AM	Lifting	Left erector spinae	AEIP	108.60	33.02	0.091	0.385
			Non-AEIP	104.27	38.88		
		Left multifidus	AEIP	107.26	38.54		
			Non-AEIP	121.63	40.58		
		Right erector spinae	AEIP	102.51	34.81		
			Non-AEIP	108.03	55.11		
		Right multifidus	AEIP	107.62	34.26		
			Non-AEIP	105.16	41.72		
11:30 AM	Lowering	Left erector spinae	AEIP	71.31	23.14	0.171	0.108
			Non-AEIP	59.23	29.77		
		Left multifidus	AEIP	67.16	30.28		
			Non-AEIP	46.33	22.67		
		Right erector spinae	AEIP	67.44	30.18		
			Non-AEIP	65.63	34.60		
		Right multifidus	AEIP	66.60	32.20		
			Non-AEIP	55.60	31.68		
11:35 AM	Lifting	Left erector spinae	AEIP	114.21	41.56	0.049	0.683
			Non-AEIP	111.49	65.99		
		Left multifidus	AEIP	113.50	43.54		
			Non-AEIP	108.51	46.05		
		Right erector spinae	AEIP	108.67	36.77		
			Non-AEIP	94.77	44.01		
		Right multifidus	AEIP	108.84	35.57		
			Non-AEIP	98.56	47.29		

[a] Multivariate test for independent samples.

training, and before-work warm-up exercise with KYT-constituted a sound, worthwhile project for reducing the low back muscular discomfort of the employees in this factory.

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Table 5
Comparison of the %MVC means of erector spinae and multifidus muscles of the AEIP and non-AEIP groups, after application of AEIP to 35 employees of the AEIP group.

Time	Position	Muscle	Group	Mean	SD	Statistical trace[a]	p-value
9:30 AM	Lowering	Left erector spinae	AEIP	48.71	19.68	Hotelling's	0.002
			Non-AEIP	73.90	22.97	trace = 0.413	
		Left multifidus	AEIP	50.08	19.90		
			Non-AEIP	75.76	39.35		
		Right erector spinae	AEIP	46.11	21.91		
		Non-AEIP	67.93	37.73			
		Right multifidus	AEIP	48.88	21.63		
			Non-AEIP	67.04	31.92		
9:35 AM	Lifting	Left erector spinae	AEIP	68.21	26.75	[b] T^2= 43.8338	0.000
			Non-AEIP	104.32	19.97		
		Left multifidus	AEIP	71.40	26.58		
			Non-AEIP	129.06	40.82		
		Right erector spinae	AEIP	64.83	30.69		
			Non-AEIP	112.23	42.20		
		Right multifidus	AEIP	69.11	26.79		
			Non-AEIP	105.64	37.96		
11:30 AM	Lowering	Left erector spinae	AEIP	50.27	23.92	Hotelling's	0.014
			Non-AEIP	69.07	22.78	trace = 0.299	
		Left multifidus	AEIP	48.64	20.94		
			Non-AEIP	64.88	24.62		
		Right erector spinae	AEIP	44.28	23.55		
			Non-AEIP	65.77	24.97		
		Right multifidus	AEIP	45.45	20.03		
			Non-AEIP	59.26	18.39		
11:35 AM	Lifting	Left erector spinae	AEIP	67.16	24.14	[b] T^2= 28.8601	0.000
			Non-AEIP	109.34	38.77		
		Left multifidus	AEIP	68.57	27.82		
			Non-AEIP	125.63	51.30		
		Right erector spinae	AEIP	66.07	26.60		
			Non-AEIP	101.26	42.13		
		Right multifidus	AEIP	68.16	22.92		
			Non-AEIP	101.73	35.65		

[a] Multivariate test for independent samples.
[b] In case of unequal variance - covariance matrices.

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