

**WORKSTATION IMPROVEMENT TO REDUCE
MUSCULAR FATIGUE OF WORKERS
IN AIR CONDITIONER FACTORY**

SUPRANEE POCHAKA

**A THESIS SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR
THE DEGREE OF MASTER OF SCIENCE
(INDUSTRIAL HYGIENE AND SAFETY)
FACULTY OF GRADUATE STUDIES
MAHIDOL UNIVERSITY**

2005

ISBN 974-04-6121-2

COPYRIGHT OF MAHIDOL UNIVERSITY

Thesis
Entitled

**WORKSTATION IMPROVEMENT TO REDUCE
MUSCULAR FATIGUE OF WORKERS
IN AIR CONDITIONER FACTORY**

.....
Miss Supranee Pochaka
Candidate

.....
Lect. Suttinun Chantanakul,
M.D.
Major-Advisor

.....
Assoc. Prof. Chalermchai Chaikittiporn,
Dr.P.H.(Epidemiology)
Co-Advisor

.....
Dr. Sasitorn Taptagaporn,
Ph.D.
Co-Advisor

.....
Assoc. Prof. Vichai Pruktharatikul,
M.Sc. (Industrial Hygiene and Safety)
Co-Advisor

.....
Assoc. Prof. Rassmidara Hoonsawat,
Ph.D.
Dean
Faculty of Graduate Studies

.....
Assoc. Prof. Pornpimol Kongtip,
Ph.D.(Occupational Health Science)
Chair
Master of Science Programme in
Industrial Hygiene and Safety
Faculty of Public Health

Thesis
Entitled

**WORKSTATION IMPROVEMENT TO REDUCE
MUSCULAR FATIGUE OF WORKERS
IN AIR CONDITIONER FACTORY**

was submitted to the Faculty of Graduate Studies, Mahidol University
for the degree of Master of Science (Industrial Hygiene and Safety)
on
20 May 2005

.....
Miss Supranee Pochaka
Candidate

.....
Lect. Suttinun Chantanakul,
M.D.
Chair

.....
Dr. Sasitorn Taptagaporn,
Ph.D.
Member

.....
Assoc. Prof. Chalermchai Chaikittiporn,
Dr.P.H.(Epidemiology)
Member

.....
Dr. Pipat Chumkasian,
M.D.(Dip. in physical medicine and
rehabilitation)
Member

.....
Assoc. Prof. Vichai Pruktharatikul,
M.Sc. (Industrial Hygiene and Safety)
Member

.....
Assoc. Prof. Rassmidara Hoonsawat,
Ph.D.
Dean
Faculty of Graduate Studies
Mahidol University

.....
Assoc.Prof. Chalermchai Chaikittiporn,
Dr.P.H. (Epidemiology)
Dean
Faculty of Public Health
Mahidol University

ACKNOWLEDGEMENT

I would like to express my sincere gratitude and deep appreciation to Lecture Suttinun Chantanakul my major advisor for his guidance, invaluable advice, supervision, encouragement throughout. He was never lacking in kindness and support. He was very nice and friendly for giving me this opportunity.

Special appreciation is submitted to the co-advisory committee, Assoc. Prof. Chalermchai Chaikittiporn, Assoc. Prof. Vichai Pruktharathikul and Dr. Sasitorn Taptagaporn for their valuable suggestions and corrections of this thesis. Dr. Pipat Chumkasian for his kindness to give information and suggestion for improvement of the research.

To all my teacher, I wish to express my appreciation for their teaching and advice during my graduate studies at Mahidol University. I wish to thank my subjects and the Mitsubishi Heavy Industries - Mahajak Air Conditioners co. Ltd. for their helpful, good cooperation and budget.

Finally, I am deeply indebted to my mother, my farther, my family and all my friends for their love, encouragement and moral support which inspired me to reach this goal.

Supranee Pochaka

WORKSTATION IMPROVEMENT TO REDUCE MUSCULAR FATIGUE OF WORKERS IN AIR CONDITIONER FACTORY

SUPRANEE POCHAKA 4337529 PHIH/M

M.Sc. (INDUSTRIAL HYGIENE AND SAFETY)

THESIS ADVISORS: SUTTINUN CHANTANAKUL, M.D.,
CHALERMCHAI CHAIKITTIPORN, Dr.P.H. (Epidemiology),
VICHAI PRUKTHARATHIKUL, M.Sc. (Industrial Hygiene and Safety),
SASITORN TAPTAGAPORN, Ph.D.

ABSTRACT

The objectives of this study were to design a workstation for reducing muscular fatigue in workers hanging materials on an overhead conveyor at an air conditioner factory by using a model to improve workstation height. The existing workstation's work height of 176 centimeters was modified to 136.6 ± 1.52 centimeters by using standing base 40 centimeters height and lifting equipment.

This quasi-experimental study was carried out with 20 male workers. All subjects had no history of serious illness or musculoskeletal injuries. The mean age of the study subjects was 27.55 ± 1.36 years. Mean weight and height were 60.80 ± 1.92 kilograms and 165.01 ± 1.59 centimeters respectively. The duration of work as workers for hanging materials on overhead conveyors was 4.67 ± 0.46 years. The subjects were both objectively and subjectively assessed for fatigue while working on the existing workstation and also on the improved workstation. The percentage of maximum voluntary contraction (MVC) was measured by electromyography every 30 minutes, and fatigue feeling was assessed by a questionnaire at 0, 3, 4 and 6 working-hours.

The results of this study demonstrated that while the workers worked on the improved workstation, the fatigue feeling of the general body, deltoideus muscle and erector spinae muscle was significantly less than that while working on the existing workstation ($\alpha = 0.05$). The percentage of MVC of deltoideus muscle and erector spinae muscle during working on the improved workstation was significantly less than that while working on the existing workstation ($\alpha = 0.05$). Workplace temperatures during the experiment remained constant. Finally, on the improved workstation, the duration of each item was significantly less than that while working on the existing workstation ($\alpha = 0.05$).

The experimentation indicated that anthropometrics data of the workers would be very useful as design criteria for workstation improvement in order to reduce muscular fatigue. Therefore, this study concluded that the improved workstation could reduce deltoideus and erector spinae muscular fatigue of workers hanging materials on conveyors.

KEY WORDS: WORKSTATION IMPROVEMENT/ FATIGUE/
ELECTROMYOGRAPHY

129 P. ISBN 974-04-6121-2

การปรับปรุงสถานีทำงานเพื่อลดความเมื่อยล้าส่วนไหล่และหลังของพนักงานแวนขึ้นงานบนราวลำเลียงใน
อุตสาหกรรมผลิตและประกอบเครื่องปรับอากาศ (WORKSTATION IMPROVEMENT TO REDUCE
MUSCULAR FATIGUE OF WORKERS IN AIR CONDITIONER FACTORY)

สุปราณี โพชะกะ 4337529 PHIH/M

วท.ม.(สุขศาสตร์อุตสาหกรรมและความปลอดภัย)

คณะกรรมการควบคุมวิทยานิพนธ์: สุทธินันท์ ถิ่นทัศนกุล M.D., เอลิมชัย ชัยกิตติภรณ์, Dr.P.H.

(Epidemiology), วิชัย พงษ์ธาราธิกุล, วท.ม. (สุขศาสตร์อุตสาหกรรม และความปลอดภัย),

สตีธร เทพตระการพร, Ph.D.

บทคัดย่อ

การวิจัยครั้งนี้มีวัตถุประสงค์ในการออกแบบปรับปรุงสถานีทำงานเพื่อลดความเมื่อยล้ากล้ามเนื้อไหล่และ
กล้ามเนื้อหลังของพนักงานแวนขึ้นงานบนราวลำเลียงในอุตสาหกรรมผลิตและประกอบเครื่องปรับอากาศ โดย
นำแบบจำลองมาประยุกต์ใช้ในการปรับสถานีทำงานเดิม ที่มีความสูงของจุดแวน 176 ซม. เป็นสถานีทำงาน
ใหม่ที่มีความสูงของจุดแวน 136.16 ± 1.52 ซม. โดยใช้แท่นยืนสูง 40 ซม. และมีอุปกรณ์ช่วยยกบรรจุน้ำมัน

ในการศึกษานี้เป็นการวิจัยแบบกึ่งทดลองในกลุ่มพนักงานแวนขึ้นงานบนราวลำเลียงเพศชาย มีสุขภาพ
แข็งแรงไม่มีประวัติการเจ็บป่วยหรือได้รับอุบัติเหตุเกี่ยวกับกระดูกและกล้ามเนื้อ จำนวน 20 คน อายุเฉลี่ย
 27.55 ± 1.36 ปี น้ำหนักเฉลี่ย 60.80 ± 1.92 กก. ส่วนสูงเฉลี่ย 165.01 ± 1.59 ซม. ประสบการณ์ในการทำงานแวน
ขึ้นงานบนราวลำเลียงเฉลี่ย 4.67 ± 0.46 ปี กลุ่มตัวอย่างถูกประเมินความเมื่อยล้ากล้ามเนื้อด้วยค่า % MCV ของค่า
คลื่นไฟฟ้ากล้ามเนื้อ ทุก 30 นาที และสอบถามความรู้สึกเมื่อยล้าในช่วงเวลาการทำงานที่ 0, 4, 5 และ 6 ชม
ทำงานในสถานีทำงานเดิมและสถานีทำงานที่ปรับปรุงใหม่

ผลการศึกษาพบว่า การประเมินระดับความรู้สึกเมื่อยล้า ความเมื่อยล้าของกล้ามเนื้อไหล่ (Deltoides)
และกล้ามเนื้อหลัง (Erector spinae) ในสถานีทำงานที่ปรับปรุงใหม่มีน้อยกว่าการทำงานในสถานีทำงานเดิมอย่างมี
นัยสำคัญทางสถิติ ($\alpha = 0.05$) และการประเมินความเมื่อยล้ากล้ามเนื้อด้วยคลื่นไฟฟ้ากล้ามเนื้อ พบว่า ขณะ
ทำงานในสถานีที่ปรับปรุงใหม่มีความเมื่อยล้าที่กล้ามเนื้อไหล่ (Deltoides) และกล้ามเนื้อหลัง (Erector spinae) น้อย
กว่าการทำงานในสถานีทำงานเดิมอย่างมีนัยสำคัญทางสถิติ ($\alpha = 0.05$) รวมถึงระยะเวลาการทำงานต่อชิ้นงานใน
สถานีทำงานที่ปรับปรุงใหม่ใช้ระยะเวลาน้อยกว่าการทำงานในสถานีทำงานเดิมอย่างมีนัยสำคัญ ($\alpha = 0.05$) สำหรับ
อุณหภูมิในการทำงานทั้ง 2 สถานีทำงานไม่มีความแตกต่างกัน

นอกจากนี้ผลการศึกษาข้างบ่งชี้ว่า การปรับปรุงสถานีทำงานโดยใช้ข้อมูลขนาดสัดส่วนร่างกายของกลุ่มคน
ผู้ซึ่งเป็นคนทำงานนั้นๆ โดยตรง เป็นเกณฑ์ในการออกแบบปรับปรุงสถานีทำงานมีความสำคัญและมีประโยชน์ที่จะ
ช่วยลดความเมื่อยล้ากล้ามเนื้อได้ และการปรับสถานีทำงานใหม่สามารถลดความเมื่อยล้ากล้ามเนื้อไหล่ และ
กล้ามเนื้อหลังของพนักงานแวนขึ้นงานบนราวลำเลียงได้

CONTENTS

	Page
ACKNOWLEDGEMENT	iii
ABSTRACT	iv
LIST OF TABLES	ix
LIST OF FIGURES	xii
CHAPTER I INTRODUCTION	
Background and rationale	1
Objectives	2
Study Hypotheses	3
Variables	3
Scope and limitation of this study	4
Definitions	5
Conceptual framework	7
CHAPTER II LITERATURE REVIEW	
Bones	8
Anatomy of the vertebral column	10
Muscles	12
Shoulder muscles	16
Muscles of the trunk	19
Function motion of the spine	21
Factors influencing muscle strength	22
Static activity of muscle	22
Mechanism of muscle and tendon injuries due to fatigue	24

CONTENTS (Continued)

	Page
Fatigue	25
Method of measurement fatigue	30
Functions of muscles and electromyography	34
Anthropometry	39
Hanging materials on overhead conveyor	41
The Design of workstation	43
Review of research study	43
CHAPTER III MATERIALS AND METHODS	
Study design	52
Population and samples	54
Materials and equipments	54
Data collection	55
Statistical analysis	59
CHAPTER IV RESULTS	
The characteristics and muscular fatigue of samples	60
The anthropometry data of samples	65
Result of fatigue feeling of fatigue by using questionnaire	68
Result of muscular activity by using electromyography	72
Correlation of fatigue indicator between fatigue feeling and muscular activity	77
Result of working conditions	79
Result of the duration per work item of samples (minutes/piece)	80
CHAPTER V DISCUSSION	
Discussion of study design	81
Discussion of study results	84

CONTENTS (Continued)

	Page
CHAPTER VI CONCLUSION AND RECOMMENDATION	
Conclusion	88
Recommendation for hanging materials on overhead conveyor workers	88
Recommendation for further study	89
REFERENCES	91
APPENDIX	96
BIOGRAPHY	129

LIST OF TABLES

Tables		Page
2-1	Shows the effects of static patterns of work which cause fatigue	24
2-2	Demonstrates the angle rang of motion, which causes fatigue	29
2-3	Shows stable postures at work which cause fatigue	29
2-4	Electrode placements on muscle	37
4-1	The characteristics of 20 males hanging materials on overhead conveyor workers	61
4-2	Physical health status of 20 males hanging materials on overhead conveyor workers	62
4-3	Anthropometry of hanging materials on overhead conveyor workers	65
4-4	Comparison of means general bodily fatigue score of working on improved workstation and existing workstation	68
4-5	Comparison of means deltoideus muscular fatigue score of working on improved workstation and existing workstation	70
4-6	Comparison of means erector spinae muscular fatigue score of working on improved workstation and existing workstation	71
4-7	Comparison of means % MVC of deltoideus muscle of working on improved workstation and existing workstation	73
4-8	Comparison of means % MVC of erector spinae muscle of working on improved workstation and existing workstation	75
4-9	Correlation coefficient of fatigue indicator between fatigue feeling from questionnaire and muscular activity measurement from electromyography while the subjects were working on the existing workstation	78

LIST OF TABLES (Continued)

Tables	Page	
4-10	Correlation coefficient of fatigue indicator between fatigue feeling from questionnaire and muscular activity measurement from electromyography while the subjects were working on the improved workstation	78
4-11	Comparison of means workplace temperature of working on improved workstation and existing workstation	79
4-12	Comparison of means the duration per work item of working on improved workstation and existing workstation.	80
C-1	Anthropometry data of the hanging materials on overhead conveyor workers	116
D-1	Average EMG of deltoideus muscle while hanging materials on overhead conveyor on improved workstation.	117
D-2	Average EMG of erector spinae muscle while hanging materials on overhead conveyor on improved workstation.	118
E-1	Average EMG of deltoideus muscle while hanging materials on overhead conveyor on existing workstation.	119
E-2	Average EMG of erector spinae muscle while hanging materials on overhead conveyor on existing workstation.	120
F-1	Comparison score of general bodily fatigue of the hanging materials on overhead conveyor workers between while working on improved workstation and existing workstation.	121
F-2	Comparison score of deltoideus muscular fatigue of the hanging materials on overhead conveyor workers between while working on improved workstation and existing workstation.	122
F-3	Comparison score of erector spinae muscular fatigue of the hanging materials on overhead conveyor workers between while working on improved workstation and existing workstation.	123

LIST OF TABLES (Continued)

Tables		Page
G-1	Comparison score of working temperature and the duration per work item of the hanging materials on overhead conveyor workers between while working on improved workstation and existing workstation.	124
H-1	Comparison of % MVC of Deltoideus muscle while hanging materials on overhead conveyor on improved workstation and existing workstation.	125
H-2	Comparison of % MVC of Erector spinae muscle while hanging materials on overhead conveyor on improved workstation and existing workstation.	126
I-1	Comparison score of local muscular fatigue of the hanging materials on overhead conveyor workers between while working on improved workstation.	127
I-2	Comparison score of local muscular fatigue of the hanging materials on overhead conveyor workers between while working on existing workstation.	128

LIST OF FIGURES

Figures		Page
2-1	Shows the skeletal of shoulder and arm	9
2-2	The vertebral column	10
2-3	The intervertebral disc	11
2-4	Structure of skeletal muscle	13
2-5	Structure of Longitudinal Tubule (LT) which stick to Z line and turns to be triad structure	14
2-6	Diagram demonstrates excitation-Contraction Coupling	14
2-7	Demonstrates the muscles help in shoulder and arm movements	17
2-8	The posterior view of the back muscles	20
2-9	The abdominal muscles	21
2-10	Sequences of severity of muscular pain to dysfunction	28
2-11	Examples of typical electrodes used in electromyography and nerve conduction studies	32
2-12	Principle of extra cellular action potential recording using surface electrodes	35
2-13	Attaching an electrode to the surface of the skin above a muscle	36
2-14	Plugging the snap connector onto the electrode	37
2-15	Positioning of electrodes on trapezius muscle and deltoid muscle	38
2-16	Positioning of electrodes on erector spinae muscle	39
2-17	The worker brings material from the carrier	41
2-18	The worker brings material to hang them on overhead conveyer	42
2-19	Hanging materials on the overhead conveyer	42
2-20	Expected time to reach significant shoulder muscle fatigue for various arm flexion postures	44

LIST OF FIGURES (Continued)

Figures		Page
2-21	The relations between the period of time that the shoulder muscular are fatigue caused by reaching in several front distance	45
2-22	The period of time of muscular fatigue caused by angled of elbow	46
2-23	The period of time of shoulder muscular fatigue caused by varies arm abduction angles	47
4-1	The design features and dimensions of improved workstation	66
4-2	The improved workstation	67
4-3	Level of general bodily fatigue score of working on improved workstation and existing workstation at various working hours	69
4-4	Level of deltoideus muscular fatigue score of working on improved workstation and existing workstation at various working hours	70
4-5	Level of erector spinae muscular fatigue score of working on improved workstation and existing workstation at various working hours	72
4-6	Mean of % MVC of deltoideus muscle of working on improved workstation and existing workstation	74
4-7	Mean of % MVC of erector spinae muscle of working on improved workstation and existing workstation	77
4-8	Level of workplace temperature of working on improved workstation and existing workstation at various working hours	80
A-1	Positioning of electrodes on deltoideus muscle and erector spinae muscle.	98
A-2	Electromyography (Muscle tester Model ME300)	100
B-1	Anthropometer	105

CHAPTER I

INTRODUCTION

1.1 Background and rationale

Although the industrial development, new technology and modern machinery are utilized in Thailand nowadays, it has been still presented the evidence of lifting or transferring objects done by man in every step of production. Musculoskeletal disease is one serious problem in many workers, which work-related injuries are critical and damage to nation's economics. The economic costs in terms of medical expense, lost production and compensation are estimated enormous. One of the significant causes is as a result of too heavy workload and inappropriate working posture. Different population has different anthropometry. Human size is very important to set criteria for machine design. The equipment design without taking into account of the impact of the force to human anthropometry is another cause of the muscular fatigue.

Moreover work-relates low back injuries are present one of the biggest problems, also. Employees in heavy industry, particularly manual materials workers who are in these jobs typically lift while twisting, reaching and lateral bending due to the characters of work or the design workplace, more likely to develop compensable low back injuries than other workers. The severity of low back injury is also found significantly greater in manual materials workers than in those with light jobs. The report showed that 53% in light to moderate manual jobs face the problems of low back pain while in 64% of heavy manual jobs face more problems in low back pain.

(1,2,3)

Statistic of work-related injuries and occupational disease were reviews by The Workmen Compensation Fund, Social Security Office. In 2004 there were 809 cases that suffered from bad posture of work. 4,425 cases of low back pain workers were suffered from back pain caused by lifting and transferring heavy objects. 4,608 cases were absent from work not more than 3 days and the rest of 621 cases were absent from work more than 3 days. It has been believed that this problem has been

yet to define and still can not present the figure, if so it should have been able to calculate the lost amounts occurring (4).

From the primary survey about the health status of hanging materials on overhead conveyor workers, the results showed that the hanging workers have problem about muscular fatigue which occurred mostly on right upper arms (90%) and low back (85%) because of working condition or bad posture. In addition, the hanging materials on overhead conveyor workers can be characterized as repetitive work. Also, the very long working period that the worker has to stand all time on the workstation. The workers must to reach with the arm forward above shoulder, twist body and bent to bring materials in carrier. This posture effect to muscular fatigue of workers, that causes the workers absent many times.

The objectives of this study are to design workstation for reducing muscular fatigue of hanging materials on overhead conveyor workers in air conditioner factory. The design was mainly based on the ergonomic principles and anthropometry data. Therefore, the improved efficiency as well as to make better workstation, which in turns leads to more job satisfaction and increase work efficiency somehow.

1.2 Objectives

1.2.1 General objective

To improved workstation for reducing muscular fatigue in hanging materials on overhead conveyor workers and compare fatigue while the workers work on improved workstation and existing workstation.

1.2.2 Specific Objectives

1.2.2.1 To find out parts of the body of hanging materials on overhead conveyor workers that was fatigue.

1.2.2.2 To compare the feeling of general bodily fatigue, deltoideus and erector spinae muscular fatigue while the workers work on improved workstation and existing workstation.

1.2.2.3 To compare muscular fatigue of deltoideus muscle and erector spinae muscle by using EMG while the workers work on improved workstation and existing workstation.

1.2.2.4 To study the relationship between fatigue feeling by questionnaire and muscular activity by electromyography.

1.2.2.5 To study the duration per work item of hanging materials on overhead conveyor workers (minutes/piece) while the workers work on improved workstation and existing work station.

1.3 Study Hypotheses

1.3.1 The feeling of general bodily fatigue while the workers work on improved workstation is less than on existing workstation.

1.3.2 The feeling of deltoideus muscular fatigue while the workers work on improved workstation is less than on existing workstation.

1.3.3 The feeling of erector spinae muscular fatigue while the workers work on improved workstation is less than on existing workstation.

1.3.4 The deltoideus muscular activity by electromyography while the workers work on improved workstation is less than on existing workstation.

1.3.5 The erector spinae muscular activity by electromyography while the workers work on improved workstation is less than on existing workstation.

1.3.6 Correlation of the fatigue indicator between fatigue feeling by questionnaire and muscular activity by electromyography are linearly correlated.

1.3.7 The duration per work item of hanging materials on overhead conveyor workers (minutes/piece) while the workers work on improved workstation is less than on existing workstation.

1.4 Variables

1.4.1 Independent Variables

1.4.1.1 Improved workstation

1.4.1.2 Existing workstation

1.4.2 Dependent Variables

1.4.2.1 Fatigue feeling

- General bodily fatigue
- Deltoideus muscular fatigue
- Erector spinae muscular fatigue

1.4.2.2 Muscular activity

- EMG record of deltoideus muscles
- EMG record of erector spinae muscles

1.4.3 Control Variables

1.4.3.1 Personal characters; age, sex, weight, height.

1.4.3.2 Medical history; no history illness or injury of the musculoskeletal system e.g., fracture of the spine, disc herniation, chronic low back pain and abnormal spine.

1.4.3.3 Restful state before the experiment at least 7 hours.

1.4.3.4 Work experience in hanging materials on overhead conveyor more than 1 year.

1.5 Scope and limitation of this study

This study is quasi-experiment in simulated of hanging materials on overhead conveyor. The scope and limitation of this study was designed as the following:

1.5.1 This study investigated muscular fatigue of workers while hanging materials on overhead conveyor at the Mitsubishi Heavy Industries - Mahajak Air Conditioners co. Ltd.

1.5.2 The samples would be interviewed by using questionnaire to express their feeling of fatigue. While an electromyography is used to display their muscular activity.

1.5.3 The sample of this study is twenty healthy male subjects, no history of musculoskeletal diseases. Age ranging from 25-30 years old, body weight 57-65 kilograms, height 162-167 centimeters, work experience 1 year minimum and took a rest at least seven hours before measurement.

1.5.4 This study was quasi-experimental research design in a real working condition and subjects. Thus, the limitations of study are time and number of subjects.

1.6 Definitions

The feeling of fatigue

An evaluation of state of discomfort feeling due to work. The muscular fatigue of workers can be reflected in these followings ; tiredness, weariness of the whole body or specific parts including the fatigue due to prolong work with fatigue accumulated or due to heavy work. In this study refers to general bodily fatigue, deltoideus and erector spinae muscular fatigue.

Muscular activity

Muscle contraction and force production are due to a change in the relative position of various thread-like molecules or filaments arranged in the interior of the muscle. It can be evaluated by %MVC of EMG.

Average EMG (AEMG)

Simply the time integral of the full-wave rectified signal divided by the integration period and simple ways of reporting the general level of activity of any given muscle over a predetermined time.

Maximum voluntary contraction (MVC)

Maximum value that a subject can voluntary generates during an isometric contraction.

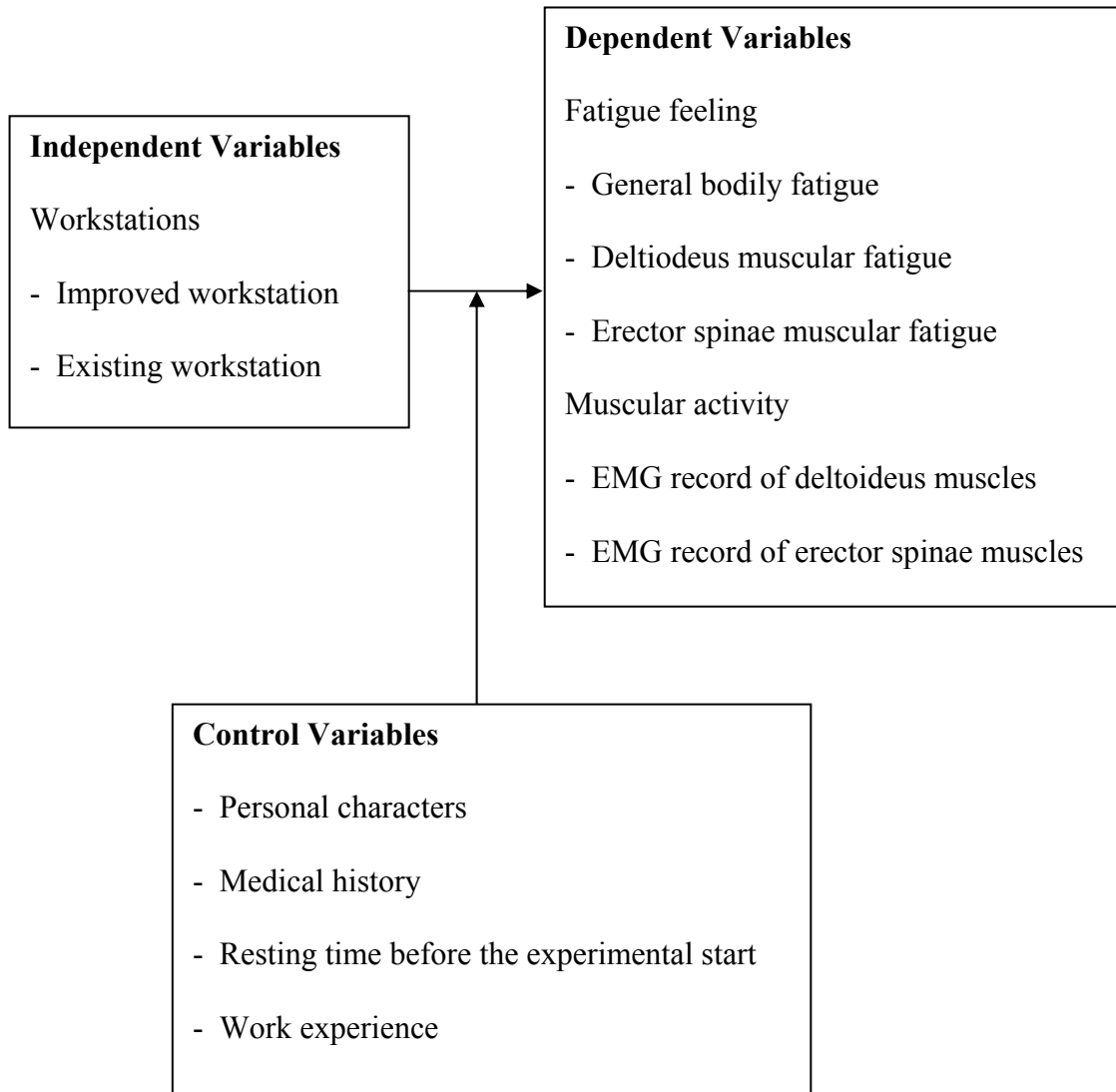
Isometric contraction

The muscle contracts and produces force without changing the angle of the joint.

$$\text{Percent of maximum voluntary contraction} = \frac{(\text{AEMG}) \times 100}{\text{MVC}}$$

Electromyography	EMG record of muscle contraction. The EMG record was measured in microvolt (μv).
Anthropometry	The measurement of the human body.
Existing workstation	The workstation of workers reached arm forward above shoulder on overhead conveyor that height was fixed. Then the workers twist and bent bodies to bring materials in carrier for hanging on overhead conveyor. These was 176 centimeters from floor that greatly contributes to the fatigue.
Improved workstation	The workstation of workers designed base on anthropometry data. It modified to 136.6 ± 1.52 centimeters work height with standing base 40 centimeters height. These was a lifting equipment for lift carrier in appropriate waist level.
Percentiles	Percentiles correspond to the value of a variable below, which a specific percentage of the group fall. For example, the 5 th percentile standing height for males is 162 cms. This means that only 5 percent of males are smaller than 162 cms. The 95 th percentile is 167 cms. It means 95 percent of males are shorter than this height.

1.7 Conceptual framework



CHAPTER II

LITURATURE REVIEW

2.1 Bones (5)

Mature human being consists of 206 bones, which can be categorized as follow.

Skull	29 bones (Including 3 small pieces of ears bone)
Vertebrae	26 bones
Shoulder, arms, hands	64 bones (Upper extremities)
Pelvic, legs, feet	62 bones (Lower extremities)
Bones of Upper extremities consist of (Shown in Figure 2-1)	

2.1.1 Shoulder regions refer to arm parts, which are attached to the trunk portion by 2 bones: clavicle and scapular called “shoulder girdle”

- Clavicle is a long bone with “S” shaped. It can be palpated along the anterior ridge through the inner ridge, which is attached to manubriun part of the sternum.

- Scapular is a flat bone in triangular shaped. The posterior part has a large spine called acromion process attached to the lateral end of clavicle.

2.1.2 Upper part of the arm has only single long bone called “humerus”. The upper part is round called “head” stretch into the glenoid cavity of the scapula. The lower part is looked like a pulley called “trachea” which allows the ulna bone to slide and moves like a hinge.

2.1.3 Forearm is consisted of 2 parts

- Ulna is located medial to the body axis. At the proximal end has a big spine called “Olecranon process” while the distal end is round and slim.

- Radius is located laterally to the body axis. The proximal end of this bone is flat small round end. This part can moves around itself in vertical plane. The distal part is expanded to attach to the wrist joint. In pronation the radius will rotate and cross to the ulna.

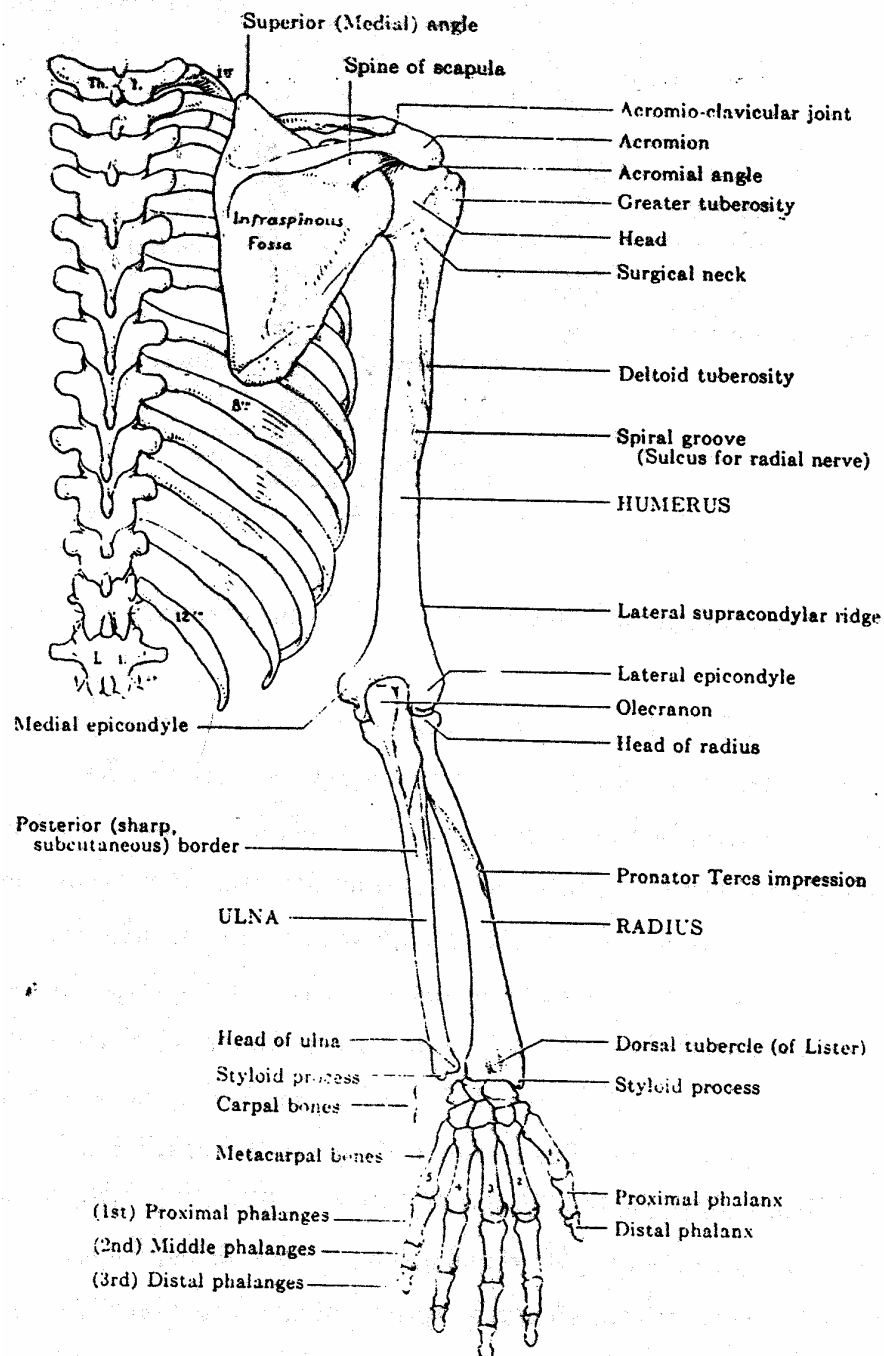


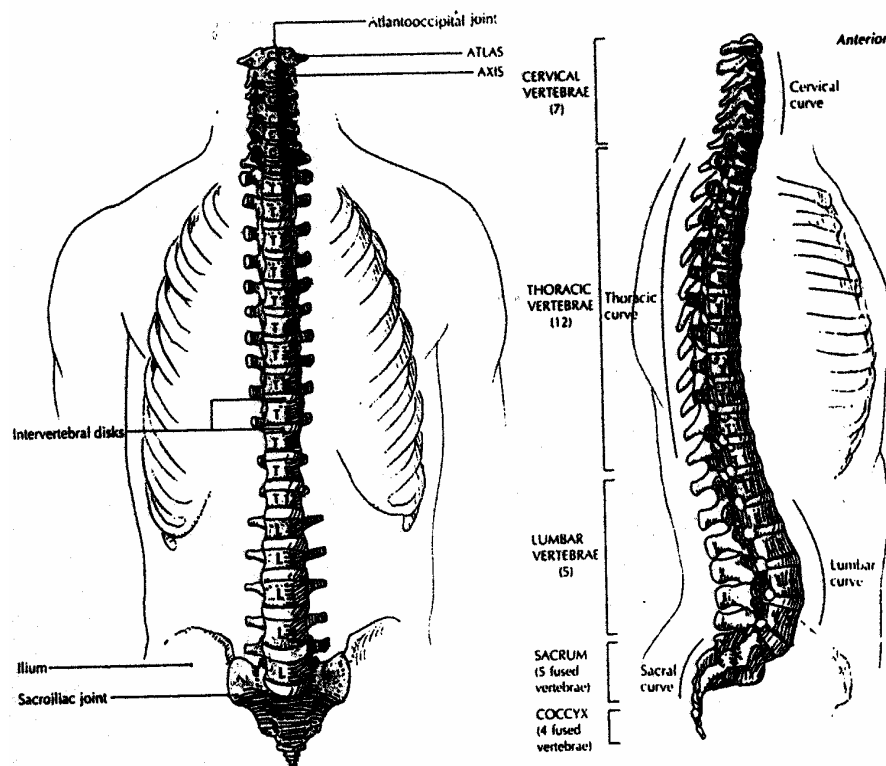
Figure 2-1 Shows the skeletal of shoulder and arm.

2.2 Anatomy of the vertebral column (6)

Vertebral column is the axial skeletal of the human body. It consists of 26 pieces of vertebrae (in children, they have 33-34 pieces) and articulated by intervertebral joints as a vertebral column or spinous column. Vertebral column is divided into 5 parts as follow:

- 1) Cervical spine part consists of 7 pieces.
- 2) Thoracic spine part consists of 12 pieces.
- 3) Lumbar spine part consists of 5 pieces.
- 4) 1 pieces of sacrum part.
- 5) 1 pieces of coccyx part.

Twenty six pieces of vertebrae are embroiled by ligaments and intervertebral disc which separates each segment of the vertebral bodies. The vertebral column is S shaped on lateral viewing due to curves that develop after birth and during childhood. These curves provide strength and flexibility for the vertebral column. As figure 2-2



A. Posterior view

B. Lateral view

Figure 2-2 The vertebral column.

2.2.1 Intervertebral disc consists of

2.2.1.1 Annulus fibrosus, is a kind of fibrous tissue and fibrocartilage. It helps in strengthening. The annulus is thicker in the anterior and lateral regions and thinner posteriorly.

2.2.1.2 Nucleus pulposus, is the remained part of notochord from the early development stage of embryo. It occupies the posterior-central aspect of the intervertebral disc. In younger people 88% contains of water and surrounded by annulus fibrosus.

2.2.2 Functions of the intervertebral disc

2.2.2.1 Shock absorber for axial force.

2.2.2.2 Semi-fluid ball bearing of joint motion.

Moreover, it helps wrapping around the spinal cord protecting spinal nerves. Therefore, if there is an injury to vertebral column it can cause ruptured disc or prolapsed disc or paraplegia. This kind of pathology is a consequence of bad posture of spine when doing work. As figure 2-3

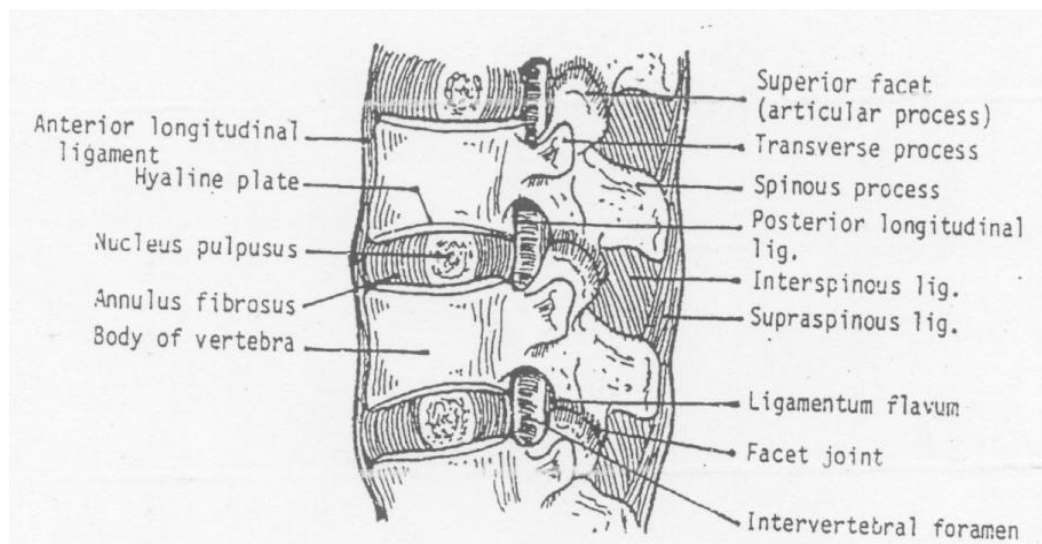


Figure 2-3 The intervertebral disc.

2.3 Muscles (7)

Muscular system is generally found in most organs 40-50% of the whole body weight is muscle. Muscular cells are considered excitable when the muscle is stimulated, it contracts as a consequence.

Striated of skeletal or voluntary muscle is the majority type muscles found in human body such as facial muscles, upper limb muscles, lower limb muscle, trunk muscles and outer structure of the body.

In this study would be emphasized on striated muscles which generate body movement only.

2.3.1 Striated muscles

Striated muscles generate body locomotion (See Figure 2-4). Because of the ends of these muscles insert at the movable parts, mostly the bones, which are, like a lever or the moment of the movement. However; somewhere we can find they insert at the soft tissue or thick connective tissue too.

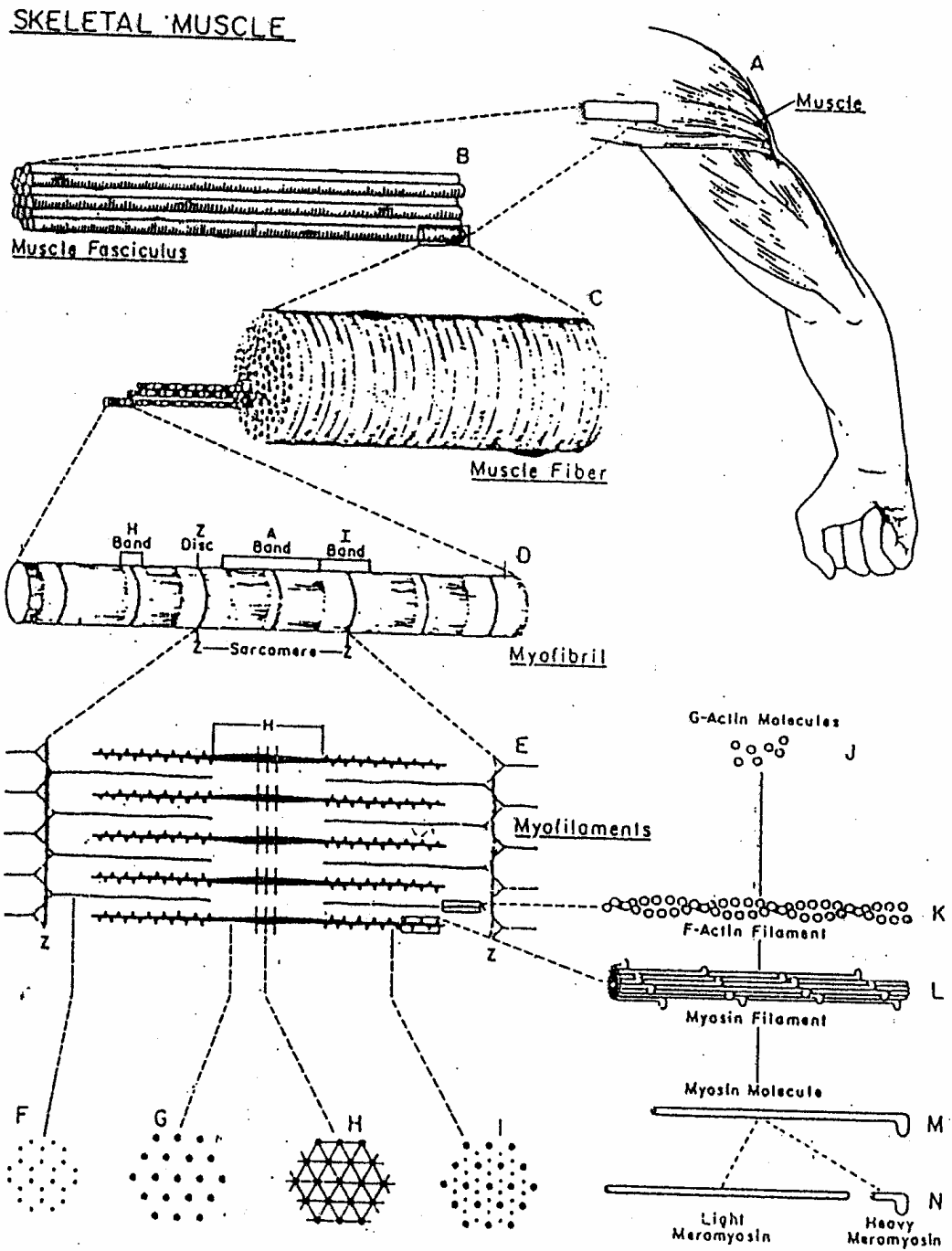


Figure 2-4 Structure of skeletal muscle.

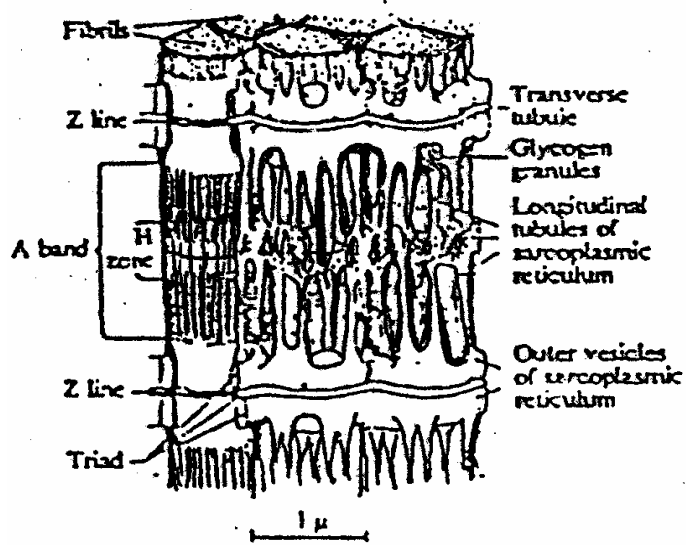


Figure 2-5 Structure of Longitudinal Tubule (LT) which sticks to Z line and turns to be triad structure.

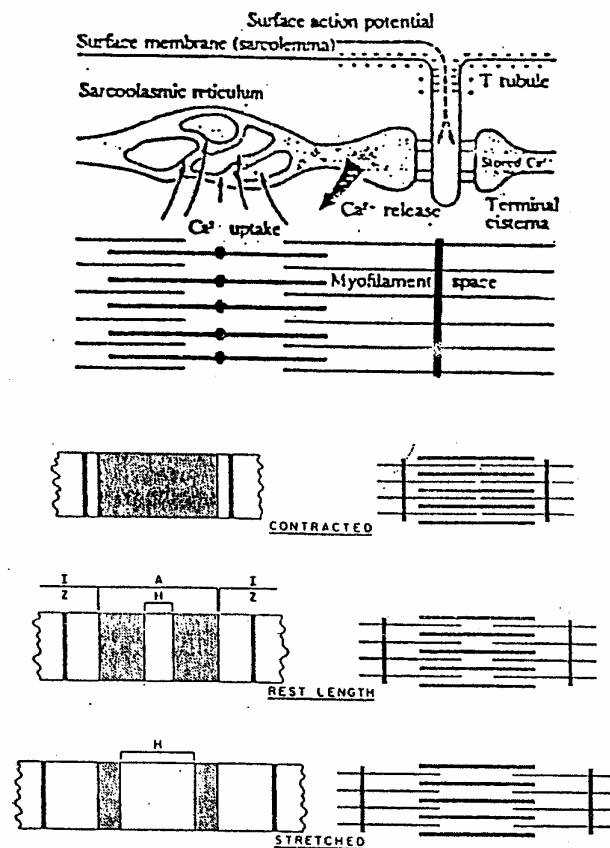


Figure 2-6 Diagram demonstrates excitation-Contraction Coupling.

Within a muscular cell is composed of

1. Nucleus (Mitochondria nucleus) is located at the cell wall, which provides myosin will catch ATP and causes the striated muscles contracts faster than other types of muscle.

2. Sacrolemma is a part of muscle fiber cell wall, which expands to the myofibril called “transverse tubular system (T system or T-tubule)”see Figure 2-5 T system contributes action potential to myofibrils constantly.

3. Sacroplasmic reticulum wraps myofilaments all along the length of the fiber that ties up many myofilaments to be a bigger size called myofibrils. Sacroplasmic reticulum also needs action potential to work. Therefore at its end expands called “terminal cisten” and joins with T system as triad.

4. Myofibril: each segment of myofibril called “sarcomere”. In each sarcomere composes of 2 types of myofilament: actin and myosin.

5. Cross bridge is the junction of actin and myosin. Head of myosin will catch both sides of actin fibers, which make muscles contracts.

2.3.2 Function of striated muscles. (8)

Provoked neuromuscular junction produces neurotransmitter to match the receptors of the muscular cell at the cell membrane. The cell wall permeability is changed within the cell membrane due to K and Na reaction as we know as “depolarization”. If intensity of the depolarization does not reach the action potential threshold, depolarization will just happen at the end plate. On contrary if it reaches the threshold, the muscle action potential will turn to be muscle impulse diffusing throughout the cell membrane through T system and finally the muscle contracts. Muscle contractions are caused by diffusion of action potential therefore action potential can be measured in volt.

When the muscles contract, they need to relax in order to be in normal state via Ca uptake back to Sacroplasmic Reticulum. In Ca pumping method, Ca would be detached from myofibrils and attached to cell membrane of sacroplasmic reticulum then ATPase will be released to digest ATP which generate the Ca intake energy into lumen of sacroplasmic reticulum back to the terminal cisternae. Therefore if there is no Ca left will detach actin and myosin which makes muscles relax.

Muscles contractions produce kinetic energy which transformed from accumulated chemical energy in the muscle fibers. Major sources of that chemical energy are taken from high-energy phosphate compounds such as ATP, CP (creatinine phosphate) which transform from carbohydrate and lipid.

Glucose is diffused throughout the whole body via vessel will be turned to be pyruvic acid if that state the body has enough oxygen, the chemical reaction will release water, carbon dioxide and energy. In case that the oxygen is insufficient, pyruvic acid will turn to be lactic acid instead which is the major cause of muscular fatigue and the energy from this reaction is considerable 20 times less than the first one. So that after working so hard the body will compensate to have sufficient oxygen intake by panting. To change lactic acid to be pyruvic acid as previous needs glucose and water because in the muscle it contain small energy there fore blood circulation is necessary to regulate the efficiency of blood supply to the muscles including blood pressure and vessel dilatation to supply the muscle.

2.4 Shoulders muscles (9)

2.4.1 Muscles that fix humerus to vertebrae are:

1. Trapezius has 2 big bases parts join together in triangular shaped.

Actions : upper part elevates shoulders
: middle part makes scapulars adducted
: lower part depressed and rotated scapulars.
2. Latissimus dorsi

Actions : shoulders extension, adduction and medial rotation.
3. Levator scapulae

Actions : elevate scapular and retracts both scapulars, rotate glenoid cavity downwardly.
4. Rhomboideus

Actions : elevate and retract scapular and help latissimus dorsi to rotate glenoid cavity downwardly.

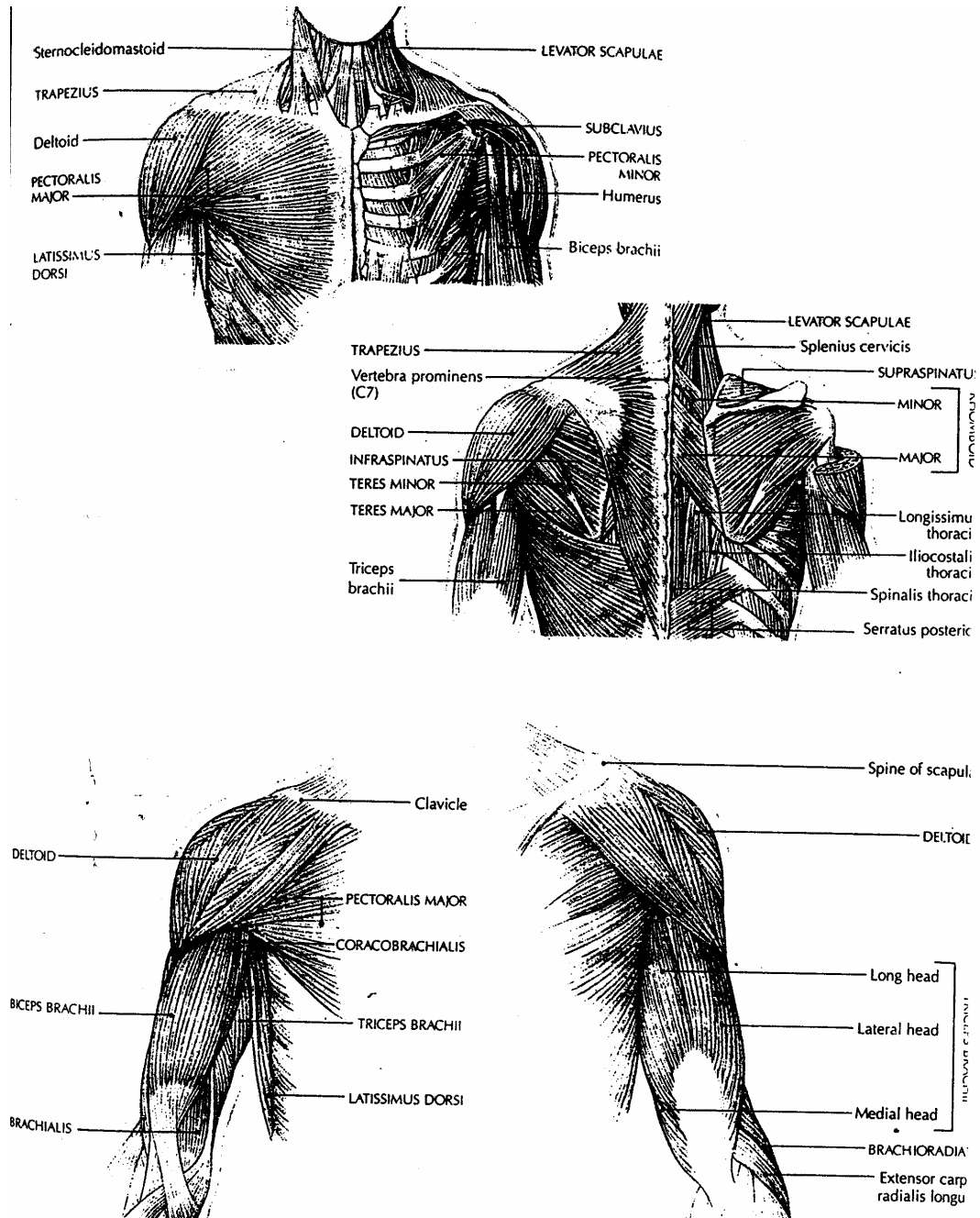


Figure 2-7 Demonstrates the muscles that help in shoulder and arm movements.

2.4.2 Muscles that fix humerus to thoracic wall.

1. Serratus Anterior

Actions : protract scapulars and rotates glenoid cavity upwardly.
Lower part helps in shoulder abduction with exceed 90⁰ range of motion.
2. Pectoralis major

Actions : shoulder adducted and medial rotation. If the insertion is stabilized will help to elevates ribs in inhale phase. Clavicular head works only in shoulder flexion. Sternal head only works in depress shoulder downwardly.
3. Pectoralis minor cooperates with serratus anterior in protract scapular and help in lifting up thoracic wall in breathing phase.
4. Subclavius works as shoulder depressor and stabilize clavicle when the shoulder joint is moving.

2.4.3 Scapular muscles

1. Deltoideus

Origin : starting from lateral 1/3 of clavicle, acromion and spine of scapula.

Insertion : ends at deltoid tuberosity of humerus.

Actions : anterior part helps in flexion and medial rotation of humerus, medial part helps in humeral abduction and posterior part helps in extension and lateral rotation of humerus.
2. Teres major

Actions : internal rotate of humerus.
3. Teres minor is a shoulder stabilizer.

Actions : external rotate and humeral adduction.

2.5 Muscles of the trunk (10)

Trunk muscle is usually divided into two major groups.

2.5.1 Trunk extensors (back muscles): As figure 2-8

This study focuses into erector spinae muscles group

Erector spinae muscles group: The superficial and deep iliocostalis lumborum and longissimus thoracis muscles.

Erector spinae is used in reference to the paraspinal muscles innervated by branches of the dorsal rami. It consists of two parts. They are a superficial and a deep part. The superficial part originates from medial border of iliac crest and lateral aspect of sacrum and extends to insert into spinous processes in the lumbar and sacral regions. The deep part originates from the ilium just anterior to the superficial part and extends superiorly, anteriorly and medially toward the lumbar transverse processes. Both parts have functions eccentrically to control the descent of the spine in forward bending and concentrically to extend the spine and isometrically to control the position of the lower thorax with respect to the pelvis. The erector spinae muscles have been shown to enter into a period electromyography silence toward the end of bending. It has been proposed that at this point the stabilization of the spine it has been relinquished or passed on to the non-contractile structures of the back, and that the muscle has been stretched to a length that minimizes its ability to contract.

2.5.2 Trunk flexors (abdominal muscles): As figure 2-9

Trunk flexors or muscles of the abdominal wall consist of the external abdominal oblique, internal abdominal oblique, transversus abdominis, and rectus abdominis muscles.

2.5.2.1 The external abdominal oblique muscle originates by way of fleshy digitations to the last eight ribs and extend inferiorly to insert into iliac crest. Between the anterior superior iliac spine and pubic tubercle it forms a thick, inrolled band known as the inguinal ligament.

2.5.2.2 The internal abdominal oblique muscle is deep to the external abdominal oblique muscle. It is attached to the lateral half of the inguinal ligament, the iliac crest and the inferior portion of the lateral raphe of the thoracolumbar fascia. From these attachments the muscle extends superiorly and medially to insert into the

cartilaginous border of the last three or four ribs, the abdominal aponeurosis, and the linea alba.

2.5.2.3 The transversus abdominis muscle is located deep to the internal abdominal oblique muscle. It is attached to the lateral one third of the inguinal ligament, the inner lip of the iliac crest, and the thoracolumbar fascia. The fiber direction is horizontally and runs to attach to the abdominal aponeurosis and the linea alba.

2.5.2.4 The rectus abdominis muscle. This muscle extends vertically from the pubic tubercles to attach to the lower rib cage on either side of the sternum.

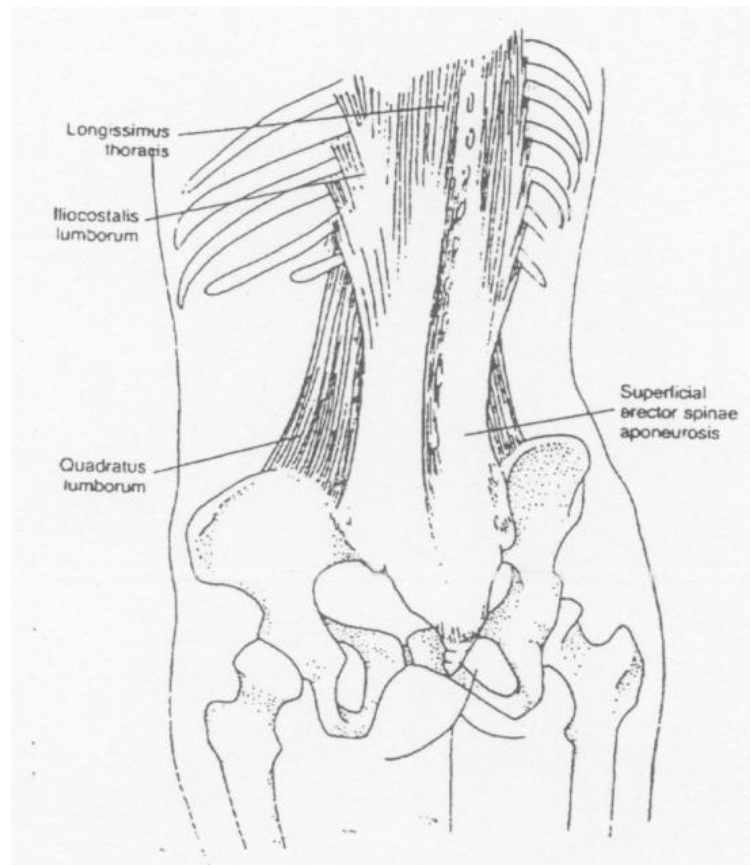


Figure 2-8 The posterior view of the back muscles.

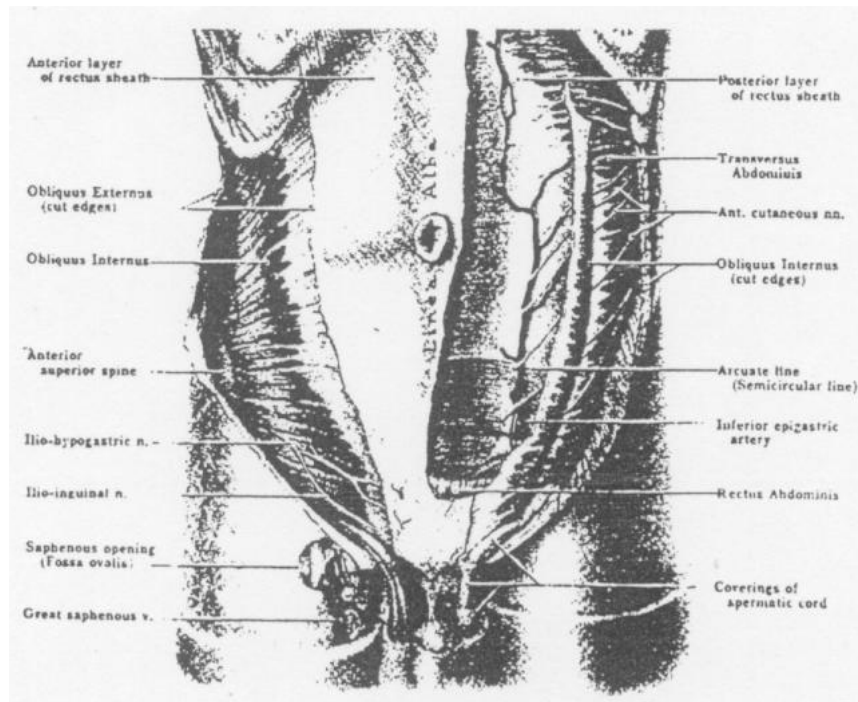


Figure 2-9 The abdominal muscles.

2.6 Functional motion of the spine

2.6.1 Flexion: The first 50-60 degrees of the spine flexion occurs in the lumbar spine and initiates by abdominal muscles and psoas muscle. The weight of the upper body produces further flexion with the pelvis tilting forward, which is controlled by the gradually increasing activity of the erector spinae muscles as the forward bending moment acting on the spine increases. In full flexion the erector spinae muscles become inactive and are fully stretched.

2.6.2 Extension: From full flexion to upright positioning of the trunk. When the trunk is extended from the upright position, the erector spinae muscles are active during the initial phase. The initial burst of activity decreases during further extension, and the abdominal muscles become active to control and modify the motion. In extreme extension erector spinae muscles activity is again required.

2.6.3 Lateral flexion: During lateral flexion of the trunk, motion may occur in the thoracic and lumbar spine. The erector spinae muscles and the abdominal muscles are active during lateral flexion. The ipsilateral contractions of these muscles initiate the motion and contralateral contractions modify it.

2.6.4 Rotation: Significant axial rotation occurs at the thoracic spine and lumbosacral region. Back and abdominal muscles are active on both sides of the spine, as both ipsilateral and contralateral muscles cooperate to produce this movement.

2.7 Factors influencing muscle strength (8)

Everyone has different degree of muscle strength. Muscle strength depends on many factors like healthy and good muscle strength in some how correlate to low back injury (Yu et. Al. 1984) (11) Factors influencing muscle strength are as follow:

- 1) Fat deposit in the muscle, fat can reduce the intensity to muscle contraction and eliminates the rate of contraction.
- 2) Tissue temperature, at higher temperature, muscle is less inert so that the contractility is better. That is why we need to warm up our muscles before doing things.
- 3) Metabolism: nutrition, oxygen and energy are required for muscle strength.
- 4) Fatigue: muscle strength is reduced due to abilities of muscle contraction and relaxation is reduced.
- 5) Muscular training: muscle strength can be gained and trained.
- 6) Age: It's increased rapidly in adolescent and slightly increased at the age of 20-30 years. The maximal strength is found at the age between 25-30 years and lasts for 5-10 years more after this age it will be declined constantly and slowly.
- 7) Occupation: types of occupation can cause different of muscle strength such as clerical work is weaker than labor work.
- 8) Tools and equipment such as back rest helps pushing force, footrest helps gaining pulling force.

2.8 Static activities of muscle

Static activity, these are activities where muscle effort is expended in a static posture. In this category human effort is a function of force and time (not displacement). There are two terms used to describe effort in static activities; static effort and isometric effort.

Static effort, sometimes referred to as static work, even though it is not work in the classic sense. Static effort creates muscular contraction, which in turn creates

physical pressure within muscle tissue. Prolonged and constant pressures restrict blood circulation to the muscle which leads to minimal oxygen supply to the muscles. These conditions should be avoided for muscular injury. Examples of static loading include prolonged fixed sitting postures, lifting and holding or carrying for long distances. Muscular effort expended in static activities could be at a sub maximal level, as in the case of holding a light weight, or could be maximal, as in the condition of maximum voluntary contraction (MVC) in static postures.

Isometric effort this term is sometimes referred to as isometric work and refers only to the internal effort within the muscle. The term isometric implies that muscle length remains constant during tension without regard to the amount of tension. Since no visible motion occurs during isometric effort, the term isometric sometimes is used interchangeably with the term static. It is preferred to use the term isometric effort describing muscle action and the term static effort describing task related activities.

To determine which kind of job or position called “Static activity”. They can be considered by these criteria as follows:

- 1) Work that needs large amount of effort at least 10 second constantly.
- 2) Work that needs moderate amount of effort at least 1 minute.
- 3) Work that needs small amount of effort (1/3 of maximal effort) at least 4 minute. (Grandjean,1988) (12)

Considering those criteria, we can find the static pattern of work in industrial works such as working in leaning position or lateral bending position, prolong work in standing position, pushing or pulling heavy objects. As we can see that those in postures the muscles need to contract for a long time, anyway we cannot see the muscular workload towards the body but has to bear the body weight, head, limbs and places in unusual positions.

Grandjean, 1989 (12) indicated that working with only moderate amount of effort can also cause muscular fatigue. Moreover if work for a long time repetitively that can cause permanent muscular pain and degeneration of musculoskeletal system. He concluded the bad effects of static patterns of work as follows: (Table 2-1)

Table 2-1 Shows the effects of static patterns of work which cause fatigue

Postures	Affected parts
Standing	Legs and feet, varicose vein
Sitting without back rest	Back muscles
Sitting on too height of chair	Knees, calves and feet
Trunk bends forward while sitting or standing position	Lumbar region, disc degeneration
Stretching arm forwardly of laterally and in overhead level	Shoulders and upper parts of arm
Head bends forward or backward	Neck, disc degeneration
Unusual tools grasping	Wrist, swelling of tendon

As we can see that the trunk bends forwardly while sitting or standing can cause muscular pain, lumbar fatigue and disc degeneration while static standing can affect legs, feet and can cause varicose vein. Stretching arm forwardly of laterally and in overhead level can cause shoulders and upper parts of arm fatigue.

2.9 Mechanism of muscular and tendon injuries due to fatigue. (7)

Anatomically, the muscle and tendon themselves will start their origins in bone and lay pass a joint or more. Muscle will be turned to be tendon to attach itself at the other end on another bone where we called “musculotendinous junction”. Muscle and tendon work together as a unit when the muscle contracts or relaxes the tendon will be the same which cause joint motion. Injuries directly to the muscle or the musculotendinous junction, the symptom will be the same. The injuries can be categorized into 2 ways.

2.9.1 Acute muscular Fatigue

The muscle or tendon have severely injured can cause exceed tension in the muscle or tendon. Too much tension effects on muscle or tendon sometime it partly tears or all is tearing. At the lesion site we can find the affected site such as strain, swelling or inflamed part can still work with pain at the affected site. If the muscle or tendon is partly torn, it’s obviously seen that it can work but loss of strength. Also we

can find completely tear the muscle injured against the tortuous force, that muscle is no longer as normal stage.

2.9.2 Chronic muscular fatigue

Injuries due to fatigue or overuse of muscle are the injuries of body structures, which are repetitively and continuously impact with small force. During continuous work, the tissue is damaged of the molecule force, and causes a small micron rupture. Meanwhile the tissue tries to heal itself. If the rate of rupture is faster than the rate of healing, the lesion will progress.

Muscles and tendons work as a shock absorber by contracting automatically and rhythmically (reflex). In weak or fatigue muscles due to overuse, the contraction cannot work rhythmically, muscles tearing or muscles strain can occur. Besides, the tendons which friction with the bone prominent for a long time can cause tendon sheath inflamed (tenosynovitis)

Muscles and tendon injuries can be caused by acute fatigue too. If the lesion at is the muscle itself or at the attaching junction between the tendon and the bone. It's called "myositis". If the injury is at the tendon, it's called "tendonitis" and we call "tenosynovitis" if the sheath is injured consequently. The sheath wraps around the tendon and help controlling the movement of the tendon. Overuse due to friction of tendon and its sheath can also cause inflammation. No residual blood remains in the chronic muscular fatigue but the effect of the chronic inflammation lead to calcification at the lesion site, especially at the insertion of the tendon. If the inflammation remains the sheath will be thicker, tendon swells, the fluid inside will be too much sticky therefore when we move there is a sound of movement inside which and affect the muscles and tendons.

2.10 Fatigue (12,13,14,15,16)

2.10.1 Definition of fatigue

Chompusakdi Pulket (1991) mentioned that the term "Fatigue" is the unusual state or feeling of discomfort. However the definition of fatigue is still controversial among scientists. Some scientists use the term "Monotony" and others use "Boredom". However, the definition of fatigue based on scientific principle means

the feeling and the changes occur and the changes are included the discomfort feeling or work efficiency decreased due to energy loss.

2.10.2 Factors which can cause fatigue

Factors influencing fatigue in industrial workers is varied such as:

1) Work conditions included work characters, work details, timing workplace, responsibilities, work security and benefits.

2) Workers condition is the most important factor causing fatigue if the worker is unhealthy, he can be easily tired. Feelings of work desire and work interest whether worker is positively to learn and create work. On the other hand if the worker is desperate, it can also affect emotion and cause fatigue. Moreover, drug, alcohol, heavy smoking and gambling are also the basic problems that relate to fatigue.

3) Family and community condition: if the worker has many children, poor economic, malnutrition, insufficient of resting time, poor sanitation of accommodation, feeling of not belong to the society are also related to fatigue.

2.10.3 Type of fatigue

Fatigue can be divided into 2 types.

1) Muscular fatigue

Muscular fatigue is an acutely painful phenomenon, which arises in the overstressed muscles and is localized there.

Penpimol Dhanmarakkit (1985) has defined "muscular fatigue" in term of physiology that "the fatigue occurs after the muscle is stimulated continuously for long time. Prolonged contraction of muscles can cause fatigue and tiredness even though the threshold of stimulation is still the same. The force supplying substance (ATP, glucose) and waste residue such as carbon dioxide, pyruvic acid, phosphoric acid especially the lactic acid can not be taken away. Chemical reaction can be obstructed if the lactic acid still remains in the muscles and also can cause muscular pain after overuse.

In an experiment with an isolated muscle from a frog, the muscle is electrically stimulated, causing it to contract and perform physical work by lifting a weight. After several seconds it is found that:

- The height of lift decrease.
- Contraction and relaxation become slower.

- An interval between stimulation and beginning of contraction becomes longer.

Essentially the same result can be obtained in mammalian muscle and human muscle. This phenomenon reduced performance of muscle after stress is called “muscular fatigue”. Muscular fatigue’s characteristic is not only by reduced muscular power, but also by slower movement. It can affect to increase error and accidents while doing work.

2) General fatigue

General fatigue is a feeling of wholly body weariness and feeling like the whole body is inhibited or can not do any activity due to low motivation to attempt or accomplish that activity. General fatigue causes drowsiness. If there is a resting time when after feeling of fatigue, the body will better recover to the normal state. On the contrary people have insufficient resting time or relax; the result can affect the body and work. Therefore, the feeling of fatigue is a sign of incidents that the body should stop doing activity and needs to take a rest for recovering.

2.10.4 Symptoms of fatigue

Fatigue symptoms are both subjective and objective, the most important are:

- 1) Subjective feeling of weariness, faintness and distance for work.
- 2) Sluggish thinking.
- 3) Reduced alertness.
- 4) Poor and slow perception.
- 5) Unwillingness to work.
- 6) Decline in both bodily and mental performance.

Some of these symptoms result in a measurable drop in bodily and mental efficiency.

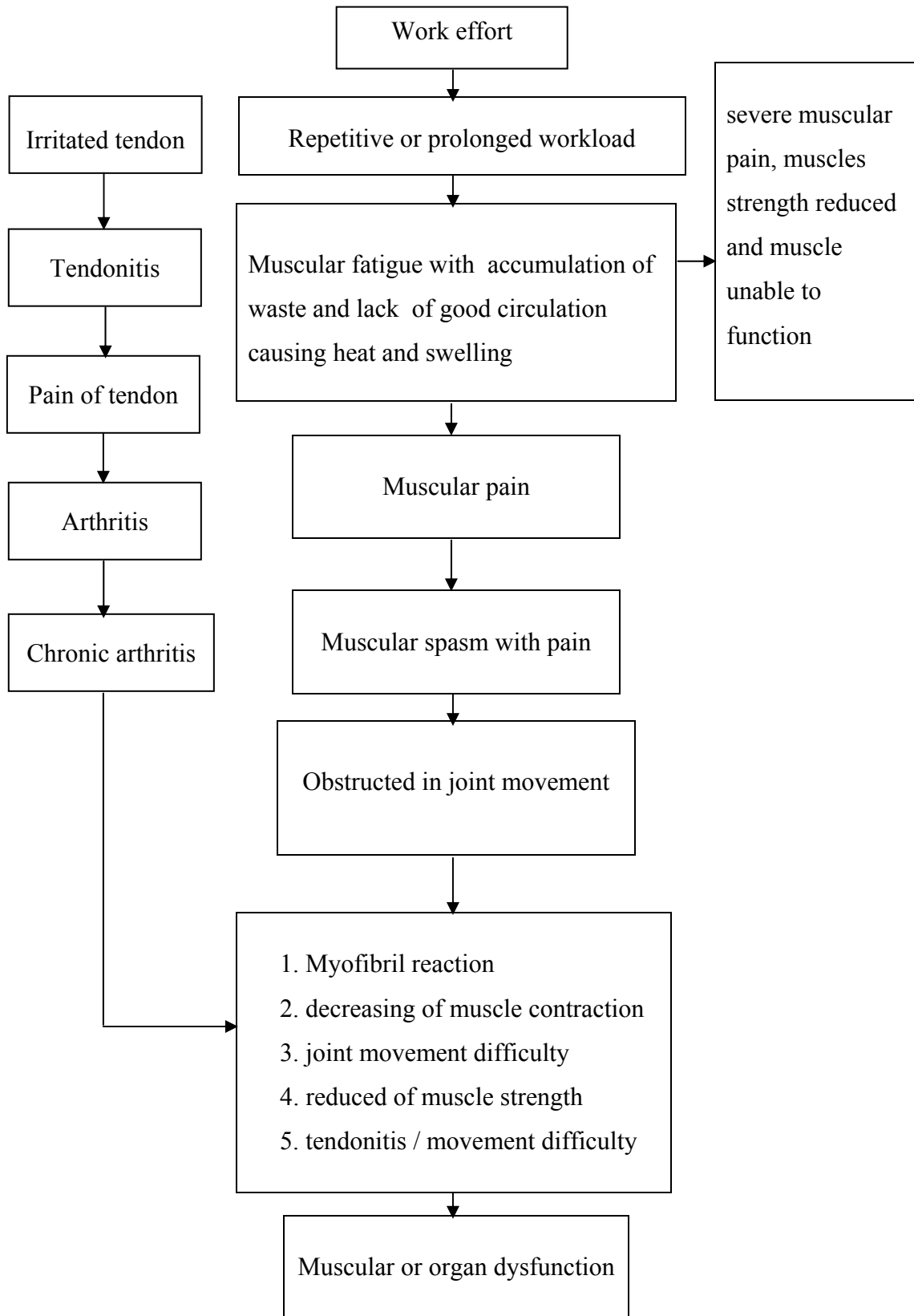


Figure 2-10 Sequences of severity of muscular pain to dysfunction. (16)

Table 2-2 Demonstrates the angle rang of motion, which causes fatigue (16)

Joints	Positions that cause fatigue
Ankle	Full range of ankle dorsi flexion. Full range of ankle plantar flexion.
Knee	Flexion ROM less than 90 degrees. Knee extension, no movement.
Hip (sitting position)	Hip flexion ROM more than 110 degrees or less than 80 degrees.
Back	Flexion or lateral bending > 20 degrees.
Neck	Neck rotation lateral bending or hyperextension > 20 degrees.
Shoulder	Elevate shoulder/lateral flexion > 45 degrees humeral rotates backwardly.
Elbow	Flexion less than 80 degrees extension > 120 degrees.
Forearm	Phonation / supination.
Wrist	Wrist deviation > 45 degrees. Wrist flexion > 30 degrees, extension < degrees.
Finger	Finger abduction > 1 inch.

Table 2-3 Shows stable postures at work which cause fatigue (17)

Stable posture in	Part of fatigue
Standing position	Feet, legs and varicose vein in legs
Upright sitting without back rest	Errector spinae
Sitting on too high chair	Knee, calves and feet
Sitting on too low chair	Trapezius, Rhomboideus, Levator scapulae
Sitting-standing/trunk leans forward	Lower back, degeneration of disc at lumbar region : erector spinae
Arm reaching out forward/backward and downward	Shoulder, upper arm
Head flexion/extension	Neck, disc degeneration
Grasping objects with bad patterns or bad positions	Upper arm, tendinitis

2.11 Method of measurement fatigue (12)

Currently used methods fall into six groups:

- 1) Quality and quantity of work performed.
- 2) Recording of subjective impressions of fatigue.
- 3) Electromyography (EMG).
- 4) Measuring subjective frequency of flicker-fusion of eyes.
- 5) Psychometer tests.
- 6) Mental tests.

More recently it is the practice to study a combination of several indicators so as to make interpretation of the results more reliable. It is particularly important that subjective feeling of fatigue should also be taken into account. A measurement of physical factors needs to be backed up by subjective feeling before it can be correctly assessed as indicating a state of fatigue.

2.11.1 Tools for evaluate fatigue (12,18)

The principles of reflex mechanism can taken and adapt to the questionnaire to any way such as tapping tester for hand and fingers fatigue. Knee reflex threshold tester for knee jerk reflex and two touching points discrimination threshold tester for the coordination of sensation stimuli and central nervous system. Color calling tables for brain fatigue and Flicker calling table for physical and mental fatigue is also included.

There are 2 modern ways to evaluate fatigue

1. Measuring of pain level in muscles, measure from each side and computed mean tenderness threshold. The measurement might be taken at any time of day such as before work, before lunch, after lunch and after work by pressure to muscles until the subjects can feel the pain.

2. Measuring by surface electromyograms is the method that examine the muscle power from body parts which take role in work action together with examine the cardiovascular efficiency by electrocardiogram. However, this method is not so common in filed of industrial hygiene due to the equipment and technique are too much complicated for field study. In industrial work the questionnaire and Flicker Test are used. Measuring by quality of work and quantity of work are not applicable for this

study because it depends on too many factors such as target of work, social factors and attitude towards work.

2.11.2 The feeling of fatigue by questionnaire

Two types of questionnaire were used in this study. One would be used in the first place to explore general condition of fatigue feeling in population. The other was modified from Gradjean (1998) (12), Corlett and Bisshop (1993) (17). This questionnaire for general bodily fatigue has seven states in a straight line, 0-7 score, 0 means not fatigue until seven means extremely fatigue, the subject was asked to currently fatigue at all of body. The questionnaire for muscular fatigue was divided approximately according across the body. A subject was asked to point to the body area which are currently giving the greatest fatigue which may involve more than one of the areas, then asked about level of fatigue in seven state, 0-7 score, 0 means not fatigue, 1-2 means slightly fatigue, 3-4 means moderate fatigue, 5-6 means very fatigue, 7 means extremely fatigue.

2.11.3 Electromyography (EMG) in ergonomics (19,20,21,22,23,24)

Electromyography has been used as a tool in this research in order to measure that activity of muscles during any movement of humans or animals.

Ergonomic uses EMG as indicators of stress and fatigue in muscles.

There are three components of electrode that are necessary for EMG and NCV testing.

- 1) A ground electrode for reducing extraneous noise and interference,
- 2) A pick-up or recording electrode (the negative electrode),
- 3) A reference electrode (the positive electrode).

The assignment of the designation of negative, positive and reference electrodes is a convention used in practice and does not imply the possession of a charge by the electrodes. There are a number of different types of electrode systems in which the three above components may be used (Figure 2-11)

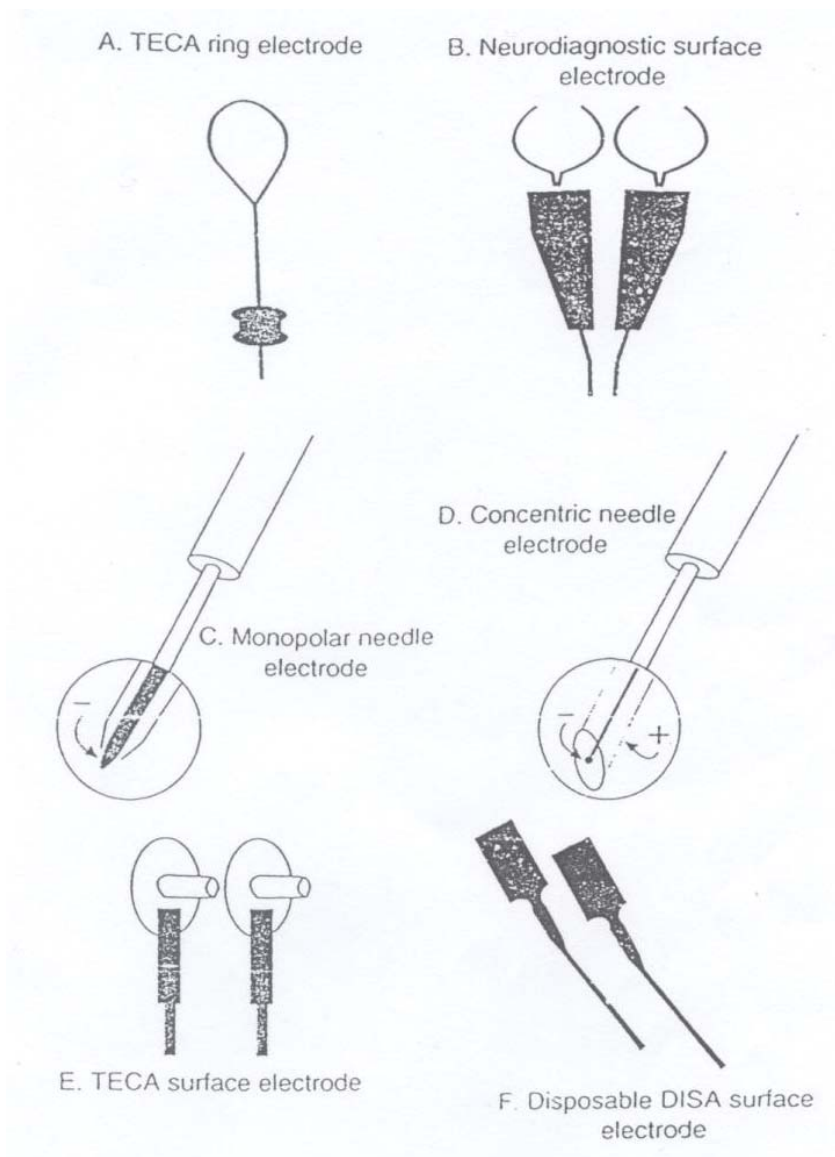


Figure 2-11 Examples of typical electrodes used in electromyography and nerve conduction studies

Surface electrodes are composed of two metal discs with attached lead off wires. One disc is the recording electrode, the other the reference electrode. These discs may be embedded in a plastic block to allow for flexible placement. Surface electrodes permit recording of the electrical activity of muscle but are not capable of recording single motor unit or the short duration potentials caused by spontaneous activity in muscle. Surface electrodes are routinely used for nerve conduction studies since the

record the summated compound potential of many motor units instead of individual ones and compound sensory potentials.

Coaxial (concentric) needle electrodes allow recording directly from within the muscle. They consist of a platinum wire located centrally inside a hypodermic needle but completely insulated from it. The bored top of the internal component acts as the recording electrode while the outside of the needle acts as the reference electrode. Both the internal wire and outside cannula are connected to the preamplifier input terminals. The type of electrode is used routinely for electromyography (EMG) studies as it is able to adequately record individual motor units as low amplitude short duration potentials arising within muscle tissue.

A separate ground electrode usually consists of a large disc electrode affixed to the skin. Triaxial (bipolar) electrodes are similar to concentric electrodes except that two platinum wires are embedded in the hypodermic needle necessitating a larger diameter needle and are, therefore, more painful upon insertion through the skin than other electrodes. Each wire inside is connected to the preamplifier input and the cannula becomes the ground; therefore, no separate surface ground electrode is necessary.

Monopolar electrodes are usually constructed from a stainless steel wire or needle sharpened to a pointed tip and insulated with Teflon except for the very tip. Monopolar electrodes are thinner than other needle electrodes and the Teflon coating reduces resistance to movement through tissues making it less painful during insertion through the skin than the other types of needle electrodes. It is necessary to use another needle or a surface electrode as a reference electrode.

2.11.3.1 Quantitative EMG

In this study the averaged EMG is used for quantification. The averaged mean EMG signal is formed by rectifying (taking the absolute value) and by taking the mean average of the raw EMG signal registered using alternative time windows. Averaging time selected for one second. Then the amplitude of the signal is normalized to the EMG record of the maximum voluntary contraction (MVC) of deltoideus and erector spinae muscle. The amplitude of this MVC record is then declared to be 100 percent of back extensor's maximum contractile activity. The EMG of the muscle in the activity is then expressed as a percentage of MVC.

2.11.3.2 EMG measurement

In this study EMG measuring used the ME 300 System. EMG measurement is performed by attaching electrodes to the surface of the skin and recording the electrical activity taking place in the muscles underneath them. The accurate recording of muscular electricity requires proper positioning of the electrodes when each individual muscle is being measured. It is essential to have a very good understanding of the anatomy of the human body as electrode location and placement. First of all, must be sure to clean the skin in order to reduce any skin resistance. Positioning of electrode should use body landmarks as a reference, and inter electrode distance should be constant.

2.12 Functions of muscles and electromyography (22, 24)

Muscles can contract and produce force. In a living organism, movements are performed by means of muscular activation. Through coordinated movement of its body parts the organism can change its position in space and exert mechanical forces on its environment. In addition to locomotion, activation of muscles is also required for transport processes within the body such as the convection of fluids in the cardiovascular and gastrointestinal systems or the transportation of gases in the respiratory system.

Muscle contraction and force production are due to a change in the relative positions of various thread-like molecules or filaments arranged in the interior of the muscle. This sliding of the filaments is triggered by an electrical phenomenon known as action potential. As explained in greater detail in the following. An action potential results from a change in the membrane potential which exists between the interior of a muscle cell and the external space. The recording of the pattern of muscle action potentials is called electromyography and the record itself is called an electromyography (EMG). Electromyography therefore records an electrical phenomenon which is causally related to muscle contraction. On account of the close functional relationship between the electrical action potential and the electromyogram, on the one hand and the mechanical muscle contraction, on the other, the EMG represents an adequate parameter for the analysis of muscle activities. Statements about the time course of a muscle contraction, the contraction force and the

coordination of the activities of several muscles derived from the amplitude and the frequency spectrum of the EMG as well as from the changes in these values overtime.

2.12.1 Recording the electromyograms

The principle of EMG derivation using surface electrodes is shown in Figure 2-12 that for purposes of simplification and clarification, the muscle is only represented by one muscle fiber. In the region of the front of excitation a current flows between the unexcited and the excited area of the muscle fiber. Arrows in Figure 2-12 indicate the current.

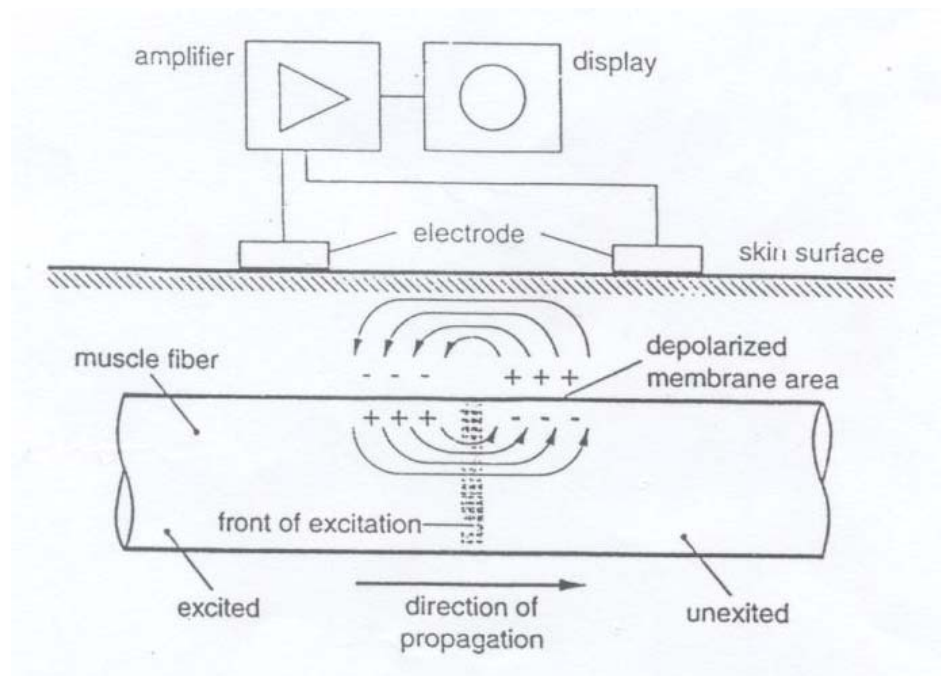


Figure 2-12 Principle of extra cellular action potential recording using surface electrodes.

The current induces local potential differences, which can be measured using two electrodes, within the extra cellular space. The potential differences are causally related to the action potential of the muscle fiber. They can therefore be regarded as an image of the muscular excitation. Either invasive electrode inserted into the extra cellular space or-as show in Figure 2-12 surface electrodes applied to the surface of the skin can be employed in the measurement of the potential difference.

2.12.2 Electrode attachment on the muscle (20,25)

EMG measurement is performed by attaching electrodes to the surface of the skin and recording the electrical activity taking place in the muscles underneath them. Accurate recording of muscular electricity requires proper positioning of the electrodes when each individual muscle is being measured. It is essential to know the main functions of the muscles to be measured and where they are located in the anatomy. The electrodes are fixed in a bipolar way (with both active electrodes measuring and reference above the muscle). The ground electrode is fastened to the snap connector of each measuring cable located below the amplifier. To ensure repeatable results, always attach the electrodes in the same places above the muscle.

The electrodes used are intended for long-term measurements and are equipped with snap connector. As shown in Figure 2-13 and Figure 2-14.

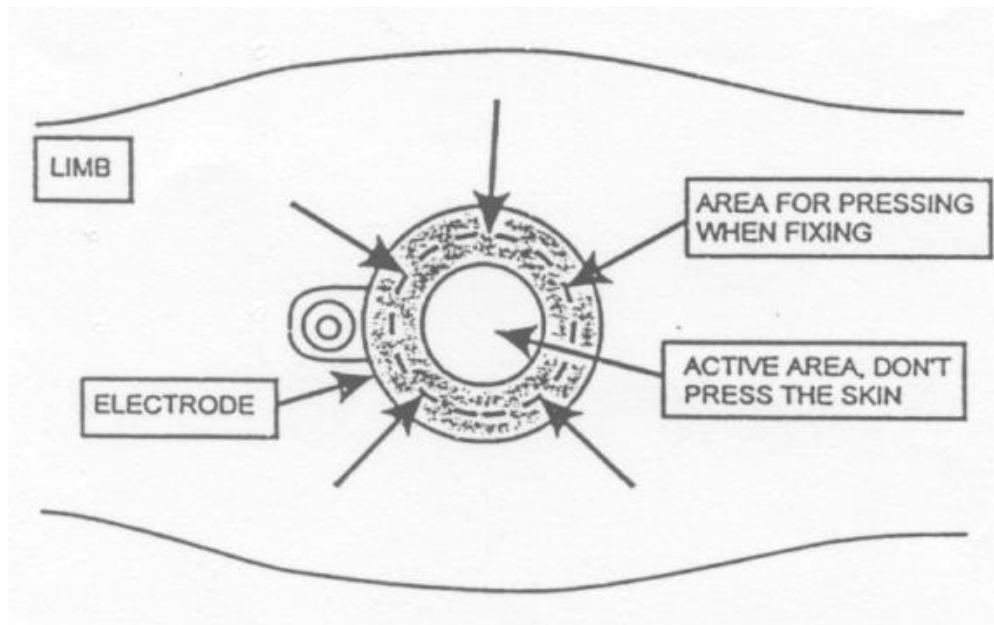


Figure 2-13 Attaching an electrode to the surface of the skin above a muscle.

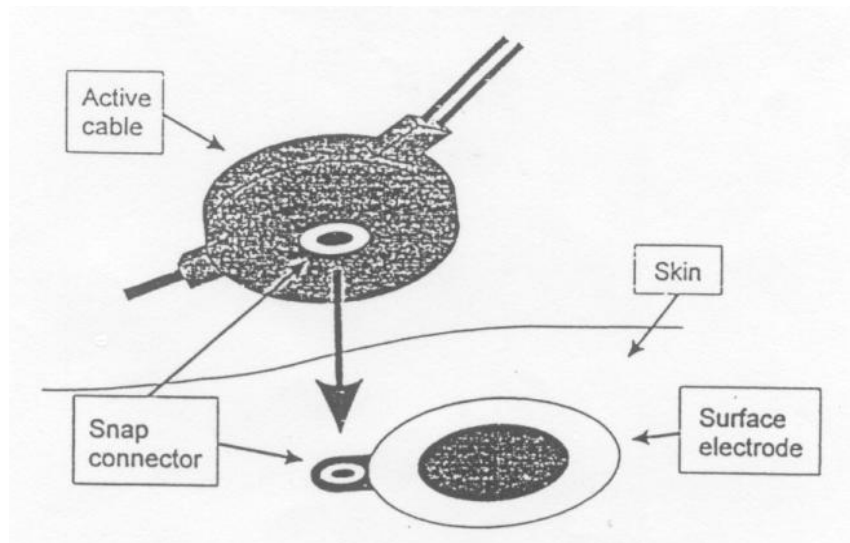


Figure 2-14 Plugging the snap connector onto the electrode.

2.12.3 The locations of electrode

Position of electrodes in the anterior part of deltoideus muscle from Feng et. al. 1999 (26) recommended. They have studied the effects of arm suspension used in assembling work simulation toward muscle function. It has been found that anterior part of deltoid muscular activity is decreased significantly. And also there are tendencies of decreasing of the lateral part of deltoid and upper part of trapezius muscular activity. (See Figure 2-15). And in the erector spinae of back muscle from Van Dieen J.H. et. al. (1993) (27) recommended. They have studied the best positioning of electrodes on erector spinae muscle used by EMG spectral analysis was L5 (See Figure 2-16), as table following:

Table 2-4 Electrode placements on muscle

Muscle	Posture	Leadline	Central lead point
M.Deltoideus	Standing	Head of the acromion	1/3 lead line length from the head of acromion.
M.Erector spinae	Standing erect	Parallel line to the spinal column on the crest of the erector muscle	1/6 of the distance from the iliac crest to the spine of the 7 th cervical vertebrae above the iliac crest.

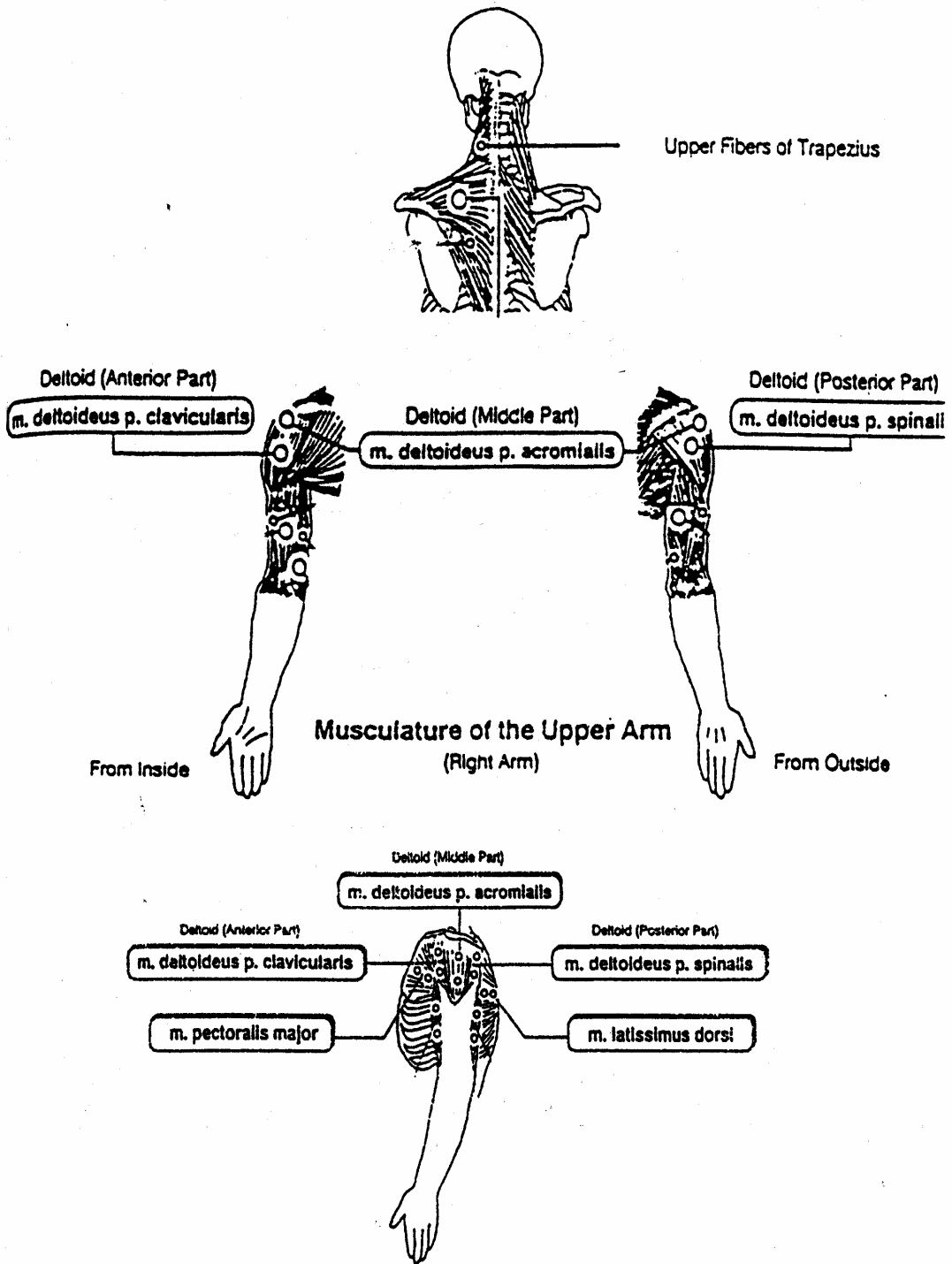


Figure 2-15 Positioning of electrodes on trapezius muscle and deltoid muscle. (26)

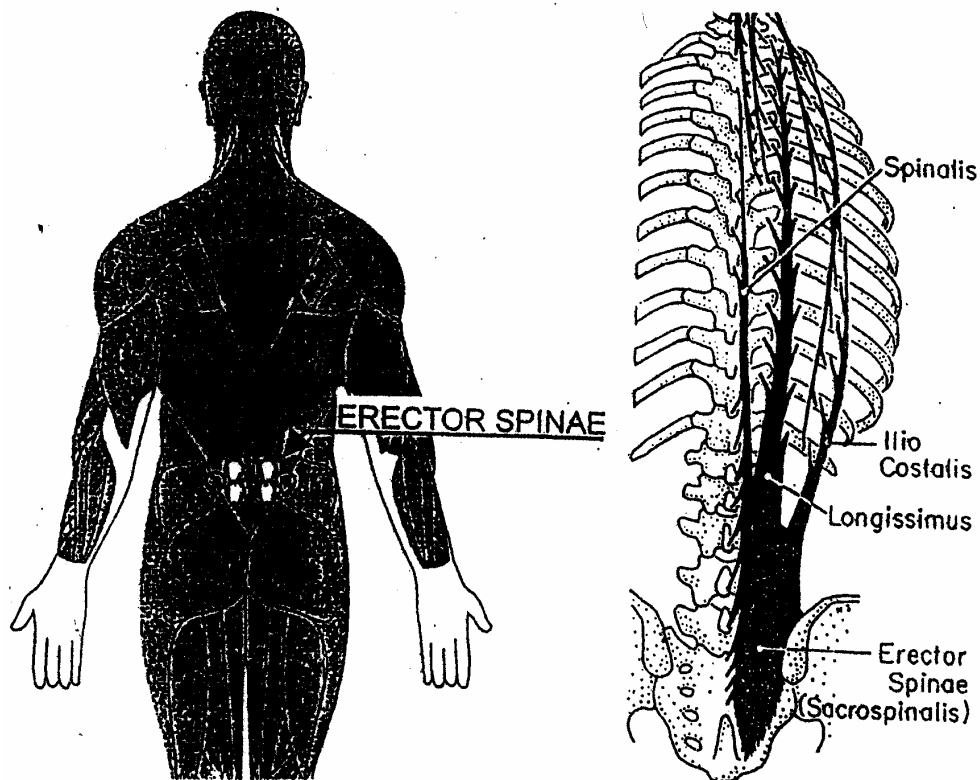


Figure 2-16 Positioning of electrodes on erector spinae muscle. (27)

2.13 Anthropometry (12, 28, 29, 30, 31)

Working requires three components to form a system generally known as “Man-Machine-Environment System”. How the efficiency and quality of the total system would be, depends on the relative coordination between these three components in the system. The people responsible for design of work should try to study the interaction between the workers and the equipment, and to provide an environment that will readily facilitate people work to the greatest degree. This is because of the fact that changing the physical conditions of workers is not easy. And sometimes cannot be achieved at all. So characteristics of the worker are an important component of the system we are considering.

Anthropometrical dimension will be one important criteria in designing and constructing such as machines, tools, equipments and workstation etc. Criteria of anthropometrics data are correctly and standard technique, studied population must be representing the people who used or working related tool and equipment. Anthropometry research and study such as:

Hertzberg (1968) (32) developed a technique of anthropometrical data measurement by considering various landmark positions of the body as initial and final points.

Kroemer (1970) (31) points out that precision and efficiency in obtaining anthropometrical data were very important in the measurement.

Van Cott and with Kinkade (1972) (33) showed that body dimensions of different populations vary by genetics, nationality and geographical and meteorological environment.

Roebuck et. al. (1975) (34) suggested that rigid instruments should be used correctly, and care should be exercised concerning measurement position by training the operators so that they could use measuring instruments correctly and skillfully under controlled conditions. It could be seen that the anthropometrical techniques, the instruments used, landmark defined and variations at the same position. They presented two acceptable anthropometrical techniques, as follows:

1. The direct method used measuring instruments such as an anthropometry and a measuring tape. The instruments actually attach the body of the subject at the positions of measurement.

2. The indirect method used photography to record details, which in turn could provide measurements and interoperation of data.

Kovit Satavuthi (1979) (35) presented data of workers in Bangkok and nearby provinces by conducting the measurements of 1,265 males and 858 females workers, and calculating the mean and standard deviation.

Kitti Intaranont (1988) (30) presented data of people in Northeast of Thailand. This study collected the data from the sample of 250 males and 250 females, aged between 17 and 25. The study showed that stature and weight vary with age. In male, weight increases until the ages of 33-40 years then decreases. For females, weight increases until the age of 41-48 years then decreases. Female stature mean are 151.20

centimeters and weight mean are 53.06 kilograms. Male stature mean are 163.04 centimeters and weight mean are 59.30 kilograms.

The office for Industrial Product Standards (2001) (36) presented anthropometrical data of Thai by conducting measurements of 2,233 boys (aged between 1 and 16), 2,288 girls (aged between 1 and 16), 4,301 males (aged between 17 and 49) and 4,525 females (aged between 17 and 49) from many regions of Thailand. The result showed the average, standard deviation maximum and minimum of each measurement for different age groups. These data were intended for use in the clothing industry and other industrial products.

2.14 Hanging materials on overhead conveyor

The hanging work on overhead conveyor is the repetitive tasks. The workers must to reach with the arm forward above shoulder, twist body and bent to bring materials in carrier. This posture effect to muscular fatigue of workers that causes the workers absent from work many times (See Figure 2-17, 2-18, 2-19).



Figure 2-17 The worker brings materials from the carrier.



Figure 2-18 The worker brings material to hang them on overhead conveyor.



Figure 2-19 Hanging materials on overhead conveyor.

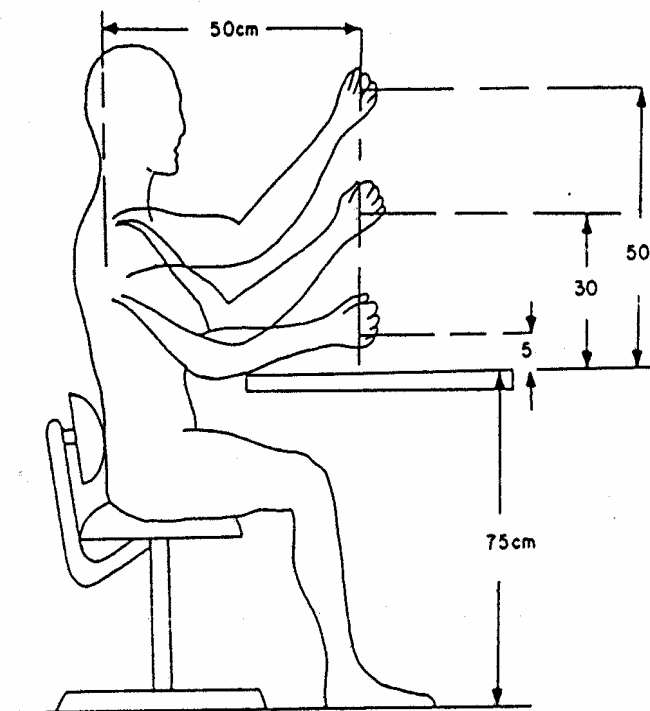
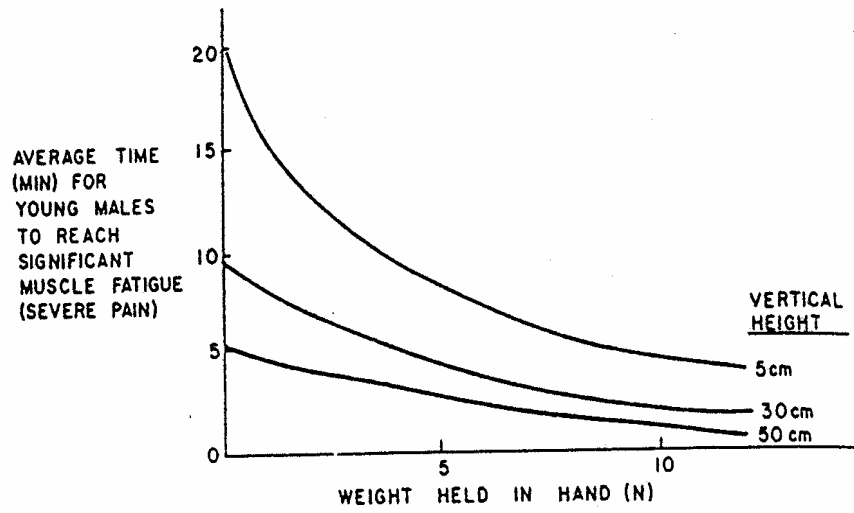
2.15 The Design of workstation (29)

In the application of anthropometric data to specific musculoskeletal disorder because of the variations in the circumstances in question and in the types of individuals for whom the facilities would be designed. Using anthropometric data in design involves art and science. As a general approach, however, Mc. Cormick and Sanders, 1993 are offered the suggestions as following:

1. Determine the body dimensions important in the design (e.g., sitting height as a basic factor in seat-to-roof dimensions in automobiles).
2. Define the population to use equipment or facilities (e.g., male, female, different age groups, world populations, and different races). This establishes the dimensional range that needs to be considered
3. Determine what principle should be applied (e.g., design for extreme individuals, for an adjustable range, or for the average).
4. When relevant, select the percentage of the population to be accommodated (for example, 90 percent, 95 percent) or whatever is relevant to the problem.
5. Locate anthropometric tables appropriate for the population and extract relevant values.
6. Build a full-scale mock-up of the equipment or facility being design and, using the mock-up, have people representative of large and small users walk through representative tasks. All the anthropometric data in the world cannot substitute for a full-scale mock-up.

2.16 Review of research study

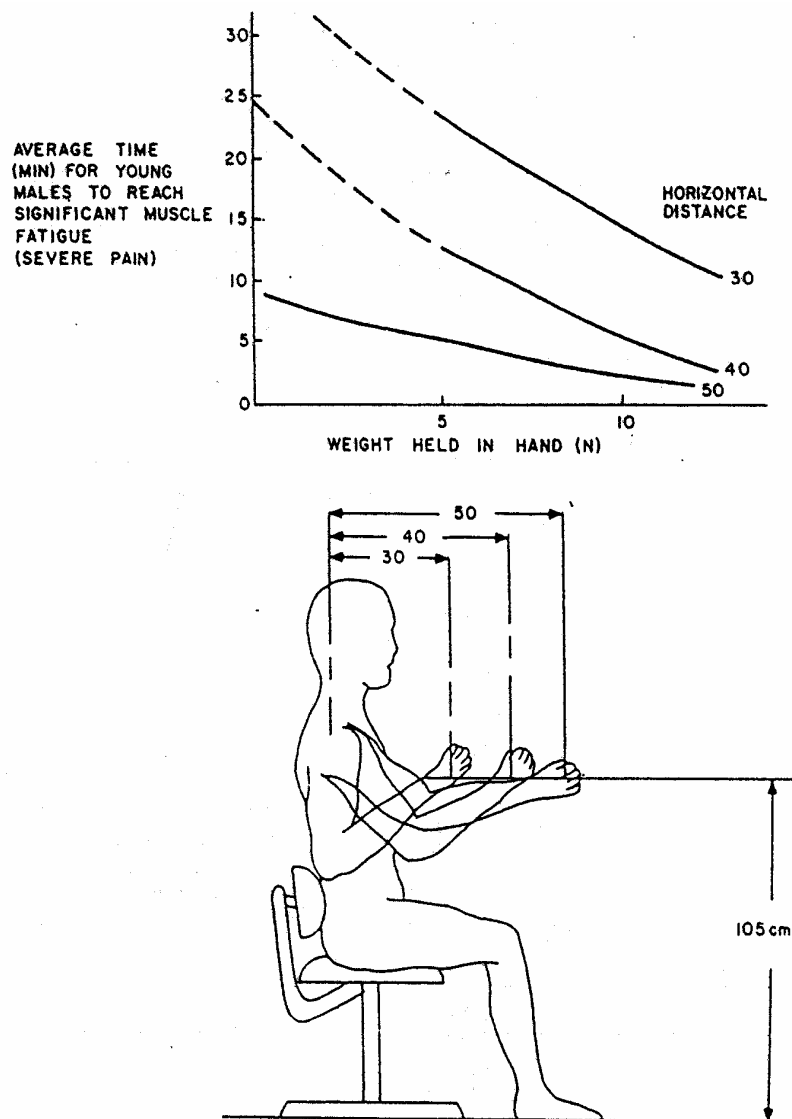
Chaffin, 1973 (37) studied the effect of carrying objects in varied height by measuring muscular fatigue by EMG study in healthy men. The study concluded that the relations of the period of muscular fatigue would be increased while elevating the arms in high level and loading objects by hands. See Figure 2-20.



Expected time to reach significant shoulder muscle fatigue for varied arm flexion postures. The larger the flexion angle, the earlier fatigue will develop (Chaffin, 1973).

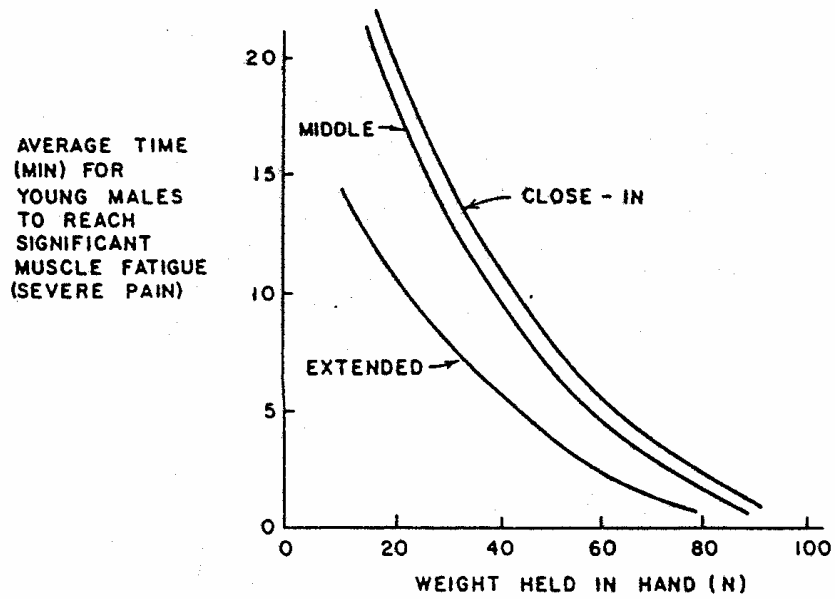
Figure 2-20 Expected time to reach significant shoulder muscle fatigue for various arm flexion postures.

Chaffin, 1973 (37) studied the effect of loading object by reaching the arm in different forward position and the fatigue of shoulder muscle and found out as showing in Figure 2-21. The distance of reaching arm in the further position and loading too much weight object will cause the fatigue in shoulder. He also studied the same way but adding elbow support (See Figure 2-22). He found out that the elbow support can help reducing muscular fatigue in shoulder and elbow.



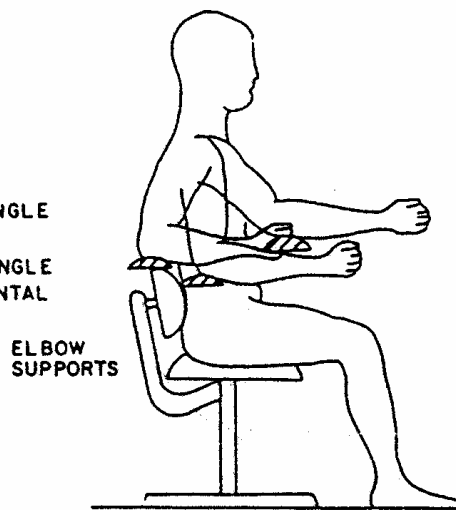
Expected time to reach significant shoulder muscle fatigue for different forward arm reach postures. The elbow is unsupported. The greater the reach, the shorter the endurance time (Chaffin, 1973).

Figure 2-21 The relations between the period of time that the shoulder muscular are fatigue caused by reaching in several front distance.



ARM POSITIONS STUDIED

CLOSE - IN = 55° ELBOW ANGLE
 MIDDLE = 90° ELBOW ANGLE
 EXTENDED = 140° ELBOW ANGLE
 FOREARM IS HELD HORIZONTAL



Expected time to reach significant shoulder and arm muscle fatigue for different arm postures and hand loads with the elbow supported. The greater the reach, the shorter the endurance time (Chaffin, 1973).

Figure 2-22 The period of time of muscular fatigue caused by angled of elbow.

Chaffin, 1973 (37) studied the angle of shoulder; 30°, 60°, 90° and 120° (See Figure 2-23). The studied showed the average time of shoulder muscular fatigue were 68, 25, 10, and 7 minutes. The summary of this study were the shoulder extend in the large angle that caused muscular fatigue in a short time.

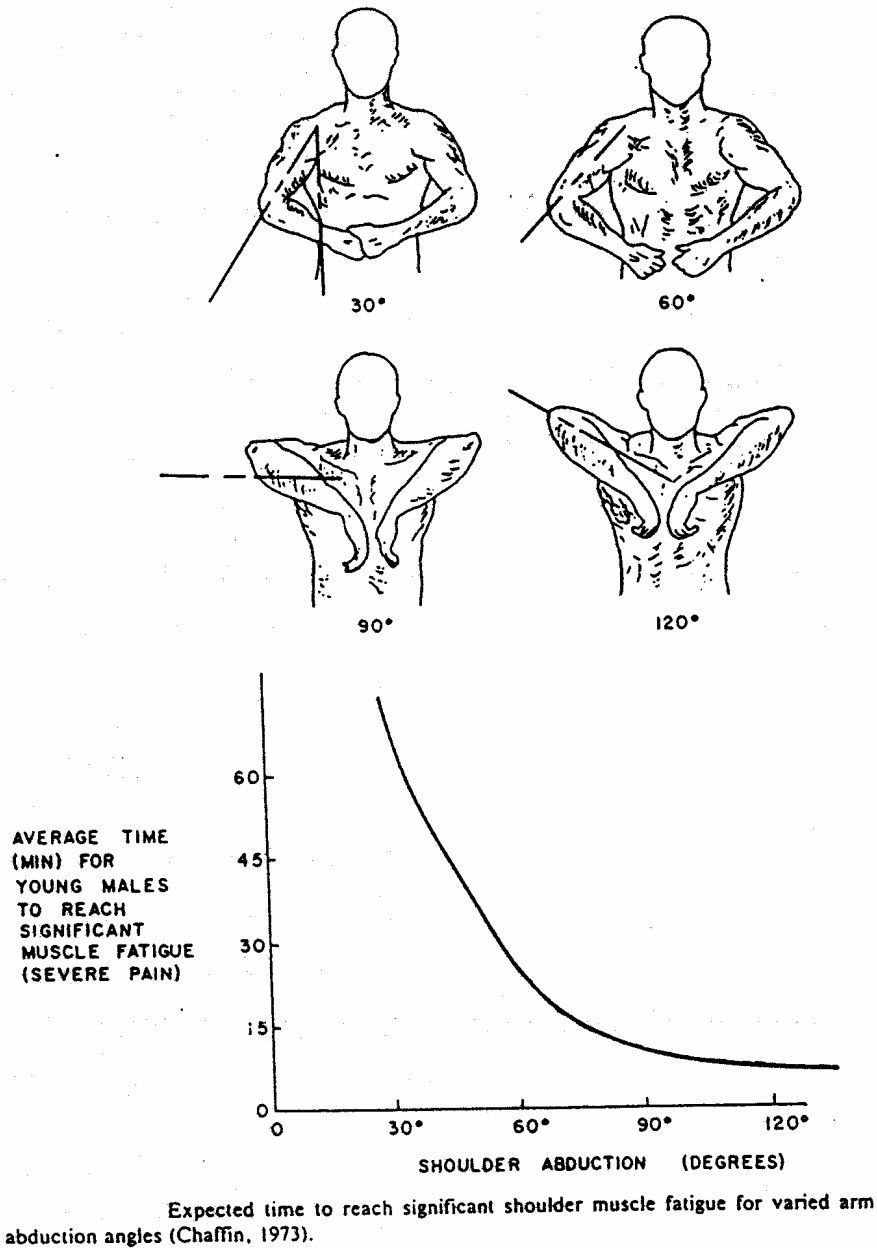


Figure 2-23 The period of time of shoulder muscular fatigue caused by varies arm abduction angles.

Punnett et al., 1985 (38) studied the comparison of shoulder pain in dress making work and hospital work. He found that finishing work was a part of dress making work needed sewing by hands such as trimming, cutting, furnishing and decorating used all joints moved repetitively. In the previous time, workers had shoulder pain 4 times more than those who worked in hospital. Sewing machine operators who moved their wrists repetitively but moving less frequently than dress making workers would have pain at shoulder 2 times more than in those who worked in hospital. It can be concluded that more frequency of moving arm repetitively can lead to shoulder pain.

Merkle L.A. and associated (1988) (39) investigated using factor analysis to identify neuromuscular synergies during treadmill walking. Ten male subjects walked on a treadmill (6.4 km/h) for 20 second during which surface electromyography (EMG) activity was obtained from the left side sternocleidomastoid, neck extensors, erector gastrocnemius. The results showed that factor analysis can be effectively used to explore relationships among muscle patterns across all body segments to increase understanding of the complex coordination necessary for smooth and efficient locomotion.

Westgard RH. and Jansen T, 1992 (40) had studied 210 sewing machine operators about muscular pain and fatigue included 35 clerical workers. It revealed that 205 sewing machine operators or 95% of them had experience of fatigue and discomfort due to work. Meanwhile, 46% of clerical workers had been found that they had the same experience. There is 71% of sewing machine operators had pain at neck and shoulder while only 41% of clerical workers suffered from neck and shoulder pain. It also had been found that there was no significant different of pain in lower back and forearm between these 2 groups. The older group gets more joint and knee pain than the young ones.

Kitti Intaranont (1992) (30) designed and constructed a workstation composed of a chair and table adjusted by a pneumatic system. Using five items, i.e., chair height, seat inclination, backrest inclination, table height and table inclination designed the experiment. The job was reading. Three factors were varied, i.e., chair height, table height and table inclination. Comfort rating scale from 0-4 was employed for eighteen

tested posture. It was found that higher seat height caused high discomfort score in the area of neck, shoulder, back, waist, buttock and thigh. But the score is low in the area of feet. Table inclination increase from 0-15 degree, reduce the discomfort score, but it was rising when table inclination reached 25 degree. It was conclude that the change of table inclination gave higher effects than the changes of chair's height and table's height.

Sommerich et.al., 1993 (41) have gathered the reports concerning the relations of work and work related injuries at shoulder muscle. They have found that working with abnormal postures, static postures, heavy work, repetitive movement, working at shoulder level and insufficient of resting can be assumed as risk factor, which related to shoulder pain.

Joseph Knapik, Everett Harman and Katy Reynolds (1996) (42) investigated the load carriage using packs: A review of physiological, biomechanical and medical aspects. Locating the load mass as close as possible to the body center of gravity appears to result in the lowest energy cost when carrying a pack. Predictive equations have been developed for estimating the energy cost of carrying loads during locomotion but these may not be accurate for prolonged (>2h) or downhill carriage. Training with loads can result in greater energy efficiency since walking with backpack loads over several weeks decreases energy cost. Load-carriage speed can be increased with physical training that involves regular running and resistance training. Erector spinae muscular activity (EMG) is lower during load carriage than in unloaded walking until loads exceed 30-40 kg, at which point erector spinae EMG activity is higher than during unloaded walking. EMG of the quadriceps and gastrocnemius, except the tibialis anterior hamstrings, increases with load.

Shihan Bao, Svend Erik Mathiassen and Jorgen Winkel (1996) (43) studied the ergonomics effects of a management based rationalization in assembly work-a case study. The results indicate that the intervention led to only minor changes in muscle load, body postures and movement patterns. Several of the planned initiatives were never implemented, e.g. teaching the workers multiple skills and designing workstations at which a major part of the assembly sequence could be performed. This

was company's original intention; the revised production system contained only minor ergonomic improvements. Thus, the rationalization of the ergonomic potential in a rationalization seems to depend on management culture, as well as factors outside the company.

Roland Kadefors and associated (1996) (44) studied the ergonomics in parallelized car assembly: a case study, with reference also to productivity aspects. The results of the analysis showed that it was necessary to develop the workstations to get better ergonomics conditions. The design and arrangement of the car body affected the ergonomics situation of the operation in the assembly work. In this case, the design of the car body could not be changed, so the improved ergonomics had to be achieved by adjustments to the placing of the car body. An analysis of the effects of different placing of the car body showed a great impact on the ergonomics of the operator. It was found to be possible to improve the ergonomics using a device to rise, lower and tilt the car body to positions suitable for the assembly work. Experiments were carried out, apart from the production with a prototype of such a tilting device. The same assembly sequence, where the car was built in four steps, was used. The ergonomics was evaluated with the FasAn method. Care was taken to adjust the position of the car, raise, lower and tilt it, to suit the operators. The results showed that the standing straight upright posture now occurred for more than 80% of the total assembly time. Further development of the workstations concentrated on finding suitable tilting devices and to find the most suitable assembling sequence for the components. Ergonomics analyses of postural and musculoskeletal strain showed that parallelized flow production, according to the production principles of the plant, was superior to traditional car assembly according to the serial flow production concept, i.e., the traditional assembly line. It was noted that this ergonomic standard was implemented without compromising productivity.

Resnick M.L. and A. Zanotti (1997) (45) studied about using ergonomics to target productivity improvements. Ergonomics has traditionally been used to decrease the number of occupational injuries by discovering those postures and tasks that create significant musculoskeletal stresses. In this study, fifteen subjects performed a typical industrial task in a variety of layouts designed within an ergonomically acceptable

work envelop. The effects of tool mass, work height and movement distance on performance time were measured. All three variables had significant effects on variables had significant effects on performance time, even within the ergonomics work envelop. The results indicated that workstations could be designed to maximize performance and reduce costs by considering both ergonomics and productivity together.

Feng et, al., 1999 (26) has studied the effects of arm suspension application in simulated assembly work found that arm suspension can reduce muscular activity in deltoideus anterior part significantly and has a tendency of reducing muscular activity in lateral part of deltoideus and trapezius muscle also.

Kazutaka Kogi and associated (2003) (46) studied the low-cost work improvement that can reduce the risk of musculoskeletal disorder. Over 2,000 improvements results from participatory activities in small groups, and many of them were found to relate to actual reduction of musculoskeletal loads. Typically, these improvements, mostly implemented at low cost during the course period of about two weeks, concerned the use of pushcarts or lifting devices, better worksite layout, worktables and chairs of appropriate height, fixing hand tools, better lighting, job rotation and inserting breaks. The effects of such improvements on reducing workloads were investigated by case study measurements applying electromyography, heart rate recording and posture study methods. Reduced muscular activities were found after work changes associated with improved materials transport, avoiding deep bending postures, fixing hand tools or better work organization. Productivity increase was also confirmed in some cases. There were thus a variety of work improvements undertaken by managers and workers of small enterprise through voluntary training steps, often with combined effects on reducing musculoskeletal loads and improving other aspects of working conditions. This flexibility in work re-design seemed necessary in promoting multiple changes linked with a reduced musculoskeletal risk. Such examples collected from WISE training courses proved useful for various training programs and advisory inspections. These results demonstrated the importance of undertaking multiple work improvements on voluntary basis in reducing the risk of musculoskeletal disorders in a large number of small enterprises.

CHAPTER III

MATERIALS AND METHODS

3.1 Study design :

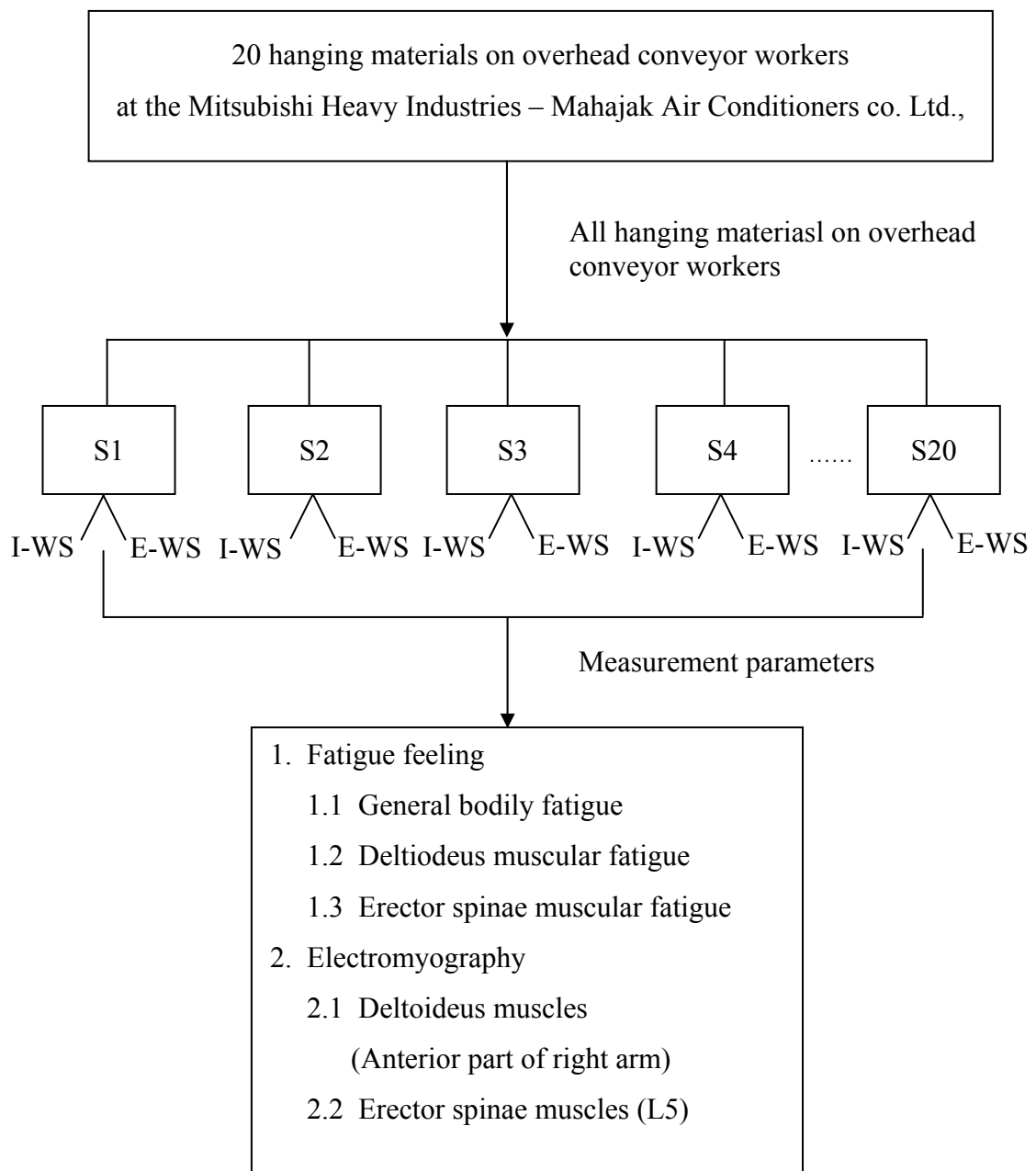
This study was quasi-experimental research design applied to the same subject group. The muscular fatigue in the subject measured while working on both existing and improved workstations. There is a kind of study called “Before-after experiment with no control group”. Subjects of the experimental group themselves will control group as well. The fatigue feeling as derived from questionnaire would be compared with the muscular activity as measured by electromyography. The study design could be shown as follows:

Existing workstation	O ₁	-	-
Improved workstation	-	X	O ₂

O₁ = Data collected during hanging materials on overhead conveyor on existing workstation.

O₂ = Data collected during hanging materials on overhead conveyor on improved workstation.

X = Hanging materials on overhead conveyor on improved workstation. (The subjects trained to work on improved workstation for 7 days before the experimental start.)



S1 – S20 : Subject no. 1-20

I-WS : Improved workstation

E-WS : Existing workstation

3.2 Population and samples

Twenty healthy male subjects from all hanging materials on overhead conveyor workers of the Mitsubishi Heavy Industries – Mahajak Air Conditioners co. Ltd., were selected by purposive sampling to participate in this study, age ranging from 25-30 years old, body weight 57-65 kilograms, height 162-167 centimeters, no history illness or injury of the musculoskeletal system e.g., fracture of the spine, disc herniation, chronic low back pain and abnormal spine, minimum work experience one year and rest before the experiment at least 7 hours. They voluntarily participated as the subjects in this study.

3.3 Materials and equipments

3.3.1 Muscular fatigue questionnaires, it was used for taking the general information such as personal data, job description data and medical history review in the past six month. These forms had fifteen questions which was adapted from Nordic Questionnaire for mapping out Work-Related Musculoskeletal Trouble.(34) (Appendix)

3.3.2 The feeling of fatigue questionnaire, it was used for asking subject before and after experiment. This questionnaire was divided two parts. (Appendix)

Part I General bodily fatigue part which was applied from Grandjean (1998) (12). The subjects would be asked for an overall assessment of discomfort. For this a seven point scale was used, with “extremely comfortable” and “extremely uncomfortable” marked at its left and right hand ends respectively. The subject was asked to indicate the point on the scale which represented the subject’s current level of overall comfort and overall discomfort.

Part II Local muscular fatigue part which was applied from Corlett and Bishop (1983) (17), this form is based on an outline diagram of the body. In this study subjects would be asked to indicate the body site, which currently have fatigue. This information then would be scored from 0 to 7 as described above.

3.3.3 Electromyography (Muscle Tester Model ME 300, Mega Electronic Ltd., Finland)has two channels with surface electrodes, personal PC and software(Appendix)

3.3.4 Workstation

1. Existing workstation

- Did not use anthropometry data in design.
- Overhead conveyor level was fixed, the worker reached arm forward above shoulder on overhead conveyor. Then the workers twist and bent bodies to bring materials in carrier to hanging on overhead conveyor.

- Work height 176 centimeters.
- Did not adjust height of carrier.
- Frequency of hanging materials on overhead conveyor 1,500 pieces/day

2. Improved workstation

- Designed base on anthropometry data.
- Suitable height for hanging materials on overhead conveyor, bring about workers have good posture.

- Work height modified 136.6 ± 1.52 centimeters with standing base 40 centimeters height and has 4 lock wheels.

- Adjust height of carrier by lifting equipment in appropriate waist level.

3.3.5 Lifting equipment, it used for adjust height of carrier up and down direction by using control switch in appropriate waist level. When the workers used this equipment, they did not bend to bring materials in carrier which cause low back pain muscular fatigue. They have a good posture.

3.3.6 Materials, it is steel plate for assembly outdoor air conditioner unit average weight 1.05 kilograms.

3.3.7 Other equipments; thermometer, anthropometer and stop clock.

3.4 Data collection

There were 6 steps for data collection in this study, as follows:

3.4.1 Survey muscular fatigue situation

Twenty male hanging materials on overhead conveyor workers from the air conditioner factory were interviewed by using the muscular fatigue questionnaire in order to investigate the muscular fatigue situation for last 6 months of having muscular fatigue. Data from muscular fatigue questionnaire were collected and analyzed.

3.4.2 Subjects preparation

3.4.2.1 The subjects did not have any record of muscular and bone disease or accident and worked as the hanging materials on overhead conveyor at least one year. All of them voluntarily participated in this study.

3.4.2.2 All of subjects were clearly informed about the study purpose for preparing themselves before the measurement in order to better understand before interview and to prevent an error. The requirement was that the subjects take a rest for seven hours at night and did not perform work before attaching electrodes. If the requirements were not fulfilled, the measurement would be postponed until they were ready.

3.4.3 Anthropometrical measurement

The principles and details of anthropometry was used to measure body dimension that applied from Kitti Intranol (1991) (35). Landmark for measurement, measuring instruments, procedures, and data forms are shown in Appendix. Ten items were measured as follows:

1. Weight
2. Stature
3. Shoulder height
4. Elbow height
5. Shoulder elbow length
6. Elbow wrist length
7. Elbow fingertip length
8. Hand length
9. Hand breadth
10. Foot length

3.4.4 Measurement of muscular fatigue while hanging materials on overhead conveyor on existing work station.

3.4.4.1 The subjects had been interviewed by using the characteristics of subject form. At first, the researcher would be described this form clearly in order to prevent an error.

3.4.4.2 Surface electrodes were attached on the subject's skin. (Appendix) Before placing electrodes the skin was cleaned with 95% alcohol. The locations of

electrodes were at deltoideus muscle (Anterior part of right arm) and erector spinae muscle (L5) before working time as follows:

1. To record the activity of deltoideus muscle.
 - The subjects were standing.
 - The research found out head of acromion.
 - To attached electrodes at midpoint between 1/3 of lead line length from the head of acromion.
2. To record the activity of erector spinae muscle.
 - The subjects were standing erect.
 - The research found out parallel line to the spinal column on the crest of the erector spinae muscle and the central load point is 1/6 of the distance from the iliac crest to the spine of the 7th cervical vertebra above the iliac crest.
 - To attached electrodes at midpoint between 1/3 of lead line length from the head of acromion.

3.4.4.3 The portable EMG (MEGA) ME 300 had been used to record the muscle activities of deltoideus and erector spinae muscle in channel 1 and 2, respectively of electromyography.

3.4.4.4 The subjects were monitored by using EMG while they were performing their work. The data were collected during 9.00 a.m. to 3.00 p.m. (six working hours) for each subject. The subject took a rest for an hour (12.00 a.m. – 1.00 p.m.)

3.4.4.5 The subjects were interviewed 4 times by questionnaires of fatigue feeling before work (9 a.m.), before lunch (12.00 a.m.), after lunch (1 p.m.) and end of work (3 p.m.)

3.4.4.6 During working, the workplace temperature and the duration per work item of hanging materials on overhead conveyor workers (minutes/piece) were recorded.

3.4.5 The process for improved workstation.

The design to improved workstation by using data from anthropometry of subjects. The percentile 5 and percentile 95 were selected as appropriate data.

3.4.6 Measurement of muscular fatigue while hanging materials on overhead conveyor on improved work station.

3.4.6.1 The improved workstation was adjusted at appropriate level.

3.4.6.2 The subjects trained to work on the improved workstation for 7 days before experiment in order to be acclimatized.

3.4.6.3 The subjects had been interviewed by using the characteristics of subject form. At first, the researcher would be described this form clearly in order to prevent an error.

3.4.6.4 Surface electrodes were attached on the subject's skin. (Appendix) Before placing electrodes the skin was cleaned with 95% alcohol. The locations of electrodes were at deltoideus muscle (Anterior part of right arm) and erector spinae muscle (L5) before working time as follows:

1. To record the activity of deltoideus muscle.
 - The subjects were standing.
 - The research found out head of acromion.
 - To attached electrodes at midpoint between 1/3 of lead line length from the head of acromion.
2. To record the activity of erector spinae muscle.
 - The subjects were standing erect.
 - The research found out parallel line to the spinal column on the crest of the erector spinae muscle and the central load point is 1/6 of the distance from the iliac crest to the spine of the 7th cervical vertebra above the iliac crest.
 - To attached electrodes at midpoint between 1/3 of lead line length from the head of acromion.

3.4.6.5 The portable EMG (MEGA) ME 300 had been used to record the muscle activities of deltoideus and erector spinae muscle in channel 1 and 2, respectively of electromyography.

3.4.6.6 The subjects were monitored by using EMG while they were performing their work. The data were collected during 9.00 a.m. to 3.00 p.m. (six working hours) for each subject. The subject took a rest for an hour (12.00 a.m. – 1.00 p.m.)

3.4.6.7 The subjects were interviewed 4 times by questionnaires of fatigue feeling before work (9 a.m.), before lunch (12.00 a.m.), after lunch (1 p.m.) and end of work (3 p.m.)

3.4.4.8 During working, the workplace temperature and the duration per work item of hanging materials on overhead conveyor workers (minutes/piece) were recorded.

3.5 Statistical analysis

Statistical analyses were computed with SPSS 11.5 for window. Statistical analyses were used as follow:

3.5.1 Descriptive Statistics

1) Percentage

- Muscular fatigue in hanging materials on overhead conveyor workers.
- Physical health status

2) Mean and standard deviation

- General information
- Level of fatigue score
- Anthropometry data
- Maximum voluntary contraction

3.5.2 Inferential statistics

1) Paired t-test

1.1 To compare the fatigue feeling of general bodily fatigue, deltoideus muscle and erector spinae muscle between working on existing workstation and improved workstation on 0,3,4,6 work-hours.

1.2 To compare of deltoideus muscular activity and erector spinae muscular activity by electromyography between working on existing workstation and improved workstation will be conducted in every 30 minute to 6 working-hours.

1.3 To compare of workplace temperature between working on existing workstation and improved workstation on 0,3,4,6 work-hours.

1.4 To compare of duration per work item of hanging materials on overhead conveyor workers (minutes/piece) between working on existing workstation and improved workstation.

2) Correlation

The correlation of the fatigue indicator between fatigue feeling by questionnaire and muscular activity by electromyography will be performed.

CHAPTER IV

RESULTS

The objectives of this study are to improved workstation for reducing muscular fatigue and evaluate the level of fatigue. The results from interview by using questionnaire and electromyography measurement would be compared. The data has been collected form the hanging materials on overhead conveyor workers of the Mitsubishi Heavy Industries – Mahajak Air Conditioners co. Ltd., Bangkok. The results of this study were divided into 7 parts as following:

- Part 1 The characteristics and muscular fatigue of samples
- Part 2 The anthropometry data of samples.
- Part 3 Result of fatigue feeling by using questionnaire.
- Part 4 Result of muscular activity by using electromyography.
- Part 5 Correlation of fatigue indicator between fatigue feeling and muscular activity.
- Part 6 Result of working conditions.
- Part 7 Result of the duration per work item of samples.(minutes/piece)

Part 1 The characteristics and muscular fatigue of samples

1.1 General information

This study was conducted from 20 males hanging materials on overhead conveyor workers of the Mitsubishi Heavy Industries – Mahajak Air Conditioners co. Ltd., Bangkok. Their general information were recorded and presented in Table 4-1. Mean age of sample was 27.55 ± 1.36 years old. Mean weight and height were 60.80 ± 1.92 kilograms, 165.01 ± 1.59 centimeters respectively. The durations of work as hanging materials on overhead conveyor workers were 4.67 ± 0.46 years.

Table 4-1 The characteristics of 20 males hanging materials on overhead conveyor workers.

Items	Frequency	%
Sample size	20	100.00
Age (years)		
25-26	4	20.00
27-28	11	55.00
29-30	5	25.00
	Mean = 27.55	SD = 1.36
Weight (cms)		
57-59	6	30.00
60-62	11	55.00
63-65	3	15.00
	Mean = 60.80	SD = 1.92
Height (cms)		
162-163	5	25.00
164-165	10	50.00
166-167	5	25.00
	Mean = 165.01	SD = 1.59
Hanging materials on overhead conveyor experience (years)		
4.1-4.5	4	20.00
4.6-5.0	11	55.00
5.1-5.5	5	25.00
	Mean = 4.67	SD = 0.46

1.2 Physical health status

All of 20 males hanging materials on overhead conveyor workers were interviewed. There are 15 items of questions regarding physical health status. The results are presented in Table 4-2. They had no accident history of bone and muscle (100%). They had no illness history of bone and muscular disease (100%). During the part six-month, they had muscular pain (100%). The most part of body subjects have usually pain were upper arms (90%), low back (85%), shoulder (75%) and legs (45%). The most duration had feeling of muscular fatigue on working-hour (75%), and after work (20%) and before work (5%). Frequency of muscular pain or fatigue in the past of six months which occurrence every day (85%). Duration of muscular pain was less than 1 day (75%). Techniques to reduce muscular fatigue were take medicine (40%), self massage (25%), not do anything (5%), consult doctor / physiotherapist (10%). They did not smoking (90%), sometimes to drink alcohol (80%). They thought that the cause of muscular pain derived from hanging materials on overhead conveyor (80%). During the past six month, they had muscular pain while hanging material on overhead conveyor were right upper arms (90%), low back (85%) and right shoulder (75%). Reducing muscular fatigue while hanging material on overhead conveyor was stopping work and take medicine (35%), only take medicine (25%), self massage (20%), stop working (15%) and not do anything (5%).

Table 4-2 Physical health status of 20 males hanging materials on overhead conveyor workers.

Items	%
1. Accident history of bone and muscle	
Yes	0.00
No	100.00
2. Illness history of bone and muscular disease	
Yes	0.00
No	100.00
3. During the part six months, have muscular pain	
Yes	100.00
No	0.00

Table 4-2 Physical health status of 20 males hanging materials on overhead conveyor workers. (Continued)

Items	%
4. The part of body, which they had muscular fatigue	
- Low back	85.00
- Shoulder (left and right)	75.00
- Upper arms (left and right)	90.00
- Leg (left and right)	45.00
5. The most duration had feeling of muscular fatigue	
- Before work	5.00
- On working-hour	75.00
- After work	20.00
6. Frequency of muscular pain or fatigue in the past of six months	
- Sometime	10.00
- Every day	85.00
- Every week	5.00
7. Duration of muscular pain	
- Less than 1 day	75.00
- 1-3 days	15.00
- More than 3 days	10.00
8. Technique to reduce muscular fatigue	
- Stop working	20.00
- Take medicine	40.00
- Consult doctor / physiotherapist	10.00
- Self massage	25.00
- Not do anything	5.00
9. Type of exercise	
- Jogging	25.00
- Football	65.00
- General exercise	10.00
- Others	5.00

Table 4-2 Physical health status of 20 males hanging materials on overhead conveyor workers. (Continued)

Items	%
10. Frequency of exercise	
- Always	25.00
- Sometime	70.00
- Never	5.00
11. Smoke habit	
- Always	10.00
- None-smoke	90.00
12. Alcohol drinking	
- Always	15.00
- Sometime	80.00
- Never	5.00
13. In your opinion, cause of muscular fatigue	
- Hanging material on overhead conveyor	80.00
- Sports / Exercise	5.00
- Present illness	5.00
- General work	10.00
14. During the past six month, have muscular pain while hanging material on overhead conveyor.	
- Low back	85.00
- Left Shoulder	60.00
- Right Shoulder	75.00
- Left Upper arms	55.00
- Right Upper arms	90.00
- Left Leg	25.00
- Right Leg	25.00

Table 4-2 Physical health status of 20 males hanging materials on overhead conveyor workers. (Continued)

Items	%
15. Reducing muscular fatigue while hanging material on overhead conveyor.	
- Stop working	15.00
- Take medicine	25.00
- Self massage	20.00
- Stop working and take medicine	35.00
- Not do anything.	5.00

Part 2 The anthropometry data of samples.

The principles and details of anthropometry were presented in Appendix. In this study, all of the 20 hanging materials on overhead conveyor were included. The data on 10 body dimensions, which are the average, minimum, maximum, standard deviation and 5th, 95th percentiles, are shown in Table 4-3.

Table 4-3 Anthropometry of hanging materials on overhead conveyor workers.(cms.)

Anthropometry	Mean	SD	Min	Max	Percentile 5	Percentile 95
1. Weight	60.80	1.92	58.50	65.00	58.53	65.00
2. Stature	165.01	1.59	162.10	167.30	162.12	167.30
3. Shoulder height	135.05	1.52	132.20	136.20	134.21	136.16
4. Elbow height	104.12	1.09	102.40	106.30	102.41	106.28
5. Shoulder elbow length	43.66	0.88	42.43	45.20	42.31	45.20
6. Elbow wrist length	34.23	0.85	32.30	35.40	32.31	35.40
7. Elbow fingertip length	51.23	0.98	49.20	52.80	49.22	52.78
8. Hand length	18.09	0.60	17.00	19.10	17.10	19.09
9. Hand breadth	8.43	0.34	7.90	9.10	7.91	9.10
10. Foot length	24.48	0.61	23.50	25.80	23.51	25.77

(Age 25-30 year, n = 20)

2.1 The improved workstation

The design and improved workstation based on the structural body dimensions. The percentile 5 and percentile 95 were selected as appropriate data, for improved workstation as shown in Figure 4-1 and 4-2.

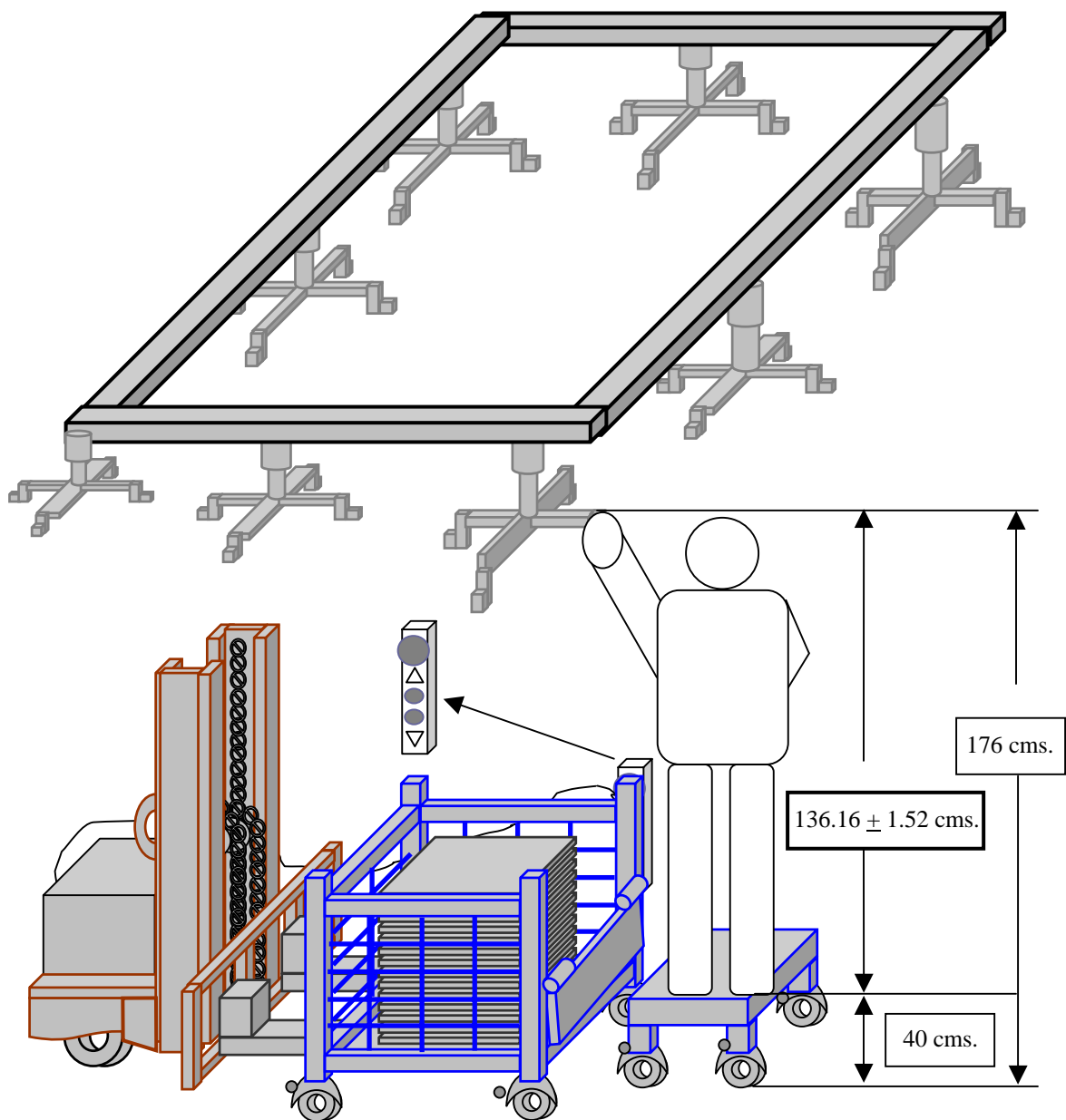


Figure 4-1 The design features and dimensions of improved workstation.



Figure 4-2 The improved workstation

Calculation for standing base height

$$\begin{aligned}\text{Standing base height} &= \text{The hanging height} - \text{percentile 95 of shoulder height} \\ &= 176 - 136.16 \pm 1.52 \text{ cms.} \\ &= 39.84 \text{ cms.}\end{aligned}$$

Therefore standing base height 40 cms.

Part 3 Result of fatigue feeling by using questionnaire.

3.1 General bodily fatigue

The results of general bodily fatigue were collected throughout the experimental time of 6 working-hours. All of subjects worked from 9.00 a.m. to 3.00 p.m. The subjects were interviewed for 4 times by questionnaires of fatigue feeling before work (9 a.m.), before lunch (12.00 a.m.), after lunch (1 p.m.) and end of work (3 p.m.) The subject took a rest for an hour (12.00 a.m. – 1.00 p.m.)

The difference of general bodily fatigue while the subjects were working on existing workstation and improved workstation was determined by paired t-test. The mean score of working on existing workstation and improved workstation was compared. This comparison must be made between the same group of samples. The result indicates that general bodily fatigue while the subjects were working on improved workstation was significantly less than while they were working on existing workstation with 95% of confidence interval (P-value < 0.05), as presented in Table 4-4.

In this study, it was found that the subjects had no general bodily fatigue before working (9.00 a.m.) at both of workstations. Mean score of general body fatigue while working on improved workstation is less than working on existing workstation was shown in Figure 4-3.

Table 4-4 Comparison of means general bodily fatigue score of working on improved workstation and existing workstation.

Time	Mean	d	SD	t	df	P-value
(12.00 a.m.)						
Existing workstation	1.80	1.05	0.39	11.917	19	0.000
Improved workstation	0.75					
(1.00 p.m.)						
Existing workstation	0.60	0.15	0.37	1.831	19	0.003
Improved workstation	0.45					
(3.00 p.m.)						
Existing workstation	2.60	1.00	0.69	6.842	19	0.000
Improved workstation	1.60					

Paired t-test application, n = 20

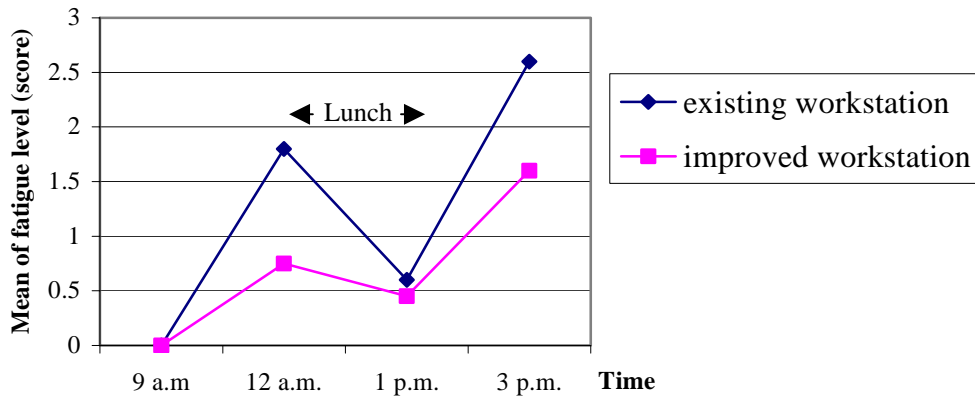


Figure 4-3 Level of general bodily fatigue score of working on improved workstation and existing workstation at various working hours.

3.2 Deltoideus muscular fatigue

The results of deltoideus muscular fatigue were collected throughout the experimental time of 6 working-hours. All of subjects worked from 9.00 a.m. to 3.00 p.m. The subjects were interviewed for 4 times by questionnaires of fatigue feeling before work (9 a.m.), before lunch (12.00 a.m.), after lunch (1 p.m.) and end of work (3 p.m.) The subject took a rest for an hour (12.00 a.m. – 1.00 p.m.)

The difference of deltoideus muscular fatigue while the subjects were working on existing workstation and improved workstation was determined by paired t-test. The mean score of working on existing workstation and improved workstation was compared. This comparison must be made between the same group of samples. The result indicates that deltoideus muscular fatigue while the subjects were working on improved workstation was significantly less than while they were working on existing workstation with 95% of confidence interval (P-value < 0.05), as presented in Table 4-5.

It was found that the subjects had no deltoideus muscular fatigue before working (9.00 a.m.), score is zero, at both of workstations. Mean score of deltoideus muscular fatigue while working on improved workstation is less than working on existing workstation was shown in Figure 4-4.

Table 4-5 Comparison of means deltoideus muscular fatigue score of working on improved workstation and existing workstation.

Time	Mean	d	SD	t	df	P-value
(12.00 a.m.)						
Existing workstation	2.00	0.95	0.22	19.000	19	0.000
Improved workstation	1.05					
(1.00 p.m.)						
Existing workstation	2.50	1.00	0.32	13.784	19	0.000
Improved workstation	1.50					
(3.00 p.m.)						
Existing workstation	4.40	1.10	0.31	15.983	19	0.000
Improved workstation	3.30					

Paired t-test application, n = 20

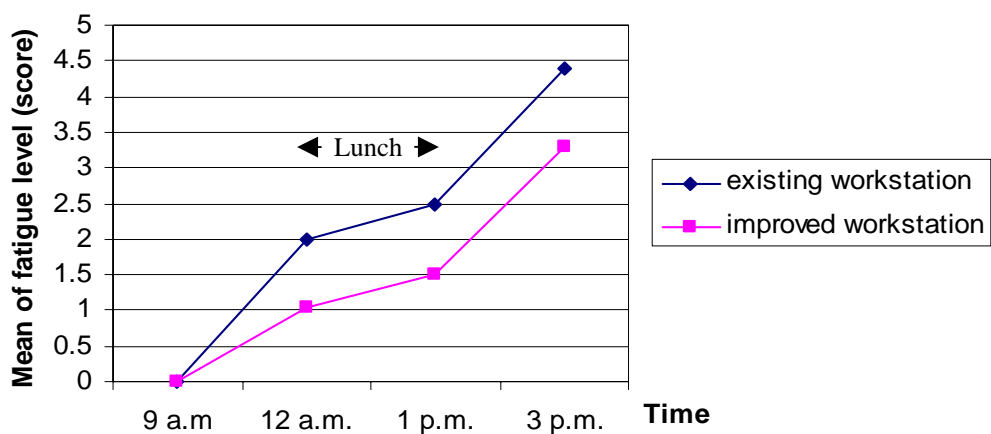


Figure 4-4 Level of deltoideus muscular fatigue score of working on improved workstation and existing workstation at various working hours.

3.2 Erector spinae muscular fatigue

The results of erector spinae muscular fatigue were collected throughout the experimental time of 6 working-hours. All of subjects worked from 9.00 a.m. to 3.00 p.m. The subjects were interviewed for 4 times by questionnaires of fatigue feeling before work (9 a.m.), before lunch (12.00 a.m.), after lunch (1 p.m.) and end of work (3 p.m.) The subjects took a rest for an hour (12.00 a.m. – 1.00 p.m.)

The difference of erector spinae muscular fatigue while the subjects were working on existing workstation and improved workstation was determined by paired t-test. The mean score of working on existing workstation and improved workstation was compared. This comparison must be made between the same group of samples. The result indicates that erector spinae muscular fatigue while the subjects were working on improved workstation was significantly less than while they were working on existing workstation with 95% of confidence interval (P-value < 0.05), as presented in Table 4-6.

It was found that the subjects had no erector spinae muscular fatigue before working (9.00 a.m.), score is zero, at both of workstations. Mean score of erector spinae muscular fatigue while working on improved workstation is less than working on existing workstation was shown in Figure 4-5.

Table 4-6 Comparison of means erector spinae muscular fatigue score of working on improved workstation and existing workstation.

Time	Mean	d	SD	t	df	P-value
(12.00 a.m.)						
Existing workstation	2.00	0.95	0.39	10.782	19	0.000
Improved workstation	1.05					
(1.00 p.m.)						
Existing workstation	1.15	0.75	0.44	7.550	19	0.000
Improved workstation	0.40					
(3.00 p.m.)						
Existing workstation	2.80	1.20	0.41	13.074	19	0.000
Improved workstation	1.60					

Paired t-test application, n = 20

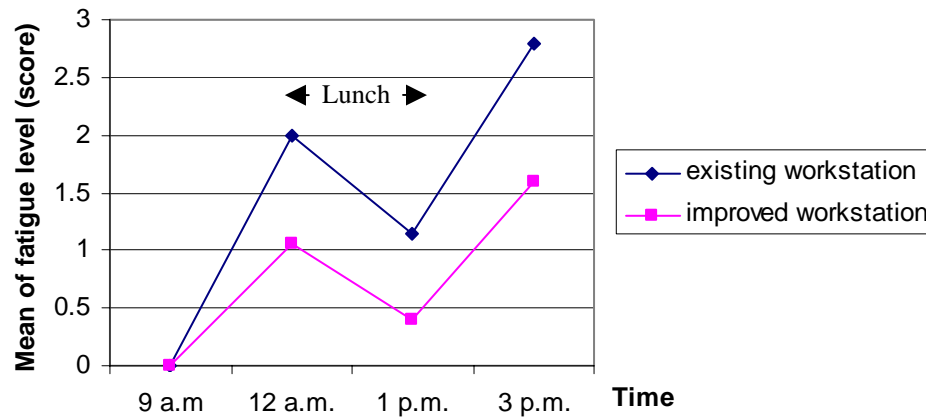


Figure 4-5 Level of erector spinae muscular fatigue score of working on improved workstation and existing workstation at various working hours.

Part 4 Result of muscular activity by using electromyography.

4.1 Deltoideus muscle

The results of deltoideus muscle activity by electromyography were collected throughout the experimental time of 6 working-hours. All of subjects worked from 9.00 a.m. to 3.00 p.m. and took lunch during 12.00 a.m. to 1.00 p.m.

The difference of % MVC of deltoideus muscle while the subjects were working on existing workstation and improved workstation was determined by paired t-test. The mean % MVC of working on existing workstation and improved workstation was compared. This comparison must be made between the same group of samples. The result indicates that % MVC of deltoideus muscle activity while the subjects were working on improved workstation was significantly less than while they were working on existing workstation with 95% of confidence interval (P -value < 0.05), as presented in Table 4-7. Mean % MVC of deltoideus muscle activity was shown in Figure 4-6.

Table 4-7 Comparison of means % MVC of deltoideus muscle of working on improved workstation and existing workstation.

Time	Mean	d	SD	t	df	P-value
(0 minute)						
Existing workstation	24.60	14.70	11.98	5.486	19	0.000
Improved workstation	9.90					
(30 minute)						
Existing workstation	21.15	10.65	8.41	5.662	19	0.000
Improved workstation	10.50					
(60 minute)						
Existing workstation	25.20	13.85	11.16	5.550	19	0.000
Improved workstation	11.35					
(90 minute)						
Existing workstation	25.40	14.55	11.50	5.660	19	0.000
Improved workstation	10.85					
(120 minute)						
Existing workstation	27.55	15.45	13.57	5.093	19	0.000
Improved workstation	12.10					
(150 minute)						
Existing workstation	27.00	14.15	11.52	5.492	19	0.000
Improved workstation	12.85					
(180 minute)						
Existing workstation	25.05	12.70	13.53	4.197	19	0.000
Improved workstation	12.35					
(210 minute)						
Existing workstation	26.75	12.90	11.07	5.212	19	0.000
Improved workstation	13.85					
(240 minute)						
Existing workstation	25.20	13.05	10.70	5.452	19	0.000
Improved workstation	12.15					

Table 4-7 Comparison of means % MVC of deltoideus muscle of working on improved workstation and existing workstation. (Continued)

Time	Mean	d	SD	t	df	P-value
(270 minute)						
Existing workstation	23.35	10.65	11.60	4.104	19	0.001
Improved workstation	12.70					
(300 minute)						
Existing workstation	24.15	13.20	10.55	5.598	19	0.000
Improved workstation	10.95					
(330 minute)						
Existing workstation	23.55	11.85	10.18	5.204	19	0.000
Improved workstation	11.70					
(360 minute)						
Existing workstation	24.60	11.10	8.18	6.072	19	0.000
Improved workstation	12.50					

Paired t-test application, n = 20

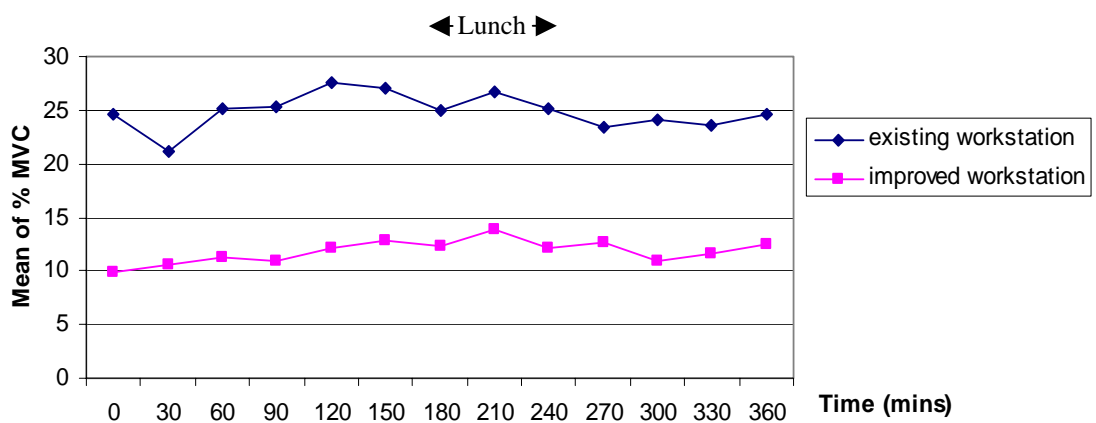


Figure 4-6 Mean of % MVC of deltoideus muscle of working on improved workstation and existing workstation.

4.2 Erector spinae muscle

The results of erector spinae muscle activity by electromyography were collected throughout the experimental time of 6 working-hours. All of subjects worked from 9.00 a.m. to 3.00 p.m. and took lunch during 12.00 a.m. to 1.00 p.m.

The difference of % MVC of erector spinae while the subjects were working on existing workstation and improved workstation was determined by paired t-test. The mean % MVC of working on existing workstation and improved workstation was compared. This comparison must be made between the same group of samples. The result indicates that % MVC of erector spinae muscle activity while the subjects were working on improved workstation was significantly less than while they were working on existing workstation with 95% of confidence interval (P-value < 0.05), as presented in Table 4-8. Mean of % MVC of erector spinae muscle activity was shown in Figure 4-7.

Table 4-8 Comparison of means % MVC of erector spinae muscle of working on improved workstation and existing workstation.(Continued)

Time	Mean	d	SD	t	df	P-value
(0 minute)						
Existing workstation	18.30	9.15	8.81	4.645	19	0.000
Improved workstation	9.15					
(30 minute)						
Existing workstation	19.45	9.65	8.15	5.294	19	0.000
Improved workstation	9.80					
(60 minute)						
Existing workstation	23.85	13.60	14.32	4.246	19	0.000
Improved workstation	10.25					
(90 minute)						
Existing workstation	23.45	12.55	12.82	4.378	19	0.000
Improved workstation	10.90					
(120 minute)						
Existing workstation	22.85	11.45	11.04	4.637	19	0.000
Improved workstation	11.40					

Table 4-8 Comparison of means % MVC of erector spinae muscle of working on improved workstation and existing workstation.

Time	Mean	d	SD	t	df	P-value
(150 minute)						
Existing workstation	26.05	14.30	13.31	4.805	19	0.000
Improved workstation	11.75					
(180 minute)						
Existing workstation	26.35	13.70	13.23	4.632	19	0.000
Improved workstation	12.65					
(210 minute)						
Existing workstation	28.65	16.75	13.51	5.545	19	0.000
Improved workstation	11.90					
(240 minute)						
Existing workstation	24.55	11.45	10.56	4.849	19	0.000
Improved workstation	13.10					
(270 minute)						
Existing workstation	22.75	10.55	9.26	5.096	19	0.000
Improved workstation	12.20					
(300 minute)						
Existing workstation	25.00	12.85	14.89	3.860	19	0.001
Improved workstation	12.15					
(330 minute)						
Existing workstation	21.20	9.75	14.74	2.958	19	0.008
Improved workstation	11.45					
(360 minute)						
Existing workstation	22.90	10.15	8.54	5.314	19	0.000
Improved workstation	12.75					

Paired t-test application, n = 20

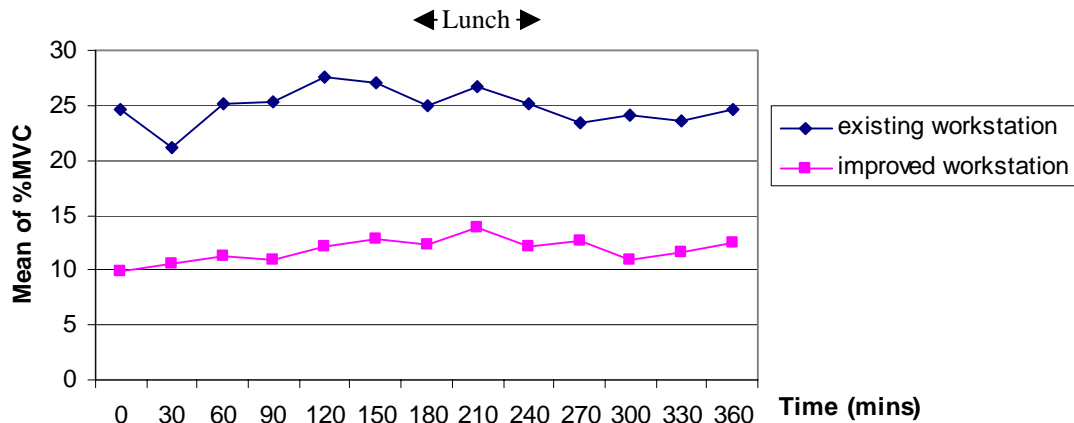


Figure 4-7 Mean of % MVC of erector spinae muscle of working on improved workstation and existing workstation.

Part 5 Correlation of fatigue indicator between fatigue feeling and muscular activity.

The correlation of fatigue indicator between fatigue from questionnaire and muscular activity measurement from electromyography while the subjects were working on two type of workstation was calculated by using the simple correlation statistics and shown in terms of correlation coefficient (r), as presented in Table 4-9 and Table 4-10.

The correlation coefficients of deltoideus muscle were calculated at 3 period of working-hour (12.00 a.m., 1.00 p.m., and 3.00 p.m.).While working at both types of workstation. The correlation coefficient of existing workstation were - 0.215, 0.166, and 0.516, respectively and the correlation coefficient of improved workstation were - 0.130, 0.220, and 0.318, respectively, which indicated little relationship and was not significant difference at 95% of confidence interval (P-value > 0.05).

The correlation coefficients of erector spinae muscle were calculated at 3 period of working-hour (12.00 a.m., 1.00 p.m., 3.00 p.m.)while working at both types of workstation. The correlation coefficient of existing workstation were - 0.202, 0.337, and - 0.089, respectively and the correlation coefficient of improved workstation were 0.088, 0.276, and - 0.204, respectively, which indicated little relationship and was not significant difference at 95% of confidence interval (P-value > 0.05).

In this case, correlation coefficient (r) was negative, the fatigue feeling from questionnaire and muscular fatigue from EMG has conversely correlation. It means that the fatigue feeling increase but muscular activity decrease.

Table 4-9 Correlation coefficient of fatigue indicator between fatigue feelings from questionnaire and muscular activity measurement from electromyography while the subjects were working on the existing workstation.

Working-hour (time)	r	P-value
Deltoideus muscle		
(12.00 a.m.)	- 0.215	0.363
(1.00 p.m.)	0.166	0.483
(3.00 p.m.)	0.516	0.511
Erector spinae muscle		
(12.00 a.m.)	- 0.202	0.392
(1.00 p.m.)	0.337	0.146
(3.00 p.m.)	- 0.089	0.275
Simple correlation statistics application, $n = 20$		

Table 4-10 Correlation coefficient of fatigue indicator between fatigue feelings from questionnaire and muscular activity measurement from electromyography while the subjects were working on the improved workstation.

Working-hour (time)	r	P-value
Deltoideus muscle		
(12.00 a.m.)	- 0.130	0.958
(1.00 p.m.)	0.220	0.351
(3.00 p.m.)	0.318	0.171
Erector spinae muscle		
(12.00 a.m.)	0.088	0.712
(1.00 p.m.)	0.276	0.239
(3.00 p.m.)	- 0.204	0.387
Simple correlation statistics application, $n = 20$		

Part 6 Result of working conditions

6.1 Workplace temperature

Workplace temperature was measured by using thermometer throughout the experimental time of 6 working-hours. All of the subjects worked from 9.00 a.m. until 3.00 p.m. The workplace temperature was monitored for 4 times: before work (9.00 a.m.), before lunch (12.00 a.m.), after lunch (1.00 p.m.) and end of work (3.00 p.m.) The subjects took lunch during 12.00 a.m. to 1.00 p.m.

The difference of workplace temperature of working on existing workstation and improved workstation was determined by using paired t-test. The result showed that while working on improved workstation and existing workstation was not significantly difference at 95% of confidence interval ($P\text{-value} < 0.05$), was presented in Table 4-11. Mean score of workplace temperature of working on improved workstation and existing workstation was shown in Figure 4-8.

Table 4-11 Comparison of means workplace temperature of working on improved workstation and existing workstation.

Time	Mean	d	SD	t	df	P-value
(9.00 a.m.)						
Existing workstation	27.00	- 0.20	0.77	1.165	19	0.258
Improved workstation	26.80					
(12.00 a.m.)						
Existing workstation	29.60	- 0.55	0.51	4.819	19	0.601
Improved workstation	29.05					
(1.00 p.m.)						
Existing workstation	30.55	- 0.10	0.31	1.453	19	0.163
Improved workstation	30.45					
(3.00 p.m.)						
Existing workstation	31.45	- 0.05	0.51	0.438	19	0.666
Improved workstation	31.40					

Paired t-test application, $n = 20$

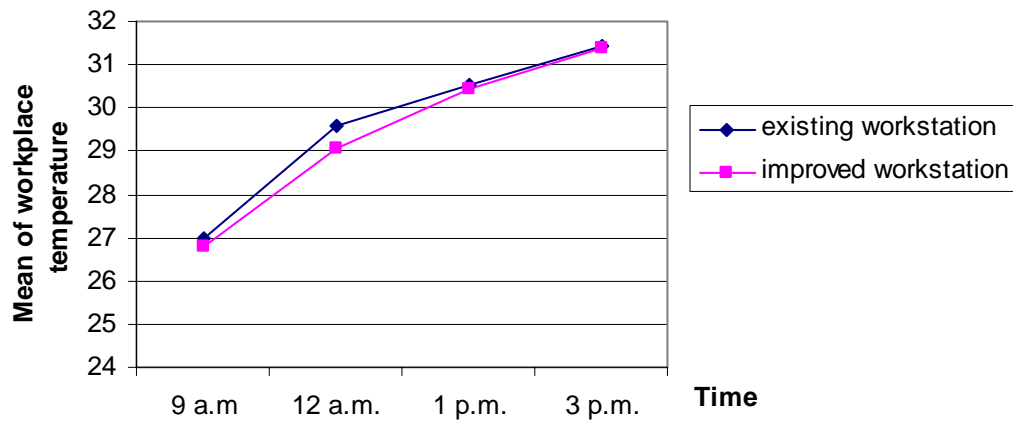


Figure 4-8 Level of workplace temperature of working on improved workstation and existing workstation at various working hours.

Part 7 Result of the duration per work item of samples (minutes/piece)

The duration per work item was evaluated by using stop clock and recording the time used for hanging each material on overhead conveyor in both working on existing workstation and improved workstation. (Six working-hours)

The difference of duration per work item was evaluated while subjects were working on existing workstation and improved workstation was determined by using paired t-test. The result showed that duration per work item of working on improved workstation was significantly less than that working on existing workstation with 95% of confidence interval (P-value < 0.05), was presented in Table 4-12.

Table 4-12 Comparison of means the duration per work item of working on improved workstation and existing workstation.

Time	Mean	d	SD	t	df	P-value
Existing workstation	1.31	0.04	0.02	11.698	19	0.000
Improved workstation	1.27					

Paired t-test application, n = 20

CHAPTER V

DISCUSSION

5.1 Discussion of study design

This study was a quasi-experiment research divided into two workstations, before-after design in order to compare working on existing workstation and improved workstation. The error of data collection and analyzing from this study might occur due to systematic error and random error as follow;

5.1.1 Systematic error

1) Instrument error:

In this study, subjective feeling of fatigue questionnaire was applied to evaluate subjective feeling of fatigue by asking subjects to answer the questionnaire before and after experiment. While electromyography (EMG) was applied to measure muscular activity.

Questionnaire for subjective feeling of fatigue. The subjects judged and indicated the level of comfort and discomfort as a rating scale. The results from using the questionnaire might introduce errors from questionnaire forms and the deviated human perceptions. Moreover some subjects might not clearly understand the questionnaire such as they could not give the actual rating scale towards level of their feeling in this questionnaire which might cause less reliability. To prevent an error the researcher described clearly the meaning of each point scale. Then asked each subject individually to answer if there was any currently comfort and discomfort and assured that the information retrieved from the questionnaires would not have any effect toward their work. However the use of only subjective feeling of fatigue questionnaire is not enough to represent the subjects' overall comfort and discomfort. The objective measurement, like electromyography (EMG), was applied in this study.

Surface electromyography (SEMG: Muscle Tester ME 300): SEMG is an equipment for measure muscular activity. It is normally used in vocational studied and qualified to the muscle specifically. It has both advantages and disadvantages. One weak point is that SEMG has large electrode, which can cause cross talk from adjacent muscles, and it can only be used for superficial muscles. Moreover the myoelectric activity value of SEMG ME 300 model is a form of average mean EMG. It is difficult to filter noise signals, therefore has more potential invalid signals. Owing to those disadvantages, before recording the researcher must be keep in mind and full consideration given to such factors that influence process of record. For example; skin preparation, electrode placement, cross talk of adjacent muscles, electrode wire and cable and other electrical sources should be ruled out. Then the myoelectric activity is valid for qualitative analysis.

2) Personal error:

This error could be occurring by the researcher. Even though the method of collecting data and equipment was standardized but if the researcher got poor skill or insufficient training or lack of good attention could also cause inaccurate recording. In this study the researcher have recognized to the accuracy and reliability of data. Thus, the researcher has tried hardest to be good at all skills necessary in order to prevent an error that could be happened, so techniques and methods were applied carefully.

There was only one person to conduct the interviewing, observing, measuring and analyzing all of data.

3) Method error:

This error of fatigue feeling might be happened from the person answering, attitude or familiarity about fatigue from hanging materials on overhead conveyor work. Whereas, the questionnaire of this study was modified from the worldwide application of ergonomics approaches. In order to prevent an error from the interview, the researcher asked them one by one to answer if there was any currently fatigue, and then apply the electromyography measurement based on Mega Electronics Ltd Recommendation. Electrodes position might cause the error in data collection then that was specific anatomical location for surface electrode and individual subject was recorded and marked position of electrode, continuously.

This error might occur due to on site measurement study. Thus, the worker posture sometimes could not be fixed throughout this study. In order to minimize the effect from the body movement, many methods had been applied such as for anytime of placing an electrode. The researcher applied curafix tape to fix an electrode to the subject's skin.

Muscular fatigue measurement, the researcher can measure muscular activity for the short period that demonstrated muscular fatigue of workers. But this study, the researcher measured muscular activity throughout working hours during 9.00 a.m. (start work) to 3 p.m. (end of work) that might increase error. Because the researcher had to know muscular activity of the workers all working hours in order to compare fatigue during work on improved workstation and existing workstation.

The posture and body dimensions of subjects must be in the same standard operating procedure. The standard and guideline of anthropometry of Kittit Intaranont (1988) (30) were applied in this study. The percentile 95 was selected as appropriate data, for improved workstation design because their value data form the most of samples. Although for this study selected 5th percentile, the standing base 40 cms. work height can use for the workers as same as 95th percentile because standard deviation was ± 1.52 cms.

4) In this study confounders were ruled out by controlling the general characters of total samples such as experiences of hanging materials on overhead conveyor, medical record, physical health status and rest was control in proximate subject.

5.1.2 Random error

The error could be occurred from selection of subject. In this study the subject would be selected by purposive sampling method. It is a conventional method which is usually applied in clinical research. According to the evaluation of the MVC of muscular activity values in hanging materials on overhead conveyor while working on improved workstation and existing workstation have normal distribution, therefore the subjects in this study could comparable.

5.2 Discussion of study results

5.2.1 Muscular fatigue situation of hanging materials on overhead conveyor workers.

The results of the primary survey about the health status of 20 male hanging materials on overhead conveyor workers showed that mean age of sample was 27.55 ± 1.36 years old. Mean weight and height were 60.80 ± 1.92 kilograms, 165.01 ± 1.59 centimeters respectively. The durations of work as hanging materials on overhead conveyor workers were 4.67 ± 0.46 years. All of them had no musculoskeletal and bone disease. However, they have problem about muscular fatigue while working, the deltoideus was the highest (90%), low back (85%) and trapezius (75%), respectively. Frequency of muscular pains, which occurred every day and stop working and take medicine (35%), is the treatment.

This outcome was similar to Ryan G.A. (1989) (47) studied in supermarket workers have a high incidence of lower extremity discomfort and pain. Legs discomfort and fatigue were also found among assembly and quality control inspection workers.

5.2.2 Subjective feeling of fatigue by questionnaire.

The evaluation of fatigue feeling of general bodily, deltoideus muscle and erector spinae muscle were conducted by interviewing and using questionnaire. This questionnaire had seven levels as straight line with the score 0-7. 0 means subjects did not fatigue and seven means extremely fatigue. The result showed that fatigue feeling of general bodily, deltoideus muscle and erector spinae muscle while working on improved workstation was significantly less than while on existing workstation with 95% confidence interval at $P < 0.05$. The data was presented in Table 4-4, 4-5, and 4-6, Figure 4-3, 4-4 and 4-5.

From the study outcome, it was found that the fatigue feeling of general bodily, deltoideus and erector spinae muscular fatigue showed the same profile. However, not only while working on improved workstation but also on existing workstation. It means that working on improved workstation could reduce the fatigue feeling. This results was similar to the study of Chaffin (1973) (37) reported the effect of carrying objects in varied height by measuring muscular fatigue by EMG study in

sampling healthy men. The relations of the period of muscular fatigue would be increased while elevating the arms in high level and loading objects by hands.

5.2.3 Muscular activity by electromyography.

5.2.3.1 Deltoideus muscle

The measurement was carried out by mean of percent maximum voluntary contraction (%MVC) of deltoideus muscle. Thus, if % MVC of deltoideus muscle while working on improved workstation was significantly less than existing workstation. It means that while the subjects were working on improved workstation, the levels of deltoideus muscle activity were less than while working on existing workstation.

The results showed that % MVC of deltoideus muscle while working on improved workstation was significantly less than existing workstation with 95% confidence interval at $P < 0.05$. The data was presented in Table 4-7, Figure 4-6. This results were similar to the study of Chaffin (1973) (37) reported that the distance of reaching arm in the further position and loading too much weight object will cause the fatigue in shoulder. Sommerich et.al. (1993) (41) recommended that working with abnormal postures, static postures, heavy work, repetitive movement, working at shoulder level and insufficient of resting can be assumed as risk factor which related to shoulder pain. Spaepen A.J. (48) studied the analysis of musculoskeletal disorders due to repetitive work and low back load in the working environment by electromyography (EMG) technique that were used to reduce the number of overload disorders during assembly tasks.

5.2.3.2 Erector spinae muscle

The measurement was carried out by mean of percent maximum voluntary contraction (%MVC) of erector spinae muscle. Thus, if % MVC of deltoideus muscle while working on improved workstation was significantly less than existing workstation. It means that the subjects were working on improved workstation, the levels of erector spinae muscle activity were less than while working on existing workstation.

The results showed that % MVC of erector spinae muscle while working on improved workstation was significantly less than existing workstation with

95% confidence interval at $P < 0.05$. The data was presented in Table 4-8, Figure 4-7.

This results were similar to the study Yamamoto et.al., (1997) (49) reported that lifting objects is one of the major risk of low back injuries and has also a higher prevalence of low back injuries.

5.2.4 Correlation of fatigue indicators between fatigue feeling by questionnaire and muscle fatigue by electromyography.

The muscle fatigue coefficient correlation evaluation by % MVC and questionnaire showed little correlation or was not significant at 95% of confidence interval ($p > 0.05$). The data was presented in Table 4-9 and Table 4-10.

This results similar to Shackel (1969) who reported that subjective feeling of fatigue by using comment of subjects was not necessary to consistent with results. Lecarpentier (1969) reported that the results of the subjective methods from the same subject on each time were difference.

5.2.5 Result of working conditions

The results of working condition; workplace temperature was evaluates by monitor throughout the experimental time about 6 working-hours. The workplace temperature was monitored for 4 times; before work (9.00 a.m.), before lunch (12.00 a.m.), after lunch (1.00 p.m.) and end of work (3.00 p.m.) The subjects took lunch during 12.00 a.m. to 1.00 p.m.

The difference of workplace temperature of working on improved workstation and existing workstation was determined by using paired t-test. The result showed no significant difference at 95% of confidence interval ($P\text{-value} < 0.05$). The data was presented in Table 4-11, Figure 4-8. Thus, the result presented no difference while working on improved workstation and existing workstation in workplace temperature. However, maintain a comfortable environment that is performed can directly and indirectly affect not only the comfort and health of hanging materials on overhead conveyor workers. One important goal is avoid temperature extremes which do not control them in real workstation.

5.2.6 Result of duration per work item (minutes/piece) of samples.

The duration per work item was evaluated by same item, same subjects and using stop clock and recording the time used for hanging each material on overhead conveyor each work item.

The difference of duration per work item was evaluated while subjects were working on existing workstation and improved workstation was determined by using paired t-test. The result showed that duration per work item of working on improved workstation was significantly less than that working on existing workstation with 95% of confidence interval ($P\text{-value} < 0.05$), was presented in Table 4-12.

This result from the change workstation was adjusted for individual worker based on the anthropometry data. The workers have good posture and have more rest time per work item that cumulative fatigue do not occurs on improved workstation. Thus, the muscular fatigue was reduced by improved workstation. This outcome was similar to the study of Resnick M.L. and A. Zanotti (1997) (45) reported that the movement of parts, more work could be done per movement lead to decrease in speed. Reducing movement distances can have a significant improvement on movement time.

CHAPTER VI

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

1. Fatigue feeling of general bodily fatigue while working on improved workstation was significantly less than on existing workstation ($P < 0.05$).

2. Fatigue feeling of deltoideus muscle fatigue while working on improved workstation was significantly less than on existing workstation ($P < 0.05$).

3. Fatigue feeling of erector spinae muscle fatigue while working on improved workstation was significantly less than on existing workstation ($P < 0.05$).

4. Deltoideus muscular activity while working on improved workstation was significantly less than on existing workstation ($P < 0.05$).

5. Erector spinae muscular activity while working on improved workstation was significantly less than on existing workstation ($P < 0.05$).

6. There was little relationship of fatigue indicator between fatigue from questionnaire and muscular activity measurement from electromyography and was not significant at 95% of confidence interval ($P\text{-value} > 0.05$).

7. The working condition; workplace temperature while working on improved workstation and existing workstation was not significant at 95% of confidence interval ($P\text{-value} > 0.05$).

8. The duration per work item (minute/piece) while working on improved workstation was significantly less than on existing workstation ($P < 0.05$).

6.2 Recommendation for hanging materials on overhead conveyor workers.

1. This study was shown that working on improved workstation is appropriated for hanging materials on overhead conveyor workers in air conditioner factory. The improved workstation can reduce the muscular activity fatigue. From this study it will be very helpful to apply improved workstation in other works such as hanging material on overhead conveyor in the other factory; motorcycle factory or food factory.

2. The future studied should include a larger number of participants in order to increase a power of the study.
3. The improved workstation should adjust for individual worker based on the anthropometry data.
4. Attach plate to prevent the workers slide down from the base while working on improved workstation.
5. Maintain a comfortable environment that is performed can directly and indirectly affect not only the comfort and health of hanging material on overhead conveyor workers but also the quality and efficiency of work being done. There are many issues here but one important goal is avoid temperature extremes which do not control them in real workstation.
6. Training to hanging material on overhead conveyor workers before working on improved workstation, because of quality efforts reinforce the need for more training of the work force, both in specific technical skill as well as more general areas such as improving communications skill and group problem solving skills. Similar, effective workplace ergonomics programs typically emphasize training in a variety of ways, such as principle of ergonomics, improved work methods and use of ergonomically improved equipment.

6.3 Recommendation for further study

1. Structure of this improved workstation could be changes for an appropriate application.
2. Muscular fatigue of trapezius muscle and legs (gastrocnemius muscle) should be measured in the further study. Because the muscular fatigue was reduced with using standing base 40 work heights that the workers stand all time while working on improved workstation. They might to occur workload on gastrocnemius muscle in stead.
3. Other aspects, such as the angle of shoulder should be investigated.
4. The capillary refilling method should test the samples before experiment.
5. The parallels between ergonomics and the quality improvement process are striking that ergonomics provide concerning both quality and productivity. It also

makes the point that ergonomics fits well into the efforts to improved quality and to rethink what really increases productivity.

6. A workplace can be designed to improve long-term performance and maximize the contribution of the job to the profitability of the organization. Additional research must be conducted to consider additional variables and tasks.

7. In the further study should be measured “dehydration condition” of subjects. Because dehydration condition more than 2% can reduce performance of hanging materials on overhead workers. However, nearby workstation has cooling water tank for the workers can drink. It can prevent for these problem.

REFERENCES

1. ชมภูศักดิ์ พูลเกษ. การยกของกับการปวดหลัง. เอกสารประกอบการศึกษาวิชาของค์ประกอบของมนุษย์เกี่ยวกับความปลอดภัย. กรุงเทพมหานคร : ภาควิชาอาชีวอนามัยและความปลอดภัย คณะสาธารณสุขศาสตร์ มหาวิทยาลัยมหิดล; 2542.
2. Mostardi RA, Noe DA, Kovacik MW, Porterfiled JA. Isokinetic lifting strength and occupational injury a prospective study. Spine 1992; 17(2): 189-193.
3. National Institute for Occupational Safety and Health. Back belts do they prevent injury?: NIOSH(Online): <http://www.cdc.gov./niosh/homepage.html>.
4. กองทุนเงินทดแทน. รายงานการประสพอันตรายหรือเจ็บป่วยจากการทำงาน. นนทบุรี : สำนักงานประกันสังคม; 2547.
5. สุทิน อยู่สุข. กลศาสตร์ชีวภาพในการทำงาน. เอกสารการสอนชุดวิชาเออร์گونอมิกส์และจิตวิทยาการทำงาน. มสช. นนทบุรี : โรงพิมพ์มหาวิทยาลัยสุโขทัยธรรมมาธิราช; 2534.
6. Nikolai, Bogduk, Twomey LT. Clinical anatomy of the lumbar spine. 2 nd ed. London : Churchill Livingstone; 1991
7. วุฒิพงษ์ ปรมัตถากร, อารี ปรมัตถากร. ระบบกล้ามเนื้อ. กรุงเทพมหานคร : คณะทันตแพทย์ศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย; 2531.
8. ราตรี สุดทรวง. ประสาทสรีรวิทยา. กรุงเทพมหานคร : คณะแพทยศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย; 2531
9. อภิชนา ไชวินทะ. กล้ามเนื้อบริเวณไหล่. กายวิภาคศาสตร์ ระบบการเคลื่อนไหว. กรุงเทพมหานคร : เมดิคัลมีเดีย; 2533
10. Back pain. เอกสารประกอบการศึกษาทางเออร์โธปีดิคส์. ขอนแก่น : คณะแพทยศาสตร์ มหาวิทยาลัยขอนแก่น; 2529.
11. Yu T, Roht LH, Wise RA, Kilian DJ, Weir FW. Low-back pain in industry. J of Occ Med 1984; 26:517-524.
12. Gradjean E. Fitting the task to the man: A textbook of Occupational Ergonomics. 4th Edition .London : Taylor & Francis; 1988

13. ชมภูศักดิ์ พูลเกษ. การปฏิบัติการจัดสภาพการทำงาน. การฝึกปฏิบัติงานอาชีพอนามัยความปลอดภัยและเออร์กอนอมิกส์ มสธ. นนทบุรี : มหาวิทยาลัยสุโขทัยธรรมาธิราช; 2534.
14. เพ็ญพิมล ชรรมรัคคิต. สรีรวิทยาของระบบกล้ามเนื้อ.ขอนแก่น : คณะแพทยศาสตร์ มหาวิทยาลัยขอนแก่น; 2528.
15. สติธร เทพตระการพร. การทำงานที่ใช้กล้ามเนื้อและความล้า. เอกสารวิชาการกองอาชีพอนามัย ; 2538: หน้า 110-122.
16. Corlett, Bishop. A technique for assessing postural discomfort. Ergonomics 1976; 19(2): 175-182.
17. นิวัต เจริญใจ. การออกแบบเชิงการยศาสตร์ของท่านั่งสำหรับงานเชื่อมท่อ (วิทยานิพนธ์ปริญญาวิศวกรรมศาสตรมหาบัณฑิต ภาควิชาวิศวกรรมอุตสาหกรรม). กรุงเทพมหานคร : บัณฑิตวิทยาลัย จุฬาลงกรณ์มหาวิทยาลัย; 2534.
18. สมพิศ พันธุเจริญศรี. การปรับปรุงบริเวณที่ทำงานเพื่อลดความเมื่อยล้าในคนงานหญิงเย็บจักรอุตสาหกรรม (วิทยานิพนธ์ปริญญาวิทยาศาสตรมหาบัณฑิต สาขาวิชาสุขศาสตร์อุตสาหกรรมและความปลอดภัย). กรุงเทพมหานคร : บัณฑิตวิทยาลัย มหาวิทยาลัยมหิดล; 2535.
19. Mega Electronic Ltd. Muscle tester ME300 professional: user's manual. Finland; 1996.
20. Ohashi j, Twanaga k, Sato H. Relation of subjective sensations to electromyograms and heart rate in sustained isometric shoulder abductions at 5-50% MVC. J Human Ergol 1987;8:3-17
21. Soderbery GL. Application of electromyography for use in the occupational setting. US: Department of Health and Human Services; 1992.
22. Mask RS. Functional muscle: effect on electromyography output. In advance in industrial ergonomics and safety II. London: Tayloy & Francis; 1992.
23. Schoenmarklin WR, Marras WS. Effects of handle angle and work orientation on hammering II. Muscle fatigue and subjective rating of body discomfort. Human Factors 1989; 31: 413-20.
24. Pertrofshy JS. Quantifacation through the surface EMG of muscle fatigue and recovery during successive isometric contrations. Env Med 1981; 52: 545-550

25. Kumar SW, Mital A. Electromyography of upper extremity muscles and ergonomic applications; electromyography in ergonomics. London: Tayloy & Francis; 1996.
26. Feng Y, Grooten W, Wretenberg P, Arborelius UP. Effects of arm suspension in simulated assembly line work: muscular activity and posture ankles. *Appl Ergo* 1999; 30: 247-253.
27. Van Dieen J.H., Toussaint H.M., Thissen C., and van de Ven. Spectral Analysis of Erector Spinae EMG during Intermittent Isometric Fatiguing Exercise. *Ergonomics* 1993;36:407-414
28. Aniruth Manothum. The construction of a ceramic painter's chair for reducing muscular fatigue. [M.Sc.Thesis in Industrial Hygiene and Safety]. Bangkok: Faculty of Graduates Studies, Mahidol University; 2000.
29. Mark S. Sanders and Ernest J. McCormick. Human factors in Engineering and design. 7th Edition. Singapore: Mc. Graw Hill; 1993.
30. Kitti Intaranont. Antropometry and Physical Work Capacity of Agricultural and Industrial Populations in Northeast Thailand. [Institute of Research and Development]. Department of Industrial Engineering. Koenkaen University; 1988.
31. Kroemer K.H.E., H.B. Kroemer and K.E. Kroemer-Elbert. Ergonomics how to design for Ease and Efficiency. New Jersey: Prentice-Hall; 1994
32. Hertzderg H.T.E. The conference on standardization of anthropometric techniques and terminology. *American Journal of Physical Anthropology*. 1968; 28 (1): 1-16.
33. Van Cott H.P. and Kinkade. Human Engineering Guide to Equipment Design. 2nd Edition. Wasington, D.C.; 1972.
34. Roebuck J.A., Kroemer K.H.E. and W.G. Thomsom. Engineering Anthropometry Methods. New York: John Wiley & Sons; 1975.
35. Kovit Satvuthi. Sume Anthropometrical Data of the works in Central Thailand. Final Reports to Engineering Research Institute: Chulalongkorn University; 1979.

36. สำนักงานมาตรฐานผลิตภัณฑ์อุตสาหกรรม กระทรวงอุตสาหกรรม. รายงานการสำรวจและวิจัยขนาดโครงสร้างร่างกายคนไทย ระยะที่ 4: พ.ศ. 2543-2544. กระทรวงอุตสาหกรรม: กรุงเทพมหานคร; 2543.
37. Chaffin DB, Andersson GB. Occupational Biomechanics. 2nd Edition. New York: John Wiley & Sons; 1991.
38. Punnett L. Soft tissue disorders in the upper limbs of female garment workers. *Scand J of Work & Env H* 1985; 3:119-125.
39. Markel A., C.S. Layne, J.J. Bloomberg and J.J. Zhang. Using factor analysis to identify neuromuscular synergies during treadmill walking. *Journal of Neuroscience Methods*. 1988; 82(2): 207-214.
40. Westgard RH, Jansen T. Individual and work related factors associated with symptoms of musculoskeletal complaints II different risk factors among sending machine operators; working at piecework rated. *Appl Ergo* 1992; 17: 66-71.
41. Sommerich CM, Meglathin JD, Marras W. Occupational risk factors associated with soft tissue disorders of the shoulder: A review of recent investigations in the literature. *Ergonomics* 1993; 119-125.
42. Joseph Knapik, Everett Harman and Katy Reynolds. Load carriage using packs: A Review of Physiological, biomechanical and medical aspects. *Applied Ergonomics*. 1996; 27 (3): 207-216.
43. Shihan Bao, svend Erik Mathiaseen and Jorgen Winkel. Ergonomic effects of a management-based rationalization in assembly work-a case study. *Applied Ergonomics*. 1996; 27 (2): 89-99.
44. Roland Kadefors, Tomas Engström, Jan Petzäll and Lars Sundström. Ergonomics in parallelized car assembly: a case study, with reference also to productivity aspects. *Applied Ergonomics*. 1996; 27 (2): 101-110.
45. Resnick M.L. and A. Zanotti. Using Ergonomics to Target Productivity Improvements. *Computers Industrial Engineering*. 1997; 33 (1-2): 185-188.
46. Kazutaka Kogi, Tsuyoshi kawakami, Toru Itani and Jose Maria Batino. Low-cost work improvements that can reduce the risk of musculoskeletal disorders.
47. Ryan G.A. The prevalence of musculoskeletal symptoms in supermarket workers. *Ergonomics*. 1989; 32: 359-370.

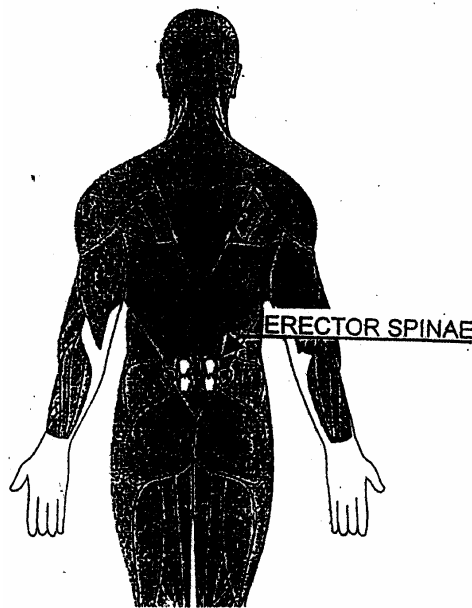
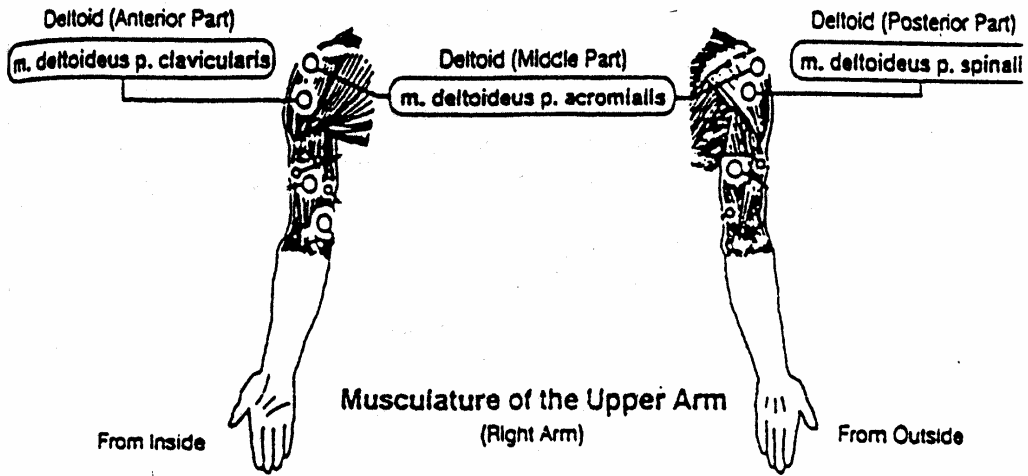
48. Spaepen A.J. Analysis of musculoskeletal disorders due to repetitive work load and low back load in the working environment. Laboratory for ergonomics and occupational Biomechanics. Katholieke Universiteit Leuven-KUL.
49. Yamamoto S. A new trend in the study of low back pain in workplace. *Industrial health* 1997; 35: 173-185.

APPENDIX

Electromyography measurement

Measurement process can be described as follow:

1. Skin was cleaned with 95% alcohol.
2. Sensor disposable 8 mm AgCl surface electrode (Blue sensor) was attached on the skin of the subject.
3. The locations of electrodes were at deltoideus muscle (Anterior part of right arm) and erector spinae muscle (L5) before working time as follows:
 - 3.1 To record the activity of deltoideus muscle.
 - The subjects were standing.
 - The research found out head of acromion.
 - To attached electrodes at midpoint between 1/3 of lead line length from the head of acromion.
 - 3.2 To record the activity of erector spinae muscle.
 - The subjects were standing erect.
 - The research found out parallel line to the spinal column on the crest of the erector spinae muscle and the central load point is 1/6 of the distance from the iliac crest to the spine of the 7th cervical vertebra above the iliac crest.
 - To attached electrodes at midpoint between 1/3 of lead line length from the head of acromion.
4. The electrodes are fixed in a bipolar way with both active electrodes measuring and reference - above the muscle and the ground electrode was attached about 10 cms. from active electrodes.
5. Surface electrode of right deltoideus muscle and erector spinae muscle was connected to channel 1 and 2, respectively of electromyography.
6. Electromyography recording was measured in the mean average of the raw electromyography signal, saving form, continuous measurement and average time every 10 seconds.



Surface electrode placement in EMG measurements

(A) M. Deltoideus (B) M. Erector spinae

Figure A-1 Positioning of electrodes on deltoideus muscle and erector spinae muscle.

7. Manual resistance was placed over the deltoideus muscle during attempted deltoideus elevation to get the MVC of deltoideus muscle.
8. Manual resistance was placed over the erector spinae muscle during attempted erector spinae elevation to get the MVC of erector spinae muscle.

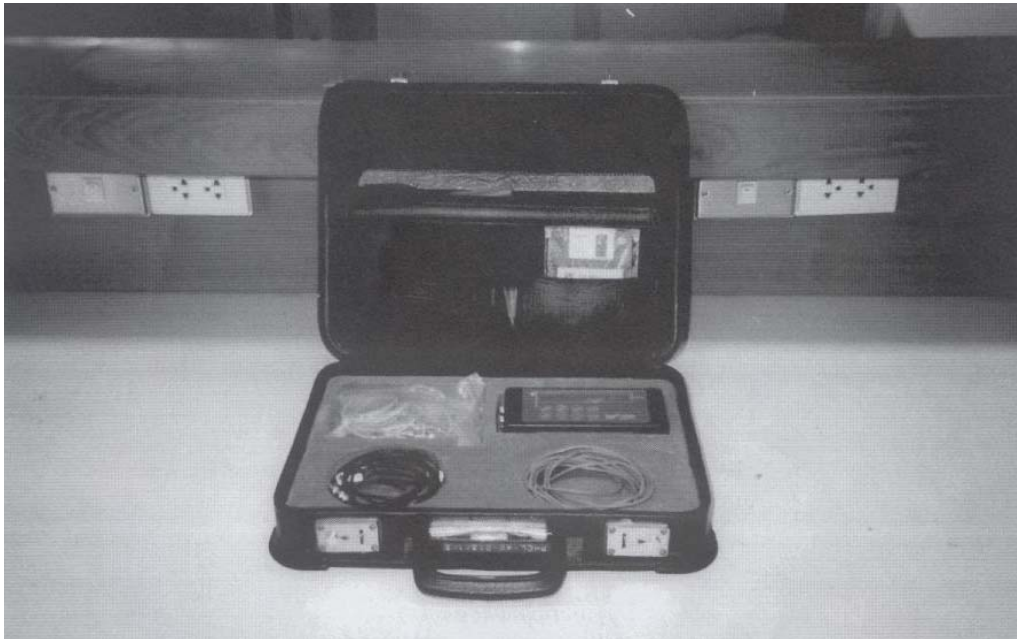
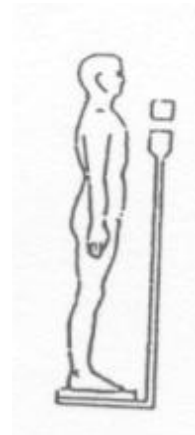


Figure A-2 Electromyography (Muscle tester Model ME300)

Measurement of anthropometric data

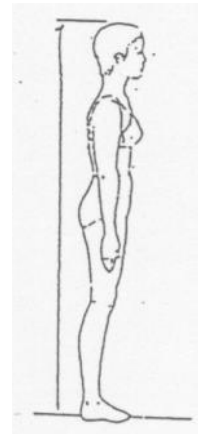
1. Weight

- Landmark : None
- Instrument : Balance type scales
- Position of subject : Subject stands on center of scale platform wearing underwear.
- Procedure : Adjust balance to within 0 kilogram and record.



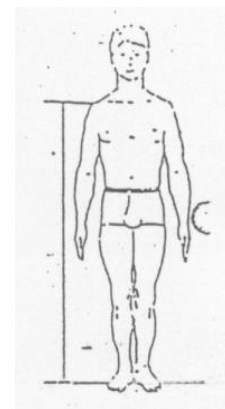
2. Stature

- Landmark : None
- Instrument : Anthropometer
- Position of subject : Subject stands erect, head in the Frankfort plane and weight distributed equality on both feet.
- Procedure : Measure the vertical distance from the standing surface to the top of the head.



3. Shoulder height

- Landmark : None
- Instrument : Anthropometer
- Position of subject : Subject stands fully erect with feet together.
- Procedure : The vertical distance from the floor to the acromion.



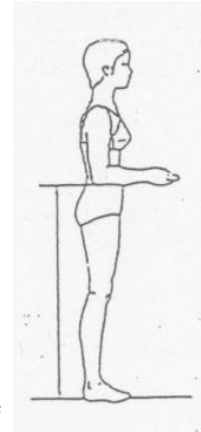
4. Elbow height

Landmark : None

Instrument : Anthropometer

Position of subject : Subject stands fully erect with feet together. The upper arm hangs freely downwards, the forearm is flexed at right angles to it.

Procedure : Measure the vertical distance from the floor to the lowest body point of the bent elbow.



5. Shoulder elbow length

Landmark : None

Instrument : Beam caliper

Position of subject : Subject stands erect with thighs fully supported and upper arm, hanging freely downwards.

Procedure : Measure the vertical distance from the acromion to the bottom of the elbow bent 90 degrees and the lower arm horizontal.

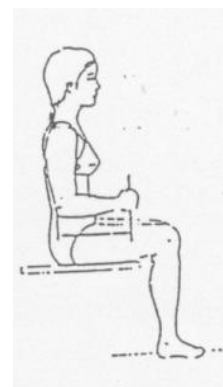


6. Elbow wrist length

Landmark : None

Instrument : Beam caliper

Position of subject : Subject stands erect with upper arm hanging downwards and the forearm bent at right angles to it. The hand holds the measuring rod upright, perpendicular to the floor (the longitudinal axis of the latter).



Procedure : Measure the horizontal distance from the back of the upper arm (at the elbow to the grip axis with the elbow bent at right angles, parallel to the floor.

7. Elbow fingertip length

Landmark : Olecranon and dactylion

Instrument : Beam caliper

Position of subject : Subject stands erect, upper arms hanging relaxed, forearms and hands extended forward horizontally.

Procedure : Measure the horizontal distance along the axis of the right forearm and hand from the posterior tip of the olecranon process to dactylion.



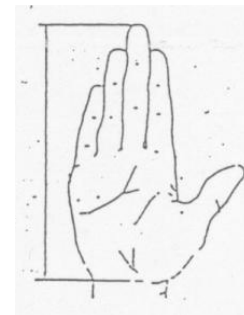
8. Hand length

Landmark : None

Instrument : Sliding caliper

Position of subject : Subject holds the forearm horizontal with hand outstretched, palm up. The point of measurement at the styloid process corresponds approximately to the middle skin furrow of the wrist.

Procedure : Measure the distance from the tip of the middle finger to the most distal point of the styloid process of the radius, measured with the hand outstretched.



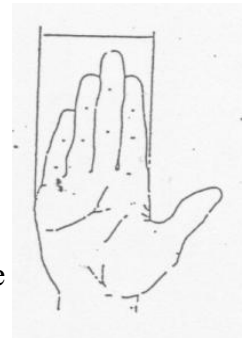
9. Hand breadth

Landmark : None

Instrument : Sliding caliper

Position of subject : Subject holds the forearm horizontal with the hand stretched out flat, palm up.

Procedure : Measure the distance along a straight line between radial and ulnar metacarpals at the level of the metacarpal heads from the second to the fifth.



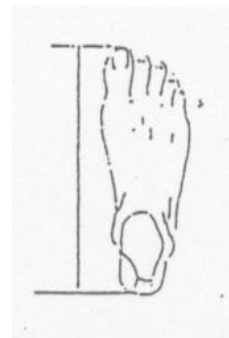
10. Foot length

Landmark : None

Instrument : Beam caliper

Position of subject : Subject stands with the weight equally distributed on both feet.

Procedure : Measure the maximum distance from rear of the heel to the tip of the longest (first or second) toe, measured parallel to the longitudinal axis of the foot.



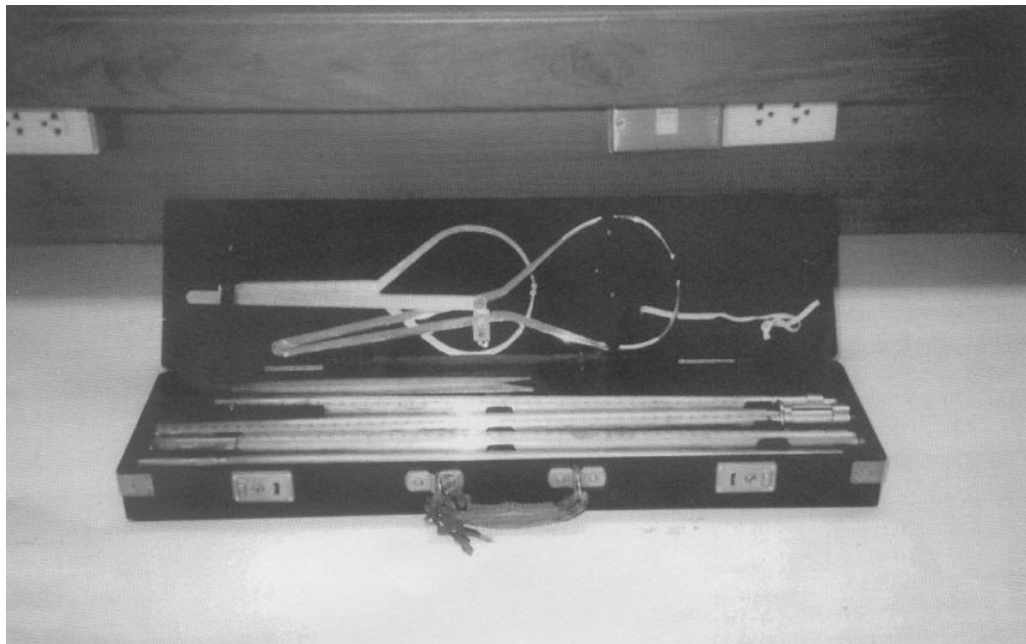


Figure B-1 Anthropometer

Anthropometric data form

Name-Surname Date

Age.....years.

Description of measurement	Measurement (cms.)
Weight	
Stature	
Shoulder height	
Elbow height	
Shoulder elbow length	
Elbow wrist length	
Elbow fingertip length	
Hand length	
Hand breadth	
Foot length	

Questionnaire of muscular fatigue survey

Please mark (X) in front of the item you agree.

Name of interviewer Date

General information

1. Name-Surname
2. Age years Weight.....kgs Height.....cms.
3. Experience in hanging material on overhead conveyer.....years.....months.

Physical health status

1. During the part six months. Have your ever been had muscular pain or fatigue?
 Yes No
2. Have you ever had bone and muscular accident?
 Yes No
3. Have you ever had bone and muscular disease?
 Yes No
4. What part of body you have usually pain or fatigue?
5. When you had mostly feeling of muscular fatigue?
 Before work On working-hour After work
6. How often does the muscular pain or fatigue in the past of six months occur?
 No muscular pain Sometime
 Every day Every week
7. How long does muscular pain or fatigue?
 Less than 1 day 1-3 days more than 3 days
 Other
8. How do you treat for reducing muscular pain or fatigue?
 Stop working Take medicine Self massage
 Consult doctor / physiotherapist Not do anything
 Other

15. How do you treat for reducing muscular pain or fatigue while hanging material on overhead conveyor?

- No muscular pain
- Stop working
- Take medicine
- Self massage
- Stop working and take medicine
- Not do anything
- Other

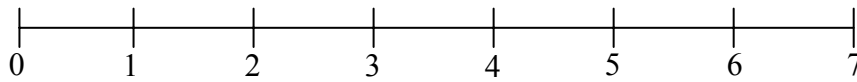
Fatigue feeling questionnaire

Name-Surname

Date Time.....

1. General bodily fatigue

Please answer your feeling of general bodily fatigue into seven score



Not fatigue

Extremely fatigue

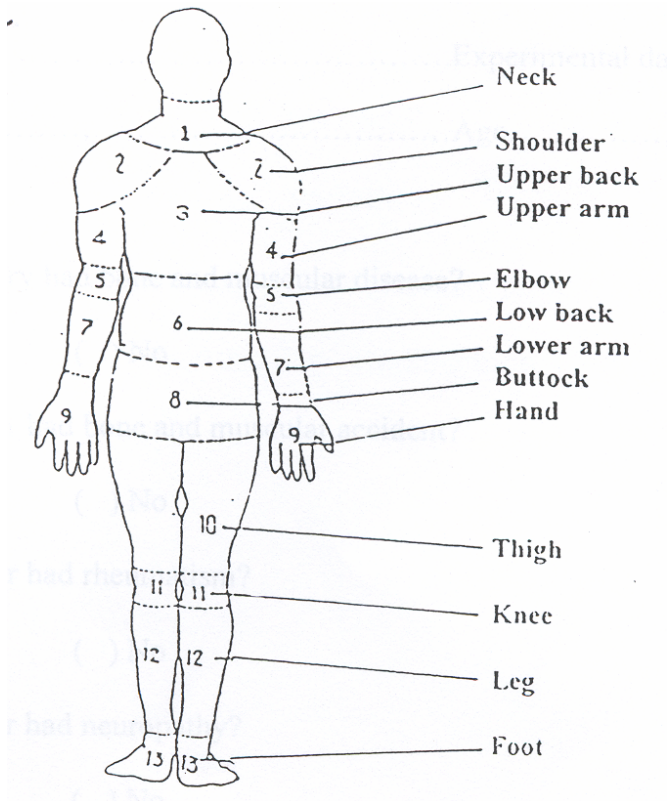
2. Local muscular fatigue

Please point to the body area, which you are currently fatigue and give the level of fatigue score.

The level of fatigue score as following:

0	means	Not fatigue
1	means	Start to feel fatigue
2	means	Slightly fatigue
3	means	Moderate fatigue, relief after resting
4	means	Moderate fatigue, can't relief even resting
5	means	Severely fatigue, relief after resting
6	means	Severely fatigue, can't relief after resting
7	means	Extremely fatigue that can't work

Left Right



Score of left feeling									Part of body	Score of right feeling								
0	1	2	3	4	5	6	7	1. Neck	0	1	2	3	4	5	6	7		
0	1	2	3	4	5	6	7	2. Shoulder	0	1	2	3	4	5	6	7		
0	1	2	3	4	5	6	7	3. Upper back	0	1	2	3	4	5	6	7		
0	1	2	3	4	5	6	7	4. Upper arm	0	1	2	3	4	5	6	7		
0	1	2	3	4	5	6	7	5. Elbow	0	1	2	3	4	5	6	7		
0	1	2	3	4	5	6	7	6. Low back	0	1	2	3	4	5	6	7		
0	1	2	3	4	5	6	7	7. Lower arm	0	1	2	3	4	5	6	7		
0	1	2	3	4	5	6	7	8. Buttock	0	1	2	3	4	5	6	7		
0	1	2	3	4	5	6	7	9. Hand	0	1	2	3	4	5	6	7		
0	1	2	3	4	5	6	7	10. Thigh	0	1	2	3	4	5	6	7		
0	1	2	3	4	5	6	7	11. Knee	0	1	2	3	4	5	6	7		
0	1	2	3	4	5	6	7	12. Leg	0	1	2	3	4	5	6	7		
0	1	2	3	4	5	6	7	13. Foot	0	1	2	3	4	5	6	7		

The characteristic of hanging materials on overhead conveyor form

Name-SurnameExperiment date

Age years Weight.....kgs Height.....cms.

Experience in hanging material on overhead conveyor.....years.....months.

Please answer the questions as following:

1. Have you ever had bone and muscular accident?

() Yes () No

2. Have you ever had bone and muscular disease?

() Yes () No

3. Have you ever had rheumatism?

() Yes () No

4. Have you ever had neuropathy?

() Yes () No

5. Do you have any present illness?

() Yes () No

6. How long do you sleep last night? hours.

7. Today, do you have any muscular pain or fatigue?

() Yes () No

8. Are you voluntarily with this experiment?

() Yes () No

Operating data recording form

Name-Surname

Date Age.....years.

() Improved workstation () Existing workstation

1. % MVC of channel # 1 = Deltoideus Muscle

2. % MVC of channel # 2 = Erector Spinae

3. Time for start =

4. Time for stop =

5. Other data

6. Remark

Time	Temperature (°C)	Duration per work item (minutes/piece)
9.00 a.m.		
12.00 a.m.		
1.00 p.m.		
3.00 p.m.		

List of abbreviations

I-WS	=	Improved workstation
E-WS	=	Existing workstation
A	=	Age (years)
W	=	Weight (kg)
H	=	Height (cm)
BMI	=	Body mass index (Kg/m ²)
SH	=	Shoulder height (cm)
EH	=	Elbow height (cm)
SEL	=	Shoulder elbow length (cm)
EWL	=	Elbow wrist length (cm)
EFL	=	Elbow fingertip length (cm)
HL	=	Hand length (cm)
HB	=	Hand breadth (cm)
FL	=	Foot length (cm)
N	=	Neck
UB	=	Upper back
LB	=	Low back
R1	=	Right shoulder and upper arm
R2	=	Right elbow
R3	=	Right lower arm
R4	=	Right wrist and hand
R5	=	Right thigh and buttock
R6	=	Right knee
R7	=	Right leg
R8	=	Right foot and ankle
L1	=	Left shoulder and upper arm
L2	=	Left elbow
L3	=	Left lower arm
L4	=	Left wrist and hand
L5	=	Left thigh and buttock

L6	=	Left knee
L7	=	Left leg
L8	=	Left foot and ankle
AVR	=	Average right of body
AVL	=	Average left of body

Table C-1 Anthropometry data of the hanging materials on overhead conveyor workers

Subject no.	A (years)	W (kg)	H (cm)	BMI (kg/m ²)	SH (cm)	EH (cm)	SEL (cm)	EWL (cm)	EFL (cm)	HL (cm)	HB (cm)	FL (cm)
1	25	59.5	165.6	21.7	133.2	104.1	44.4	34.2	51.3	18.1	8.7	25.1
2	25	62.0	166.8	22.2	132.6	102.5	42.7	32.3	49.2	17.8	8.4	23.6
3	28	65.0	164.2	24.1	134.4	105.1	44.6	34.1	52.3	18.7	9.1	24.9
4	28	61.0	165.5	22.3	132.7	102.4	42.3	32.5	50.2	17.9	8.2	24.3
5	29	60.0	162.1	22.8	134.8	104.6	43.7	33.2	50.6	18.4	8.7	24.8
6	27	60.0	165.8	21.8	132.2	103.1	44.9	35.3	49.5	17.1	7.9	23.5
7	26	59.0	166.7	21.2	133.5	104.5	43.4	34.5	51.7	18.3	8.4	24.8
8	29	60.0	164.1	22.3	136.2	106.3	45.2	35.4	52.1	17.2	8.9	25.8
9	28	59.0	166.4	21.3	132.9	103.5	42.4	33.8	51.2	18.9	8.1	24.6
10	27	61.0	164.5	22.5	133.2	104.7	43.8	34.2	51.6	18.5	8.2	24.3
11	30	65.0	162.4	24.7	133.5	104.3	43.1	34.1	52.2	19.1	8.4	25.1
12	29	58.5	167.2	20.9	132.8	103.4	43.1	34.6	50.5	17.0	8.0	23.6
13	28	62.0	165.9	22.5	132.6	104.2	43.6	34.2	51.7	18.2	8.6	24.3
14	28	60.5	163.5	22.6	132.5	103.4	43.5	34.7	52.1	17.7	8.1	24.1
15	27	64.0	162.5	24.2	135.4	105.5	45.1	35.2	50.4	18.1	8.7	24.7
16	27	60.0	165.5	21.9	132.4	102.7	42.4	33.5	50.3	17.9	8.2	23.8
17	28	59.0	163.8	22.0	132.9	104.2	43.7	34.1	51.4	18.8	8.1	23.9
18	26	60.0	165.7	21.9	133.1	104.6	43.9	34.9	52.2	18.3	8.7	24.5
19	29	61.0	164.6	22.5	134.3	105.9	44.2	35.1	52.8	18.4	8.9	25.2
20	27	59.5	167.3	21.2	132.7	103.3	43.1	34.6	51.2	17.3	8.2	24.7
Min	25	58.5	162.1	20.9	132.2	102.4	42.3	32.3	49.2	17.0	7.9	23.5
Max	30	65.0	167.3	24.7	136.2	106.3	45.2	35.4	52.3	19.1	9.1	25.8
Mean	27.6	60.8	165.0	22.3	135.0	104.1	43.7	34.2	51.2	18.1	8.4	24.5
S.D.	1.36	1.92	1.59	1.00	1.52	1.09	0.88	0.85	0.98	0.60	0.34	0.61

Table D-1 Average EMG of deltoideus muscle while hanging materials on overhead conveyor on improved workstation.

Subject no.	Average EMG (μv) min													MVC (μv)
	0	30	60	90	120	150	180	210	240	270	300	330	360	
1	34	44	39	35	40	54	41	37	45	36	46	49	36	453
2	25	35	43	37	28	41	36	44	16	23	26	45	22	251
3	13	16	12	18	23	24	20	22	28	23	18	28	20	232
4	24	22	14	16	25	16	12	20	17	14	23	21	21	184
5	40	18	41	51	32	36	52	35	40	32	38	42	32	381
6	15	11	12	14	15	24	11	11	11	14	26	11	14	331
7	15	21	14	16	35	20	15	13	29	49	17	12	25	259
8	33	35	29	23	27	31	58	76	38	46	27	31	27	171
9	15	23	20	13	28	23	25	15	15	12	20	27	25	244
10	56	49	48	22	36	54	37	44	42	40	20	40	35	473
11	24	11	20	18	11	13	20	16	15	25	20	21	20	195
12	14	30	36	53	61	33	32	61	22	23	30	29	38	514
13	19	29	35	15	34	34	31	37	37	35	31	37	20	256
14	31	28	35	38	40	51	50	54	48	39	29	35	38	171
15	21	20	24	17	13	37	20	29	26	29	16	23	26	313
16	26	31	39	42	39	41	29	56	26	36	37	26	35	174
17	24	25	33	26	35	21	19	20	33	25	24	31	39	229
18	18	14	18	12	12	15	9	12	12	12	16	12	12	278
19	24	28	27	32	30	36	30	36	37	55	32	32	38	190
20	35	53	53	66	61	66	71	48	89	58	56	53	63	291

Table D-2 Average EMG of erector spinae muscle while hanging materials on overhead conveyor on improved workstation.

Subject no.	Average EMG (μv) min													MVC (μv)
	0	30	60	90	120	150	180	210	240	270	300	330	360	
1	24	23	17	31	26	19	42	27	50	34	41	33	14	357
2	22	28	26	18	11	34	31	40	16	14	17	31	16	300
3	14	12	20	21	36	21	25	15	18	16	15	20	25	236
4	27	26	17	37	38	42	48	41	36	57	48	46	58	250
5	14	13	18	13	13	12	28	14	21	14	11	28	18	160
6	34	23	28	22	21	18	55	39	37	42	38	21	46	331
7	11	16	10	20	22	23	23	24	26	26	33	24	18	185
8	15	10	24	23	12	22	16	19	12	24	25	12	25	193
9	19	19	25	22	37	32	21	11	24	33	13	14	36	305
10	40	42	47	38	39	34	42	29	30	40	26	40	25	429
11	12	18	28	30	27	13	15	36	17	26	31	19	20	537
12	24	23	20	26	32	18	25	28	28	18	34	23	29	191
13	20	25	24	21	20	31	29	30	32	24	16	21	31	165
14	30	22	28	46	41	30	35	40	23	33	34	38	30	356
15	22	22	18	14	24	22	22	25	42	39	34	43	46	260
16	26	50	44	43	40	56	39	41	50	27	50	21	41	148
17	34	45	41	36	48	47	58	34	39	48	44	46	45	398
18	16	12	17	20	24	19	12	23	28	24	16	19	16	134
19	37	38	33	35	28	43	39	41	62	48	42	43	48	232
20	27	20	26	18	28	33	27	19	30	26	28	32	28	281

Table E-1 Average EMG of deltoideus muscle while hanging materials on overhead conveyor on existing workstation.

Subject no.	Average EMG (μv) min													MVC (μv)
	0	30	60	90	120	150	180	210	240	270	300	330	360	
1	163	154	208	215	213	209	285	202	223	207	149	203	156	425
2	101	64	69	80	111	72	53	60	44	44	69	75	69	319
3	13	22	18	27	25	24	24	27	30	22	67	26	21	203
4	32	23	20	30	60	40	40	24	27	27	43	40	44	189
5	150	101	152	134	158	112	141	126	157	154	139	140	157	426
6	63	55	52	48	33	52	14	33	15	52	12	26	36	379
7	55	48	65	60	51	70	52	53	53	43	76	53	54	224
8	88	85	91	107	101	99	134	112	97	62	67	69	73	213
9	20	34	36	42	36	39	31	25	44	39	38	36	36	265
10	55	41	35	33	52	41	60	77	75	63	57	37	28	301
11	36	19	27	35	79	73	18	30	49	39	25	28	50	154
12	58	61	60	76	104	57	63	72	79	99	102	65	54	434
13	52	47	65	38	41	37	43	44	40	43	46	46	48	273
14	34	41	38	51	36	58	55	80	43	43	43	45	42	149
15	78	115	126	108	99	105	104	98	67	125	126	128	67	289
16	32	31	58	37	39	57	31	51	50	32	32	35	39	143
17	40	32	36	26	38	26	28	33	30	19	32	50	54	203
18	46	49	79	62	76	93	59	75	52	51	33	59	43	335
19	70	61	64	56	65	59	66	67	60	84	64	49	55	237
20	156	65	69	113	74	83	76	119	116	68	75	74	73	242

Table E-2 Average EMG of erector spinae muscle while hanging materials on overhead conveyor on existing workstation.

Subject no.	Average EMG (μv) min													MVC (μv)
	0	30	60	90	120	150	180	210	240	270	300	330	360	
1	100	117	204	198	158	139	180	212	155	141	262	146	107	356
2	20	28	27	45	23	49	48	95	20	28	24	31	23	292
3	40	46	43	40	51	37	46	52	53	31	65	29	49	188
4	18	23	18	46	39	41	35	58	29	45	33	39	60	177
5	60	49	60	53	45	62	65	78	29	74	63	67	53	360
6	58	63	68	55	58	61	86	123	92	78	85	85	83	498
7	25	24	39	37	34	27	30	48	48	42	47	32	31	204
8	42	36	37	26	31	24	32	33	52	39	30	25	29	197
9	28	30	31	34	42	40	34	35	88	42	34	31	66	349
10	73	84	82	80	90	81	84	73	76	66	73	26	27	259
11	27	25	31	29	34	33	33	59	31	35	21	27	28	116
12	64	69	57	69	85	75	65	89	80	67	97	69	124	469
13	72	87	112	101	79	104	131	106	63	41	75	79	62	255
14	32	22	55	44	40	19	24	54	38	35	26	25	47	125
15	26	32	41	36	39	64	53	32	48	45	52	39	48	226
16	56	59	78	81	73	116	84	61	76	57	61	94	59	123
17	25	25	29	20	31	49	54	37	39	63	27	25	42	215
18	45	76	51	70	66	69	62	62	79	64	63	87	62	351
19	32	31	37	30	34	52	79	45	49	61	86	34	39	174
20	21	17	24	22	26	38	39	29	34	28	24	26	62	220

Table F-1 Comparison score of general bodily fatigue of the hanging materials on overhead conveyor workers between while working on improved workstation and existing workstation.

Subject no.	General bodily fatigue (score)							
	Working - hour							
	0 (9.00 a.m.)		3 (12.00 a.m.)		4 (1.00 p.m.)		6 (3.00 p.m.)	
	I-WS	E-WS	I-WS	E-WS	I-WS	E-WS	I-WS	E-WS
1	0	0	0	1	0	0	1	3
2	0	0	0	0	0	0	1	2
3	0	0	1	2	1	1	1	2
4	0	0	1	2	1	1	1	3
5	0	0	0	1	0	0	1	1
6	0	0	1	3	1	1	2	3
7	0	0	0	1	1	1	1	3
8	0	0	0	1	0	0	1	1
9	0	0	1	2	0	0	1	1
10	0	0	1	3	1	1	2	3
11	0	0	1	2	1	2	3	4
12	0	0	2	3	0	1	2	4
13	0	0	0	1	0	0	1	1
14	0	0	1	2	1	1	3	4
15	0	0	2	3	1	1	2	3
16	0	0	1	2	0	0	1	3
17	0	0	0	1	0	0	1	2
18	0	0	1	2	1	1	3	4
19	0	0	1	2	0	1	2	3
20	0	0	1	2	0	0	2	3

I-WS = Improved workstation / E-WS = Existing workstation

Table F-2 Comparison score of deltoideus muscular fatigue of the hanging materials on overhead conveyor workers between while working on improved workstation and existing workstation.

Subject no.	Deltoideus muscular fatigue (score)							
	Working - hour							
	0 (9.00 a.m.)		3 (12.00 a.m.)		4 (1.00 p.m.)		6 (3.00 p.m.)	
	I-WS	E-WS	I-WS	E-WS	I-WS	E-WS	I-WS	E-WS
1	0	0	1	1	0	1	3	4
2	0	0	2	3	1	2	3	4
3	0	0	2	3	1	2	3	4
4	0	0	1	2	0	1	2	3
5	0	0	1	2	1	2	3	4
6	0	0	0	1	1	2	3	4
7	0	0	1	2	1	2	3	4
8	0	0	1	2	0	1	2	3
9	0	0	1	2	0	1	2	3
10	0	0	2	3	1	2	3	4
11	0	0	1	2	1	2	3	4
12	0	0	0	1	0	1	2	3
13	0	0	0	1	0	1	2	3
14	0	0	1	2	1	2	3	4
15	0	0	1	2	1	2	3	4
16	0	0	2	3	1	2	3	4
17	0	0	2	3	1	2	2	3
18	0	0	1	2	2	3	4	5
19	0	0	1	2	1	2	3	4
20	0	0	0	1	1	2	3	4

I-WS = Improved workstation / E-WS = Existing workstation

Table F-3 Comparison score of erector spinae muscular fatigue of the hanging materials on overhead conveyor workers between while working on improved workstation and existing workstation.

Subject no.	Erector spinae muscular fatigue (score)							
	Working - hour							
	0 (9.00 a.m.)		3 (12.00 a.m.)		4 (1.00 p.m.)		6 (3.00 p.m.)	
	I-WS	E-WS	I-WS	E-WS	I-WS	E-WS	I-WS	E-WS
1	0	0	1	1	0	1	2	3
2	0	0	1	2	0	1	2	3
3	0	0	0	1	0	0	1	2
4	0	0	1	2	0	0	1	2
5	0	0	2	3	1	1	2	3
6	0	0	1	2	1	1	3	4
7	0	0	1	2	1	2	3	4
8	0	0	2	3	0	1	3	4
9	0	0	1	2	0	1	2	3
10	0	0	1	2	1	2	3	4
11	0	0	0	1	1	2	3	4
12	0	0	0	1	0	1	2	3
13	0	0	1	2	0	1	2	3
14	0	0	2	3	0	1	3	4
15	0	0	1	1	1	2	3	4
16	0	0	1	2	1	2	3	4
17	0	0	1	3	0	1	2	3
18	0	0	2	3	0	1	3	4
19	0	0	1	2	1	1	2	3
20	0	0	1	2	0	1	2	3

I-WS = Improved workstation / E-WS = Existing workstation

Table G-1 Comparison score of working temperature and the duration per work item of the hanging materials on overhead conveyor workers between while working on improved workstation and existing workstation.

Subject no.	Temperature (⁰ C)								Work items	
	0 (9.00 a.m.)		3 (12.00 a.m.)		4(1.00 p.m.)		6 (3.00 p.m.)		(minutes/piece)	
	I-WS	E-WS	I-WS	E-WS	I-WS	E-WS	I-WS	E-WS	I-WS	E-WS
1	26	26	29	30	31	31	32	32	1.29	1.32
2	28	27	30	30	31	31	31	31	1.24	1.31
3	25	26	30	31	32	32	32	32	1.25	1.31
4	26	27	30	30	30	30	31	31	1.24	1.32
5	28	28	29	30	31	31	32	33	1.25	1.31
6	27	27	28	29	30	30	31	32	1.24	1.28
7	26	27	28	29	30	30	31	31	1.26	1.29
8	25	26	28	29	30	30	30	30	1.29	1.32
9	26	26	29	29	29	30	32	32	1.26	1.30
10	27	27	30	30	32	32	33	32	1.29	1.31
11	27	28	30	30	31	31	32	32	1.24	1.29
12	28	29	31	31	32	32	33	32	1.28	1.33
13	27	28	30	30	30	30	31	31	1.26	1.31
14	26	25	27	28	29	30	31	32	1.26	1.31
15	27	27	28	29	30	30	31	31	1.29	1.31
16	25	26	28	29	30	30	31	31	1.29	1.32
17	28	27	29	29	30	30	30	30	1.29	1.31
18	28	28	30	30	31	31	32	32	1.26	1.31
19	29	28	29	30	30	30	31	31	1.29	1.33
20	27	27	28	29	30	30	31	31	1.28	1.33

I-WS = Improved workstation / E-WS = Existing workstation

Table H-1 Comparison of % MVC of Deltoides muscle while hanging materials on overhead conveyor on improved workstation and existing workstation.

Subject no.	0		30		60		90		120		150		180		210		240		270		300		330		360		
	I-WS	E-WS	I-WS	E-WS	I-WS	E-WS	I-WS	E-WS	I-WS	E-WS	I-WS	E-WS	I-WS	E-WS	I-WS	E-WS	I-WS	E-WS	I-WS	E-WS	I-WS	E-WS	I-WS	E-WS	I-WS	E-WS	
1	8	38	10	36	9	49	8	51	9	50	12	49	9	67	8	48	10	52	8	49	10	35	11	48	8	37	
2	10	32	14	20	17	22	15	25	11	35	16	23	14	17	18	19	6	14	9	14	10	22	18	24	9	22	
3	6	6	7	11	5	9	8	13	10	12	10	12	9	12	9	13	12	15	10	11	8	33	12	13	9	10	
4	13	17	12	12	8	11	9	16	14	32	9	21	7	21	11	13	9	14	8	14	13	23	11	21	11	23	
5	10	35	5	24	11	36	13	31	8	37	9	26	14	33	9	30	10	37	8	36	10	33	11	33	8	37	
6	5	17	3	15	4	14	4	13	5	9	7	14	3	4	3	9	3	4	4	4	14	8	3	3	7	4	9
7	6	25	8	21	5	29	6	27	14	23	8	31	6	23	5	24	11	24	19	19	7	34	5	24	10	24	
8	19	41	20	40	17	43	13	50	16	47	18	46	34	63	44	53	22	46	27	29	16	31	18	32	16	34	
9	6	8	9	13	8	14	5	16	11	14	9	15	10	12	6	9	6	17	5	15	8	14	11	14	10	14	
10	12	18	10	14	10	12	5	11	8	17	11	14	8	20	9	26	9	25	8	21	4	19	8	12	7	9	
11	12	23	6	12	10	18	9	23	6	51	7	47	10	12	8	19	8	32	13	25	10	16	11	18	10	32	
12	3	13	6	14	7	14	10	18	12	24	6	13	6	15	12	17	4	18	4	23	6	24	6	15	7	12	
13	7	19	11	17	14	24	6	14	13	15	13	14	12	16	14	16	14	15	14	16	12	17	14	17	8	18	
14	18	23	16	28	20	26	22	34	23	24	30	39	29	37	32	54	28	29	23	29	17	29	20	30	22	28	
15	7	27	6	40	8	44	5	37	4	34	12	36	6	36	9	34	8	23	9	43	5	44	7	44	8	23	
16	15	22	18	22	22	41	24	26	22	27	24	40	17	22	32	36	15	35	21	22	21	22	15	24	20	27	
17	10	20	11	16	14	18	11	13	15	19	9	13	8	14	9	16	14	15	11	9	10	16	14	25	17	27	
18	6	14	5	15	6	24	4	19	4	23	5	28	5	18	4	22	4	16	4	15	8	10	4	18	4	13	
19	13	30	15	26	14	27	17	24	16	27	19	25	16	28	19	28	19	25	29	35	17	27	17	21	20	23	
20	12	64	18	27	18	29	23	47	21	31	23	34	24	31	16	49	31	48	20	28	19	31	18	31	22	30	

I-WS = Improved workstation / E-WS = Existing workstation

Table H-2 Comparison of % MVC of Erector spinae muscle while hanging materials on overhead conveyor on improved workstation and existing workstation.

Subject no.	0		30		60		90		120		150		180		210		240		270		300		330		360	
	I-WS	E-WS	I-WS	E-WS	I-WS	E-WS	I-WS	E-WS	I-WS	E-WS	I-WS	E-WS	I-WS	E-WS	I-WS	E-WS	I-WS	E-WS	I-WS	E-WS	I-WS	E-WS	I-WS	E-WS	I-WS	E-WS
1	7	28	6	33	5	57	9	56	7	44	5	39	12	51	8	60	14	44	10	40	11	74	9	41	4	30
2	7	7	9	10	9	9	6	15	4	8	11	17	10	16	13	33	5	7	5	10	6	8	10	11	5	8
3	6	21	5	24	8	23	9	21	15	27	9	20	11	24	6	28	8	28	7	16	6	35	8	15	11	26
4	7	10	10	13	7	10	15	26	15	22	17	23	19	20	16	33	14	16	23	25	19	19	18	22	23	34
5	9	17	8	14	11	17	8	15	8	13	8	17	18	18	9	22	13	8	9	21	7	18	18	19	11	15
6	10	12	7	13	8	14	7	11	6	12	5	12	17	17	12	25	11	18	13	16	11	17	6	17	14	17
7	6	12	9	12	5	19	11	18	12	17	12	13	12	15	13	24	14	24	14	21	18	23	13	16	10	15
8	8	21	5	18	12	19	12	13	6	16	7	12	8	16	10	17	6	26	12	20	13	15	6	13	13	15
9	6	8	6	9	8	9	7	10	12	12	10	11	7	10	4	10	8	25	11	12	4	10	5	9	12	19
10	9	28	10	32	11	32	9	31	9	35	8	31	10	32	7	28	7	29	9	25	6	28	9	10	6	10
11	2	23	3	22	5	27	6	25	5	29	2	28	3	28	7	51	3	27	5	30	6	18	4	23	4	24
12	13	14	12	15	10	12	14	15	17	18	11	28	13	14	15	19	15	17	9	14	18	21	12	15	15	26
13	12	28	15	34	15	44	13	40	12	31	19	41	18	51	18	42	19	25	15	16	10	29	13	31	19	24
14	8	26	6	18	8	44	13	35	12	32	8	15	10	19	11	43	6	30	9	28	10	21	11	20	8	38
15	8	12	8	14	7	18	5	16	9	17	8	30	8	22	10	14	16	21	15	20	13	23	17	17	18	21
16	18	46	34	48	30	63	29	66	27	59	38	94	26	68	28	50	34	62	18	46	34	50	14	76	28	48
17	9	12	11	12	10	13	9	9	12	14	12	23	15	25	9	17	10	18	12	29	11	13	12	12	11	20
18	12	13	9	22	13	15	15	20	18	19	14	20	9	18	17	18	21	23	18	18	12	18	14	25	12	18
19	16	18	16	18	14	21	15	17	12	20	19	30	17	45	18	26	27	28	21	35	18	49	19	20	21	22
20	10	10	7	8	9	11	6	10	10	12	12	17	10	18	7	13	11	15	9	13	10	11	11	12	10	28

I-WS = Improved workstation / E-WS = Existing workstation

Table I-1 Comparison score of local muscular fatigue of the hanging materials on overhead conveyor workers between while working on improved workstation.

Subject no.	N	UB	LB	R1	R2	R3	R4	R5	R6	R7	R8	AVR	L1	L2	L3	L4	L5	L6	L7	L8	AVL
1	4	1	5	4	3	3	5	3	2	3	4	3.4	5	3	3	4	3	1	2	2	2.9
2	4	2	5	3	3	3	4	2	2	2	3	2.8	5	3	2	4	3	2	3	2	3.0
3	5	3	4	4	2	3	4	2	2	3	3	2.9	6	2	1	3	3	1	2	2	2.5
4	4	2	6	5	3	2	3	2	1	3	4	2.9	7	2	3	4	2	1	2	1	2.8
5	3	2	5	6	4	3	5	3	2	1	3	3.4	5	4	2	5	2	2	1	3	3.0
6	4	2	4	5	3	4	4	3	2	2	3	3.3	4	3	3	3	1	2	2	2	2.5
7	4	2	4	4	4	3	5	1	2	3	3	3.1	5	3	2	4	3	1	1	3	2.8
8	4	3	4	3	4	2	5	3	1	4	2	3.0	4	2	3	5	2	2	2	2	2.8
9	5	4	4	4	3	4	5	3	1	3	3	3.3	5	2	3	4	3	1	1	1	2.5
10	4	2	5	6	5	3	6	4	2	3	3	4.0	6	3	3	3	4	2	4	1	3.3
11	3	3	4	5	4	4	4	3	2	2	3	3.4	7	2	4	4	3	2	3	2	3.4
12	4	4	5	6	3	5	5	1	2	4	4	3.8	4	3	3	6	3	3	3	2	3.4
13	3	4	4	7	4	4	6	2	2	3	4	4.0	5	3	4	5	2	2	2	1	3.0
14	3	3	3	6	3	4	6	3	3	2	3	3.8	5	2	3	3	3	2	3	2	2.9
15	4	4	6	5	3	3	5	4	2	2	3	3.4	5	1	3	4	3	1	1	3	2.6
16	4	3	5	6	2	2	4	3	2	1	3	2.9	4	2	2	5	2	2	2	1	2.5
17	5	2	4	7	2	4	5	4	2	3	2	3.6	5	3	3	4	3	1	3	1	2.9
18	4	4	5	6	3	3	4	3	2	2	4	3.4	4	3	3	3	2	2	3	3	2.8
19	6	4	4	5	2	3	3	2	2	3	3	2.9	4	3	2	4	4	2	2	2	2.9
20	4	3	5	4	3	4	5	3	1	2	2	3.0	5	3	2	4	2	1	1	2	2.5
SUM	81	57	91	101	63	66	93	54	37	51	62	65.9	100	52	54	81	53	33	42	38	56.6
MEAN	4.1	2.9	4.6	5.1	3.2	3.3	4.7	2.7	1.9	2.6	3.1	3.3	5.0	2.6	2.7	4.1	2.7	1.7	2.1	1.9	2.8
S.D.	0.76	0.93	0.76	1.19	0.81	0.80	0.88	0.86	0.49	0.83	0.64	0.38	0.92	0.68	0.73	0.83	0.75	0.59	0.85	0.72	0.28

Table I-2 Comparison score of local muscular fatigue of the hanging materials on overhead conveyor workers between while working on existing workstation.

Subject no.	N	UB	LB	R1	R2	R3	R4	R5	R6	R7	R8	AVR	L1	L2	L3	L4	L5	L6	L7	L8	AVL
1	5	2	6	8	5	5	6	4	3	4	3	4.8	7	4	4	6	5	2	3	2	4.1
2	5	3	6	8	4	4	7	3	3	4	5	4.8	7	4	5	5	4	2	4	3	4.3
3	6	4	7	7	3	4	6	3	2	3	4	4.0	8	3	3	5	3	1	3	3	3.6
4	6	5	8	7	4	3	6	3	1	3	4	3.9	6	3	2	5	4	1	2	2	3.1
5	5	3	6	8	5	4	7	4	2	2	3	4.4	6	5	3	6	3	3	1	4	3.9
6	7	2	7	8	4	5	5	4	3	2	4	4.4	7	4	3	4	2	2	3	3	3.5
7	5	3	5	7	6	4	6	2	2	4	3	4.3	6	5	2	5	4	1	3	2	3.5
8	4	4	7	6	4	3	6	4	1	5	2	3.9	6	3	3	6	3	2	3	1	3.4
9	6	5	8	7	4	6	6	3	1	4	3	4.3	7	3	4	5	3	1	2	2	3.4
10	7	2	8	8	5	4	7	5	3	4	3	4.9	7	4	3	4	5	2	5	2	4.0
11	5	4	7	8	3	5	8	4	3	5	4	5.0	8	2	5	6	3	2	4	3	4.1
12	4	5	7	7	4	6	6	2	2	6	5	4.8	5	3	4	5	4	4	4	3	4.0
13	4	4	5	8	5	5	7	3	2	4	4	4.8	6	4	5	6	2	2	5	2	4.0
14	5	3	6	7	4	5	5	4	4	3	4	4.5	6	4	4	4	3	2	3	3	3.6
15	6	4	7	7	4	4	6	5	3	2	3	4.3	6	3	4	5	4	1	1	4	3.5
16	6	3	7	8	3	3	7	4	2	1	3	3.9	6	3	2	6	3	2	2	2	3.3
17	7	2	8	8	3	6	6	4	1	4	2	4.3	7	3	4	5	4	1	4	1	3.6
18	5	4	6	8	4	5	5	3	3	3	5	4.5	6	4	3	5	4	2	3	4	3.9
19	8	5	8	7	3	4	6	4	2	5	3	4.3	6	4	2	4	5	3	3	2	3.6
20	5	3	7	8	4	5	6	4	3	3	2	4.4	7	3	4	5	2	1	2	2	3.3
SUM	111	70	136	150	81	90	124	72	46	71	69	87.9	130	71	69	102	70	37	60	50	73.6
MEAN	5.6	3.5	6.8	7.5	4.1	4.5	6.2	3.6	2.3	3.6	3.5	4.4	6.5	3.6	3.5	5.1	3.5	1.9	3.0	2.5	3.7
S.D.	1.10	1.05	0.95	0.61	0.83	0.95	0.77	0.82	0.86	1.23	0.94	0.34	0.76	0.76	1.00	0.72	0.95	0.81	1.12	0.89	0.33

BIOGRAPHY

NAME	Miss Supranee Pochaka
DATE OF BIRTH	25 December 1976
PLACE OF BIRTH	Bangkok, Thailand
INSTITUTION ATTENDED	Mahidol University, 1993-1997: Bachelor of Science (Public Health) Major in Occupational Health and Safety Mahidol University, 2000–2005: Master of Science (Industrial Hygiene and Safety)
POSITION & OFFICE	System Assurance Officer, 2003-present Safety and Quality Department, Bangkok Metro Public Company Limited
HOME ADDRESS	107/268 Kritsana Village, Minburi-Romkhlao Road, Minburi District, Bangkok Province, 10510.