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(Original article)

Application of motion economy for reducing musculoskeletal disorders risk factors among cable packers in an enterprise

การประยุกต์ใช้หลักการการเคลื่อนที่แบบประหยัดเพื่อลดปัจจัยเสี่ยงต่อการเกิดความผิดปกติของระบบกล้ามเนื้อและกระดูกในคนงานบรรจุม้วนสายไฟในองค์กรแห่งหนึ่ง

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ABSTRACT: This study examined the risk factors for developing musculoskeletal disorders (MSDs). The principles of motion economy were applied to improve work methods for reduce the MSDs risk in ten volunteer cable packers. This study used a one-group quasi-experimental design. Working procedures were investigated using the flow process chart. Posture analysis evaluations using the Rapid Entire Body Assessment (REBA) tools have been used to analyses the working postures of cable packers in an enterprise. The risk factors were found to include twisting/bending/flexing the wrists, lifting/moving, flexing/twisting/lateral bending of the trunk, bending/twisting/tilting of the neck, knee flexion, unilateral weight bearing on the legs, and continuous standing. The intervention included the use of the human body, the arrangement of the workplace, and the design of tools and equipment. Post-intervention results showed the reduction of risk factors of twisting/flexing, bending/flexing, hand, and forearm reaching, and significant unilateral weight bearing on the legs ($p < 0.005$). The risk level as for REBA, the score was reduced for 13 to 7 indicated a decrease from very high to moderate risk levels. Findings implied that principles of motion economy could be applied to improve work methods by reducing the risk factors that may affect the workers' musculoskeletal disorders.

Keywords: Motion economy; Musculoskeletal disorders; Risk factors; Cable wire packing workers

บทคัดย่อ: การศึกษาครั้งนี้ศึกษาปัจจัยเสี่ยงต่อการเกิดความผิดปกติของระบบกล้ามเนื้อและกระดูก (MSDs) โดยใช้หลักการของการเคลื่อนที่แบบประหยัดมาปรับปรุงวิธีการทำงานเพื่อลดความเสี่ยง MSDs ในคนงานบรรจุม้วนสายไฟที่อาสาเข้าร่วมงานวิจัยจำนวน 10 คน รูปแบบการศึกษาเป็นการกึ่งทดลองกลุ่มเดียว ตรวจสอบขั้นตอนการทำงานโดยใช้ผังกระบวนการไหล และการประเมินการวิเคราะห์ท่าทางโดยใช้เครื่องมือประเมินร่างกายทุกส่วนแบบรวดเร็ว (Rapid Whole Body Assessment: REBA) ผลการศึกษาพบว่า ปัจจัยเสี่ยง ได้แก่ การบิด/งอ/งอข้อมือ การยก/เคลื่อนย้าย การงอ/บิด/งอลำตัวด้านข้าง การงอ/บิด/เอียงคอ การงอเข่า การแบกน้ำหนักที่ขาข้างเดียว และยืนอย่างต่อเนื่อง หลังการปรับปรุงวิธีการทำงานตามหลักการเคลื่อนที่แบบประหยัดด้วยการใช้ประโยชน์จากร่างกาย การจัดสถานีงาน และการออกแบบเครื่องมือและอุปกรณ์ ผลลัพธ์แสดงให้เห็นการลดลงของปัจจัยเสี่ยงของการบิด/งอ การงอ/งอ การเอื้อมมือและปลายแขน และการแบกน้ำหนักข้างเดียว อย่างมีนัยสำคัญ ($p < 0.005$) ระดับความเสี่ยงสำหรับ REBA คะแนนลดลง 13 เป็น 7 บ่งชี้ว่าลดลงจากระดับความเสี่ยงสูงมากถึงปานกลาง ข้อค้นพบบ่งชี้ว่าสามารถนำหลักการเคลื่อนที่แบบประหยัด มาใช้ปรับปรุงวิธีการทำงานโดยการลดปัจจัยเสี่ยงที่อาจส่งผลต่อความผิดปกติของระบบกล้ามเนื้อและกระดูกของคนงาน

คำสำคัญ: การเคลื่อนที่แบบประหยัด; ความผิดปกติของระบบกล้ามเนื้อและกระดูก; ปัจจัยเสี่ยง; คนงานบรรจุม้วนสายไฟ

1. INTRODUCTION

This study examines the risk factors for developing musculoskeletal disorders (MSDs) in the one of necessary process in the automotive wire's enterprise is the packing of reels from automated machines. The operator has to move the cable reel out of the cable injection machine, wrap it with clear plastic attach a barcode to the wire details, and then moved to a pallet for storing. A preliminary survey of the abovementioned process showed that the risk factors, such as twisting, bending, flexing the wrists, reaching of arms and shoulders, lifting exertion, moving with lateral bending of the trunk, tilting of the neck, knee flexion, unilateral weight bearing on the legs, and continuous standing. The average frequency of risk posture was 48.81%, and the posture risk score using Rapid Entire Body Assessment (REBA) indicated a very high level[1].

A few "principles" concerning the economy of movements have been developed as a result of experience and provide a good basis for the development of improved methods at the workplace. These principles may be grouped under three headings, namely, use of the human body, arrangement of the workplace, and design of tools and equipment[2]. Motion economy principles were used to improve the work methods of chicken meat miners, and results show a significant reduction of the number of symbols as movements and the level of risk for their hands[3]. Therefore, the present study aims to improve working methods of cable reel operators by applying the motion economy principles to reduce their risk factors and to prevent the occurrence of musculoskeletal disorders.

2. MATERIAL AND METHODS

The study was carried out using a one group, quasi-experimental pre- and post-test design. The sample consisted of ten of cable packers in an enterprise who agreed to participate in our study. The study protocol was approved by the Ethics Committee of Burapha University in Thailand (no. 120/29-03-2021). The study steps were carried out as follows:

2.1 Risk factors analysis

The flow process chart was developed to the outline process chart, with the addition of "operation," "inspection" "transport," "delay," and "storage" symbols[2]. It was applied to find risk factors performed on the work piece during the operation as shown in the Table 1

2.2 Posture analysis

The Rapid Entire Body Assessment (REBA) was adopted to evaluate risk factors of musculoskeletal disorders (MSD) associated with certain job tasks. A worksheet was used to evaluate the body posture, forceful exertions, type of movement or action, repetition, and coupling[3].

Table 1 Arrangement of chairs and the base set for workers.

Before the intervention	After the intervention
A. Reduced standing for long periods of work	
	
B. Reduced back bending and knee flexion	
	

2.3 Application of motion economy[4]

Principles of motion economy were developed because of experience and implement to improve the working methods. These principles were grouped under three headings (Table 1):

A. Using the body of a human to learn how to reduce posture movement, especially inappropriate posture at work[5]. By keeping a natural, balanced working posture and minimizing work-related movement, particularly the use of inappropriate posture (Awkward posture), the following actions can be taken:

- Improve both hands' range of motion, for example, by bending the wrist less when packing cable reels and when lifting and moving them.

- Enhance trunk and other mobility, such as by lowering effort and twisting/bending to the side when lifting/moving cable reels. While checking cable reels, minimize bending your neck as well.

B. Organizing the workspace (workplace arrangement) to make it more user-friendly and comfortable, such as[6]:

- Reducing the amount of time spent reaching for hands and arms while working can be achieved by moving work-related items, such as identifying signs, scissors, clear tape, rolls of clear plastic, and other equipment, to a distance of no more than 40 centimeters.

- Reducing body and knee bending can be achieved by adjusting the pallet placement position to a height of 65 and 90 cm.

C. In order to reduce the requirement for lengthy standing and continuous labor, tool and equipment design involves placing seats so that employees can sit while they wait for the wire injection machine to signal. In addition, the creation of equipment to support the pallet support set so that the height of the pallet racking area may be altered. Throughout the project's design phase, the factory's professional safety officers and industrial engineers were contacted. Primarily, the apparatus needs to be able to sustain a total weight of the wire roll equal to or greater than 1,000 kg or double the weight of the wire roll that must be put on a pallet for the apparatus to function safely[7].

For a month, the study participants were permitted to use the new techniques[8]. Subsequently, the video clips were examined using the flow process diagram and REBA as a guide. Lastly, the Wilcoxon signed rank test was used to analyze the mean number of gesture symbols found in a process flow diagram before and after the intervention was implemented.

3. RESULTS

Based on the demographic features of the individuals, 90% of them were male. Nine hours a day is the typical amount of time spent working, with two hours and ten minutes of breaks, a fifty-minute lunch break, and an additional thirty minutes in the evening. Every two weeks, the workers switch between morning and night shifts, packing 200–300 rolls of wires every day, and working five or six days a week.

Before and after the improvement of work methods, the numbers of motion symbols during work with process flow charts were examined (Table 2). Motion symbols decreased during the intervention compared to before the work procedures were enhanced. Tables 3 and 4 illustrate how the process went from having 28 stages with an average of 71.70 movements to 22 steps with an average of 66.40 movements (p-value < 0.05).

Table 2 Symbol and meaning of risk postures.

Symbols	Meaning	Risk postures
○	Operation	Wrists deviation or twisting for wrapping the plastic around cable reel
		Wrists flexing for holding the plastic rope into the winding machine
		Arms reaching to the reel of wires
		Standing to work packing reels of wires
□	Inspection	Neck bending to look at the end of the cable reel
		Neck bending to look at the position to put the plastic rope
⇨	Transport	Arms flexion to lift the cable reel
		Neck twisting to look before walking
		Truck twisting and side bending during lift the cable reel
		Walking to put the cable reel
D	Delay	Standing to wait for the wires to be rolled
▽	Storage	Trunk flexion to put cable reel
		Knee flexion during put cable reel
		Unilateral weight bearing on the leg

Table 3 Comparison of the mean of motion symbols during work between before and after implementation of motion economy

Symbols	Meaning	Awkward postures	Before the intervention		After the intervention		p-value
			X	SD	X	SD	
○	Operation	Wrists deviation or twisting for wrapping the plastic around cable reel	8.70	8.45	4.30	2.40	.008*
		Wrists flexing for holding the plastic rope into the winding machine	14.90	2.20	12.70	1.70	.005*
		Arms reaching to the reel of wires	0.50	0.74	0.00	0.00	.025*
		Standing to work packing reels of wires	1.00	0.00	1.00	0.00	.102
□	Inspection	Neck bending to look at the end of the cable reel	0.90	1.03	0.50	1.23	.102
		Neck bending to look at the position to put the plastic rope	0.90	1.22	0.50	1.03	.102

Table 3 Comparison of the mean of motion symbols during work between before and after implementation of motion economy (continued)

Symbols	Meaning	Awkward postures	Before the intervention		After the intervention		p-value
			X	SD	X	SD	
⇨	Transport	Arms flexion to lift the cable reel	1.00	0.00	1.00	0.00	1.00
		Neck twisting to look before walking	0.90	0.44	0.20	0.62	.008*
		Truck twisting and side bending during lift the cable reel	0.70	0.67	0.10	0.46	.014*
		Walking to put the cable reel	1.00	0.00	1.00	0.00	1.00
D	Delay	Standing to wait for the wires to be rolled	1.00	0.00	0.50	0.77	.025*
▽	Storage	Trunk flexion to put cable reel	1.00	0.00	0.00	0.00	.002*
		Knee flexion during put cable reel	0.90	0.44	0.00	0.00	.002*
		Unilateral weight bearing on the leg	0.60	0.72	0.00	0.00	.002*

Table 4 Comparison of the mean of summary motion symbols during work between before and after implementation of motion economy

Symbols	Mean of symbols	Before the intervention		After the intervention	
		X	SD	X	SD
○	Operation	55.70	24.89	51.80	22.02
□	Inspection	4.50	1.65	4.80	0.92
⇨	Transport	8.00	2.98	7.00	2.67
D	Delay	1.00	0.00	0.50	0.53
▽	Storage	3.49	0.38	2.30	0.00

The analysis and comparison of the number of inappropriate movement gestures revealed all 14 steps, with fewer inappropriate movements, such as wrist twist and bending, hand and arm reaching, movements such as neck side bending, trunk twist and bending, knee bending, standing on one leg, and reduction in delay (waiting for cord reeling). The reduction is significant ($p < 0.05$).

The comparison of awkward postures by REBA assessment found that the risk scores of the postures while packing cable reels decreased after the improvement of the working methods. Part A included the neck, trunk, and legs, for which the scores decreased from 11 to 5. Part B consisted of the upper limb (shoulder), forearm (elbow), and wrist, for which the scores decreased from 7 to 5. The summary of REBA scores decreased from 13 to 7, which implied a reduction from a very high to a medium risk level, as shown in Table 5.

Table 5 Comparison of the REBA scores during work before and after the implementation of motion economy

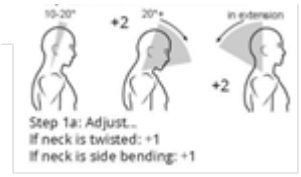
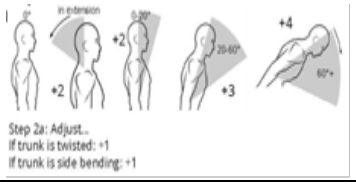
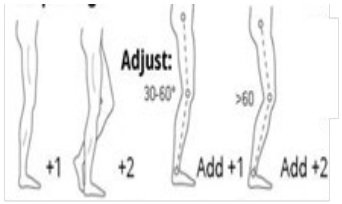
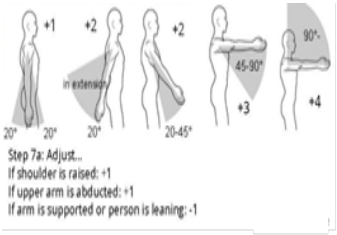
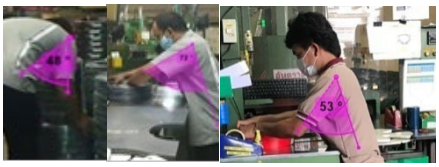
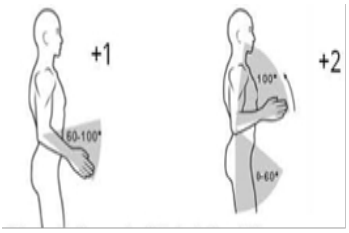
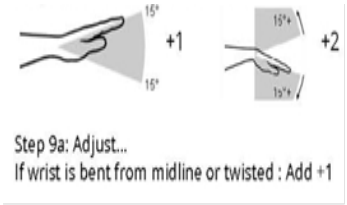
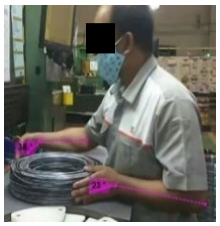
REBA Assessment	Posture		REBA Score	
	Before the intervention	After the intervention	Before the intervention	After the intervention
1.Neck posture 			3	2
2.Trunck posture 			5	2
3.Leg 			3	1
4. Part A score			9	3
5. Force or load score			2	2
6. Part A score summary			11	5
7. Upper arms score 			4	3

Table 5 Comparison of the REBA scores during work before and after the implementation of motion economy (continued)

REBA Assessment	Posture		REBA Score	
	Before the intervention	After the intervention	Before the intervention	After the intervention
8 Lower arms score			1.80	1.60
				
9.Wrists score			3	3
				
10. Part B score			6.60	5
11. Coupling score			0	0
12. Part B score summary			6.60	5
13. Matrix part A and part B score			12	6
14. Repetitive motion over four time/minute score			1	1
15. REBA score			13	7

4. DISCUSSION

Improving the working methods can help reduce awkward occupational posture, as follows: reduction of wrist bending, flexion and exertion, body twisting and turning, and twisting and bending of the neck while working[9]. The results are in line with those of the study on reducing hand risks among chicken scraping workers, for which the number of movement symbols and the risk level of the hand decreased significantly ($p < .05$) after the improvement of their working methods[10]. In the present study, the working method improvements reduced the following: effort to lift/move the workpiece; body swaying, tilting, twisting, and bending; and standing for a long period of time. This finding was consistent with a previous study that explored the improvement of vermicelli packing using ergonomics and found a reduced risk associated with working. The

problem was caused by the risk of improper working postures, such as lifting the arms and shoulders, strong force of fingers and hands in gripping, and a standing posture with a twist or side bending of the trunk. These movements increased the chance of injury from awkward postures[11].

Improving the arrangement of the workplace by adjusting the placement of product identification tags and work equipment to a more easily accessible and convenient distance, specifically within 40 centimeters, could reduce the reach of hands and arms. Workpieces were rearranged to facilitate optimal movement by adjusting the height of the pallet to help reduce knee and trunk bending and standing with the weight on one leg. The findings were in line with those of a study on the reduction of risk factors for musculoskeletal disorders among employees in the automotive manufacturing industry. The effectiveness of ergonomic solutions was combined with engineering, and the results demonstrated that remedial measures on workstation improvements can reduce physical workload and symptoms of musculoskeletal disorders[12]. This result was consistent with those of Jaruporn Duangsri (2016), who studied the effect of improving workstations for old wood handicrafts to reduce the risk of low back. The results showed that improving workstation height can reduce stooping, provide workers with more appropriate working postures, and reduce its associated risks[13].

Tools and equipment as the base set that could adjust the pallet height were designed to help reduce body bending, minimize leg and knee flexion, and the stressful standing on one leg when placing the cable reel[14]. In addition, arranging chairs for employees to sit and rest while waiting for the signal from the wire injection machine helped reduce long and constant standing. As a result, according to the motion symbols in the flow process chart, the number of movements in cable reel packing decreased after the improvement of work methods from 28 to 22 steps. These results showed that the work method could be improved by analyzing and identifying the dangers of the number of inappropriate movements in each work step. Then, the cause of problems from work posture could be identified and used as a guide to reduce the risk of work posture. Including the assessment of working posture of the whole body using the REBA showed that after the improvement of working methods, the risk of working posture in various organs including the neck, trunk, and the legs. The risk score declined from 11 to 5. Moreover, the upper arms, lower arms, and hand showed lower risk scores from 7 to 5. Therefore, the total risk score after the improvement of working methods decreased from 13 to 7, resulting in the reduced risk of working postures from severe to moderate level.

Recommendations

Not only may motion economy concepts be used to improve working processes, but they can also help lower the dangers connected with difficult occupational postures. As a result, other workstations where the subjects were somewhat at risk due to their posture and working

techniques can also use the motion economy concepts. Businesses should always keep an eye on workers' health and implement electrical or hydraulic systems to make pallet height adjustment equipment easier to operate. This strategy may encourage and support lowering ergonomic risks and preventing disorders of the musculoskeletal system in the workplace.

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