TORCH DESIGN TO REDUCE UPPER ARM AND SHOULDER FATIGUE IN WELDING PROCESS OF AN AIR CONDITIONING PRODUCTION FACTORY

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TORCH DESIGN TO REDUCE UPPER ARM AND SHOULDER FATIGUE IN WELDING PROCESS OF AN AIR CONDITIONING PRODUCTION FACTORY

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ABSTRACT

Prolonged use of inappropriate hand and welding tools can cause fatigue at work. Therefore, the objectives of this study were to design a new torch using the principles of ergonomics for reducing fatigue in upper arm and shoulder muscles. The results were measured by comparison of electromyography (EMG) monitoring on the upper arms and shoulders of welders, postural load indeces of the upper body from the LUBA assessment technique, and subjective feelings of fatigue. The efficiency of the new torch in welding copper capillary tubes was studied at an air conditioning production factory.

This quasi- experimental study was carried out with nine subjects who had no history that may affect fatigue in arms, hands and shoulders. Anthropometers were used to measure body dimension of subjects and the 5th and 95th percentiles of body dimension were used to design the new torch for reducing shoulder abduction angle, angle between arm and trunk, and angle of twist in the wrist while welding. The EMG of deltoid, bicep, and tricep muscle activity was measured and was represented as the mean of the RMS. EMG of each subject was measured by electromyograph for 20 minutes, postural loading on the upper body was assessed by the LUBA technique, and cycle time for welding per piece were measured from time records by video camera. All results measured while using the existing torch and the new torch were compared statistically.

Handle length, handle diameter, and distance between middle handle to the end of the new torch are 12, 3, and 25 cm, respectively, and a curved end was used for the new torch design shape. The results of this study demonstrated that while subjects were welding using the new torch, deltoid muscle activity, bicep muscle activity, postural load index of the upper body, and cycle time for welding per piece were significantly less than while they were welding using the existing torch ($P< 0.05$). The results of subjective feelings of fatigue on three muscles when welding using the new torch were significantly less than when using the existing torch ($P< 0.05$). In terms of comfort acceptance, the ergonomically designed new torch was accepted by all nine of the subjects. Only tricep muscle activity was significantly greater than when they were welding using the existing torch ($P< 0.05$). The experiment concluded that the new torch designed using ergonomic principles and anthropometric data can reduce fatigue in upper arm and shoulder muscles and can increase efficiency of copper capillary tube welding.

KEY WORDS: TORCH DESIGN / ERGONOMIC / FATIGUE / ELECTROMYOGRAPHY / ANTHROPOMETRY

125 pages

การออกแบบหัวเชื่อมกับการลดความเมื่อยล้าของกล้ามเนื้อแขนท่อนบนและไหล่จากการเชื่อมในโรงงานผลิตเครื่องปรับอากาศ

TORCH DESIGN TO REDUCE UPPER ARM AND SHOULDER FATIGUE IN WELDING PROCESS OF AN AIR CONDITIONING PRODUCTION FACTORY

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บทคัดย่อ

การใช้หัวเชื่อมที่ไม่เหมาะสม และการเชื่อมเป็นระยะเวลานาน จะทำให้เกิดความเมื่อยล้าของผู้ทำงาน ดังนั้น งานวิจัยนี้จึงทำการออกแบบหัวเชื่อมใหม่ตามหลักการยศาสตร์เพื่อลดความเมื่อยล้าของกล้ามเนื้อแขนและไหล่ โดยศึกษาเปรียบเทียบผลการตรวจวัดค่าคลื่นไฟฟ้ากล้ามเนื้อแขนและไหล่ของผู้ทำการเชื่อมท่อทองแดงด้วยหัวเชื่อมเดิมกับหัวเชื่อมใหม่, เปรียบเทียบดัชนีภาระจากท่าทางการทำงานของร่างกายส่วนบนด้วยเทคนิคการประเมิน LUBA, เปรียบเทียบความรู้สึกเมื่อยล้า พร้อมกับศึกษาประสิทธิภาพของหัวเชื่อมใหม่ในการเชื่อมที่โรงงานผลิตเครื่องปรับอากาศแห่งหนึ่ง

การศึกษานี้เป็นการศึกษากึ่งทดลองดำเนินการกับกลุ่มตัวอย่างที่เป็นพนักงานเชื่อม 9 คนที่ไม่มีประวัติที่อาจมีผลกระทบต่อความเมื่อยล้าของแขน มือและไหล่ โดยนำเครื่องมือวัดสัดส่วนร่างกายมาวัดขนาดของร่างกายของกลุ่มตัวอย่าง จากนั้นนำค่าเปอร์เซนต์ไทล์ที่ 5 และ 95 ของสัดส่วนร่างกายที่เกี่ยวข้องมาใช้ออกแบบหัวเชื่อมใหม่เพื่อลดการกางไหล่ ลดมุมระหว่างแขนและลำตัว และลดการบิดของข้อมือขณะที่ทำการเชื่อม ประเมินความเมื่อยล้าจากการตรวจวัดค่าคลื่นไฟฟ้ากล้ามเนื้อ Deltoid, Biceps และ Triceps ขณะทำการเชื่อมเป็นค่าเฉลี่ย RMS EMG ด้วยเครื่องวัด EMG เป็นเวลา 20 นาที, ประเมินภาระจากท่าทางการทำงานของร่างกายส่วนบนด้วยเทคนิค LUBA และบันทึกระยะเวลาที่ใช้ในการเชื่อมท่อทองแดงแต่ละชิ้นจากกล้องบันทึกภาพ และผลการศึกษาขณะที่ทำการเชื่อมด้วยหัวเชื่อมที่มีอยู่เดิมกับด้วยหัวเชื่อมใหม่ถูกนำไปเปรียบเทียบทางสถิติ

หัวเชื่อมใหม่มีขนาดความยาวด้ามจับ เส้นผ่าศูนย์กลางของด้ามจับและระยะระหว่างกึ่งกลางด้ามจับถึงปลายหัวเชื่อมเท่ากับ 12, 3 และ 25 เซนติเมตร ตามลำดับ ปลายหัวเชื่อมเป็นรูปโค้ง ผลการศึกษาแสดงให้เห็นว่าขณะที่กลุ่มตัวอย่างทำการเชื่อมด้วยหัวเชื่อมใหม่พบว่า ค่าคลื่นไฟฟ้ากล้ามเนื้อ Deltoid และกล้ามเนื้อ Biceps ดัชนีภาระจากท่าทางการทำงานของร่างกายส่วนบน และระยะเวลาที่ใช้ในการเชื่อมท่อทองแดงต่อชิ้นน้อยกว่าขณะที่ทำการเชื่อมด้วยหัวเชื่อมเดิมอย่างมีนัยสำคัญ (P< 0.05)และพบว่าระดับความรู้สึกเมื่อยล้าเมื่อกลุ่มตัวอย่างทำการเชื่อมด้วยหัวเชื่อมใหม่น้อยกว่าเมื่อทำการเชื่อมด้วยหัวเชื่อมเดิมอย่างมีนัยสำคัญ (P< 0.05) นอกจากนี้ยังพบว่ากลุ่มตัวอย่างทั้ง 9 คน ให้การยอมรับหัวเชื่อมใหม่ว่าสามารถใช้งานได้สะดวกสบาย มีเพียงค่าคลื่นไฟฟ้าของกล้ามเนื้อ Triceps เท่านั้นที่มากกว่าขณะที่กลุ่มตัวอย่างทำการเชื่อมด้วยหัวเชื่อมที่มีอยู่เดิมอย่างมีนัยสำคัญ (P< 0.05) การทดลองนี้จึงสรุปได้ว่า การออกแบบหัวเชื่อมใหม่ตามหลักการยศาสตร์สามารถลดความเมื่อยล้าของกล้ามเนื้อแขนและไหล่ และสามารถเพิ่มประสิทธิภาพในการทำงานเชื่อมท่อทองแดงได้

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LIST OF ABBREVIATIONS

BMI	Body Mass Index
CTD	Cumulative Trauma Disorder
CTS	Carpal Tunnel Syndrome
cm.	Centimeter
df	Degree of freedom
ECG	Elbow to Center of Grip
EFL	Elbow Fingertip Length
EH	Elbow Height
EMG	Electromyography
EWL	Elbow Wrist Length
kg.	Kilogram
GD	Grip Diameter
HB	Hand Breadth
HL	Hand Length
LUBA	An assessment Technique for Postural Loading on the Upper Body
Max	Maximum
Min	Minimum
RMS	Root Mean Square
RSI	Repetitive Strain Injury
SEL	Shoulder Elbow Length
SH	Shoulder Height
SD	Standard Deviation
WMSDs	Work related Musculoskeletal Disorders

CHAPTER I
INTRODUCTION

1.1 Background and Rationale

At present, the world is suffering with the problem from a crisis of a global warming that increase violently. This situation is the cause of expanding of air conditioning business (1). In the production process of air conditioning can cause of many impacts e.g. environmental, energy including occupational health and safety etc. These aspects can affect to economy overall. The main impact on occupational health and safety is being and more and more attended from countries around the world is occupational injury or diseases from working posture (ergonomics). For Thailand, an occupational injury or diseases from working posture (ergonomics) statistics of labor who are insured person from year 2004- 2009 of compensation fund, Social Security Office, Ministry of labour shows increasing level continually.

Compensation fund, Social Security Office, Ministry of labour had collected occupational diseases from working (ergonomics) statistics classified by categories of disease from year 2004- 2009 shows occupational injury or diseases from working posture (ergonomics) data as, (2-7)

Year 2004 amount 6,306 cases (to be the rate of occupational injury or diseases from working posture (ergonomics) 85 cases per 100,000 insured persons)

Year 2005 amount 6,951 cases (to be the rate of occupational injury or diseases from working posture (ergonomics) 90 cases per 100,000 insured persons)

Year 2006 amount 7,090 cases (to be the rate of occupational injury or diseases from working posture (ergonomics) 89 cases per 100,000 insured persons)

Year 2007 amount 7,345 cases (to be the rate of occupational injury or diseases from working posture (ergonomics) 90 cases per 100,000 insured persons)

Year 2008 amount 5,925 cases (to be the rate of occupational injury or diseases from working posture (ergonomics) 67 cases per 100,000 insured persons)

Year 2009 amount 5,447 cases (to be the rate of occupational injury or diseases from working posture (ergonomics) 63 cases per 100,000 insured persons)

This statistics was collected from only employees who are insured person of social security office, employees who are not covered by welfare compensation fund and government officials are not included, but these are still high level.

In an air conditioning production factory, welders shall weld capillary tube with posture that can effect to their health, these shall move repeatedly with the same posture all the working hours. And these can give fatigue and pain on theirs wrist, arm and shoulder e.g. they shall twist arm and wrist to adjust direction of torch, shall abduct and raise arm over their shoulder because of high level of welding table, jig and part to adjust direction of flame from torch to aim at the welding point, shall extend elbows away from the trunk, shall use repeatedly of static posture of muscle and shall use static posture continually etc. Approximately, welder shall hold torch with weight at about 1 kilogram for 8 working hours per day. Some welder shall hold one for 10 work hours (including over time). Although the weight of torch is not over than standard as the labour law of Ministry of labour by Ministerial regulations on determination of weight ratio as employer gets employees to work B.E. 2005. Due to the characteristics and durations of working hour can affect to the same muscles that were used repeatedly and prolong, if that the stress in their muscle is occurred and lead into fatigue of muscle from welding to cause of admitted. When the fatigue statistics of muscle from welding were verified, in year 2009, there were 11 of fatigue cases from all 90 welders (to be 12% of all welders) and year 2010 (especially Jan- June 2010), there were 10 of fatigue cases from all 90 welders (to be 11% of all welders). These are regarded high statistic to cause of cost for health surveillance and cure. In addition, there were 2 cases at welding section and weren’t covered in the fatigue statistics mentioned were admitted in year 2010 (data from clinic room of an air conditioning production factory). The first case, she was admitted because of chronic muscle pain symptom on arm that was abducted and raised repeatedly over than the neutral position while she weld. The second, she was admitted and operated because the symptom of tendosynovitis on palm and finger from bending or twisting at the wrist with non neutral posture while welding as well. This affected to the cost for cure that was not less than 10,000 baht. When assess the discomfort from posture work by sampling on copper capillary tube welder with “an Assessment Technique for Postural Loading on the Upper Body (LUBA)” (8) discovered postural load index was classified on category 4. It is the category of postural load index of 15 or more and these posture requires consideration and corrective action immediately.

As the reasons mentioned, it expressed that arm and shoulder muscle fatigue problem from welding on copper capillary tube were raised in this section. And the cause may be from the lack of an existing hand tools, torch for welding. Therefore, it should have new torch designed to fit welder. Then, experimental shall be fix the arm and shoulder muscles fatigue from work.

1.2 Objectives

Objectives in this study as,

1.2.1 To design new torch as principles of ergonomic for reducing fatigue on upper arm and shoulder muscle.

1.2.2 To compare an EMG monitoring results on upper arm and shoulder of welder while using existing torch and new torch to weld.

1.2.3 To compare the postural load index from discomfort assessment by LUBA while using existing torch and new torch to weld.

1.2.4 To compare level of subjective feeling of fatigue while using existing torch and new torch to weld.

1.2.5 To study the efficiency of new torch.

1.3 Study hypotheses

Hypotheses of this study as,

1.3.1 EMG monitoring results on upper arm and shoulder from postures while using new torch to weld on copper capillary tube is lower than while using existing torch.

1.3.2 Postural load index from discomfort assessment by LUBA while using new torch to weld on copper capillary tube is lower than while using existing torch.

1.3.3 Level of subjective feeling of fatigue while using new torch is lower than using existing torch to weld.

1.3.4 New torch can reduce a cycle time for welding per piece of copper capillary tube.

1.4 Variables

1.4.1 Independent variables

1.4.1.1 Postures from welding on copper capillary tube by existing torch.

1.4.1.2 Postures from welding on copper capillary tube by new torch.

1.4.2 Dependent variables

1.4.2.1 EMG on upper arm and shoulder muscle while welding on copper capillary tube.

1.4.2.2 Postural load indexes by LUBA while welding on copper capillary tube.

1.4.2.3 Level of subjective feeling of fatigue while welding on copper capillary tube.

1.4.2.4 A cycle time for welding per piece of copper capillary tube.

1.4.3 Control variables

1.4.3.1 Personal factor; subject (welder) shall be controlled personal factor that can effect to the result in this study e.g. height, body mass index etc. and female subject shall not be in menstruation while study.

1.4.3.2 Service year; at least 6 months of experience of subject about welding on piping tube.

1.4.3.3 Accident history; subject shall not have an accident that can be the cause of fatigue on muscle of shoulder, arm and hand within the last a year.

1.4.3.4 Health record and ill health; subject shall have a good health and without a heart trouble, gall bladder disease, hepatitis and other that can cause of fatigue on muscle of shoulder, arm and hand.

1.4.3.5 Behavior; subject shall not smoke or drink frequently.

1.4.3.6 Rest; subject shall rest for at least 6 hours before testing.

1.4.3.7 Model of part; Model shall be copper capillary.

1.4.3.8 Tool; Tool in this study shall be an existing torch and new torch which be designed as ergonomic principle.

1.5 Scope and limitation of this study

This study is quasi- experimental about postures from welding on copper capillary tube by using existing torch and new torch designed as principle of ergonomics in welding process of an air conditioning production factory. This study was conducted for 20 minutes per an experimental of each torch.

1.6 Conceptual framework

Independent variables

1. Postures from welding on copper capillary tube by existing torch.
2. Posture from welding on copper capillary tube by new torch.

Dependent variables

1. EMG on arm and shoulder muscle while welding on copper capillary tube.
2. Postural load indexes by LUBA while using existing torch and new torch to weld on copper capillary tube.
3. Level of subjective feeling of fatigue while using existing torch and new torch to weld on copper capillary tube.
4. A cycle time for welding per piece of copper capillary tube.

Control variables

1. Personal factor
2. Service year
3. Accident history
4. Health record and ill health
5. Behavior; subject shall not smoke or drink frequently
6. Rest hours; subject shall rest for at least 6 hours before test
7. Model of part; Model shall be copper capillary
8. Tool; Tool in this study shall be an existing torch and new torch which be designed as ergonomic principle

1.7 Definition

A round of experimental means 1 round of continuous EMG recording while subject is welding copper capillary tube by using existing torch or new torch for totally 20 minutes.

Anthropometry means the measurement of the human body.

Cycle time means duration time to weld per a piece of copper capillary tube. It was measured as second.

Efficiency means ability of reducing time to weld on copper capillary tube of welder by comparison the cycle time between using existing torch and using new torch.

Electromyography or EMG means electrical signal from contraction of upper arm and shoulder muscle occurred from postural welding.

Existing torch means means the current torch which is used to weld copper capillary tube. It is not designed by using anthropometry and ergonomics data.

Fatigue means means the loss of efficiency to work including the loss of feeling to try to do any physical or mental activities. It is specific perceived of an individual to discomfort and unhappy.

Level of subjective feeling of fatigue means state of fatigue feeling due to welding by using existing torch or new torch.

New torch means means the new torch designed by using data from anthropometry of subject as principle of ergonomics and was used to weld copper capillary tube instead an existing torch.

Postural load index means final score which was calculated from postural load of joints motions relate with discomfort score on copper capillary tube welding posture assessment by "An assessment technique for postural loading on the upper body (LUBA)"

Upper arm muscle means Biceps and triceps muscle.

Shoulder muscle means Deltoid muscle.

Time kept	means each of duration for finding EMG measurement results was distributed from a round of experimental. In this study, time kept was 5 minutes per duration.

CHAPTER II
LITERATURE REVIEWS

The principle of work is based on the relationship between three factors since it become to the work system. These factors consist of man, machine or equipment, and environment. If each factor is more complex, as well as system shall be more complex; e.g. if machine or equipment has complex of control system, it's more difficult to use, if workers are more different size and shape but they shall work at the same station it can be work condition problem and affect to health of some worker etc. If the design is not considered to control whole of three factors to cooperate with each other, an error or failure of system and health effect may be occurred. Therefore, the design should be considered. For the system, the design shall study a relationship between man and machine in that environmental working carefully, determine the scope, set objective and target of system clearly for the relationship of each factors and comfort to work.

Actually, it is difficult to change the human physical condition. Therefore, the characteristic of human is based to design by consideration the data of body dimension and structure of human to design other factors to get human can interact seamlessly to any factors. Due to instruction of welding on copper capillary tube can cause of fatigue and pain on arm and shoulder muscle. Therefore, this aims to study about structure and work system of upper arm and shoulder or upper extremity and injury from movement to work of upper arm and shoulder.

2.1 Anatomy and Physiology

Bone and muscle structure are the parts to support movement of body. Bone is like as a stretcher can work by flexion and extension of muscle. To design a system of man, machine and environment appropriately base on characteristic of human, therefore, it is necessary to understand biomechanics of body

2.1.1 The skeletal system (9)

The skeletal system, it’s duty is to support body shape to be sustained. There are 206 pieces of bone on whole body of human and they are distributed into 2 groups as shown in the figure 2.1

2.1.1.1 Axial Skeleton

It is the axial bone of body. It’s duty is to support and protect harm that may occur to the main internal organ of body. Whole are 80 pieces and consist of,

1) Skull consists of 29 pieces

2) Vertebrate consists of 26 pieces (Cervical Vertebrate consists of 7 pieces; Thoracic Vertebrate consists of 12 pieces; Lumbar Vertebrate consists of 5 pieces; Sacrum consists of 1 piece and Coccyx consists of 1 piece)

3) Rib consists of 24 pieces

4) Sternum consists of 1 piece

2.1.1.2 Appendicular Skeletal

It is the bone connects with axial skeleton. It’s duty is to support and relate to movement of body. There are 126 pieces and consists of

1) Upper limb consists of 60 pieces (30 pieces per each side) are to be Humorus, Radius, Ulna, Carpals, Metacarpals and Phalanges

2) Lower limb consists of 60 pieces (30 pieces per each side) are to be Femur, Patella, Tibia, Fibula, Tarsals, Metatarsals and Phalanges

3) Clavicle consists of 2 pieces (1 piece per each side)

4) Scapula consists of 2 pieces (1 piece per each side)

5) Pelvic consists of 2 pieces (1 piece per each side)

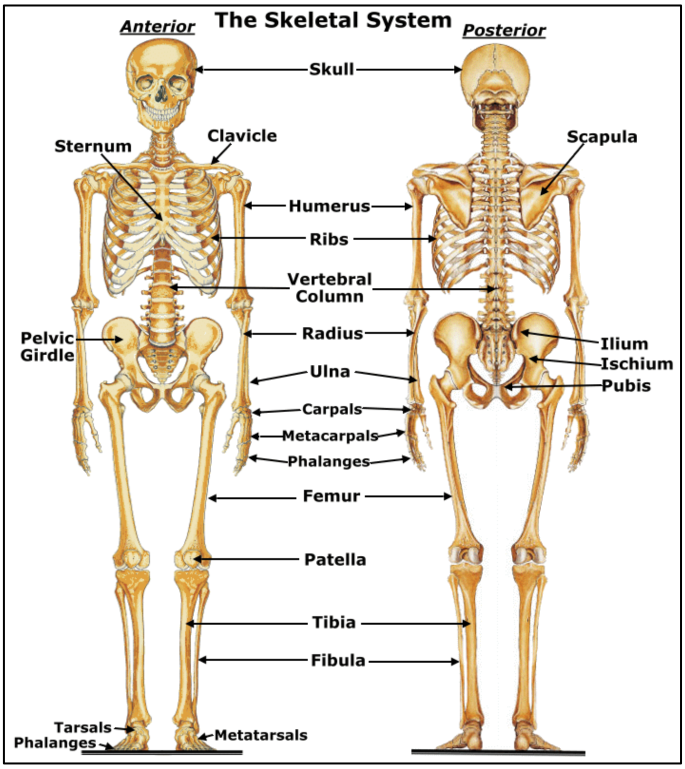


Figure 2.1 Skeletal systems (10)

Due to in this study concern with the upper limb, therefore, arm and shoulder bone details are mentioned as the figure 2.2. These consists of,

1) Clavicle, it's duty is to connect with trunk; there are 2 pieces, S shape as horizontal line, an internal end connect with Manubrium which is the upper end bone of Sternum

2) Scapula is triangle flat bone with a big hump called Acromion process that connect with the external end of Clavicle, stretch it'self at the backside opposite with chest.

3) A humerus is the biggest of upper bone. The upper part of this bone connects with Scapula at **Glenohumeral joint**. The characteristic of the end of upper part is circular is called **Head** reach into **Glenoid cavity** of Scapula. The characteristic of the lower end likes a pulley is called **Trochear** for putting on and bending of Ulna as figure 2.2, the lower part connects with Radius and Ulna at the elbow joint shows as figure 2.3

4) Ulna is interior end of arm helps to contribute a stability of the end of arm and it is the bone in a middle part with size longer than another one of the end of arm bone, there are 2 hump reach from elbow; first called **Olecranon** and it's duty is to lever the elbow when extension of arm occurred and second is in front part called **coronoid process**

5) Radius is exterior end of arm; it's size is shorter than another one of the end of arm bone. The characteristic of the end of proximal side is small circular and rotate around in vertical line, and distal end is expandable to connect with carpals. While it is pronation posture, radius shall rotate around and cross with Ulna.

6) Carpals are eight small bone queues up to be four lines. These small bones contribute the flexible of wrist movement. The characteristic of carpal are protrude when see through the side of back hand and are curve when see at the front of arm. When the movements of wrist are over, two lines of carpals shall sail over each other line. Furthermore, each bone shall sail up on the other bone near it'self.

7) Metacarpals are 5 bones, each consist of base, branch and head. Base of metacarpals connect with carpals and the end connect with phalanges.

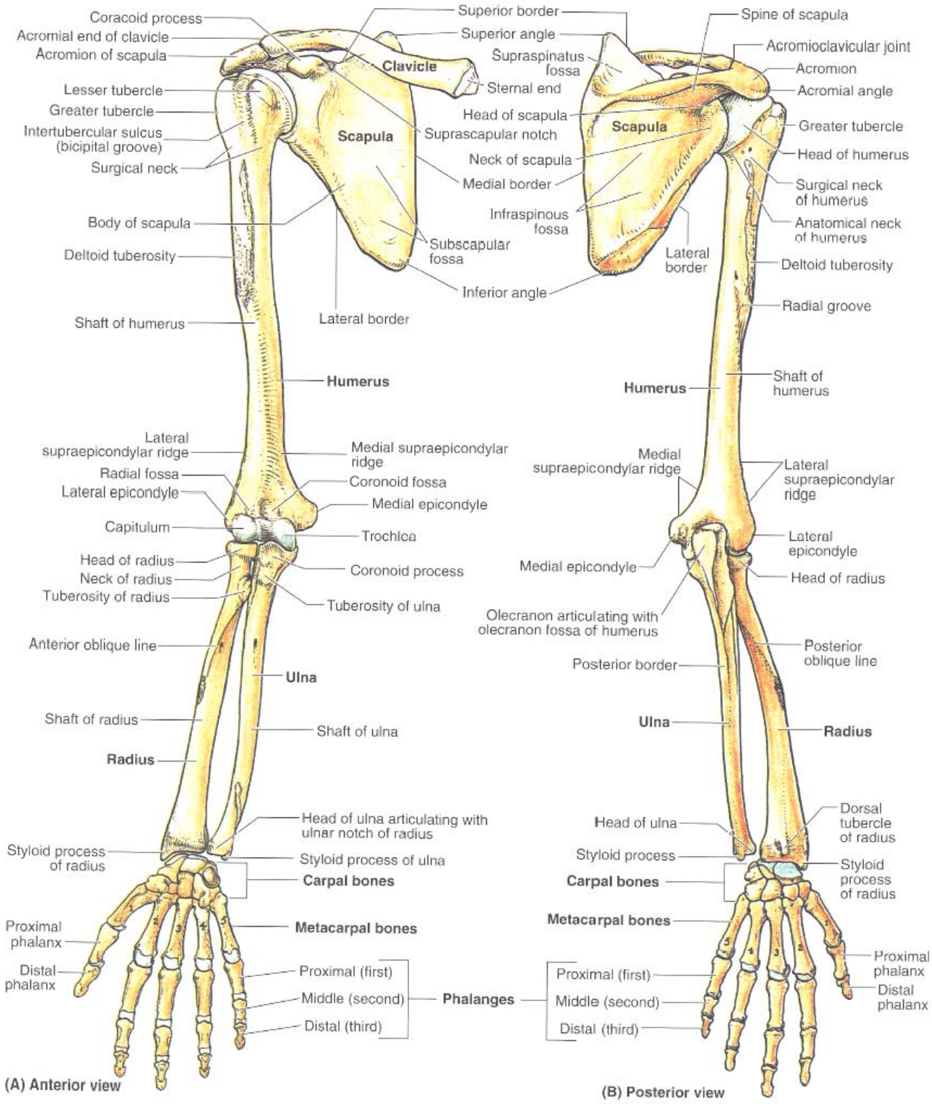


Figure 2.2 Bone of upper limb (9)

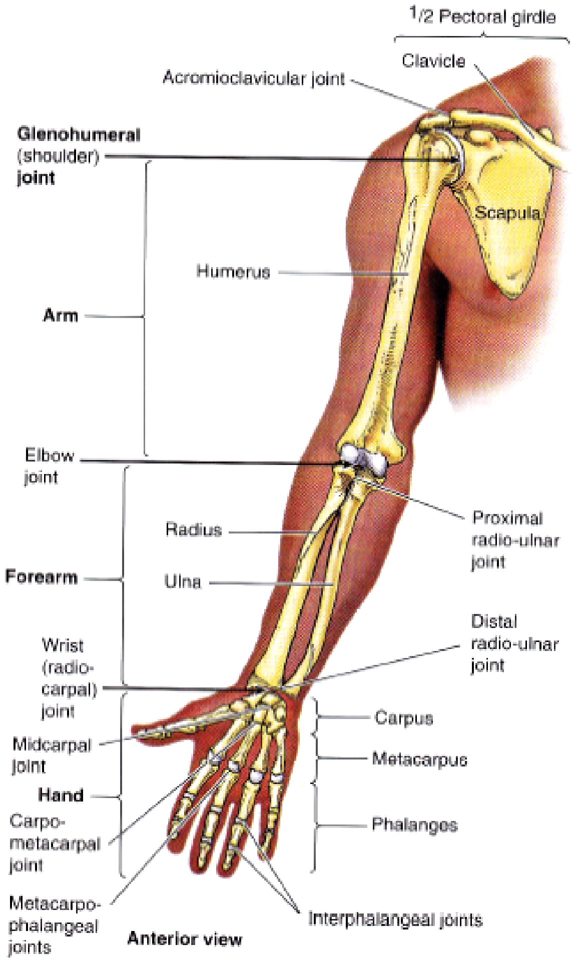


Figure 2.3 Bone of arm (9)

Skeleton of human connect with each other by joint which can make many direction of body movement. The joints are classified to be two types as,

1) Immoveable Joints are the joint that it's duty is to snatch the bone to fix and cannot movement e.g. joint of skull called Suture etc.

2) Movable Joints are the joint connect between bones and make a body movement, there are many type such as,

- Multi directional movement joints because of a connection of bone like a ball and socket, they are met in Glenohumeral joint and Hip joint.
- Pivotal joint, it's can bend, lift and twist to left and right side e.g. Atlantoaxial joint.
- Gliding joint e.g. Radio carpal joints, it can rotate with multi directions.

At the region of joints shall create liquid like a mucous of albumin to protect a friction from a movement of bone and help to rotate comfortable. Furthermore, it has tendon or ligament that is strong and durable connective tissue to fix the bone.

2.1.2 Muscle system

Muscle is the tissue which it's duty concern movement of body directly. In addition, it's duties are to maintain balance of body, fix joint, produce energy to maintain body temperature, control blood circulation in red blood vessels etc. There are 3 types of muscle are smooth muscle, cardiac muscle and striated muscle. In this study would only mention to striated muscle.

Striated muscle is the muscle with conspicuous stain; consist of long cylinder cell with many nucleuses line up close with cell membrane. Striated muscle is classified to be voluntary muscle and can be controlled by central nervous system. Striated muscle is the greatest number of muscle found in human body. It's attached to the various bone in whole body e.g. arm, leg, trunk and face etc. It helps to move various part of body. Therefore, we can call the other name of striated muscle that "Skeletal muscle". Internal structure of striated muscle consists of muscle cells with long cylinder characteristic call "Muscle fiber".It has many nucleus closes with cell membrane call "Sarcolemma". Inside of cytoplasm of muscle cell is called "Sarcoplasm" consist of many fibers diffused in general call "Myofibril". Myofibril consists of small unit's call "Filament". There are 2 types of filament in striated muscles as,

1) **Thick filament** consists of protein call "Myosin" assemble to a bundle. In each a bundle consists of myosin molecules are built from two lines of

protein wrapped each other to be strand. At the end of each line is curled to be globular shape like a hook.

2) **Thin filament** consists of protein call “Actin” with globular Actin molecules line up to be long line and wrapped each other to be strand.

Due to the line up to be in order of both in striated muscle, therefore, striated muscle is looked like dark and light color alternate tidily. In other word, the dark color area is thick filament which end of both sides is overlapped with thin filament. Therefore, an overlap areas are the dark color called "A- band" (Anisotropic band). At the middle areas of thick filament that is not overlapped with thin filament are light color called "H- Zone", therefore, H- Zone is a part of A- Band. For the light color area, there is only thin filament called "I- Band" (Isotropic Band). At a middle areas of thin filament of each I- Band, there is a small streak of dark color that is a joint of thin filament to join together called "Z- Line" and distance between Z-line to another Z- line called "Sarcomere" or "one muscle unit"

2.1.3 Mechanism of striated muscle (11)

A.F. Huxley and H.E. Huxley had set hypotheses and demonstrate about mechanism of striated muscle in body. They met that contraction and relaxation of muscle are from move in or move out between thick and thin filament. Start with Myosin molecule in thick filament which the end like a hook raises to connect with Actin molecule in thin filament (1). And then, thick filament release ADP+P to build a bridge connect with thin filament, bending and pull both of filament to slide and overlap to each other (2). Next, energy from ATP shall make Myosin molecule come off from Actin molecule (3). When hydrolysis reaction occurs, the end of Myosin molecule shall come back to original position (4) and catch to Actin molecule again at the new position (5). Then, a bridge which connects both of filaments would be bent affect to an overlap or move out between thick and thin filament and affect to contraction or relaxation. And finally, cause of body movement.

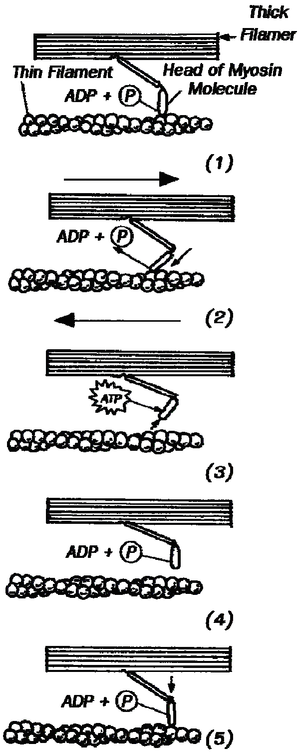


Figure 2.4 Mechanism of striated muscle

2.1.4 Mechanism of arm muscle

Movements of each part of human body are the work in cooperation in couples as antagonism of muscles that holding with bone in each part of human body.

Flexion and extension of arm is from to work in cooperation of two set of muscles namely **Biceps** muscle attached to in front of Humerus and Radius, and **Triceps** muscle to rear of Humerus and Ulna. When contraction of Biceps is occurred, state of Triceps is relaxation and flexion of arm shall be appeared. In opposite, when relaxation of Biceps is occurred, state of Triceps is contraction and extension of arm shall be appeared.

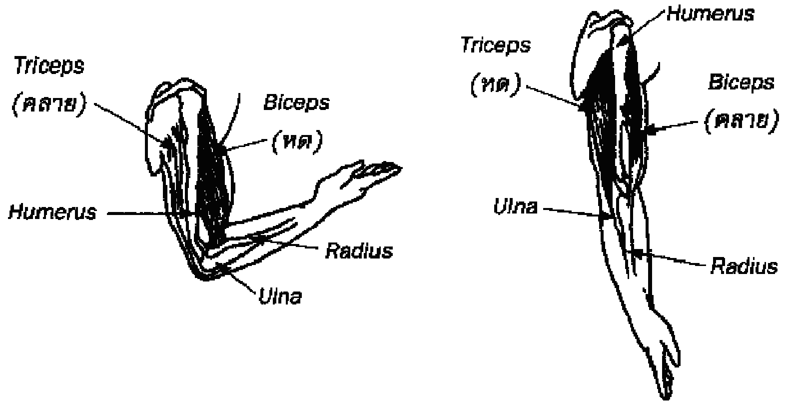


Figure 2.5 Antagonism on arm muscles

2.1.5 Muscles of the upper extremities

2.1.5.1 Muscles of the shoulder consist of,

1) Deltoid; it's duty is to abduct a humerus to be a right angle.

2) Supraspinatus, Infraspinatus, Teres minor; theirs duties are to support a shoulder, adduct an arm and rotate a humerus to the side of body.

3) Teres major; it's duties are to adduct an arm and rotate a humerus to interior side of body.

4) Subscapularis; it's duties are to rotate a humerus to interior side of body and support a shoulder.

2.1.5.2 Muscles of the arm consist of,

1) Biceps brachii; it's likes a reel with two head on the upper end. It's duties are to flex an elbow and turn a hand.

2) Triceps brachii; a large bundle is back of Humerus. There are three head on the upper end. It's duties are to extend the end of arm and adduct an arm.

3) Brachialis cover the front of elbow; it's duty is to flex the end of arm.

4) Coracobrachialis; it's duties are to flex and adduct an arm, support head of Humerus to fix into Glenoid.

2.1.5.3 Volar group consist of,

1) Pronator teres; it’s duties are pronation and flex the end of arm.

2) Pronator guadatus; it’s duty is to back a humerus.

3) Flexor carpi ulnaris; it’s duties are to back the end of arm, flex and adduct a hand.

4) Flexor digitorum profundus; it’s duties are to flex a hand and the end of fingers.

2.1.5.4 Dorsal group

1) Brachioradialis; it’s duties are to flex the end of arm and supination.

2) Extensor carpi radialis brevis; it’s duties are to extend the end of arm and abduct the wrist.

3) Extensor carpi ulnaris; it’s duties are to extend and abduct the wrist.

4) Extensor digitorum; it’s duties are to extend fingers and wrist.

2.1.5.5 Muscles of the hand are a short muscle; it’s duty is to move the fingers. Furthermore, there are small muscles at the fingers help to move fingers.

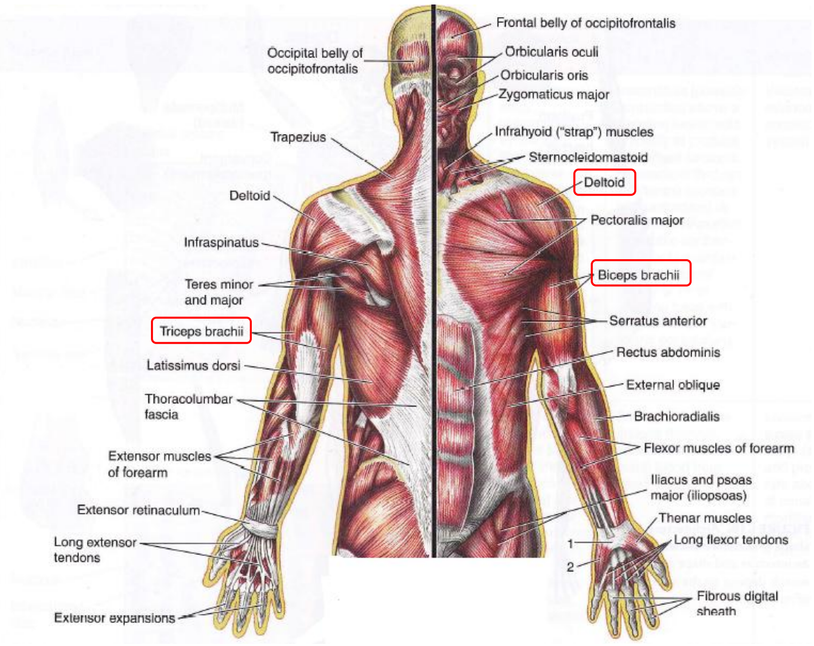


Figure 2.6 Muscles of the upper extremities (9)

Summarization: In process of hand tool design to fit with worker for reducing work load and fatigue from work including an evaluation of work load and fatigue, researcher shall know about structure and biomechanics of concerned muscles. In this study, researcher aims to design new torch for reducing fatigue on upper arm and shoulder from welding and evaluates by EMG monitoring and postural load assessment. Therefore, structure and biomechanics of arm and shoulder muscle must be studied and understood as data shown in this item.

2.2 Risk factors affect to work related musculoskeletal disorders

Work related musculoskeletal disorders (WMSDs) are disorders of body structure tissue namely bone, muscle, joint, tendon, ligament including nerve vessel. These are always related with work in environmental condition or work condition that may be risk factor of WMSDs. These problems often occurs in chronic accumulation such as repetitive job, work with non neutral postures for long time and affect to feel pain locally and limit of movement. Finally, it would be the cause of lack of ability to work.

Beside the name of musculoskeletal disorders (WMSDs), it has known in the other names that have the same mean in view of cause of WMSDs e.g. Cumulative Trauma Disorders (CTD), Repetitive Strain Injury (RSI), Occupational Overused Syndrome etc.

These can be classified by the period of disorders. At first, **Reversible WMSDs** that will appear in a short time, pain symptom shall occur at specific area where these muscle and tendon are injured, it will recover when stop that related work. And second, **Persistent WMSDs**, beside of pain symptom at that muscle and tendon injured, the symptom can also spread to the adjacent joint and tissue. Even if the related works are stopped but the symptom is still appear because of inflammation and deterioration of tissue that are worked continuously for long time. These problems are met in group of aged workers and workers who work with the same machine for long time and more than 1 year. Especially, when control button of machine is at unnatural level namely too high or too low level. Violence of these problems shall increase if former style of work are done consecutively without improvement, and finally, it will bring on inflammation of tendon or lose of shape of joint.

Risk factors that is the cause of work related musculoskeletal disorders are classified to be two groups namely personal factors and job factors, anyhow, ergonomics principle is “Put the right job to the right man” therefore, it necessary to focus on personal factors as well as job factors.

2.2.1 Personal factors that shall be considered are,

2.2.1.1 Sex; in case of exercise training are equal, female can force at about only 70 percentages of male because of muscles size of female are smaller than muscle size of male.

2.2.1.2 Age; strength of muscle shall increase quickly in teenage and increasing rate of strength will slow down when they are 20-30 years old. After that, it will be stable for 5-10 years. Gently then, it shall slow down continuously. When their age is 40 years old, strength of muscle shall have at about 90 percentages of 20 years old and remain at 85 percentages when their age is 50 years old. Because of strength is decreased as a stage, while their skill and work experience are increased as stage and work duration, these shall replace a lack of efficiency. Therefore, a young man should be protected and taken care more than an aged man.

2.2.1.3 Healthiness; always exercise shall make healthiness and flexibility. Therefore, lack of exercise is the risk factor of musculoskeletal disorder.

2.2.1.4 Smoking; after 20-30 minutes of smoking, it can release blood circulation, reduce blood and nutrient circulation around vertebral discs. This reason can describe about the rate of low back pain in smoking person is more than in non smoking person. (Rydevik and Holm, 1992)

2.2.1.5 Special necessity; Sometime, worker may face to a higher risk if they are in special necessity status namely pregnancy, return to work after sick leave in a stage or after taking leave for long time, malnutrition including personal disease that can increase a risk of work related musculoskeletal disorders.

2.2.2 Job factors are classified to be physical factors and psychosocial factors as follow, 2.2.2.1 Physical factors; namely

1) Force; Usually, characteristics of work with a higher forces increasingly a higher risk. Job characteristics or job conditions that the high effort is used by hand are as a characteristic of job with a little friction between hand and material shall make high effort to grasp, a characteristic of too small handle or troublesome shape, a condition of too big or thick glove can decrease grip strength of 20-30 percentages. These are the causes of using high effort. (12)

2) Static muscular effort; when muscle works with static effort it shall need more blood to feed it. If blood flow is not enough, muscle shall work with anaerobic state because of oxygen lack. Then, fatigue and pain shall be occurred because of cumulative of lactic and by product from metabolism.

3) Precision of movement; work with precision of movement, especially skill job which concern using hands and fingers.

4) Visual demand; beside of fatigue of eyesight that may occur from works with visual demand, continuous contraction of neck and shoulder muscle to maintain static space to look at work point every time can cause of work related musculoskeletal disorders.

5) Unnatural posture; unnatural posture means work posture which have some part of body deviates from natural posture. Work with bend down, lift shoulder, reach out, abduct, twist or kneel to lift at the narrow place are the characteristic of unnatural posture can increase the risk of work related musculoskeletal disorders.

Risk factors affect to injury of wrist, hand, finger and arm from using hand tool to work are awkward postures, repetition or Static effort, force, contact stress and temperature. (12)

Four factors may bring on work related cumulative injury namely 1) hard force 2) bending or over movement of joint 3) repetition work and 4) duration of work. General symptom relate with cumulative injury from work are pain, difficult of movement and inflammation of tissue. (13)

Movement of wrist joint can move with 2 plane at 90 degree in flexion, extension, ulna deviation and redial deviation posture. Not only that, rotation of the end of arm can appear in pronation and supination posture and movement of the top of arm can appear in adduction and abduction posture as figure 2.7. Over work or work with non neutral posture from failure of hand tool design or repetition work can cause of cumulative trauma disorders. (14)

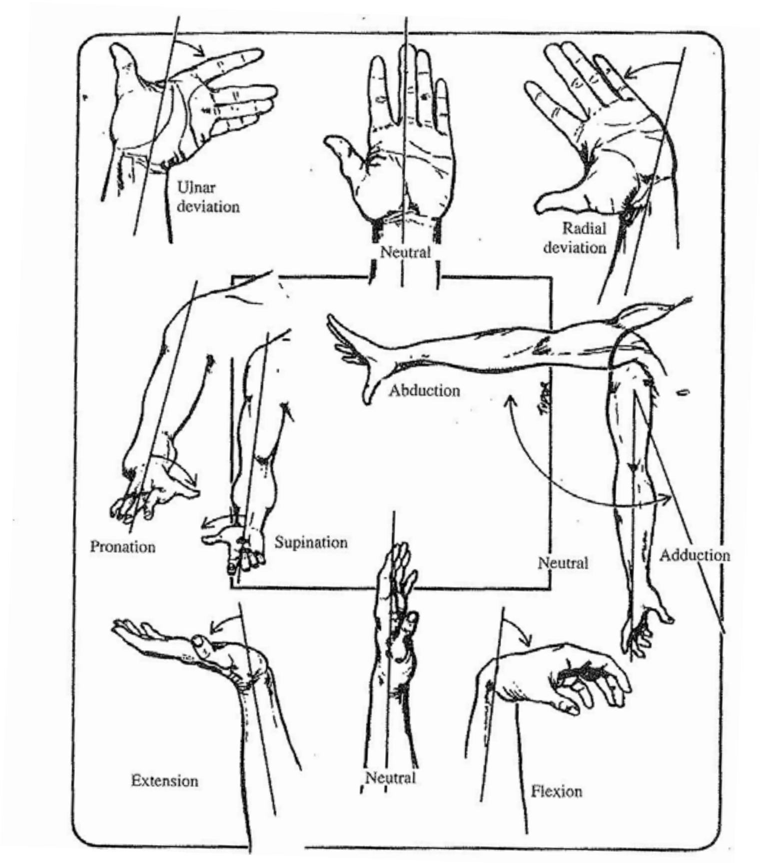
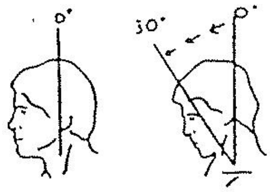


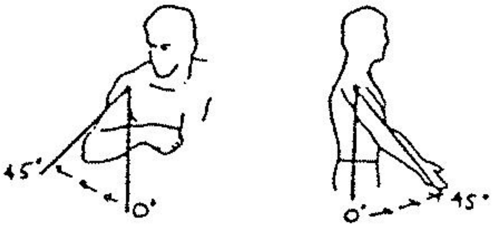
Figure 2.7 Hand and arm with neutral and non neutral postures (13)

Movement postures can affect to muscular fatigue shows as below,

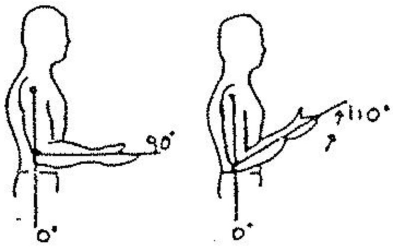
Neck in a position 0- 30 degree



Shoulder in a position 0- 45 degree



Elbow in a position 90- 110 degree



Wrist in a position 0 degree

Finger in a position as picture

Figure 2.8 Working postures that can least affect to muscular fatigue (15)

6) Repetitive job; repetitive job means activities which it's cycle time is less than or equal to 2 minutes and repetitive all shift work. As for highly repetitive job, it's cycle time is less than or equal to 30 seconds. Repetitive job may produce fatigue on muscle or tendon if the period of rehabilitation is not enough for reducing this effect or that repetitive is worked with unnatural posture or high effort. Similarly, the risk of damaged tissue including work related musculoskeletal disorders are increased. However, non neutral postures and high effort shall also effect to reducing of repetitive job per time.

The risk of cumulative trauma disorders are caused by characteristic of work should be careful such as repetitive job, high effort job, static muscular effort, unnatural posture, stress from wok with machine, vibration and cold exposure. (16)

7) Work period; if unnatural work postures are prolonged, health risk effects are also high.

8) Mechanical stress; sectional mechanical stress is the effort compresses on varied part of body continuously, classified to be two groups as follow,

- Internal compression; it was appeared when static contraction of muscle occurs for long time, which can reduce of blood circulation to feed nerve fibers and nerve fibers are also pressed.
- External compression is the compression on varied part of body continuously, it is occurred when exposure with solid or sharpen material.

9) Working environment namely vibration, heat, cold, light and noise.

- Vibration; in case of vibration are passed through hand, it can cause of blood flow stopping and the blood is not enough to fed at hand and fingers areas. Finally, cause of "Reynaud's disease" or "vibration white finger" and also reduce force to grip hand tool.
- Heat; beside of dehydration in body, heat cramp, heat stroke and unconsciousness from heat, it is also cause of loss of physical and psychological efficiency.

- Cold; exposure to cold affect to loss of body temperature. Symptoms are feel cold, chill, pain, dilate of pupil, constrictive blood vessel especially at the end of fingers to cause of white finger like "Hand-arm vibration syndrome". Not only that, cold is the cause of reducing strength of hand grip including cooperation between hands.

2.2.2.2 Psychosocial factors

Psychosocial demand may affect to individual response mechanism and cause of stress from work which increase a tension on muscle while make a rest and work, easy to injure and sensitiveness to feel pain is more than general person who is not stress.

Summarization: In process of hand tool design to fit with welder for reducing work load and fatigue from welding including an evaluation of work load and fatigue, researcher shall know both of appropriate posture that can reduce fatigue and inappropriate postures that can cause of fatigue when welder weld. In addition, risk factors should be studied as data shown in this item.

2.3 Types of work related musculoskeletal disorders on upper extremity

Musculoskeletal disorders are distributed into two groups are **reversible work related musculoskeletal disorders** and **Persistent work related musculoskeletal disorders.** In this study, work related musculoskeletal disorders are only mentioned on upper extremity. Usually, they are occurred at the hand, wrist, shoulder and elbows thus,

2.3.1 Tendinitis or Tendonitis is inflammation of the tendon at the connection area of muscles and ligaments. The symptoms are pain, swelling on the area of tendon's inflammation. Usually, they occur in ligament of wrist, shoulder and elbow. If the cause of inflammation is from degeneration of tendon, it shall be called "tendonitis".

Works related tendonitis are the work with characteristics of force dropped repeatedly such as screw driving, repetition force work on hand or wrist such as folding boxes, type writer etc.

2.3.2 Tenosynovitis is inflammation of tendon and tendon sheath of wrist and finger; symptoms are swelling and pain due to more of synovial fluid under tendon sheath and noise of tendon when moving of muscle on tenosynovitis area.

Works related tenosynovitis are repetitive motion of specific organ although exertion is not much or sudden. If the work is never done before or new production process is conducted, an acute inflammation of the wrist may occur.

2.3.3 Carpal Tunnel Syndrome; CTS is caused by inflammation and swelling of tendon sheath which press median nerve on the palm through carpal tunnel at wrist. It's usually hot, itch, pain and numb at wrist, thumb, index, middle and ring fingers. Sometime, it may also bring on tenosynovitis at fingers**.**

Works related carpal tunnel syndrome are using hand in unnatural position such as an over extension of wrist, ulna deviation while exertion or using fingers while bending of wrist, pinch grip by exertion on fingers. This is founded in a professional typist.

2.3.4 Trigger-finger syndrome is inflammation of tendon and tendon sheath of finger and caused by contraction of fingers repeatedly to anti-vibration. The cause of locking of tendon is the swelling of tendon sheath, and the tendon can't be flexible. Therefore, it is called "**Trigger finger**". Theirs symptom are pain, swell and dexterity of finger. It is often found in female more than in male and in the age group 40-60 years.

Summarization: In appropriate postures of upper extremity and repetitive jobs can cause of musculoskeletal disorders. Therefore, structure and work system of upper arm and shoulder (upper extremity) and injury from movement of upper arm and shoulder should be studied for finding corrective and preventive measurement by ergonomics design.

2.4 Fatigue

Fatigue means loss of efficiency to work including the loss of feeling to try to do any physical or mental activities. (17)

Fatigue is a specific perceive of an individual to discomfort and unhappy. It can be the levels of feeling, since weak to exhaustive which interfere to various acts and/ or using abilities of each individual, to both of physical and psychological operation and to intention or motivation. In addition, it can reduce the perceived ability that affect to decision or solving problem. (18)

When the fatigue appeared, it shall be known as,

1) Observed symptoms such as slow motion, ability to work is decreased, a stable of fingers are reduced.

2) Biochemical changes; lactic acid and carbon dioxide in the muscles that is more acidic.

3) The physical phenomena of electricity. When the muscle fatigue appeared, the electrical stimulation of the skin shall occur which is the results of the central nervous system.

4) Electromyography changes in fatigued muscle.

2.4.1 Cause of fatigue

In the operation, many factors are the cause of fatigue including work exertion, static work, prolong time, unsuitable environmental work, anxiety or conflict in the workplace etc. This fatigue shall cumulative much more if no stops work right to recovery. And it has known that metabolism in oxygen deficient condition will offer very low energy and increases accumulation of lactic acid that interfere to muscle contraction and feel pain. Therefore, lack of oxygen in blood while work with static posture is the cause of reducing efficiency of work including fatigue on that muscle. Local muscular fatigue may occur even if only little exertion or exertion in short time with static posture and with monotonous work. Factors to be cause of fatigue in worker group are as follow,

2.4.1.1 Work factors such as characteristic of work, work load, work posture, work force, duration work time, environmental work namely heat stress, noise, vibration, light and chemical including responsibility, stability in job, conflict, compensation and etc.

2.4.1.2 Personal factors; these are an important factor affect to fatigue. If the worker has a basic of good health, an experience, an interest and looking forward to learning and create job for better likely to cause less fatigue than those who have no interest in the work and discouraged. In addition, the problem of drug addiction, alcohol, smoking and gambling. It is a fundamental issue of worker-related fatigue as well.

2.4.1.3 Organizational factors include the payment of compensation, welfare and shift work schedules.

2.4.1.4 Family and environmental factors in the community; Workers who have family and social obligation such as have many children, poor economic conditions, nutritional incomplete, leisure time is not enough, environmental sanitation is not good and feeling in mind to it is not accepted in society. All these can affect the fatigue. (19)

2.4.2 Type of fatigue

Fatigue can be classified to be 2 types according to the time when fatigue appeared as below,

2.4.2.1 Acute fatigue; it occur rapidly in a short time for day or week and theirs symptom will persist continuously but is not over than one month. It may occur with the various or specific part of the body such as the neck, shoulder and arm due to excessive exertion. Therefore, it is like a mechanism for warning to rest for prevention an injury from working hard or prolongs time. Fatigue will be healed if the work is managed properly. Therefore, it is a little impact to daily living and quality of life.

2.4.2.2 **Chronic fatigue;** it occur for long time, the symptom are gradually became more and more patients and survived longer than a month. The most common cause of stress and psychological problems occurred continually for a long time. It's symptom is stable and could be back to repeat. This type of fatigue can't be healed with time, require many solutions to correct. And it may quite severe affect to their daily living and quality of life. If this type of fatigue occurs more than 6 months is called. "Chronic Fatigue Syndrome".

2.4.3 Fatigue assessment

In the current, there are many methods to assess the fatigue. As below methods are available,

- The Subjective feelings of fatigue of workers.
- The use of medical devices to measure brain waves, electromyography on muscle and biological substances in the body.
- The observation of concentration and productivity from working, observation by walk through survey and assess work posture or image/ video record before analysis by estimation the level of exertion or the level of posture and fatigue. Then, scored shall be present as the risk index.
- The fatigue of the response of brain neurons with flash signals (Flicker Test).
- The use of a fatigue test of the functionality of the hand and fingers (Tapping Test).
- To test the fatigue of the body on the leg part by using a knee-jerk chain (Knee-Reflex Threshold Tester).
- To test the relationship between the senses and mid brain by using Two Touching-Points Discrimination Threshold Tester.
- To test the fatigue of the brain with Color Calling Table.

2.4.3.1 An assessment technique for postural loading on the upper; LUBA (20)

There are many observation methods for quantification of postural stress during work. They were not chosen to assess in this study due to theirs many disadvantages as

1) Schemes of observational classification are not based on experimental data.

2) The current methods have been developed for specific application purposes.

3) Many methods concern with only a few representative joint motions which is specific joint motions related musculoskeletal disorder

4) There is a few scheme use specific criteria to evaluate for classified postures such as OWAS (21), RULA (22).

5) Criteria for evaluation of RULA and OWAS are not based on experimental results. They rather depend on the ranking arranged by ergonomist and occupational physiotherapist using criteria of biomechanics and muscle function.

Due to LUBA was developed directly for postural load assessment on upper body and it was based on experimental data for composite index of perceived discomfort. Therefore, it was chosen for fatigue assessment in this study. LUBA is an observation on work posture to assess feeling and the risk of the individual. It is a technique for assessment by considering on motion of each joint of upper part body with wrist, elbow, shoulder, neck and back which divides process into 4 steps as appendix A. And the last step, postural load index shall be assessed by using criteria of the management of the following four categories

Category I: it is category of postures with postural load index is less than or equal to 5. This category of postures is acceptable. Except in specific circumstances, such as pretend repeatedly or long term position. This condition is acceptable and do not require corrective measurements.

Category II: it is category of postures with postural load index is from 5 to 10. This category of postures must be further investigated and change measurement to correct during next regularly check but it do not need to be taken immediately.

Category III: it is category of postures with postural load index is from 10 to 15. This category of postures must be taken a measurement for corrective action through redesign workstations or working methods without delay.

Category IV: it is category of postures with postural load index is 15 or more. This category of postures shall be considered and set a measurement correct immediately.

2.4.3.2 The observation of concentration and productivity at work: A cycle time for welding per piece of copper capillary tube are observed to assess fatigue including concentration and productivity from working.

2.4.3.3 Fatigue assessment by Electromyography measurement: The contraction of the muscle coincides with the electric current phenomenon known as "Action Potential" of those muscle fibers that can be recorded by using amplifier with electromyography recording of muscle technique. It is recording of an electric released during muscle contraction by attaching surface electrodes on muscle studied to record the electromyography increased which show a higher exertion or contraction of muscle. Accordingly this technique is useful in the study of the muscles exertion while working; it is used to be information for improvement working condition by recording an electromyography released after improvement to identify that an exertion on muscle is decreased which is also means that probability of fatigue is decreased.

2.4.3.4 The Subjective feelings of fatigue of workers: In this study, questionnaire for finding the state of fatigue feeling due to working modify from grandjean (23) and Corlett and Bishop (24). The subjective feeling of fatigue is classified to seven states with scores as below

0 means not fatigue
1 means start to feel fatigue
2 means slightly fatigue
3 means moderately fatigue and can relief after resting
4 means moderately fatigue and can't relief even resting
5 means severely fatigue and can relief after resting
6 means severely fatigue and can't relief after resting
7 means extremely fatigue and can't work

Summarization: Although there are many methods for assess fatigue but postural load index from LUBA technique, electromyography (EMG) measurement, the observation of productivity from working and the subjective feeling of fatigue of subjects were chosen to assess in this study.

2.5 Electromyography and Nervous system

Muscle and neural have the mechanism to charge an electric and it can be released ion when they are stimulated and semi-permeable cell membranes including electrolytes with different concentrations are appeared. The main components of electrolytes consist of Sodium (Na^+) and Potassium (K^+). It has mechanism of Sodium- potassium pump to feed potassium into and out of cell all the time as figure 2.9

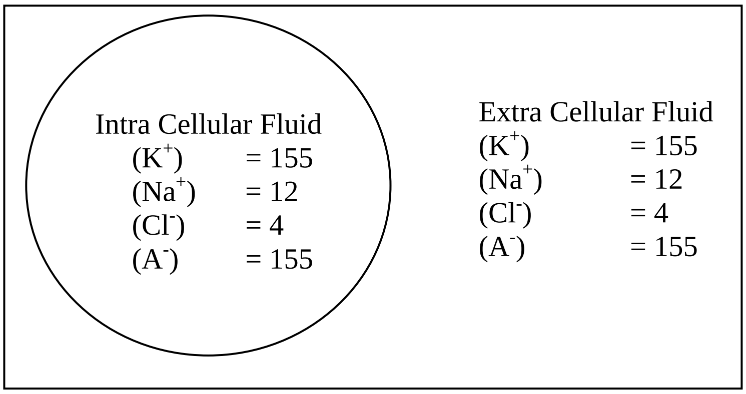


Figure 2.9 Concentration of Electrolyte

At the resting phase, cell membrane allows potassium percolate into cell more than sodium up to 50 times, thus potassium brings on anion out of the cell. Due to anion cannot spread far from membrane because a sucking of anion which cannot pass through the outside, therefore, they line up near the outside of cell membrane and anion at outside is rather than at inner as the figure 2.10. It has been that, function of cell membrane is to be same as a capacitor, membrane acts as insulation and there are conductive electrolytes on both sides.

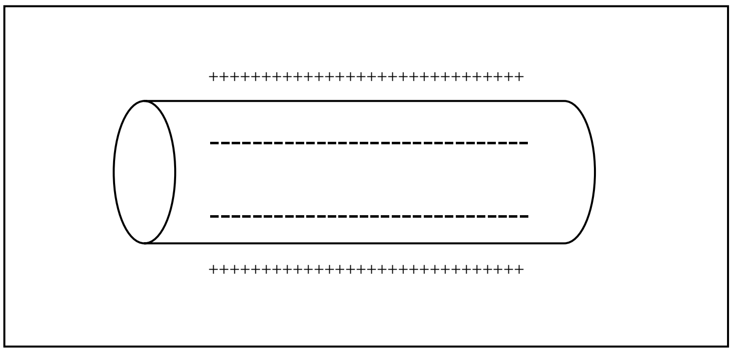


Figure 2.10 Exchange between anion and cation through cell membrane

When muscle contraction appears, an electric will spread on muscle. Next, this spread electric shall stimulate mechanism of muscle contraction. Due to changing of electric potential while muscle contraction are the process occurs in it'self, energy shall be released every time that is stimulated, therefore, an electric potential while working is not reduced even if it shall be spreaded over long distances.

An electric current occur from muscle fiber contraction can be measured by using surface electrode put on the skin at that muscle area or using Needle electrode insert into that muscle (but needle electrode is the cause of discomfort are to produce constriction or spasm in muscle increasingly and sometimes to cause the cramps, therefore, in this study uses surface electrode to measure electric current). Amount of electric current indicates amount of motor unit related with electric current of that muscle.

2.5.1 Detection of surface electromyography signal (25)

Principle of electromyograph divided into 4 parts as below,

2.5.1.1 Signal receiver part; this is equipped with surface electrodes attach to the skin over target muscle.

2.5.1.2 Amplifier part; the signal from surface electrodes shall be amplified to be a larger signal.

2.5.1.3 Filter part; the filter shall be used to cut out unwanted signal.

2.5.1.4 Display part; Computer shall be used for processing of measurement and shall process, display and record by infinity software.

Muscle | Electrode+ Cable+ Encoder (Electromyograph Series MP36) | Computer/ Infiniti software

Fibers --> ┊ Electrodes --> Amplifier --> Filter ┊ --> A/D converter --> ┊ Processor/Monitor

Figure 2.11 Detection of surface electromyography signal

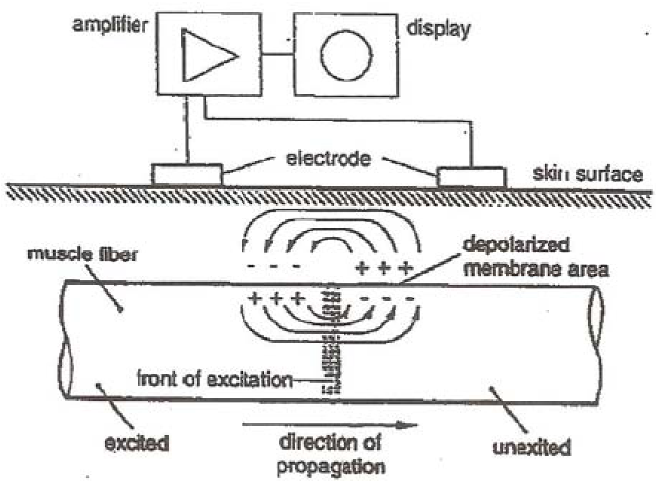


Figure 2.12 Flow of ions activated (Action Potential) from the muscle fibers. This electric potential difference can be measured by 2 discs of surface electrodes.

2.5.2 An electrodes attaching (26)

An error of measurements by using surface electrode attach to the skin at the area of muscle is more than using needle electrodes insert into the muscle. Especially, when the body or muscle of subjects is moved, it may the cause of movement or position change of surface electrode. However, a needle electrode is ideal to use with experimental animal. The main of process is that electrodes shall be placed at the point required where is the belly or the midpoint of muscle to measure. Gregory S. Rassh, EdD provides information for setting the surface electrodes as below,

2.5.2.1 Preparation of the skin (27)

1) Get the subject to wear the shoes.

2) Take cotton wool moistened with normal saline and wipe on the skin where will be attached to by surface electrodes. If the measurement shall be done on the either side of arm, the right side should be chosen.

3) Take cotton wool moistened with alcohol and clean the dirt, lipid and dead skin. Then scrub on skin thoroughly. (This cleaning can reduce the resistance of the skin almost 200 percent).

4) Shave off an excess, if necessary.

Remark:

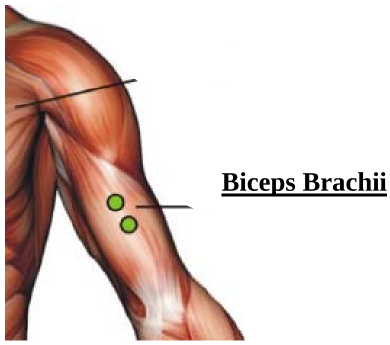
If the skin is dry, the electrode gel should be applied to that skin. If the sweat is release, spray for reducing the sweat on the skin should be used after cleaning with alcohol.

5) Put surface electrodes on skin by putting on the biggest area of muscle (belly or midpoint of muscle to measure) and put electrode as the line of muscle fiber in a bundle of 3 points are the first is anode (red), the second is cathode (white) and the third is a ground (black).

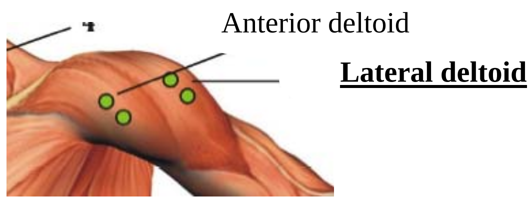
Remark:

Be careful, don’t to touch the metal plate at each electrode and do not allow the air into this plate.

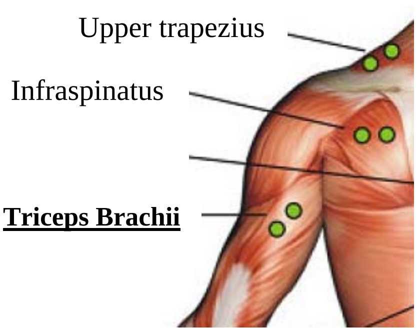
2.5.2.2 Uses the tape attaches to the round sheet around electrode to avoid movement of electrode and avoid causing of tension on the wire. It shall be ensured that the wire be loosen under the tape or the material that is embed in place. And must be careful, the tape shall not touch with the metal part of the electrode.



Front view



Side view



Back view

Figure 2.13 Attached points of electrodes on shoulder and upper arm muscles (25)

2.5.3 Processing and analysis (25)

While an over exertion on muscle occurs, the body cannot produce energy supply sufficiently as demand and there is not enough of oxygen supply, therefore, acidity will be formed in inner cell and affect to the decreasing of electric conduction of cell membrane and electric potential while working is low. In addition, the nerve that will be transmitted to the muscle is obstructed. In the other words, if the fatigue occurs, rapidity of nervous conduction is reduced. Although electromyograph is not possible to measure the rapidity of the nervous energy conduction but it can indicate the level of activation of muscle by using root mean square (RMS) value. Actually, muscle generates EMG signal and it is displayed as raw EMG. In the raw graph in time domain, time is displayed on X axis and amplitude in microvolt is displayed on Y axis. When muscle contraction occurs, the number and amplitude of line increase. In opposite, they decrease when muscle relaxes. RMS is a technique to rectify the raw EMG and convert it to an amplitude envelope. It represents the mean power of EMG signal.

EMG signal analysis can be divided in 3 groups are amplitude analysis, temporal analysis and spectral analysis. Area or integrate EMG is one of amplitude analysis that is the mathematical integral of the EMG amplitude. It conforms to the area under the curve in a given period of time. It is a good indicator of the quantity of power produced at that period of time.

2.5.4 SEMG & Muscle Fatigue Monitoring

While the muscle contraction occurs, contractile force would be used together. Due to contractile force can no longer be maintained, muscle fatigue is appeared, therefore, additional fibers shall be recruited for generate the same force. It affects to an increase of EMG amplitude (RMS is a technique to rectify the raw EMG and convert it to an amplitude envelope). **RMS is as fatigue indicator, it would be used when movements are required**. RMS shall increase with fatigue. (25)

In time domain, root mean square value of EMG signal is considered that it is the most reliable of parameter. Increasing of RMS and increasing of fatigue are reported in several studies (28)

Summarization: Electromyography monitoring is one method of fatigue assessment. To compare the results and prove torch designed in this study, researcher shall study and understand about processing of electromyography monitoring including concerned muscle and tool for monitoring as showed in this item.

2.6 Working conditions, the cause of fatigue.

Copper Capillary tube welding is a step of equipment preparing for using to be pipe line system to distribute the cool of air conditioning. Condition of table and work piece installation show as the figure 2.14 Part height (Copper capillary tube) is 10, jig height, a vertical distance between end of torch and welding point and a horizontal distance between middle hands to the welding point are 5, 5 and 20 cm. respectively.

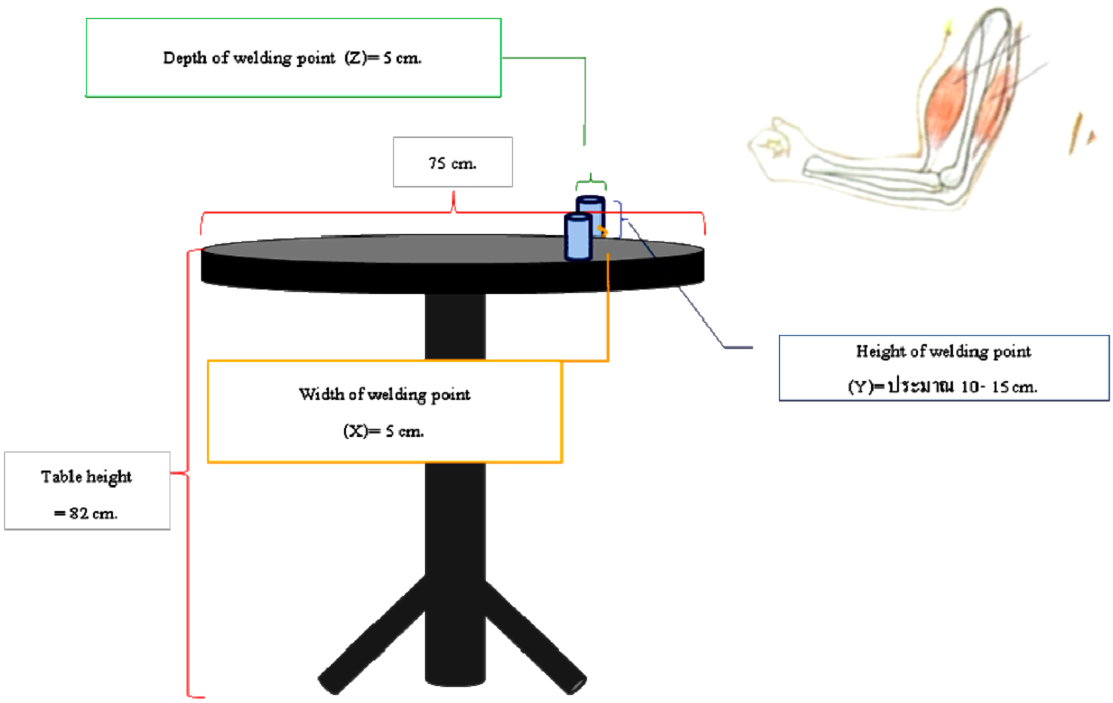


Figure 2.14 Condition of table and work piece installation

Instructions of Copper capillary tube welding are as follows,

1) The operator set distributors and pipe on the table by using the jig to hold them and turn the side of a round hole to top. The number of round holes depends on the model of the air, these round holes are drilled and sorted to be a circle on distributor. (In this experiment, there were 13 holes).

2) The operator use copper capillary tube assembles with all the round holes on distributor, the end of each copper capillary tube shall be placed on jig. Then, rotate the assemble side of the table to welding point on opposite side.

3) The operator light on torch by using LPG to be fuel source.

Remark: Characteristic of an existing torch are a handle is a linear line to the end of exit way of flame of pipe, it is not designed by using data from anthropometry of operator as ergonomic principle, the distance between the middle of torch handle to the end of exit way of flame is 40 centimeters and the diameter of handle is 1.9 centimeters as figure 2.15

Figure 2.15 Existing torch which is not designed as ergonomic principle.

4) The operator weld copper capillary tube

Remark: As characteristic of torch, it can affect to health of operator when they weld the copper capillary tube. That is they shall raise theirs arm over shoulder level and twist the wrist to aim the direction of flame to the welding point which is a connection of copper capillary tube and distributor as figure 2.16. These are non neutral posture of hand shoulder and arm and can make pain and fatigue on theirs arm and shoulder muscle and have been often served at clinic room and hospital cause from repeatedly and continually act in every day by these postures work. Some operator had ever gone to hospital for treating a chronic arm muscle pain symptom related work, the symptom of some operator are severe and need for surgical treatment of tendon sheath covering the palm and inflammation on fingers due to repetitive bending and twisting of wrist with non neutral posture while welding work.

5) The operator removes the setting of copper capillary tube from welding on the table to place on tray.

Figure 2.16 Copper capillary tube welding posture

Summarization: For correction the fatigue from welding by design new torch as principle of ergonomics, it’s necessary to understand about existing conditions to verify the cause of fatigue as shown in this item.

2.7 Prevention and control fatigue

An operation to relieve fatigue from work, the first important to consider is an engineering control by focus on work condition improvement to reduce postural loading from work. In particular, using of muscle strength by static posture with non neutral posture work. And work environmental improvement such as noise control, ventilation, lighting control etc. can reduce fatigue from work as well. In addition, conduction of management measures e.g. setting an appropriate timing work and duration to stay etc. can help to prevent fatigue.

2.8 Principle to design

In this will study the prevention and correction fatigue from welding on copper capillary tube. An engineering control measurement will be main consideration by aim at an improvement on working condition of copper pipe welding which is to design new torch for reducing fatigue on arm and shoulder muscular from an existing welding process with non neutral posture. Therefore, this section aims to the content of principle for design to be an element of torch design only.

2.8.1 Principle to design on hand tools

CCOH (29) mentions to the principles involved in the hand tools design as,

2.8.1.1 Weight of the tool.

In principle, Operators should be able to control the tool with one hand. If that, weight of the tool should not exceed 1 kilogram, especially for repetitive job. In addition, the center of gravity shall be aligned with the center of hand grip.

2.8.1.2 Handles

Due to working with hand tool on a precision work such as watch making, microsurgery and carving, handle and grip of hand tool should be designed for a power grip. The beliefs that smaller hand tool should have a smaller handle and larger hand tool should have larger ones are still debated.

1) Handle shape

Hand tool with bent or angled handle is beneficial for work that requires a force in straight line with same direction as arm and wrist, especially when force in horizontal line.

Hand tools with straight handles are for tasks that the force is exerted perpendicular to the straightened forearm and wrist

It is known that layout of workplace and equipment are important to decision for choosing appropriate hand tools, tools are not to cause of pronation, supination or deviation on wrist. Similarly, it should be the tools make the wrist in straight line or in neutral posture.

Main ergonomic principle to design hand tool is "**bend the tool, not the wrists**" but it may be not prevent discomfort and injuries every time. If bent handle tools are used without consideration the difference and kind of work situation.

2) Diameter

In a cross section, handle should be cylinder or oval shape with diameter of between 30-45 mm. For a precision work recommend of between 5-12 mm. And for a large screwdrivers need a greater torque should be between 50-60 mm.

3) Length

For too short of handle can cause of compression in a middle of palm. The length of handle should extend across the entire breadth of palm. Hand tools with handles length is more than 100 mm. (preferably 115-120 mm.) will reduce effect of compression in middle of palm. Rounded handles will minimize palm compression on the palm. If the gloves were worn, the length of handle should be longer.

4) Separation between handles

Gripping or cutting tool such as pliers or tongs are equipped with 2 handles. Distance between separated handles is recommended of 50-65 mm. This range is appropriate with both of male and female. Hand tool with separated distance is larger or smaller will reduce grip strength and can cause of "Carpal Tunnel syndrome"

5) Materials and texture of handles

To ensure that gripping on handle is good, it shall have sufficient friction between hands and handle. Especially, while the hand tools are chosen for use with a sweaty hand. Hand tools should be made of non slip, non conductive and compressible materials such as textured rubber handles can make a good gripping, do not need more effort while using hand tool and prevent slipping out of hand. Avoid using a coating and polishing handle. For a power tool, heat and electrical insulation properties of handle are important to consider. Handle can be made of plastic or compound rubber. For a sharpen edges or contours, it can be covered by cushioned tape to minimize lacerations.

For reducing fatigue and injuries of muscle from work, these are principle to design hand tool, (13)

1) Design by using power grip for work requires an exertion, and pick design for work requires accuracy as figure 2.17

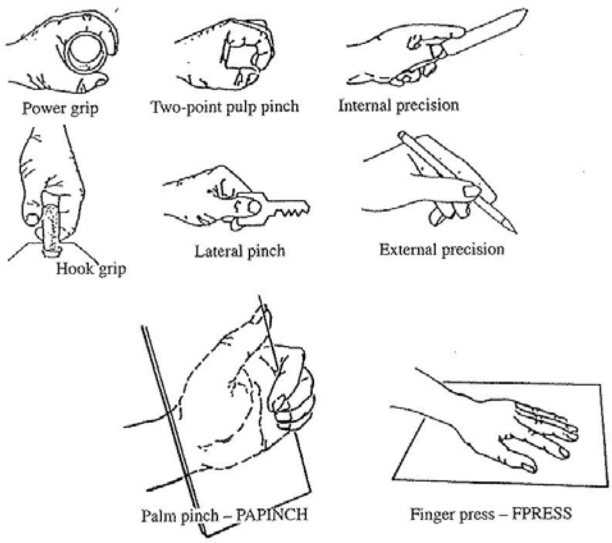


Figure 2.17 The different of grips

2) Avoid using prolonged static muscle strength.

3) Design to twist arm by bending elbow.

4) Design by maintain direction of wrist in natural position (Neutral posture) when working with it. European Committee for standardization prEN 1005-3 recommends that the horizontal included angle when holding the handle should be around 70 degree (clockwise direction).

5) Avoid compression on tissue as figure 2.18

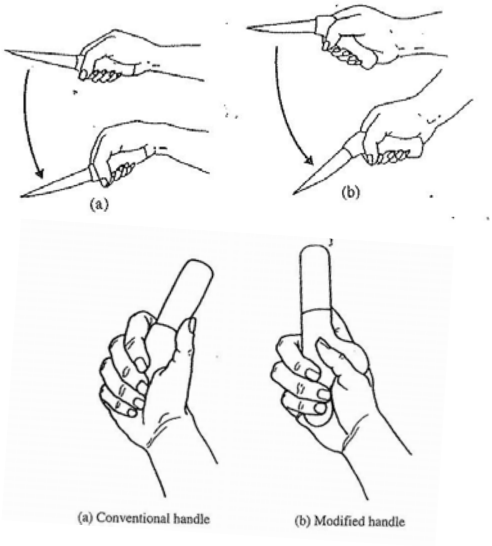


Figure 2.18 Handles design

6) Design for getting hand tools are used with either hand and for each person as much as possible.

7) Avoid repetitive job of fingers.

8) Designed to be used by the strongest fingers.

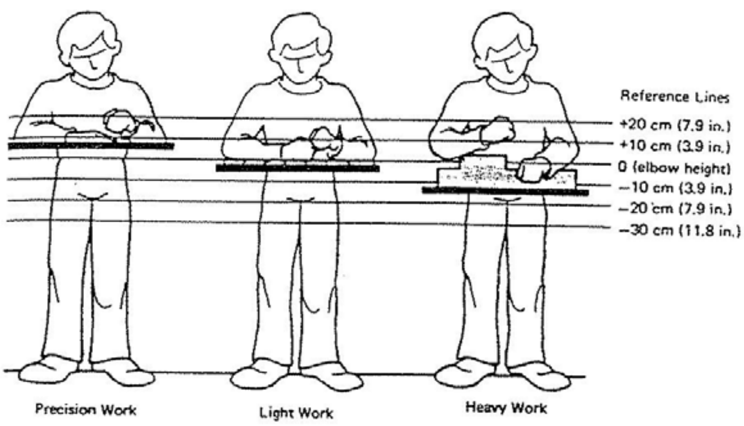


Figure 2.19 Recommendation height level of work station as kind of work.

9) For standing workplace, Colin G. Drury, 1985 (30) recommends the working height that it should be 2 inches or at about 5 cm. or more below elbow height.

Summarization: For correction of fatigue problem correctly from welding, researcher shall study and understand ergonomics principle for design hand tool (new torch) to fit with welder as shown in this item.

2.9 Anthropometry and design

Anthropometry is the science to measure body dimension of population

Anthropometric measurement procedure on each position appeared in "Appendix A Anthropometric measurement procedure and Anthropometer" of this document referred from Office of Industrial Standard, Ministry of Industry that use standard criterion of International organization for standardization regarding to ISO 7250-1: 2008 Basic human body measurements for technological design- Part 1: Body measurement definition and landmarks.

Scott Openshaw and Erin Taylor (31) said that it shall always recognize that there are many sizes and shapes of population when the material will be designed. In addition, he had translated and written "Ergonomics and Design A Reference Guide" book that the width, length and depth of each population will be arranged in order of size and described by percentile. By generally, material will be designed for percentile 5^{th} value of female to percentile 95^{th} value of male. Percentile 5^{th} of female will be used to specific dimension such as seat height, usually be representative of a smallest size in population. In opposite, percentile 95^{th} value of male may be used to be representative of a biggest size in population

Percentile 5^{th} value to percentile 95^{th} value portion is adjusted value for 90 percent of population to make the design appropriately for a large size of population.

Kitti Intranon (32) mentioned philosophy of ergonomics design that there are 3 characteristics of taking physical qualification and body dimension to apply in design for specific of a large of population as,

1) Design for average; this may not suit for anybody because nobody has an average dimension in every shape. Usually, it was used to design for building and public place.

2) Design for extremes; this will design for smallest or largest dimension. If the design by using a smallest dimension was conducted, it would affect to a largest dimension. Therefore, the study of population should be done before design. Besides, the design for extremes can affect to the cost.

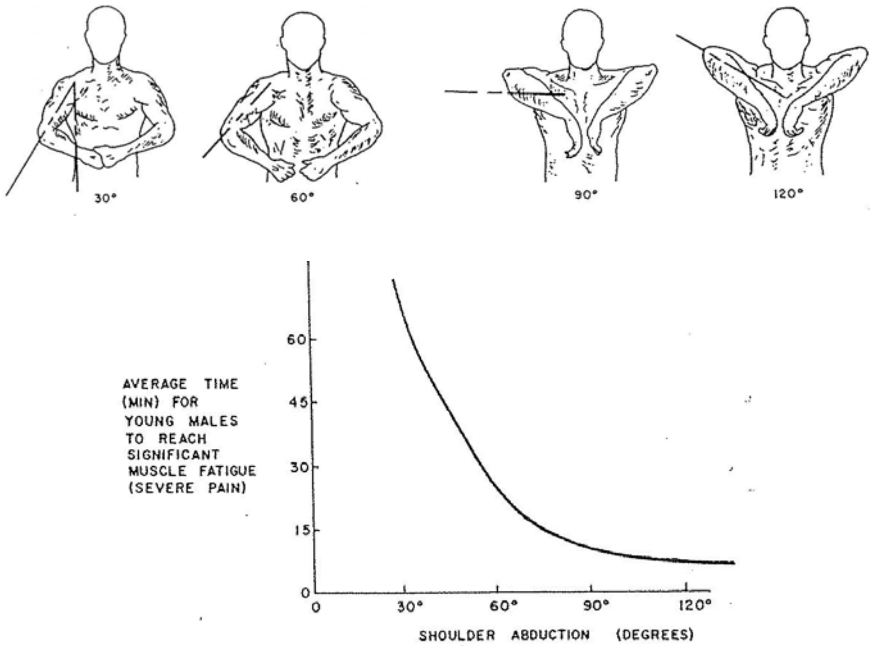
3) Design for range; it means the design for group of population. Usually, this shall cover 90 percent of population based on size of population between percentiles 5^{th} value to percentiles 95^{th} value portion. This can adjust to be narrower or wider portion depend on product, characteristic of work or cost.

K.N. Dewangan et al, 2008 (33) surveyed body dimension of female employees in agriculture in India. This body dimension was used in the design of tool in sector. Percentile 95^{th} value of hand breadth should be considered for the design of handle length and the clearance area should be 0.5 centimeter at each end of both sides of handle. For a good gripping, Nag et al., 1988 (34) recommended that diameter of handle should not be over than inside grip diameter and to cover the majority of population, it should be based on percentile 5^{th} value of inside grip diameter of employees.

Summarization: To correct fatigue problem from welding, researcher shall design new torch fit to welder. Concerned body dimension of welder would be brought to design as principle of ergonomics. Therefore, anthropometry measurement in this item should be studied and made understanding.

2.10 Literatures related fatigue and work postures

Chaffin, 1973 (35) studied the relationship between shoulder abduction of young man at working in various angles with the duration of fatigue of shoulder muscle as figure 2.20. The young man was asked for to abduct shoulder with angles of 30, 60, 90 and 120 degree and studied the duration of fatigue; this study found that average durations of fatigue of shoulder muscle are 86, 25, 10 and 7 minutes respectively. He concluded that a higher degree of extension of shoulder postures can cause of muscle fatigue faster.



Expected time to reach significant shoulder muscle fatigue for varied arm abduction angles (Chaffin, 1973).

Figure 2.20 The relationship between shoulder abduction of young man at working in various angles with the duration of fatigue of shoulder muscle

Majid Motamedzade et al, 2007 (36) studied the relationship between prevalence of arm problem and the design of hand tool with comb and scissors in carpet industry by examining of the design of existing hand tools for carpet weaving and the design of new hand tools by using body dimension and principle of ergonomics and assess the perceive of comfort and ability of staff woven carpets to use hand tool designed woven carpets. The statistical analysis revealed differences between the scores of existing hand tool and new hand tool designed is that employees had satisfied significantly for the comfort and ability to use new hand tool design (P <0.01) and the new hand tool design has been recognized by the staff woven carpets.

Helenice Gil Coury et al, 1998 (37) studied electromyography (EMG) of 4 pairs of arms and shoulders muscle (Biceps, anterior deltoid, pectoralis and pector carpi radialis) of 10 healthy males during the normal force and shoulder and elbow is in different positions while subject was in static adduction arm. The results showed that the EMG increased when shoulder forward flexion increased, but force decreased.

CHAPTER III
MATERIALS AND METHODS

3.1 Study design

This study was quasi- experimental by design new torch to comply with ergonomics principles. This tool would be applied in the experimental called “Before-After experiment with no control group” This experimental will compare electromyography on upper arm and shoulder muscle from postures on copper capillary tube welding process by the use of both existing torch and new torch, compare postural load index from postures assessment on copper capillary tube welding process by the use of both existing torch and new torch by an assessment technique for postural loading on the upper body and study efficiency of welding by observation on cycle time of copper capillary tube welding by the use of both existing torch and new torch of subject who operate on welding process at an air conditioning production factory in Thailand.

3.2 Population and sample

Reference population: Study on population who welding on copper capillary tube totally 90 persons at an air conditioning production factory in Thailand. Sample size is calculated from formula as

$$n = \frac{(Z_\alpha+Z_\beta)^2*(\sigma_d)^2}{(\mu_d)^2}$$

Where

n is sample size

Z_α is 1.64 (at 95% confidence interval)

Z_β is1.28 (when power factor is 90%)

σ_d is the difference value of standard deviation of population and it is equal to 11.78

μ_d is the difference value of mean of population and it is equal to 11.99

Instead value in this formula as follow,

$$n = \frac{(1.64+1.28)^2*(11.78)^2}{(11.99)^2}$$

$$n = 8$$

Summarization: Sample size from calculation is 8 persons and they would be chosen by Purposive sampling.

Remarks: Due to population is a large size, it is necessary to refer the data of sample from previous study. In this study, the value of σ_d and μ_d came from study of Supranee Pochaka, 2005 (38) was a reference.

Inclusion criteria: Someone who has qualification comply the criterion as below would be included to be subject in this study,

3.2.1 Be the worker at an air conditioning production factory in Thailand.

3.2.2 Be the copper capillary tube welder.

3.2.3 Body mass index is normal for 18.5- 22.9 (39)

3.2.4 Height between 150- 170 centimeters

3.2.5 Experience at least 6 months on welding

3.2.6 General healthy, no have hepatitis, heart disease, gallbladder disease and other or no have accident history that may affect to fatigue on shoulder, arm and hand

3.2.7 No smoking or drink alcohol regularly

If qualification of any one was not comply as criterion mentioned, they would be excluded in this research. All subjects shall take a rest at least 6 hours before measurement, shall be not during menstruation, shall have willing and voluntary participation in this project and shall have been told the details of the study and signed in inform consent form.

3.3 Material and Equipment

Material and equipment using in this study are,

3.3.1 Anthropometer are,

3.3.1.1 Scale; it is used to weight of the subject.

3.3.1.2 Anthropometry; it is used to measure body stature of the subject such as tape measurement, beam and calipers as figure 3.1

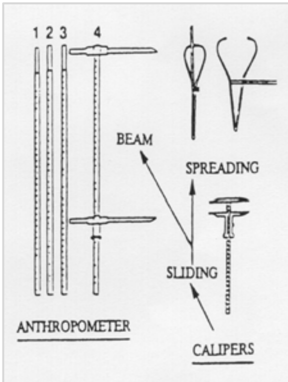


Figure 3.1 Examples of anthropometer

3.3.2 Anthropometry of welder who connect copper capillary tube record form

3.3.3 The interview form for finding muscle fatigue situation of the population; it is form for finding the general information of the subject such as general history, health history and work experience.

3.3.4 Table for Postures assessment by An Assessment Technique for Postural Loading on the Upper Body (LUBA)

3.3.5 Table of time record in copper capillary tube welding process with an existing torch and new torch

3.3.6 Electromyograph (Electromyograph Series MP36 with BP EL503 disposable electrodes). It is used to measure electromyography on upper arm and shoulder of subject when they weld with an existing torch and new torch.

3.3.7 Torch

3.3.7.1 An existing torch; it is on welding table of each subject at present. It shows as figure 2.14 and was not be designed to comply with ergonomics principle.

3.3.7.2 New torch; it is designed by using anthropometry data of subject. It is characteristics are the head is straight line and the end area of torch is bent. Therefore, subjects do not lift his arms to high level and do not twist the wrist to control the direction of the flame to point at the target area.

3.3.8 Copper Capillary tube and Distributor

3.4 Data collection

Before process of data collection, researcher had made a request to Ethical Review Committee for Human Research, Faculty of Public Health, Mahidol University and certificate no. MUPH 2011-224 was approved (See as appendix D Documentary proof of ethical clearance).

Procedure of data collection consist shows as below,

3.4.1 Researcher survey the problem from copper capillary welding on worker in factory of air conditioning production to find work posture that may affect to harm or illness from ergonomics by consideration on statistics of illness from clinic room of air-conditioning company, the medical treatment data due to copper capillary welding and the results of an assessment technique for postural loading on the upper body (LUBA) to pose the discomfort score from copper capillary welding posture by using an existing torch and evaluate postural load index comply by 4 categories of criterion of action (as background and rationale).

3.4.2 Researcher informs about objective and instruction on experiment to subject and requires the consent of participated subjects.

3.4.3 Researcher makes an individual interview to each subject to find characteristics and physical health status of subject with "muscle fatigue situation interview form" before welding. In preliminary, subjects will be explained about interview form in order to understand clearly to prevent the error of data collection. The data of characteristics of subject would be present as "Table 4.1 The characteristics of 9 subjects who operation on welding process" and physical health status of subject would be present as “Table 4.4 Physical health status of subject who operation on welding process.”

3.4.4 Researcher chooses subjects who has qualification comply the criterion in article 3.2

3.4.5 Researcher measure body dimension of subject by applying variety body position measurement procedure Listed in of this document based on ISO 7250-1: 2008 Basic human body measurements for technological design- Part 1: Body measurement definitions and landmarks. If any statures of the body are two sides, the right side will be measured as,

3.4.5.1 Weight

3.4.5.2 Stature

3.4.5.3 Shoulder Height

3.4.5.4 Elbow Height

3.4.5.5 Shoulder Elbow Length

3.4.5.6 Elbow Wrist Length

3.4.5.7 Elbow to Center of Grip

3.4.5.8 Elbow Fingertip Length

3.4.5.9 Hand Length

3.4.5.10 Hand Breadth

3.4.5.11 Grip Diameter

Body dimension data of each subject would be filled in “Table A-1 Anthropometry data of copper capillary tube welder”.

3.4.6 Body dimension data would be sorted in ascending order. And then calculated to find value of percentile 5^{th} and 95^{th}. They would be presented in “Table 4.2 Anthropometry of subject who operation on welding process (cms).”

3.4.7 Value of percentile 5^{th} and 95^{th} are directed to designed new torch for reducing shoulder level, the angle between arm and body and angle to twist the wrist while welding. The characteristic of welding would be shown in "Table 4.3 Comparison of the characteristic of welding with an existing torch and new torch (design by ergonomic principles)"

3.4.8 Get subject fill the state of subjective feeling of fatigue including comfort acceptance, measure EMG on each subject along with image recording to assess postural load index on the upper body while welding with an existing torch and record the time spent per cycle of welding. The process display as,

3.4.8.1 Researcher describes criterion to state the subjective feeling of fatigue and gets subject fill the state by him or herself before welding by existing torch.

3.4.8.2 Researcher makes understanding to subject about criterion and instruction when they are equipped with electromyograph.

3.4.8.3 Get the subject to wear their shoes.

3.4.8.4 Take a cotton wool moistened with normal saline and wipe the skin over the right upper arm muscle or shoulder muscles that are attached to surface electrode.

3.4.8.5 Take a cotton wool moistened with alcohol and wipe off dirt, fat and dead skin thoroughly. Then scrub skin points where will be attached by surface electrodes.

3.4.8.6 Shave an excess off. If dry skin, use a gel electrode applied to the skin. If the sweat, spray the sweat on the skin after cleaning with alcohol.

3.4.8.7 Place surface electrode on the skin by putting upper the largest muscle (at the belly part or the midpoint of upper arm muscle to measure) and place along the muscle fiber of three points in a bundle as first is anion (white), the second is cation (red) and third is ground (black). It must be careful; the hand must not contact to the metal sheet on each electrode and avoid occurrence of air cavity.

3.4.8.8 Use tape attach to the round plate of each electrode to avoid the movement of the electrodes and to avoid causing of tension on the wire. It should be ensured that the wires are loosen under the tape or the material and are frozen. Avoid attachment between tape and metal sheet of electrodes.

3.4.8.9 Install camera to record the image of welding posture and the time spent per cycle while welding by each subject with an existing torch.

3.4.8.10 Measure EMG in a round of experimental by electromyograph at upper arm and shoulder muscle of each subject while welding with an existing torch for 20 minutes. During welding are running, the ambient temperature will be recorded together.

3.4.8.11 Get subject continue weld for 2 hours, after that gets him or her fill the state of subjective feeling of fatigue including comfort acceptance by him or herself after welding by existing torch.

3.4.8.12 Follow as the steps of 3.4.8.1 to 3.4.8.11 with the other to the last subject.

3.4.9 Get subject to train the using new torch designed to weld the copper capillary tube to become familiar with new torch before test. The time spent in training with new torch is equal to the time spent with an existing torch (at the beginning before being staff of welding work section).

3.4.10 Measure EMG by electromyograph at upper arm and shoulder muscle of each subject (same group on step of 3.4.8) including record the image to assess postural load index on the upper body while welding with a new torch designed and record the time spent per cycle of welding by following as step of 3.4.8

3.4.11 Find mean of RMS EMG of each muscle (deltoid, biceps and triceps muscle respectively) while welding by using existing torch and new torch from EMG records file by Acq*Knowledge* Software. Then, fill the results in

- Table 4.5 The results from EMG monitoring (mean of RMS EMG) on deltoid muscle while welding by using existing torch and new torch
- Table 4.6 The results from EMG monitoring (mean of RMS EMG) on biceps muscle while welding by using existing torch and new torch
- Table 4.7 The results from EMG monitoring (mean of RMS EMG) on triceps muscle while welding by using existing torch and new torch

And finally, they would be compared and present as "Table 4.8 Comparison mean of RMS EMG of each muscle from welding by using existing torch and new torch" by paired- samples t test application.

3.4.12 Bring the image recorded on the step of 3.4.8 and 3.4.10 to consider and assess the postural load index from welding posture. Data from postural loading on the upper body assessment by LUBA would be filled in "Table 4.9 The result of postural loading on the upper body assessment by LUBA from welding posture by using existing torch" and "Table 4.10 The result of postural loading on the upper body assessment by LUBA from welding posture by using new torch." Then, They would be compared and present as "Table 4.11 Comparison of postural load index of welding by using new torch and existing torch" by paired- samples t test application.

3.4.13 Fill the time spent per cycle of welding by using both of existing torch and new torch in "Table 4.12 The time spent per piece of copper capillary tube from welding with both of existing torch and new torch." Then, they would be compared and present as "Table 4.13 Comparison of cycle time for welding per piece of copper capillary tube by using torch." by paired- samples t test application.

3.4.14 Fill the subjective feeling scores of fatigue in before and after welding process by existing torch and new torch in "Table 4.14 The subjective feeling scores of fatigue in before and after welding by using existing torch and new torch." The difference scores between before and after welding process by existing torch and new torch would be compared and present as "Table 4.15 Comparison the difference scores of subjective feelings of fatigue in welding process by existing torch and new torch" by Wilcoxon matched-pairs signed-rank test application.

3.5 Statistical analysis (40)

Statistical data analysis is as follows.

3.5.1 Descriptive Statistics

3.5.1.1 Use mean and standard deviation to describe

1) General and health information of the subjects
2) Anthropometry
3) Postural load index
4) Time spent per cycle of welding
5) Electromyography

3.5.1.2 Use percentage to describe

1) Characteristic of subjects
2) Health information of the subjects
3) Anthropometry

3.5.1.3 Use min, max, average and percentile to describe

1) Anthropometry
2) Postural load index
3) Electromyography
4) Time spent per cycle of welding

3.5.2 Inferential Statistic

In this study use

1) Pair t- test statistical to compare electromyography on upper arm and shoulder from copper capillary tube welding between by using existing torch and by using new torch of subject.

2) Pair t- test statistical to compare postural load index from copper capillary tube welding between by using existing torch and by using new torch of subject.

3) Wilcoxon matched-pairs signed-rank test to compare subjective feeling scores of fatigue from copper capillary tube welding between by using existing torch and by using new torch of subject.

CHAPTER IV
RESULTS

Objectives in this study are to design new torch as principle of ergonomic for reducing fatigue on arm and shoulder muscle, to compare an EMG monitoring results on arm and shoulder of welder while using existing torch and new torch to weld, to compare the postural load index from risk assessment by LUBA while using existing torch and new torch to weld, and to study the efficiency of new torch. The results are from anthropometry and design new torch, electromyography measurement and postural load index process from assessment technique for postural loading on the upper body (LUBA) and recording a cycle time for welding per piece of copper capillary tube. The data has been collected from subjects who operate on welding process at an air conditioning production factory in Thailand. The results have divided into 6 parts as below,

Part 1 The characteristics of subject

Part 2 The anthropometry data of subjects and hand tool design

Part 3 Physical health status of subject

Part 4 The result from electromyography measurement

Part 5 The result of postural loading on the upper body assessment by LUBA

Part 6 A cycle time for welding per piece of copper capillary tube

Part 7 The Subjective feelings of fatigue of subjects.

Part 1 The characteristics of subject

The copper capillary tube welding process was conducted to study from 9 subjects of an air conditioning production factory in Thailand. Their general information was presented in table 4.1 Mean age of subject was 28.44± 6.02 years old, mean weight was 50.33± 4.12 kilograms, mean height was 156.78± 3.53 centimeters, mean body mass index was 20.49± 1.67 and mean of service year on welding 6.78± 3.42 years

Table 4.1 The characteristics of 9 subjects who operation on welding process

Item	Frequency	Percent (%)
Sample size	9	100.00
Age (years)		
<25	1	11.11
25- 29	6	66.66
>29	2	22.22
	Mean= 28.44 SD= 6.02 Min= 21 Max= 42	
Weight (kgs.)		
40-44	1	11.11
45-49	3	33.33
>49	5	55.55
	Mean=50.33 SD= 4.12 Min= 44 Max= 57	
Height (cms.)		
150-154	3	33.33
155-159	5	55.55
>159	1	11.11
	Mean=156.78 SD= 3.53 Min= 152 Max= 163	
Body mass index		
18.00- 19.99	5	55.55
20.00- 21.99	2	22.22
>21.99	2	22.22
	Mean=20.49 SD= 1.67 Min= 18.59 Max= 22.55	
Service on welding (years)		
<5	1	11.11
5-9	7	7.77
>9	1	1.11
	Mean=6.78 SD= 3.42 Min= 2 Max= 15	

Part 2 The anthropometry data of subjects and hand tool design

2.1 The anthropometry data

All of nine subjects in capillary tube welding process of an air conditioning production factory in Thailand were included and measured body stature (data was recorded as table A-1 as appendix A). The data on 11 body dimensions were presented in table 4.2. The details showed mean, standard deviation, minimum, maximum and percentile 5^{th}, 95^{th}

Table 4.2 Anthropometry of subject who operation on welding process (cms)

Anthropometry	Mean	SD	Min	Max	Percentile 5	Percentile 95
Height	156.78	3.53	152.00	163.00	152.00	163.00
Weight (kg)	50.33	4.12	44.00	57.00	44.00	57.00
Shoulder height	129.44	4.61	118.00	133.00	118.00	133.00
Elbow height	97.44	4.25	87.00	102.00	**87.00**	102.00
Shoulder Elbow Length	32.00	1.12	31.00	34.00	31.00	34.00
Elbow Wrist Length	26.33	1.73	24.00	28.00	24.00	28.00
Elbow Fingertip Length	43.72	1.98	41.00	47.00	41.00	47.00
Elbow to Center of Grip	52.55	2.24	49.50	56.50	49.50	56.50
Hand Length	17.67	0.75	17.00	19.00	17.00	19.00
Hand Breadth	9.17	0.61	8.00	10.00	8.00	**10.00**
Inside Grip Diameter	4.47	0.35	3.80	5.00	**3.80**	5.00

(Age 21-42 years old, n=9)

2.2 Hand tool (New torch) design

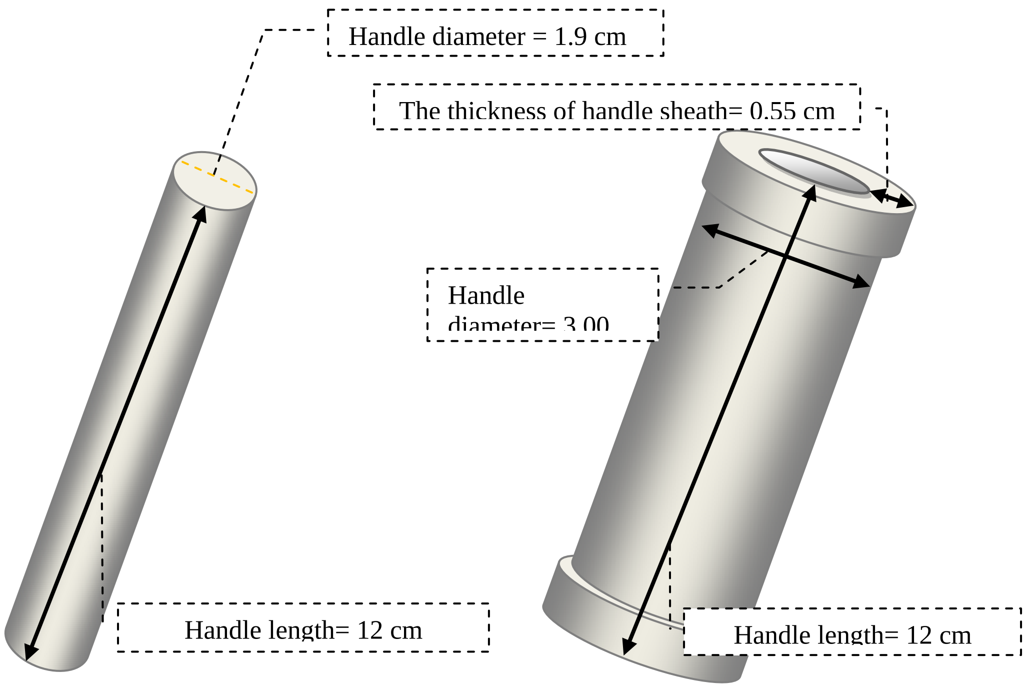
The hand tool design (New torch) based on the structural body dimensions. The percentile 5^{th} and percentile 95^{th} were selected appropriately. For dimension of new torch design was shown in figure 4.1 and 4.2. In a cross section, handle is cylinder shape with diameter 3.00 cm. with the sheath of handle built from textured rubber handles which can make a good gripping. The length of handle extend across the entire breadth of palm is 12 cm. The distances between middle handle to the end of torch is 25 cm. with curve shape.

Calculation for a handle of new torch size as

See 2.8 Principle to design as recommendation of CCOH and item 2.9 Anthropometry and design

1. Handle length = percentile 95th of HB + Clearance of each end area 0.50 cm.
   + Stopper of each end area 0.50 cm.
   = 10 cm. + (0.50+0.50) cm. + (0.50+0.50) cm.
   = 12.00 cm.

2. Handle diameter should be less than percentile 5th of GD
   In this study percentile 5th of GD = 3.80 cm.
   Thus, diameter of the handle recommended is 3.00 cm.
   Existing handle diameter = 1.90 cm.
   Therefore the thickness of handle sheath = (3.00-1.9)/2 = 0.55 cm.



Existing handle torch **New handle torch**

Figure 4.1 Comparison the handle of existing torch and new torch design

3. The distances between middle handle to the end of torch (Find Z in figure 4.2)

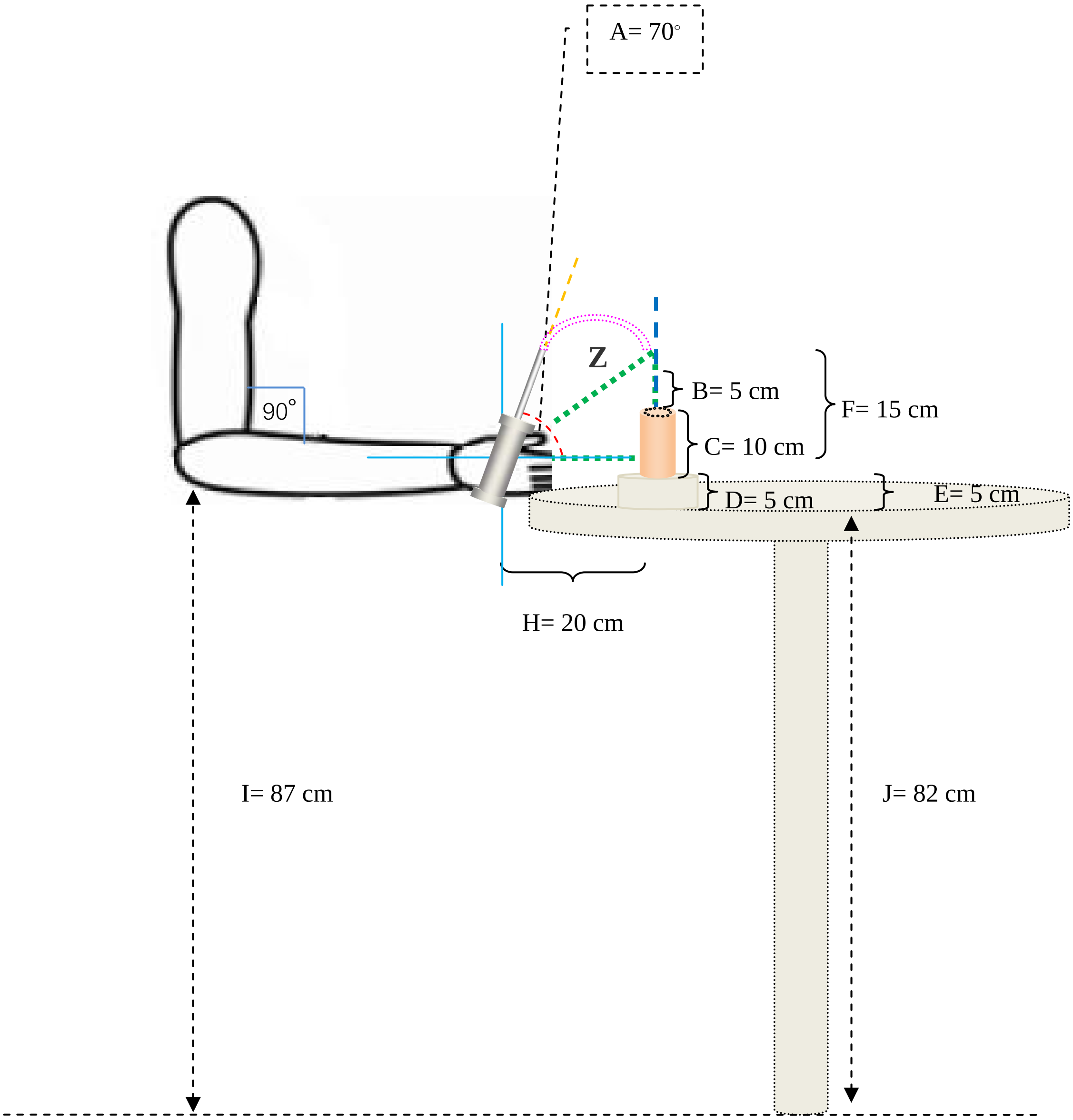


Figure 4.2 New torch designs

As item 2.8 principles to design for reducing fatigue and injuries of muscle from work, there are concerned recommendations as

1. Hand tool should be designed by maintain direction of wrist in natural position (neutral posture) when working. To avoid direction of wrist in non natural position. Inclination of the grip should be between 10 and 20 degree from vertical (In

this study, Inclination of the grip recommended is 20 degree from vertical or **70 degree from horizontal)**

2. Elbow in a position 90- 110 degree. (In this study, elbow position recommended is **90 degree**)

3. The working height that it should be 2 inches or at about **5 centimeters** or more below elbow height

From figure 4.2

A= inclination of grip (when holding the handle should be 70◦ clockwise direction)

B= a vertical distance between end of torch and welding point is 5 cm.

C= part height (Copper capillary tube) of 10 cm.

D= jig height of 5 cm.

E= a vertical distance between table plate to middle hand is 5 cm.

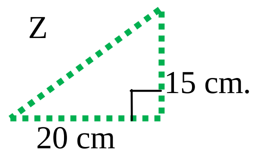
F= a vertical distance between elbow height to welding point

= (B+C+D) – E

= (5+10+5) -5 = 15 cm.

G= a horizontal distance between middle hand to welding point is 20 cm.

Therefore, calculation the distances between middle handle to the end of torch as



As trigonometry functions formula

$Z^2= G^2+F^2$

$Z^2= (20)^2+(15)^2$

Z= 25 cm

When finding of Z is completed, the end of torch shall be bent to be new torch as figure 4.4

A comparison of feature of an existing and a new torch was shown in figure 4.3, 4.4 and table 4.3 respectively

Figure 4.3 Existing torch features

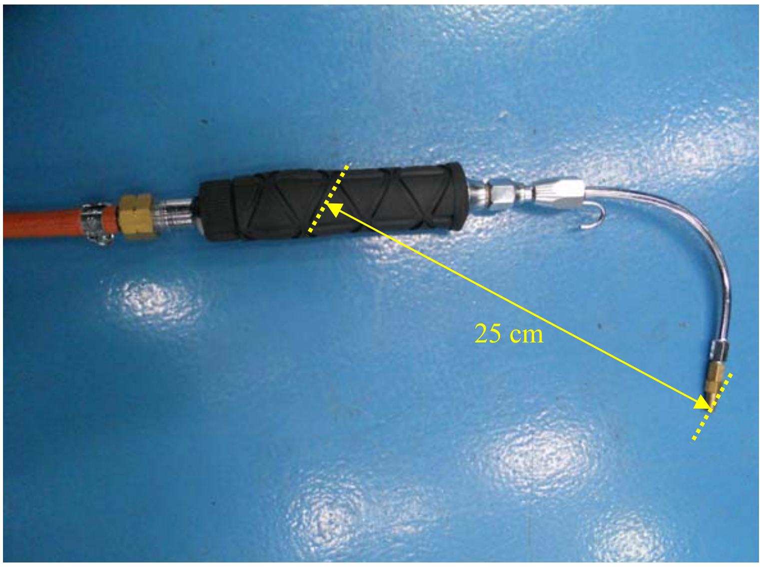


Figure 4.4 New torch features

Table 4.3 Comparison of the characteristic of welding with an existing torch and new torch (design by ergonomic principles)

Item to compare	**Existing torch**	**New torch**
Design	Design without the data from anthropometry	Design by using data from anthropometry
Shape of torch	The shape was straight line from handle to the end of torch. The distances between middle handle and the end of torch is 40 cm.	Handle is a linear line and the end of torch is bent into curve. The distances between middle handle and the end of torch is 25 cm.
welding postures	- Raise arms above shoulder/abduction greater than 45° degrees, forward flexion of shoulder. - An elbow angle is not between 90-110° to the body. - The wrist is twisted (Radial deviation) greater than 30° to adjust the direction of the flame from end of torch which point to welding point. - Twisting the forearm and hand (Pronation), which causes deviations from the neutral postures for more than 70°	- Do not raise arms above shoulder/ abduction is not greater than 45°, without forwards flexion of shoulder. - An elbow angle is between 90-110° to the body - The wrist is twisted not over than 30° to adjust the direction of the flame from end of torch which point to welding point. - A little twist at the end of the arm.
Handle Diameter	1.9 centimeters	3 centimeters
Weight	About 1 kilogram	About 1 kilogram

Part 3 Physical health status of subject

There are 12 questions regarding physical health status were used to interview all of nine subjects in capillary tube welding process of an air conditioning production factory in Thailand. In the table 4.4 presents the results. All of subjects had the right dominant hand (100%). They had at least 6 hours of rest before experimental (100%). Frequency of exercise was infrequency (77.78%). All of subjects had no disease or accident history that may affect to fatigue on arm or shoulder (100%). They had no alcohol drinking habit (88.89%) and had no smoking habit (88.89%). During the past 6 months, all of subjects had no symptom of fatigue on hand, arm or shoulder (100%). The part of body which subject had muscular fatigue were shoulder and upper arm (100%), ankle or foot (100%), neck (33.33%), thighs or hips (33.33%) and calf (33.33%). The date that symptom of fatigue appeared was final date of week (88.89%). Duration of fatigue was equal or less than 1 day (100%). Technique for reducing muscular fatigue was to do not anything (88.89%). And cause of muscular fatigue in all subject's opinion was copper capillary welding posture (100%)

Table 4.4 Physical health status of subject who operation on welding process

Item	Percent (%)
1. The dominant hand	
Right	100.00
Left	0.00
2. Number of hours for rest before experimental	
At least 6 hours	100.00
Less than 6 hours	0.00
3. Frequency of exercise	
Daily	11.11
Infrequently	77.78
Never	11.11

Table 4.4 Physical health status of subject who operation on welding process. (Continued)

Item	**Percent (%)**
4. Disease or accident history that may affect to fatigue on arm or shoulder	
Yes	0.00
No	100.00
5. Alcohol drinking	
Never	88.89
Sometime	11.11
Always	0.00
6. Smoking habit	
No smoke	88.89
Infrequency	11.11
Always	0.00
7. During the past 6 months , subject has symptom of fatigue on hand, arm or shoulder	
No	0.00
Yes	100.00
8. The part of body which subject has muscular fatigue	
Neck	33.33
Upper back	22.22
Shoulder or Upper arm	100.00
Lower back	0.00
Elbow	0.00
End of arm	0.00
Wrist, arm	0.00
Thighs or hips	33.33
Knee	0.00
Calf	33.33
Ankle or foot	100.00

Table 4.4 Physical health status of subject who operation on welding process. (Continued)

Item	Percent (%)
9. The date that symptom of fatigue appeared.	
The first date of week	11.11
Final date of week	88.89
Someday uncertainty	0.00
Every day of work	0.00
10. Duration of fatigue	
Equal or less than 1 day	100.00
2-3 days	0.00
More than 3 days	0.00
11. Technique for reducing muscular fatigue	
Do not anything	88.89
Take medicine	11.11
Self massage	0.00
Treated by a doctor or physiotherapist	0.00
12. Cause of muscular fatigue in subject's opinion	
Sport or exercise	0.00
Copper capillary welding posture	100.00
Illness or accident in the past	0.00
Other	0.00

Part 4 The result from electromyography monitoring

The results from electromyography monitoring was measured by electromyograph at upper arm and shoulder muscle of each subject while welding on copper capillary tube by using existing torch for 20 minutes and by new torch for 20 minutes. Data had sheen as table 4.5, 4.6 and 4.7

Table 4.5 The results from EMG monitoring (mean of RMS EMG) on deltoid muscle while welding by using existing torch and new torch

Subject no.	Time kept = at min	Existing torch (μV)	New torch (μV)
1	T1 = 05-10	101.29	63.85
2	T1 = 05-10	40.32	31.89
3	T1 = 05-10	49.98	47.69
4	T1 = 05-10	58.76	27.89
5	T1 = 05-10	46.24	40.73
6	T1 = 05-10	60.90	38.53
7	T1 = 05-10	59.76	49.15
8	T1 = 05-10	28.99	43.66
9	T1 = 05-10	40.58	36.67
1	T2 = 10-15	90.10	68.18
2	T2 = 10-15	36.57	31.69
3	T2 = 10-15	47.53	46.09
4	T2 = 10-15	60.85	28.95
5	T2 = 10-15	47.13	37.33
6	T2 = 10-15	53.12	38.28
7	T2 = 10-15	59.60	47.77
8	T2 = 10-15	30.54	36.47
9	T2 = 10-15	38.84	32.11
1	T3 = 15-20	92.23	63.92
2	T3 = 15-20	41.76	33.82
3	T3 = 15-20	50.39	46.02
4	T3 = 15-20	70.29	28.35
5	T3 = 15-20	44.89	37.32
6	T3 = 15-20	53.85	37.84
7	T3 = 15-20	59.78	48.57
8	T3 = 15-20	24.73	32.12
9	T3 = 15-20	41.92	33.31
1	T4 = 20-25	95.81	64.02
2	T4 = 20-25	37.72	33.09
3	T4 = 20-25	47.33	44.96
4	T4 = 20-25	52.93	29.56
5	T4 = 20-25	42.53	37.16
6	T4 = 20-25	55.00	39.39
7	T4 = 20-25	58.62	46.22
8	T4 = 20-25	27.27	36.13
9	T4 = 20-25	37.03	37.76

Table 4.6 The results from EMG monitoring (mean of RMS EMG) on biceps muscle while welding by using existing torch and new torch

Subject no.	Time kept = at min	Existing torch (μV)	New torch (μV)
1	T1 = 05-10	119.58	82.77
2	T1 = 05-10	43.06	37.15
3	T1 = 05-10	95.16	89.16
4	T1 = 05-10	93.77	34.92
5	T1 = 05-10	68.14	57.69
6	T1 = 05-10	142.97	101.57
7	T1 = 05-10	143.91	172.57
8	T1 = 05-10	100.12	77.89
9	T1 = 05-10	91.68	63.98
1	T2 = 10-15	102.24	76.76
2	T2 = 10-15	42.10	34.46
3	T2 = 10-15	95.34	89.25
4	T2 = 10-15	93.85	37.83
5	T2 = 10-15	73.48	52.50
6	T2 = 10-15	146.62	98.11
7	T2 = 10-15	138.00	159.35
8	T2 = 10-15	107.93	72.01
9	T2 = 10-15	84.74	61.35
1	T3 = 15-20	106.47	79.20
2	T3 = 15-20	43.24	37.10
3	T3 = 15-20	97.48	89.48
4	T3 = 15-20	113.64	37.66
5	T3 = 15-20	68.12	52.35
6	T3 = 15-20	146.76	95.10
7	T3 = 15-20	141.13	159.28
8	T3 = 15-20	95.39	67.40
9	T3 = 15-20	90.86	61.70
1	T4 = 20-25	112.58	78.18
2	T4 = 20-25	44.68	35.03
3	T4 = 20-25	94.96	87.75
4	T4 = 20-25	98.68	37.94
5	T4 = 20-25	62.74	52.61
6	T4 = 20-25	143.49	99.72
7	T4 = 20-25	137.53	160.04
8	T4 = 20-25	100.04	72.45
9	T4 = 20-25	79.13	70.38

Table 4.7 The results from EMG monitoring (mean of RMS EMG) on triceps muscle while welding by using existing torch and new torch

Subject no.	Time kept = at min	Existing torch (μV)	New torch (μV)
1	T1 = 05-10	30.22	50.59
2	T1 = 05-10	13.19	29.93
3	T1 = 05-10	83.32	71.95
4	T1 = 05-10	55.51	66.74
5	T1 = 05-10	70.08	67.80
6	T1 = 05-10	63.81	161.39
7	T1 = 05-10	140.98	142.02
8	T1 = 05-10	34.05	37.51
9	T1 = 05-10	89.20	405.46
1	T2 = 10-15	25.74	50.68
2	T2 = 10-15	12.05	30.06
3	T2 = 10-15	80.99	70.53
4	T2 = 10-15	57.10	67.78
5	T2 = 10-15	72.56	63.36
6	T2 = 10-15	57.72	144.77
7	T2 = 10-15	127.85	132.83
8	T2 = 10-15	31.96	34.88
9	T2 = 10-15	80.82	390.74
1	T3 = 15-20	26.04	48.53
2	T3 = 15-20	13.89	29.82
3	T3 = 15-20	83.31	71.50
4	T3 = 15-20	62.15	68.20
5	T3 = 15-20	68.49	62.89
6	T3 = 15-20	57.93	161.54
7	T3 = 15-20	126.70	132.79
8	T3 = 15-20	29.18	31.18
9	T3 = 15-20	87.84	396.20
1	T4 = 20-25	28.31	49.25
2	T4 = 20-25	14.70	30.01
3	T4 = 20-25	79.25	69.41
4	T4 = 20-25	56.16	73.00
5	T4 = 20-25	64.23	63.06
6	T4 = 20-25	53.12	138.08
7	T4 = 20-25	125.74	132.17
8	T4 = 20-25	30.73	34.34
9	T4 = 20-25	75.58	407.39

The difference of mean of electromyography root mean square (RMS EMG) while the subjects were using existing torch and new torch to weld was determined by paired- samples t test. The mean of RMS EMG of welding by using existing torch and new torch was compared. The same groups of samples were compared and the results shows as follow,

1. Mean of RMS EMG of deltoid muscle activity while subject were welding by using new torch was significantly less than while they were welding by using existing torch with 95% of confidence interval ($P< 0.05$) as present in Table 4.8 and figure 4.5.

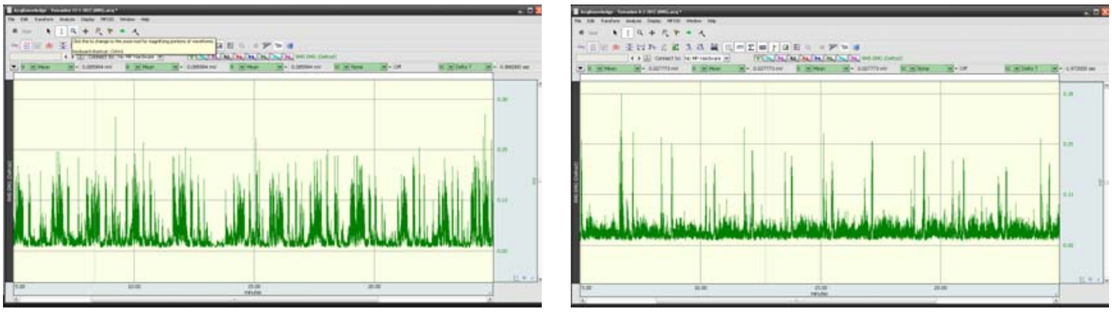
2. Mean of RMS EMG of biceps muscle activity while subject were welding by using new torch was significantly less than while they were welding by using existing torch with 95% of confidence interval ($P< 0.05$) as present in Table 4.8 and figure 4.6.

3. Mean of RMS EMG of triceps muscle activity while subject were welding by using new torch was significantly more than while they were welding by using existing torch with 95% of confidence interval ($P< 0.05$) as present in Table 4.8 and figure 4.7

Table 4.8 Comparison mean of RMS EMG of each muscle from welding by using existing torch and new torch

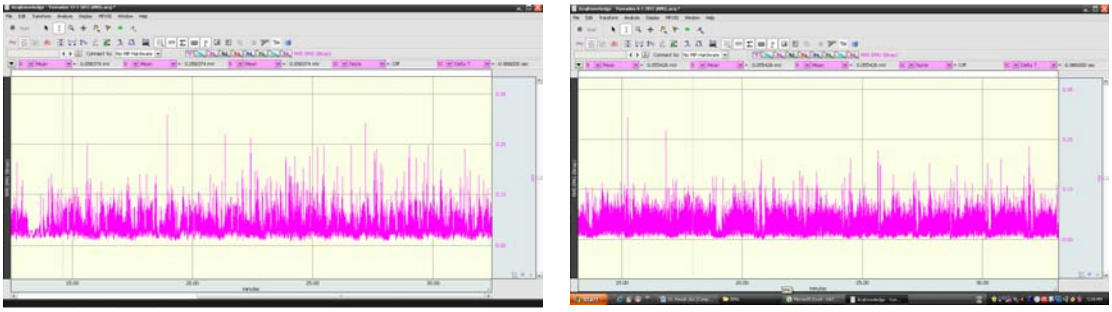
Muscle	**Torch type**	**Mean**	**SD**	**t**	**df**	***P***
Deltoid	Existing torch	52.37	18.59	5.19	35	<0.001
	New torch	41.01	10.53			
Biceps	Existing torch	98.88	30.87	5.43	35	<0.001
	New torch	77.02	37.12			
Triceps	Existing torch	61.40	34.09	-3.01	35	0.002
	New torch	111.62	110.90			

Paired- samples t test application, n= 36



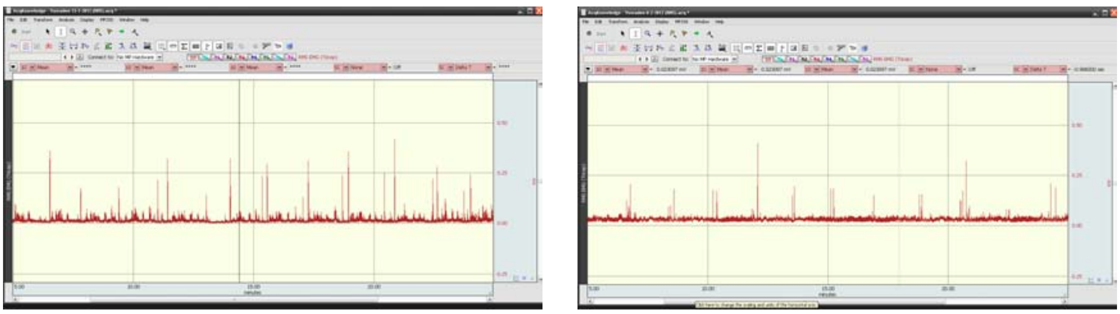
Existing torch New torch

Figure 4.5 Mean of RMS EMG of deltoid muscle while welding by existing torch and new torch.



Existing torch New torch

Figure 4.6 Mean of RMS EMG of biceps muscle while welding by existing torch and new torch.



Existing torch New torch

Figure 4.7 Mean of RMS EMG of triceps muscle while welding by existing torch and new torch.

Part 5 Result of postural loading on the upper body assessment by LUBA

The results of postural loading on the upper body assessment by LUBA were conducted by consideration welding posture from the image recorded of each subject. After that, rate the discomfort score as the table of postural classification scheme for the wrist, the elbow, the shoulder, the back and the neck. Then, calculate to be postural load index as table 4.9 and 4.10

Table 4.9 The result of postural loading on the upper body assessment by LUBA from welding posture by using existing torch

Joint	Motion	Class	Score	Score in each round of each subject																			
				Subject no.1				Subject no.2				Subject no.3				Subject no.4				Subject no.5			
				1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Wrist	Flexion	0- 20°	1																				
		20- 60°	4																				
		>60°	9																				
	Extension	0- 20°	1																				
		20- 45°	5																				
		>45°	11																				
	Radial deviation	0- 10°	1																				
		10- 30°	5																				
		>30°	10																				
	Ulna deviation	0- 10°	1																				
		10- 20°	5													5	5	5	5				
		>20°	9																				
Elbow	Flexion	0- 45°	1																				
		45- 120°	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
		>120°	7																				
	Supination	0- 90°	3									3	3	3	3	3	3	3	3	3	3	3	3
		>90°	9	9	9	9	9																
	Pronation deviation	0- 70°	3																				
		>70°	9																				
Shoulder	Flexion	0- 45°	1																				
		45- 90°	5	5	5	5	5	5	5	5	5					5	5	5	5	5	5	5	5
		90- 150°	9																				
		>150°	14																				
	Extension	0- 20°	1																				
		20- 45°	7																				
		45- 60°	12																				
		>60°	16																				
	Adduction	0- 10°	1																				
		10- 30°	4																				
		>30°	11																				
	Abduction	0- 30°	1																				
		30- 90°	6					6	6	6	6					6	6	6	6				
		>90°	13	13	13	13	13					13	13	13	13					13	13	13	13
	Medial rotation	0- 30°	1																				
		30- 90°	4																				
		>90°	10																				
	Lateral rotation	0- 10°	1																				
		10- 30°	5																				
		>30°	10																				
Neck	Flexion	0- 20°	1																				
		20- 45°	5																				
		>45°	8																				
	Extension	0- 30°	1																				
		30- 60°	9																				
		>60°	15																				
	Lateral bending	0- 30°	1																				
		30- 45°	5																				
		>45°	13																				
	Rotation	0- 30°	1																				
		30- 60°	4																				
		>60°	11																				
Back	Flexion	0- 20°	1																				
		20- 60°	6																				
		>60°	13																				
	Lateral bending	0- 10°	1																				
		10- 20°	5									5	5	5	5								
		20- 30°	12																				
		>30°	16																				
	Rotation	0- 20°	1																				
		20- 30°	3																				
		30- 45°	7																				
		>45°	14																				
	POSTURAL LOAD INDEX			30	30	30	30	14	14	14	14	24	24	24	24	22	22	22	22	24	24	24	24

Table 4.9 The result of postural loading on the upper body assessment by LUBA from welding posture by using existing torch (Continued)

Joint	Motion	Class	Score	Score in each round of each subject															
				Subject no.6				Subject no.7				Subject no.8				Subject no.9			
				1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Wrist	Flextion	0- 20°	1																
		20- 60°	4																
		>60°	9																
	Extension	0- 20°	1																
		20- 45°	5																
		>45°	11																
	Radial deviation	0- 10°	1																
		10- 30°	5																
		>30°	10																
	Ulna deviation	0- 10°	1																
		10- 20°	5									5	5	5	5				
		>20°	9																
Elbow	Flextion	0- 45°	1																
		45- 120°	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
		>120°	7																
	Supinatio n	0- 90°	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
		>90°	9																
	Pronation deviation	0- 70°	3																
		>70°	9																
Shoulder	Flextion	0- 45°	1																
		45- 90°	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
		90- 150°	9																
		>150°	14																
	Extension	0- 20°	1																
		20- 45°	7																
		45- 60°	12																
		>60°	16																
	Adduction	0- 10°	1																
		10- 30°	4																
		>30°	11																
	Abduction	0- 30°	1																
		30- 90°	6	6	6	6	6												
		>90°	13					13	13	13	13	13	13	13	13	13	13	13	13
	Medial rotation	0- 30°	1																
		30- 90°	4																
		>90°	10																
	Lateral rotation	0- 10°	1																
		10- 30°	5																
		>30°	10																
Neck	Flextion	0- 20°	1																
		20- 45°	5									5	5	5	5				
		>45°	8																
	Extension	0- 30°	1																
		30- 60°	9																
		>60°	15																
	Lateral bending	0- 30°	1																
		30- 45°	5																
		>45°	13																
	Rotation	0- 30°	1																
		30- 60°	4																
		>60°	11																
Back	Flextion	0- 20°	1																
		20- 60°	6																
		>60°	13																
	Lateral bending	0- 10°	1																
		10- 20°	5																
		20- 30°	12																
		>30°	16																
	Rotation	0- 20°	1																
		20- 30°	3																
		30- 45°	7																
		>45°	14																
	POSTURAL LOAD INDEX			17	17	17	17	24	24	24	24	34	34	34	34	24	24	24	24

Table 4.10 The result of postural loading on the upper body assessment by LUBA from welding posture by using new torch

Joint	Motion	Class	Score	Score in each round of each subject																			
				Subject no.1				Subject no.2				Subject no.3				Subject no.4				Subject no.5			
				1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Wrist	Flexion	0- 20°	1																				
		20- 60°	4																				
		>60°	9																				
	Extension	0- 20°	1																				
		20- 45°	5																				
		>45°	11																				
	Radial deviation	0- 10°	1																				
		10- 30°	5																				
		>30°	10																				
	Ulna deviation	0- 10°	1																				
		10- 20°	5																				
		>20°	9																				
Elbow	Flexion	0- 45°	1																				
		45- 120°	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
		>120°	7																				
	Supinatio n	0- 90°	3																				
		>90°	9																				
	Pronation deviation	0- 70°	3																				
		>70°	9																				
Shoulder	Flextion	0- 45°	1																				
		45- 90°	5																				
		90- 150°	9																				
		>150°	14																				
	Extension	0- 20°	1																				
		20- 45°	7													7	7	7	7				
		45- 60°	12																				
		>60°	16																				
	Adduction	0- 10°	1																				
		10- 30°	4																				
		>30°	11																				
	Abduction	0- 30°	1																				
		30- 90°	6																				
		>90°	13																				
	Medial rotation	0- 30°	1																				
		30- 90°	4																				
		>90°	10																				
	Lateral rotation	0- 10°	1																				
		10- 30°	5																				
		>30°	10																				
Neck	Flexion	0- 20°	1																				
		20- 45°	5																				
		>45°	8																				
	Extension	0- 30°	1																				
		30- 60°	9																				
		>60°	15																				
	Lateral bending	0- 30°	1																				
		30- 45°	5																				
		>45°	13																				
	Rotation	0- 30°	1																				
		30- 60°	4																				
		>60°	11																				
Back	Flexion	0- 20°	1																				
		20- 60°	6																				
		>60°	13																				
	Lateral bending	0- 10°	1																				
		10- 20°	5																				
		20- 30°	12																				
		>30°	16																				
	Rotation	0- 20°	1																				
		20- 30°	3																				
		30- 45°	7																				
		>45°	14																				
	POSTURAL LOAD INDEX			3	3	3	3	3	3	3	3	3	3	3	3	10	10	10	10	3	3	3	3

Table 4.10 The result of postural loading on the upper body assessment by LUBA from welding posture by using new torch (Continued)

Joint	Motion	Class	Score	Score in each round of each subject															
				Subject no.6				Subject no.7				Subject no.8				Subject no.9			
				1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Wrist	Flexion	0- 20°	1																
		20- 60°	4																
		>60°	9																
	Extension	0- 20°	1																
		20- 45°	5																
		>45°	11																
	Radial deviation	0- 10°	1																
		10- 30°	5																
		>30°	10																
	Ulna deviation	0- 10°	1																
		10- 20°	5																
		>20°	9																
Elbow	Flexion	0- 45°	1																
		45- 120°	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
		>120°	7																
	Supinatio n	0- 90°	3																
		>90°	9																
	Pronation deviation	0- 70°	3																
		>70°	9																
Shoulder	Flextion	0- 45°	1																
		45- 90°	5																
		90- 150°	9																
		>150°	14																
	Extension	0- 20°	1																
		20- 45°	7																
		45- 60°	12																
		>60°	16																
	Adduction	0- 10°	1																
		10- 30°	4																
		>30°	11																
	Abduction	0- 30°	1																
		30- 90°	6																
		>90°	13																
	Medial rotation	0- 30°	1																
		30- 90°	4																
		>90°	10																
	Lateral rotation	0- 10°	1																
		10- 30°	5																
		>30°	10																
Neck	Flexion	0- 20°	1																
		20- 45°	5																
		>45°	8																
	Extension	0- 30°	1																
		30- 60°	9																
		>60°	15																
	Lateral bending	0- 30°	1																
		30- 45°	5									5	5	5	5				
		>45°	13																
	Rotation	0- 30°	1																
		30- 60°	4																
		>60°	11																
Back	Flexion	0- 20°	1																
		20- 60°	6																
		>60°	13																
	Lateral bending	0- 10°	1																
		10- 20°	5																
		20- 30°	12																
		>30°	16																
	Rotation	0- 20°	1																
		20- 30°	3																
		30- 45°	7																
		>45°	14																
	POSTURAL LOAD INDEX			3	3	3	3	3	3	3	3	8	8	8	8	3	3	3	3

The difference of postural load index from welding while the subjects were using existing torch and new torch to weld was determined by paired- samples t test. The postural load indexes from welding of same groups of samples were compared. The results indicates that postural load index while subject were welding by using new torch was significantly less than while they were welding by using existing torch with 95% of confidence interval (*P*< 0.05) as present in Table 4.11 and figure 4.8

Table 4.11 Comparison of postural load index of welding by using new torch and existing torch

Torch type	Mean	SD	t	df	*P*
Existing torch	23.67	5.74	21.04	35	<0.001
New torch	4.33	2.57			

Paired- samples t test application, n= 36

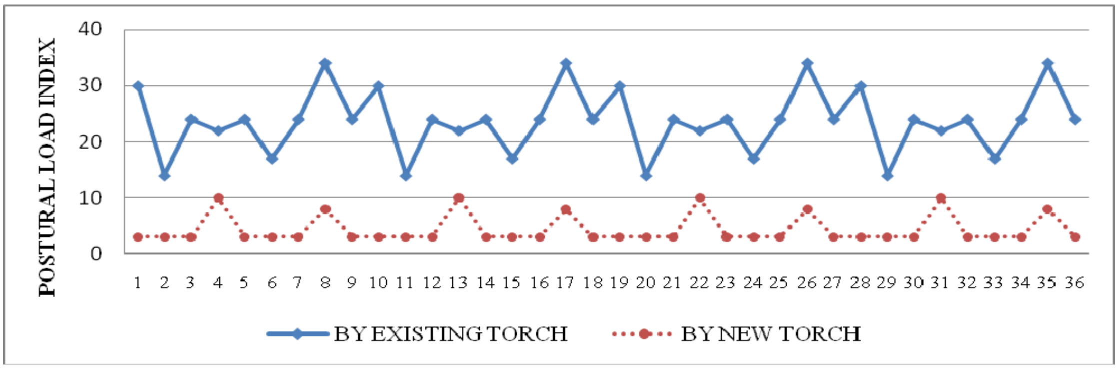


Figure 4.8 Postural load indexes while welding by using of existing torch and new torch.

Part 6 A cycle time for welding per piece of copper capillary tube

The time spent per piece of copper capillary tube from welding with both of existing torch and new torch were recorded together with the image recorded of each subject by camera and fill in table 4.12

Table 4.12 The time spent per piece of copper capillary tube from welding with both of existing torch and new torch

Subject no.	Cycle time no.	Existing torch (s)	New torch (s)
1	1	51	53
2	1	83	72
3	1	71	62
4	1	58	46
5	1	54	48
6	1	60	47
7	1	62	59
8	1	97	88
9	1	62	53
1	2	56	56
2	2	71	71
3	2	59	48
4	2	73	45
5	2	50	45
6	2	56	49
7	2	55	53
8	2	79	75
9	2	56	51
1	3	53	52
2	3	73	75
3	3	81	53
4	3	79	53
5	3	60	48
6	3	52	48
7	3	63	54
8	3	77	55
9	3	51	54
1	4	49	51
2	4	69	68
3	4	80	54
4	4	79	52
5	4	58	49
6	4	56	53
7	4	53	55
8	4	64	57
9	4	67	51

The difference of time spent per piece of copper capillary tube from welding while the subjects were using existing torch and new torch to weld was determined by paired- samples t test. The mean of time spent per piece from welding of same groups of samples were compared. The results indicates that mean of time spent per piece while subject were welding by using new torch was significantly less than while they were welding by using existing torch with 95% of confidence interval (*P*< 0.05) as present in table 4.13 and figure 4.9

Table 4.13 Comparison of cycle time for welding per piece of copper capillary tube by using torch

Torch type	**Mean**	**SD**	**t**	**df**	***P***
Existing torch	64.36	11.77	5.64	35	<0.001
New torch	55.64	9.80			

Paired- samples t test application, n= 36

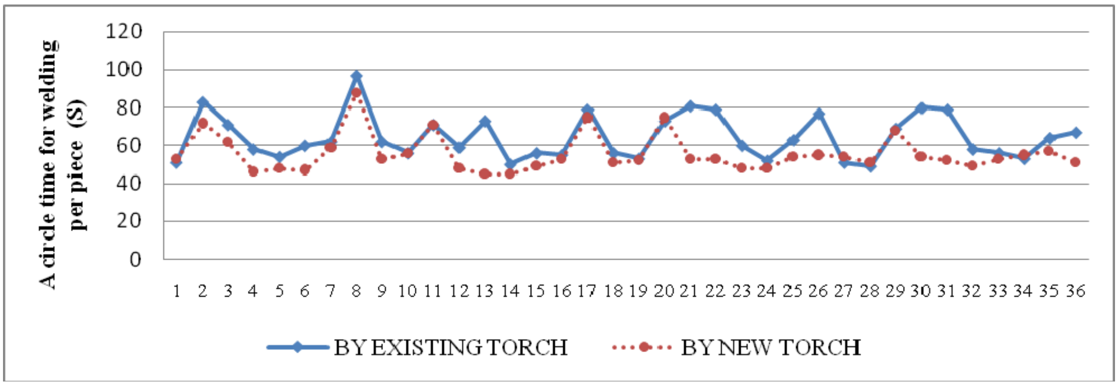


Figure 4.9 A cycle time for welding per piece while welding by existing torch and new torch.

Part 7 The Subjective feelings of fatigue of subjects.

The Subjective feelings scores of fatigue on muscle were come from questionnaire for finding the state of fatigue feeling due to welding by using both of existing torch and new torch appeared in table 4.14

Table 4.14 The subjective feeling scores of fatigue on upper arm and shoulder muscles in before and after welding process by using existing torch and new torch

Muscle	Subject no.	Existing torch scores			New torch scores		
		Before	After	difference	Before	After	difference
upper arm and shoulder	1	1	6	5	1	3	2
	2	1	6	5	1	3	2
	3	1	6	5	1	3	2
	4	1	6	5	1	4	3
	5	1	6	5	1	3	2
	6	1	5	4	1	4	3
	7	1	5	4	1	3	2
	8	1	6	5	1	3	2
	9	1	6	5	1	3	2

Remark: Score 1 means start to feel fatigue to score 7 means extremely fatigue and can't work

Statistic values of ranking of the difference of subjective feeling score of fatigue on upper arm and shoulder muscle when welding by using new torch with using existing torch was present in table 4.15

Table 4.15 Statistic value of ranking of the difference of subjective feeling score of fatigue on upper arm and shoulder muscle when welding by using new torch with using existing torch

Pairs of subjective feelings scores test		Number of pairs	Mean rank	Sum of ranks
when using new torch- when using existing torch	Negative ranks	9[a]	5.00	45.00
	Positive ranks	0[b]	0.00	0.00
	Ties	0[c]		
	Total	9		

Wilcoxon Signed Ranks Test

a. Subjective feeling from using new torch < Subjective feeling from using existing torch
b. Subjective feeling from using new torch > Subjective feeling from using existing torch
b. Subjective feeling from using new torch = Subjective feeling from using existing torch

The difference of subjective feeling score of fatigue on upper arm and shoulder muscle test statistic when welding between from using new torch with from using existing torch was present in table 4.16

Table 4.16 The difference of subjective feeling score of fatigue on upper arm and shoulder muscle test statistic when welding between from using new torch with from using existing torch

	Subjective feeling from using New torch – Subjective feeling from using Existing torch
Z	-2.754[(a)]
Asymp. Sig. (1-tailed)	.0030

Wilcoxon Signed Ranks Test, N=9
(a) Based on positive ranks

Remarks: From subjective feeling of fatigue and comfort acceptance questionnaire, the ergonomically designed new torch was accepted by all of 9 subjects.

CHAPTER V
DISCUSSION

The main propose of this study was to design new torch as principle of ergonomic for reducing fatigue on arm and shoulder muscle in an air conditioning production factory. Methods to prove are to compare an EMG monitoring results on arm and shoulder of welder while using existing and new torch to weld, compare the postural load index from discomfort assessment by LUBA while using existing torch and new torch to weld and compare a cycle time for welding per piece of copper capillary tube. The data from these processes were analyzed and interpreted. These results were discussed and clarified as follow,

5.1 Discussion of study design

5.1.1 Random error

In this study, Random error can occur in process of selection subjects. Researcher selected subjects who work at process of copper capillary tube welding by purposive sampling method. It is a conventional method usually applied for clinical research. According to the evaluation of means of RMS EMG on upper arm and shoulder muscles , postural load indexes and a cycle time for welding per piece of copper capillary tube on subjects who have responsibility to weld by using of existing torch and new torch have normal distribution, therefore, samples in this study could comparable.

5.1.2 Systematic error

5.1.2.1 Instrument error:

In this study, LUBA (an assessment technique for postural loading on the upper body) was applied to assess the index of perceived discomfort (ratio values) that occurs from motion of a set of joint on upper body. Welding postures were taken by video camera while each subject was welding by using existing torch and new torch and while electromyography was monitored. A possible worst postural stresses in video camera was considered and assessed to get a postural load index.

An assessment technique for postural loading on the upper body is an instrument to assess postural load index of perceived discomfort, if battery of video camera was come to end before end of photo recording, it can affect to welding cycle recorded that may be less than the actual and the posture varied which may be the worst posture in some welding cycle may not be recorded for using in an assessment process. To prevent error, the researcher had prepared battery charging before recording in each welding cycle and reserving battery more than one piece.However, only use of LUBA to assess the index of perceived discomfort is not enough to be representative of comfort or discomfort. Therefore, in this study the researcher uses electromyography to be their representative.

Surface electromyography was applied to measure muscular activity by attaching on target muscle. SEMG has both of advantages and disadvantages. The weak point of SEMG is a large size of electrode, it affects to cross talk from adjacent muscle. And it can only be used to monitor for superficial muscles. In addition, because of an electrode acts as a connector between skin of subject and MP 36 acquisition unit, if the difference of electrode series were used, it may affect to the accurate of results for comparison. To reduce errors and act appropriately in this study, researcher chose only one series of electrode (EL503) as Biopac System, Inc. mentioned. This series consist of a small piece of metal to contact indirectly with the skin of subject and a small piece of plastic mesh fill with bluish gel. This gel can conduct electricity better than skin of subject, and it is more flexible than attaching by metal part of electrode directly because skin can change shape and flex without losing the electric connection with the metal part of electrode. Furthermore, before recording data the researcher shall keep in mind and consider the factor that can affect to the process of record. For example, cross talk from adjacent muscles, skin preparation, and wire of electrode and other source of electric should be rule out etc.

5.1.2.2 Personal error:

Although the method and equipment for collecting data are standardized, it should be recognized that if the researcher lack of knowledge and skills can cause of an error of data. Thus in this study, for muscular activity measurement, the researcher has tried to reduce an error by reviewing the standard protocol for using electromyography and measuring method, inviting an expert of electromyography measurement equipment vendor come to advise how to use the equipment thoroughly one by one. In the end, researcher had practiced using equipment and measuring method before actual collecting data. For knowledge of choosing concerned muscle and attaching electrode were recommended by specialist physician For LUBA, researcher had reviewed an assessment method and studied an example of assessment of relevant document before assessment on welding posture.

5.1.2.3 Method error:

In this study, the measurement of muscular activities was carried out by SEMG. Electrodes acts as a connector between skin of subject and MP 36 acquisition unit, it shall be attached to the skin. If an electrode makes well attached to the skin, the signals are generated will be accurate. In contrast, if an electrode does not attached well to skin, the signal plotted on the screen may appear fussy is called "noise". These can affect to muscular activity measurement, it is results might be errors. Although noise always exists to some degree, it should be reduced noise as much as possible. To prevent an error, when electrodes are attached and connected, the researcher follows as,

1. Take a cotton wool moistened with normal saline and wipe the skin over arm or shoulder muscles that will be attached by surface electrode.

2. Take a cotton wool moistened with alcohol and wipe off dirt, fat and dead skin thoroughly.

3. Scrub skin points where will be attached surface electrodes, shave an excess off. If dry skin, use a gel electrode applied to the skin. If the sweat, spray the sweat on the skin after cleaning with alcohol.

4. Place surface electrode on the skin by putting upper the largest muscle at the belly part or the midpoint of muscle to measure. Be careful while

place surface electrode, the hand shall not contact to the metal sheet on each electrode and avoid occurrence of air cavity.

5. Use the tape attach to the round plate of each electrode to avoid the movement of the electrodes and to avoid the cause of tension on the wire. It shall be ensured that the wires are loosen under the tape or the material and are frozen. Avoid attachment between tape and metal sheet of electrodes.

6. Put the electrodes on skin about five minutes before recording data is begun to give the electrodes time to contact tightened with the skin.

For an assessment technique of postural loading on the upper body, while subject was welding with many movement postures of many joints on upper body, the video camera was recording welding postures together. The results from taking video camera might be errors from vary movements of subjects and affect to the results of assessment the index of perceived discomfort. By mean of the index might deviate from actual results. To prevent an error, the researcher positioned video camera at an angle to subject and record postures during several welding cycle for getting 3 dimensional welding postures. Next, select a possible worst postural stresses for assessment.

5.1.2.4 Confounder:

In this study, researcher had avoid confounder that may occur in study process by controlling characteristics of subjects such as physical health status of subjects who operation on welding process, disease or accident history that may affect to fatigue on arm or shoulder, service year on welding.

5.2 Discussion of study results

5.2.1 The results from electromyography monitoring on muscle

5.2.1.1 The results from electromyography monitoring on deltoid muscle.

From observation on welding postures in this study, postural welding of subject when they weld by using existing torch were present with unnatural postures is that their right arm was raised above shoulder level or abduction posture, extends shoulders backward and forwards flexion of shoulder. Difference from postural welding of subject when they weld by using new torch, they were present with natural postures is that subjects did not raise their arms above shoulder level or abduction, without extends shoulders back and forwards flexion of shoulder.

The measurement of muscle activity from postural welding was carried out by comparison of means of RMS EMG of deltoid muscle. If means of RMS EMG of deltoid muscle on welding by using of new torch was significantly less than existing torch, it means that while subjects were welding by using new torch, the levels of deltoid muscle activity was less than while welding by using existing torch. In this study, the results from electromyography monitoring on deltoid muscle shows that means of RMS EMG on welding by using of new torch was significantly less than existing torch, it means that while subjects were welding by using new torch, the levels of deltoid muscle activity was less than while welding by using existing torch with 95% confidence interval ($P < 0.05$). The data was presented in table 4.8 and Figure 4.5 Similarly, the levels of deltoid muscle activity in postural welding by using new torch was less than while postural welding by using existing torch. These results were

1) similar to the study of Therese Öhrling , et al., 2012 (41) reported about muscular activity on right deltoid muscle of cleaner when subjects use the ergonomic tools (adjustable mop handle) with techniques in process of cleaning and when subjects use non adjustable mop handle. The results presented that muscular activity on right deltoid when cleaning by using adjustable mop handle is lower than when using non adjustable mop handle. And when observed postures from cleaning, it showed that subject’s arm and hand were raised above natural level (unnatural postures)

2) similar to the study of Helenice Gil Coury , et al., 1998 (42) about the electromyography activity of shoulder and arm muscle in difference positions and reported that the electromyography activity increased in forward flexion of shoulder.

3) similar to the study of Gary A. Mirka , et al., 2011 (43) report about testing of two ergonomic intervention (crab pot without hook (no intervention) and crab pot with hook support (intervention)) to reduce shoulder stress in process of shaking the crabs from the pots by using EMG analysis to quantify

changes in muscle force. When ergonomic intervention was using, the results showed significant reductions of deltoid activity when compare with no intervention.

4) similar to the study of Stephanie A. Southard, et al., 2007 (44) reported about evaluation of two ergonomic intervention design (handle attachment) during weighting beef calves process in laboratory and field study. For handle attachment was designed to decrease shoulder abduction angle by modify handle attached to existing scale to reduce vertical point of hand to the calf. They reported that handle attachment can reduce muscle activity.

5) similar to the study of Rebecca L. Brookham , et al., 2009 (45) reported affect of shoulder flexion in difference postures while using a light hand tool that electromyography activity level of flexion on deltoid muscle for 70, 80 and 90 degree is more than electromyography activity in flexion on middle deltoid muscle for 60 degree and 0 degree respectively.

5.2.1.2 The result from electromyography monitoring on biceps muscle.

From observation, postural welding of subject when they weld by using existing torch were present with the range of elbow angle is not 90-110 degrees including forward flexion of shoulder that difference from postural welding of subject when they weld by using new torch that were present with the range of elbow angle of 90-110 degrees and forward flexion posture of shoulder.

The measurement of muscle activity from postural welding was carried out by comparison of means of RMS EMG of biceps muscle. If means of RMS EMG of biceps muscle on welding by using of new torch was significantly less than existing torch, it means that while subjects were welding by using new torch, the levels of biceps muscle activity was less than while welding by using existing torch. In this study, the results from electromyography monitoring on biceps muscle shows that means of RMS EMG on welding by using new torch was significantly less than using existing torch, it means that while subjects were welding by using new torch, the levels of biceps muscle activity was less than while welding by using existing torch with 95% confidence interval ($P < 0.05$). The data was presented in table 4.8 and Figure 4.6 Similarly, the levels of biceps muscle activity in postural welding by using new torch was less than while postural welding by using existing torch. These results were

1) similar to the study of Helenice Gil Coury , et al., 1998 (42) reported that the electromyography activity of shoulder and arm muscle in difference positions and reported that as the posture change and forward flexion of shoulder increased, the electromyography activity increased for the biceps and deltoid muscle.

2) similar to Chaffin, 1973 (35) reported that a position of elbow angle of 90-110 degrees can least affect to muscular fatigue, it means that muscle activity in a position elbow angle of 90-110 degrees is less than muscle activity in other position of elbow angle.

5.2.1.3 The result from electromyography monitoring on triceps muscle.

In this study, researcher found that an elbow angle while welder was using existing torch was more than when they was using new torch. The measurement of muscle activity was carried out by comparison of means of RMS EMG of triceps muscle. If means of RMS EMG of triceps muscle on welding by using of new torch was significantly less than existing torch, it means that while subjects were welding by using new torch, the levels of triceps muscle activity was less than while welding by using existing torch and means that while elbow was flexing with less degree, levels of triceps muscle activity was less than while elbow was flexing with more degree.

In this study, the results from electromyography monitoring on triceps muscle shows that means of RMS EMG on welding by using of new torch was significantly more than existing torch, it means that while subjects were welding by using new torch, the levels of triceps muscle activity was more than while welding by using existing torch with 95% confidence interval ($P < 0.05$). The data was presented in table 4.8 and Figure 4.7 These results were similar to the study of Praagman M. et al, 2010 (46) reported about the effect of elbow angle at 50, 70 , 90 and 110 degree to occurrence of EMG on triceps muscle. They reported that EMG amplitude of triceps muscle increase when elbow angle was decreased.

Due to movements of biceps muscle and triceps muscle are working in cooperation in couples as antagonism. Therefore, their activity is opposite.

5.2.2 Result of postural loading on the upper body assessment by LUBA

In this study, researcher had designed new torch by using anthropometry data of subject. It's characteristics are the head is straight line and the end area of torch is bent. Therefore, subjects do not lift his arms to high level, do not twist the wrist to control the direction of the flame to point at the target area and present lower degree of shoulder flexion posture. Difference from using existing torch is that when subject weld by using existing torch, subject shall lift his arms to high level, twist the wrist to control the direction of the flame to point at the target area and present higher degree of shoulder flexion posture. An assessment was carried out by comparison of postural load indexes on upper body while the subjects were using existing torch and new torch to weld. If postural load index while welding by using of new torch was significantly less than existing torch, it means that while subjects were welding by using new torch, perceived discomfort was less than while welding by using existing torch.

The results indicates that postural load index while subjects were welding by using new torch was significantly less than while they were welding by using existing torch with 95% of confidence interval ($P < 0.05$) as present in Table 4.11 and figure 4.8. It means that perceived discomfort while subjects were welding by using new torch was significantly less than while they were welding by using existing torch. These results were

1) similar to Motamedzade M, Choobineh A, Mououdi MA, Arghami S., 2007 (36) reported the comfort assessment of upper limb of carpet weavers from using hand tools design and redesign based on anthropometric dimensions and ergonomics principles, the results presented that new ergonomically redesigned weaving hand tools were found a significant preference toward the comfort of hand tools redesign and acceptable by subjects.

2) similar to Chih-Long Lin, et al., 2009 (47) reported that when the flexions of shoulder were increased from 60, 90 and 120 degree, the upper arm discomforts rating were also increased. It means that the higher degree of shoulder

flexion can present the upper arm discomfort rating more than lower degree of shoulder flexion.

5.2.3 A cycle time for welding per piece of copper capillary tube

In this study, welding postures of subjects by using new torch difference from using existing torch, welding postures of subjects by using new torch tended to be neutral postures and movement postures can least affect to muscular fatigue is that while subjects was welding, theirs wrist was not flexion or extension, elbow was in a position 90- 110 degree, shoulder was in a position 0- 45 degree. The measurement of time for welding was carried out by comparison of the cycle time for welding per piece of copper capillary tube while the subjects were using existing torch and new torch to weld. If time for welding per piece of copper capillary tube while welding by using of new torch was significantly less than existing torch, it means that while subjects were welding by using new torch, the time for welding per piece of copper capillary tube was less than while welding by using existing torch.

In this study, The results indicates that time for welding per piece of copper capillary tube while subjects were welding by using new torch was significantly less than while they were welding by using existing torch with 95% of confidence interval ($P< 0.05$) as present in Table 4.13 and figure 4.9 It means that the new torch can increase efficiency of copper capillary tube welding. These results were similar to the study of Bheem P. Kattel, et al., 1996 (48) reported that peak grip strength from using hand tool was presented in combination of shoulder, elbow and wrist angle in neutral postures that can reduce the risk of musculoskeletal disorder and also increase productivity. It means that neutral postures can increase efficiency of work.

5.2.4 The result of Subjective feelings of fatigue of subjects

The results indicates that when subject weld by using new torch, the subjective feeling of fatigue score of upper arm and shoulder muscle when subject weld by using new torch was significantly less than when subject weld by using existing torch with 95% of confidence interval ($P< 0.05$) as present in table 4.16 It means that the ergonomically designed new torch can reduce the fatigue on upper arm and shoulder muscle from welding. This results were similar to the study of Therese Ohrling, et al., 2012 (49) reported about subjective assessment when subject uses the adjustable (as body dimension of user) and the non- adjustable mop handle that the scores for self- reported comfort rating when using the adjustable mop handle is higher than using the non- adjustable mop handle.

In addition, the result of comfort acceptance of new torch, the ergonomically designed new torch was accepted by all of 9 subjects.

CHAPTER VI
CONCLUSION AND RECOMMENDATION

6.1 Conclusion

The main objectives of this study are to design new torch as principles of ergonomic for reducing fatigue on arm and shoulder muscle of worker who weld copper capillary tube in an air conditioning production factory. It was quasi-experimental which is called “Before- After experiment with no control group” in order to compare electromyography on arm and shoulder muscle, compare postural load index by LUBA and study efficiency of welding by observation on cycle time of copper capillary tube welding by using both of existing torch and new torch. The results of this study were concludes as below,

1. Deltoid muscle activities while welding by using new torch was significantly less than while welding by existing torch with 95% of confidence interval ($P < 0.05$).

2. Biceps muscle activities while welding by using new torch was significantly less than while welding by existing torch with 95% of confidence interval ($P < 0.05$).

3. Triceps muscle activities while welding by using new torch was significantly more than while welding by existing torch with 95% of confidence interval ($P < 0.05$).

4. Postural load index while welding by using new torch was significantly less than while welding by using existing torch with 95% of confidence interval ($P < 0.05$).

5. Time for welding per piece of copper capillary tube while welding by using new torch was significantly less than while welding by using existing torch with 95% of confidence interval ($P < 0.05$).

6. Subjective feeling of fatigue score of upper arm and shoulder muscle when subject weld by using new torch was significantly less than when subject weld by using existing torch with 95% of confidence interval ($P< 0.05$).

6.2 Recommendation for copper capillary tube welder and organization.

In this study was presented that welding by using new torch is appropriate for welding on copper capillary tube of welder in an air conditioning production factory. The new torch can reduce fatigue from muscular activity and time for welding per piece of copper capillary tube. The air conditioning production factory should design new torch base on ergonomics, biomechanics and anthropometric principles. After that, instruction for using new torch should be trained to welder before using in order to reduce fatigue and increase work efficiency.

6.3 Recommendation for future study

For an improvement of ergonomic and design, the data as below are the recommendations for further study.

1. In practical, the muscular activity of other concerned muscle group should be measured because many of arm and shoulder muscles were used in welding process and theirs postures are difference from muscle in this study. For example, brachioradialis muscle that it’s duties are to flex the end of arm and supination, extensor carpi ulnaris muscle that it’s duties are to extend and abduct the wrist. These postures are also occurred when welding.

2. This new torch was designed to appropriate for welding copper capillary part which it has a small or narrow size. Because of a bigger or wider size of welded material can present unnatural posture of hand, wrist, arm and shoulder which they can cause of the musculoskeletal disorders. Therefore, the future study is needed to design and field trial of new torch for the material which it has a bigger or wider size.

3. In this study, EMG monitoring was recorded in short time which it can only present the increasing or the reducing of muscular work load. For the further study, if researcher needs to assess accumulative fatigue by using only electromyograph, an EMG shall be recorded for longer time.

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APPENDICES

APPENDIX A

ANTHROPOMETRIC MEASUREMENT PROCEDURE AND ANTHROPOMETER

1. Weight

   Landmark: None

   Instrument: Balance type scale

   Position of subject: Subject stands on center of balance type scale wearing underwear.

   Procedure: Adjust balance to within 0 kilogram and record

2. Stature

   Landmark: Highest point of the head

   Instrument: Anthropometer

   Position of subject: Subject stands erect, head in the Frankfort plane and weight distributed equally on both feet.

   Procedure: Measure the vertical distance from the standing surface to the top of the head.

Figure A-1 Stature

3. Shoulder Height

   Landmark: Right Acromion

   Instrument: Anthropometer

   Position of subject: Subjects stands fully erect with feet together and weight distributed equally on both feet.

   Procedure: The vertical distance from the floor to the right Acromion.

Figure A-2 Shoulder Height

4. Elbow Height

Landmark: Lowest bony point of the bent elbow.

Instrument: Anthropometer

Position of subject: Subjects 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.

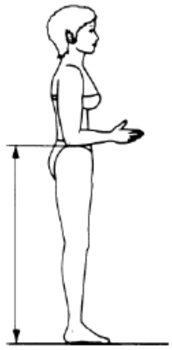


Figure A-3 Elbow Height

5. Shoulder Elbow Length

Landmark: None

Instrument: Anthropometer (Large sliding caliper)

Position of subject: Subjects sits erect with thighs fully supported and lower legs hanging freely downwards and forearms are horizontal.

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

Figure A-4 Shoulder Elbow Length

6. Elbow Wrist Length

Landmark: None

Instrument: Beam caliper

Position of subject: Subjects sits or 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.

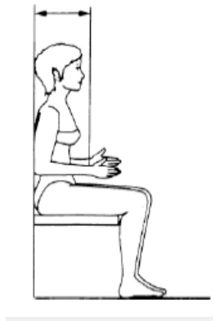


Figure A-5 Elbow Wrist Length

7. Elbow to Center of Grip

Landmark: None

Instrument: Anthropometer, Rod of 20 mm. diameter for determining grip axis.

Position of subject: Subjects sits or stands erect, upper arm hanging freely downwards, elbow bent at right angles. Hand hold measuring rod with grip axis vertical.

Procedure: Measure the horizontal distance along the axis of the right forearm to grip axis.

Figure A-6 Elbow to Center of Grip

8. Elbow Fingertip Length

Landmark: Olecranon and dactylion

Instrument: Large Sliding caliper

Position of subject: Subjects sits or stands erect, upper arms hanging freely downwards, forearms and hands extended forward horizontally.

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

Figure A-7 Elbow Fingertip Length

9. 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.

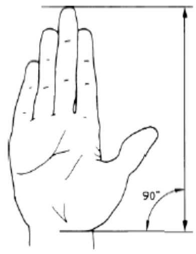


Figure A-8 Hand Length

10. 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 ulna metacarpals at the level of metacarpals heads from the second to the fifth.

Figure A- 9 Hand Breadth

11. Grip diameter (Inner)

Landmark: None

Instrument: Cone diameter

Position of subject: Maximum inner curvature of the hand at the touching level between tip of the middle finger and thumb.

Procedure: Measure the maximum inner curvature of the hand by using cone diameter insert to inner curvature of the hand at the touching level between tip of the middle finger and thumb.

Figure A- 10 Grip diameter

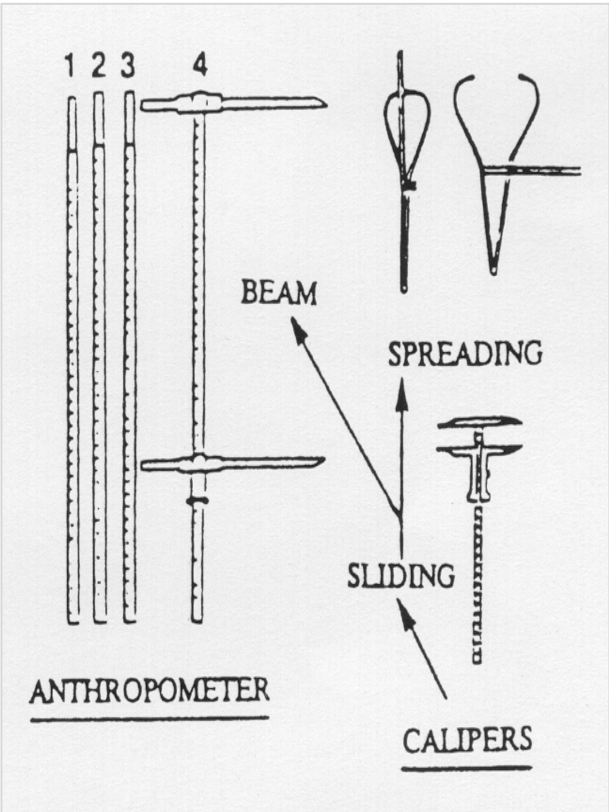


Figure A-11 Anthropometer

Table A-1 Anthropometry data of copper capillary tube welder.

Subject no.	Age (year)	Service (Year)	Height (cm)	Weight (kg)	BMI (kg/m2)	SH (cm)	EH (cm)	SEL (cm)	EWL (cm)	EFL cm)	ECG (cm)	HL (cm)	HB (cm)	GD (cm) inside
1	21	2	158.00	48.00	19.23	129.00	98.00	31.00	25.00	43.00	52.00	18.00	9.50	4.60
2	29	7	154.00	52.00	21.93	128.00	96.00	32.00	26.00	43.00	51.50	17.00	8.50	4.20
3	33	7	153.00	51.00	21.79	130.00	99.00	31.00	24.00	41.00	49.50	17.00	8.00	3.80
4	27	7	159.00	47.00	18.59	132.00	98.00	34.00	28.00	47.00	56.50	19.00	9.50	4.70
5	42	15	159.00	57.00	22.55	133.00	102.00	31.00	26.00	44.00	53.00	18.00	9.50	4.70
6	27	8	152.00	44.00	19.04	118.00	87.00	31.00	28.00	45.00	53.50	17.00	9.00	4.40
7	25	7	158.00	47.00	18.83	131.00	99.00	32.00	24.00	41.00	49.50	17.00	9.00	4.30
8	27	8	163.00	53.00	19.95	131.00	98.00	33.00	28.00	44.00	53.25	18.50	10.00	5.00
9	25	7	155.00	54.00	22.48	133.00	100.00	33.00	28.00	45.50	54.25	17.50	9.50	4.60

APPENDIX B
AN ASSESSMENT TECHNIQUE FOR POSTURAL LOADING ON THE UPPER BODY (LUBA)

An Assessment Technique for Postural Loading on the Upper Body is assessment technique by considering the motion of the set of joints on the upper body which consist of shoulder, elbow, wrist, neck and back. Technique is divided into four stages of the procedure as follow,

A. The camera to record the motion stage: VDO record the postures while working. In generally, they need to see 3-Dimension to specify the angle of joints thoroughly when playback. The multiple shooting of job cycle should be recorded because of the postures in each cycle may vary depending on the nature and requirement of job. Any conditions that may harm occurred in job cycle should be also recorded.

B. Selection of posture for evaluation stage: The posture selected depends on duration of work or posture that cause of stress. Posture selected for evaluation may have the most of job cycle or operator / auditor have considered that it cause of stress on the musculoskeletal system.

C. Relative Discomfort Score stage: Observe the motion of each joint from posture selected in stage 2. And then, point relative discomfort score as following table. To evaluate only the left or right of the upper body with more stress only.

Table B- 1 Postural classification scheme for the wrist

Posture and discomfort Score/ Joint motions	Sitting posture		Standing posture	
	Class	Relative discomfort score	Class	Relative discomfort score
Flexion	0-20°	1	0-20°	1
	20-60°	2	20-60°	2
	>60°	5	>60°	5
Extension	0-20°	1	0-20°	1
	20-45°	2	20-45°	2
	>45°	7	>45°	7
Radial deviation	0-10°	1	0-10°	1
	10-30°	3	10-30°	3
	>30°	7	>30°	7
Ulna deviation	0-10°	1	0-10°	1
	10-20°	3	10-20°	3
	>20°	6	>20°	6

Table B-2 Postural classification scheme for the elbow

Posture and discomfort Score/ Joint motions	Sitting posture		Standing posture	
	Class	Relative discomfort score	Class	Relative discomfort score
Flexion	0-45°	1	0-45°	1
	45-120°	2	45-120°	3
	>120°	5	>120°	5
Pronation	0-70°	2	0-70°	2
	>70°	7	>70°	7
Supination	0-90°	2	0-90°	2
	>90°	7	>90°	7

Table B-3 Postural classification scheme for the shoulder

Posture and discomfort Score/ Joint motions	Sitting posture		Standing posture	
	Class	Relative discomfort score	Class	Relative discomfort score
Flexion	0-45°	1	0-45°	1
	45-90°	3	45-90°	3
	90-150°	6	90-150°	6
	>150°	11	>150°	11
Extension	0-20°	1	0-20°	1
	20-45°	4	20-45°	3
	45-60°	9	45-60°	6
	>60°	13	>60°	10
Adduction	0-10°	1	0-10°	1
	10-30°	2	10-30°	2
	>30°	8	>30°	8
Abduction	0-30°	1	0-30°	1
	30-90°	3	30-90°	3
	>90°	10	>90°	7
Medial rotation	0-30°	1	0-30°	1
	30-90°	2	30-90°	2
	>90°	7	>90°	5
Lateral rotation	0-10°	1	0-10°	1
	10-30°	3	10-30°	2
	>30°	7	>30°	5

Table B-4 Postural classification scheme for the back

Posture and discomfort Score/ Joint motions	Sitting posture		Standing posture	
	Class	Relative discomfort score	Class	Relative discomfort score
Flexion	0-20°	1	0-30°	1
	20-60°	3	30-60°	3
	>60°	10	60-90°	6
			>90°	12
Extension	a	a	0-10°	1
			10-20°	4
			20-30°	8
			>30°	15
Lateral bending	0-10°	1	0-10°	1
	10-20°	3	10-20°	4
	20-30°	9	20-30°	9
	>30°	13	>30°	13
Rotation	0-20°	1	0-20°	1
	20-30°	2	20-60°	3
	30-45°	7	>60°	10
	>45°	11		

a= Not measured.

Table B-5 Postural classification scheme for the neck

Posture and discomfort Score/ Joint motions	Sitting posture		Standing posture	
	Class	Relative discomfort score	Class	Relative discomfort score
Flexion	0-20°	1	0-20°	1
	20-45°	3	20-45°	3
	>45°	5	>45°	5
Extension	0-30°	1	0-30°	1
	30-60°	6	30-60°	4
	>60°	12	>60°	9
Lateral bending	0-30°	1	0-30°	1
	30-45°	3	30-45°	2
	>45°	10	>45°	7
Ulna deviation	0-30°	1	0-30°	1
	30-60°	2	30-60°	2
	>60°	8	>60°	8

The figure B-1 can be used to make it easier and faster to calculate the postural load index from work. Just mark it down and analyze the results corresponding to each of the joints moving.

Department: Task: Operator:
Analyst name: Date:

Joint	Motion	Class	Score		Motion	Class	Score	
Wrist	Flexion	0- 20°	1	______	Extension	0- 20°	1	______
		20- 60°	4	______		20- 45°	5	______
		>60°	9	______		>45°	11	______
	Radial deviation	0- 10°	1	______	Ulna deviation	0- 10°	1	______
		10- 30°	5	______		10- 20°	5	______
		>30°	10	______		>20°	9	______
Elbow	Flexion	0- 45°	1	______	Supination	0- 90°	3	______
		45-120°	3	______		>90°	9	______
		>120°	7	______				______
	Pronation deviation	0- 70°	3	______				______
		>70°	9	______				______
Shoulder	Flexion	0- 45°	1	______	Extension	0- 20°	1	______
		45- 90°	5	______		20- 45°	7	______
		90- 150°	9	______		45- 60°	12	______
		>150°	14	______		>60°	16	______
	Adduction	0- 10°	1	______	Abduction	0- 30°	1	______
		10- 30°	4	______		30- 90°	6	______
		>30°	11	______		>90°	13	______
	Medial rotation	0- 30°	1	______	Lateral rotation	0- 10°	1	______
		30- 90°	4	______		10- 30°	5	______
		>90°	10	______		>30°	10	______
Neck	Flexion	0- 20°	1	______	Extension	0- 30°	1	______
		20- 45°	5	______		30- 60°	9	______
		>45°	8	______		>60°	15	______
	Lateral bending	0- 30°	1	______	Rotation	0- 30°	1	______
		30- 45°	5	______		30- 60°	4	______
		>45°	13	______		>60°	11	______
Back	Flexion	0- 20°	1	______	Extension	Not included		
		20- 60°	6	______				
		>60°	13	______				
	Lateral bending	0- 10°	1	______	Rotation	0- 20°	1	______
		10- 20°	5	______		20- 30°	3	______
		20- 30°	12	______		30- 45°	7	______
		>30°	16	______		>45°	14	______

Postural load=

Figure B-1 Checklist for evaluating postures

D. Calculation the postural load and classification stage: Using the following equation to calculate postural load index of joint deviated from their neutral position. That is this equation will be used to calculate postural load of joint motions relate with discomfort score.

E. Management of each Category.

Category I: Postures with the MHT of more than 10 min, and postural load index of 5 or less. This category of postures is acceptable, except in special situations such as repeating and sustaining them for long periods of time, etc. No corrective actions are needed.

Category II: Postures with the MHT of 5- 10 min, and postural load index from 5 to 10. This category of postures requires further investigation and corrective changes during the next regular check, but immediate intervention is not needed.

Category III: Postures with the MHT of 5 or less minutes, and postural load index from 10 to 15. This category of postures requires corrective action through redesigning workplaces or working methods soon.

Category IV: Postures with the MHT of less than 2 min, and postural load index of 15 or more. This category of postures requires immediate consideration and corrective action.

Table B-6 Postural load index by an assessment technique for postural loading on the upper body from welding posture by using existing torch and new torch

Subject no.	Posture round	Existing torch	New torch
1	1	30	3
2	1	14	3
3	1	24	3
4	1	22	10
5	1	24	3
6	1	17	3
7	1	24	3
8	1	34	8
9	1	24	3
1	2	30	3
2	2	14	3
3	2	24	3
4	2	22	10
5	2	24	3
6	2	17	3
7	2	24	3
8	2	34	8
9	2	24	3
1	3	30	3
2	3	14	3
3	3	24	3
4	3	22	10
5	3	24	3
6	3	17	3
7	3	24	3
8	3	34	8
9	3	24	3
1	4	30	3
2	4	14	3
3	4	24	3
4	4	22	10
5	4	24	3
6	4	17	3
7	4	24	3
8	4	34	8
9	4	24	3

APPENDIX C
ELECTROMYOGRAPH AND MEASUREMENT

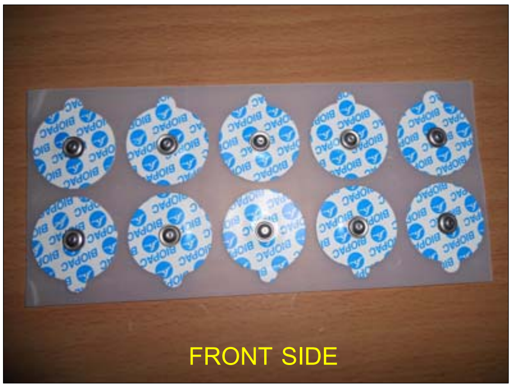


Figure C-1 Show 2 sides of surface electrode (BP EL503 Disposable electrodes)

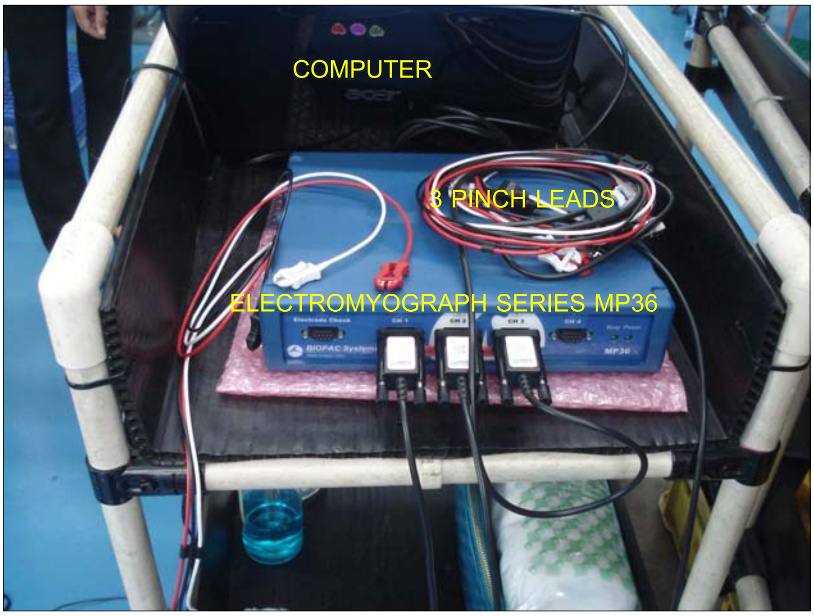
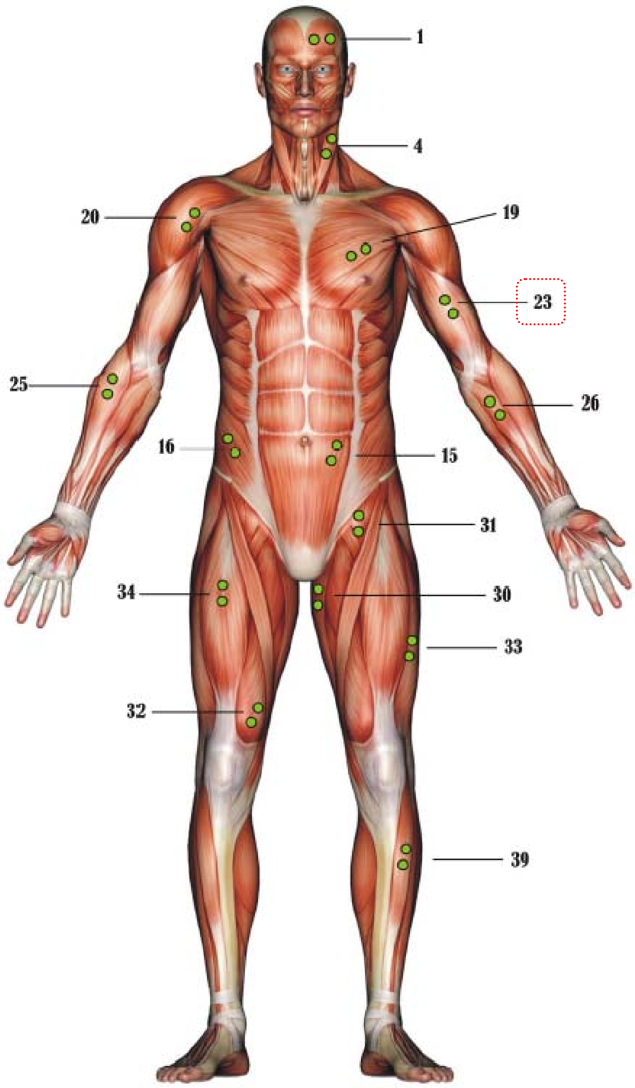


Figure C-2 Show Computer, Electromyograph series MP36 acquisition unit and 3 Pinch leads



Front view

Head and Neck

1. Frontalis
2. Temporalis
3. Masseter
4. Sternocleidomastoid (SCM)
5. C4 Cervical Paraspinals (CP)

Trunk

6. Upper Trapezius
7. Lower Trapezius
8. Infraspinatus
9. Latissimus Dorsi
10. T2 Paraspinals
11. T8 Paraspinals
12. T10 Paraspinals
13. L1 Paraspinals
14. L5 Paraspinals
15. Rectus Abdominal
16. Abdominal Oblique
17. Internal Oblique
18. Serratus Anterior
19. Pectoralis Major

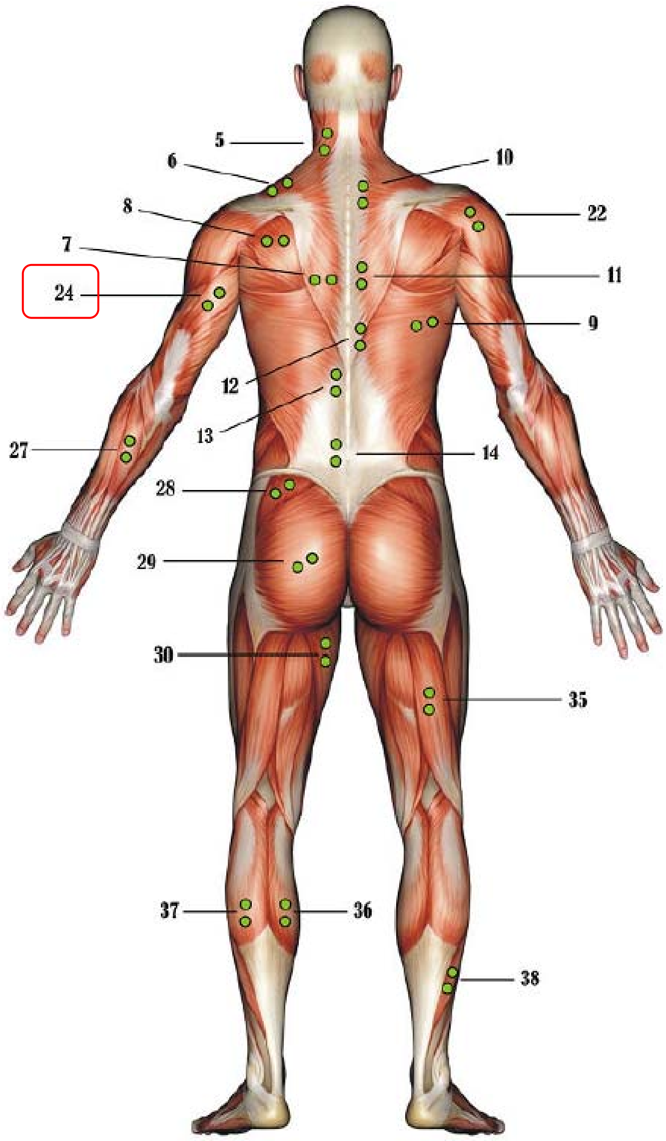
Arm

20. Anterior Deltoid
21. Lateral Deltoid
22. Posterior Deltoid
23. Biceps Brachii
24. Triceps Branchii
25. Brachioradialis
26. Wrist Flexor
27. Wrist Extensor

Leg

28. Gluteus Medius
29. Gluteus Maximus
30. Hip Adductor
31. Hip Flexor
32. Vastus Medialis Oblique (VMO)
33. Vastus Lateralis (VL)
34. Quadriceps Femoris
35. Medial Hamstring
36. Medial Gastrocnemius
37. Lateral Gastrocnemius
38. Soleus
39. Tibialis Anterior

Figure C-3 Show position for attaching electrode on Biceps Brachii muscle.



Back view

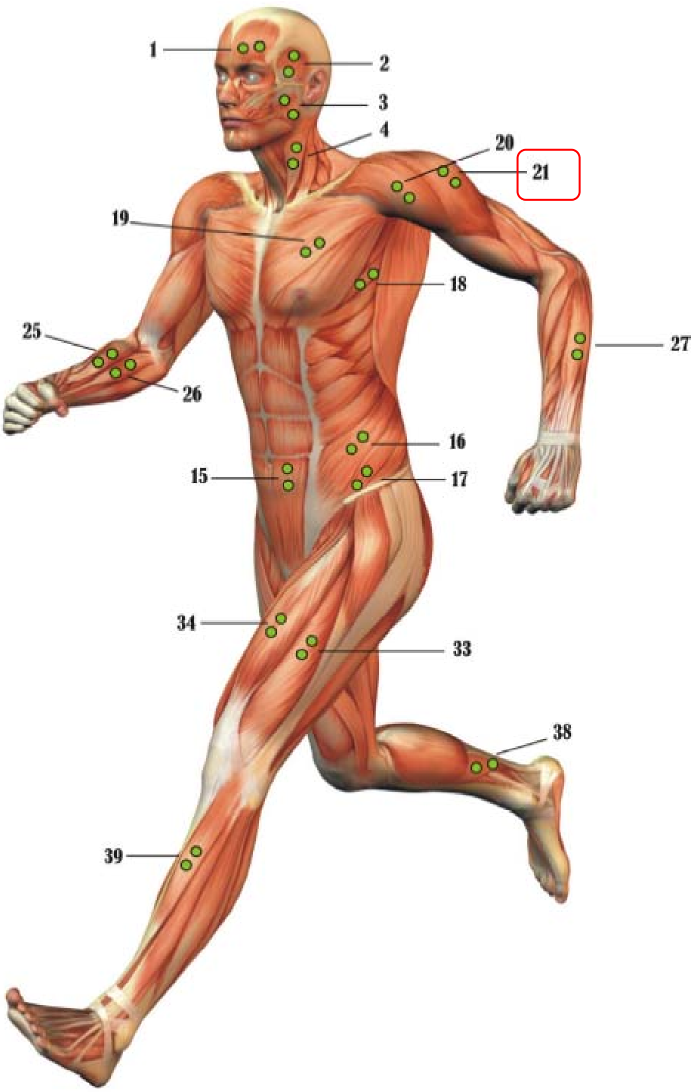
Head and Neck
1. Frontalis
2. Temporalis
3. Masseter
4. Sternocleidomastoid (SCM)
5. C4 Cervical Paraspinals (CP)

Trunk
6. Upper Trapezius
7. Lower Trapezius
8. Infraspinatus
9. Latissimus Dorsi
10. T2 Paraspinals
11. T8 Paraspinals
12. T10 Paraspinals
13. L1 Paraspinals
14. L5 Paraspinals
15. Rectus Abdominal
16. Abdominal Oblique
17. Internal Oblique
18. Serratus Anterior
19. Pectoralis Major

Arm
20. Anterior Deltoid
21. Lateral Deltoid
22. Posterior Deltoid
23. Biceps Brachii
24. Triceps Branchii
25. Brachioradialis
26. Wrist Flexor
27. Wrist Extensor

Leg
28. Gluteus Medius
29. Gluteus Maximus
30. Hip Adductor
31. Hip Flexor
32. Vastus Medialis Oblique (VMO)
33. Vastus Lateralis (VL)
34. Quadriceps Femoris
35. Medial Hamstring
36. Medial Gastrocnemius
37. Lateral Gastrocnemius
38. Soleus
39. Tibialis Anterior

Figure C-4 Show position for attaching electrode on Triceps Brachii muscle.



Side view

Head and Neck

1. Frontalis
2. Temporalis
3. Masseter
4. Sternocleidomastoid (SCM)
5. C4 Cervical Paraspinals (CP)

Trunk

6. Upper Trapezius
7. Lower Trapezius
8. Infraspinatus
9. Latissimus Dorsi
10. T2 Paraspinals
11. T8 Paraspinals
12. T10 Paraspinals
13. L1 Paraspinals
14. L5 Paraspinals
15. Rectus Abdominal
16. Abdominal Oblique
17. Internal Oblique
18. Serratus Anterior
19. Pectoralis Major

Arm

20. Anterior Deltoid
21. Lateral Deltoid
22. Posterior Deltoid
23. Biceps Brachii
24. Triceps Branchii
25. Brachioradialis
26. Wrist Flexor
27. Wrist Extensor

Leg

28. Gluteus Medius
29. Gluteus Maximus
30. Hip Adductor
31. Hip Flexor
32. Vastus Medialis Oblique (VMO)
33. Vastus Lateralis (VL)
34. Quadriceps Femoris
35. Medial Hamstring
36. Medial Gastrocnemius
37. Lateral Gastrocnemius
38. Soleus
39. Tibialis Anterior

Figure C-5 Show position for attaching electrode on Lateral Deltoid muscle.

Figure C-6 Show posture by usage of existing torch to weld

Figure C-7 Show posture by usage of new torch to weld

APPENDIX D
"MUSCLE FATIGUE SITUATION INTERVIEW FORM" AND "SUBJECTIVE FEELING OF FATIGE AND COMFORT ACCEPTANCE QUESTIONAIRE"

PART I
Muscle fatigue situation interview form

Subject code: ……………………. Interview date: …………………

A. General information

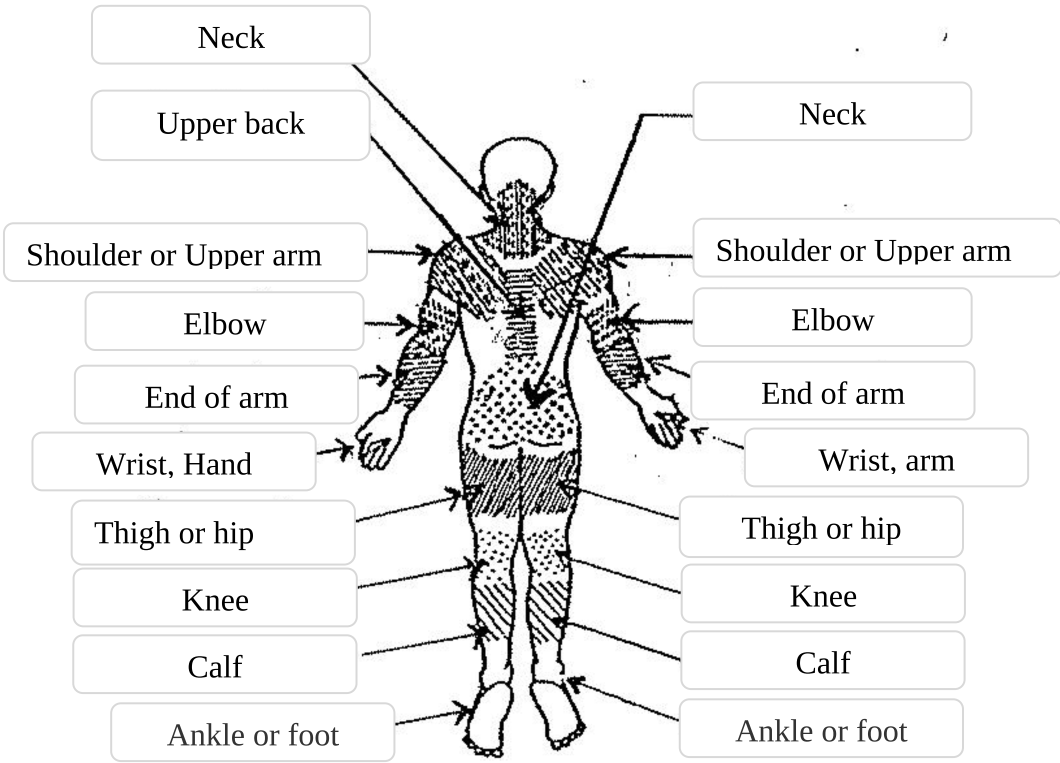
1. Welding table no: …..……………………………
2. Sex……………………………………………..
3. Age: …………years Weight: ....…kg. Height: ....…cm.
4. Service on copper capillary tube…………….…. years……………..months.

B. Physical health status

5. Which is your dominant hand ( ) Left ( ) Right
6. Relax hours before testing ………………hours
7. How frequency of exercise ( ) Daily ( ) Infrequently ( ) Never
8. Do you have any accident or disease that can affect to upper arm and shoulder muscular fatigue such as heart disease, gall bladder, hepatitis etc?
   ( ) Yes ( ) No
9. Alcohol drinking ( ) Always ( ) No smoke
10. Smoke habit ( ) Always ( ) Sometime ( ) Never
11. Had you ever had symptom of fatigue on hand, arm or shoulder in during 6 months ago? ( ) Yes ( ) No
12. Are you in menstrual cycle during test? ( ) Yes ( ) No

C. Muscle fatigue information

13. As the below figure, Could you identify by marking on the body part which you has muscular fatigue feeling when welding on copper capillary tube?



( ) Neck ( ) Upper back ( ) Shoulder or Upper arm
( ) Lower back ( ) Elbow ( ) End of arm ( ) Wrist, Hand
( ) Thighs or hips ( ) Knee ( ) Calf ( ) Ankle or foot

14. Which the date that symptom of fatigue appeared mostly.
( ) The first date of week ( ) Final date of week
( ) Someday uncertainty ( ) Every day of work

15. How long is duration of your fatigue?
( ) Equal or less than 1 day ( ) 2-3 days ( ) More than 3 days

16. Which is the technique for reducing your muscular fatigue?
( ) Do not anything ( ) Take medicine
( ) Self massage ( ) Treated by a doctor or physiotherapist

17. What is the cause of muscular fatigue in your opinion?
( ) Sport or exercise ( ) Copper capillary welding posture
( ) Illness or accident in the past ( ) Other: ………………

PART II

Subjective feeling of fatigue and comfort acceptance questionnaire

Interview date: …………………

Subject code: ……………………. ( ) Existing torch ( ) Existing torch

18. Could you please mark the level of fatigue on the muscle as you identify on item 13?

No.	Fatigue area	Duration to assess	Fatigue score
1	Neck	Before welding	start to feel fatigue --> extremely fatigue and can't work 1 2 3 4 5 6 7
		After welding	start to feel fatigue --> extremely fatigue and can't work 1 2 3 4 5 6 7
2	Upper back	Before welding	start to feel fatigue --> extremely fatigue and can't work 1 2 3 4 5 6 7
		After welding	start to feel fatigue --> extremely fatigue and can't work 1 2 3 4 5 6 7
3	Shoulder or Upper arm	Before welding	start to feel fatigue --> extremely fatigue and can't work 1 2 3 4 5 6 7
		After welding	start to feel fatigue --> extremely fatigue and can't work 1 2 3 4 5 6 7
4	Elbow	Before welding	start to feel fatigue --> extremely fatigue and can't work 1 2 3 4 5 6 7
		After welding	start to feel fatigue --> extremely fatigue and can't work 1 2 3 4 5 6 7
5	End of arm	Before welding	start to feel fatigue --> extremely fatigue and can't work 1 2 3 4 5 6 7
		After welding	start to feel fatigue --> extremely fatigue and can't work 1 2 3 4 5 6 7
6	Wrist, Hand	Before welding	start to feel fatigue --> extremely fatigue and can't work 1 2 3 4 5 6 7
		After welding	start to feel fatigue --> extremely fatigue and can't work 1 2 3 4 5 6 7
7	Thigh or hip	Before welding	start to feel fatigue --> extremely fatigue and can't work 1 2 3 4 5 6 7
		After welding	start to feel fatigue --> extremely fatigue and can't work 1 2 3 4 5 6 7
8	Knee	Before welding	start to feel fatigue --> extremely fatigue and can't work 1 2 3 4 5 6 7
		After welding	start to feel fatigue --> extremely fatigue and can't work 1 2 3 4 5 6 7
9	Calf	Before welding	start to feel fatigue --> extremely fatigue and can't work 1 2 3 4 5 6 7
		After welding	start to feel fatigue --> extremely fatigue and can't work 1 2 3 4 5 6 7
10	Ankle or foot	Before welding	start to feel fatigue --> extremely fatigue and can't work 1 2 3 4 5 6 7
		After welding	start to feel fatigue --> extremely fatigue and can't work 1 2 3 4 5 6 7

Remark 1 means start to feel fatigue; 2 means slightly fatigue
3 means moderately fatigue and can relief after resting; 4 means moderately fatigue and can't relief even resting
5 means severely fatigue and can relief after resting; 6 means severely fatigue and can't relief after resting
7 means extremely fatigue and can't work

19. In your opinion, do you accept about the comfort and usability of new torch (the ergonomically designed)?

( ) Accept ( ) No accept

บัณฑิตวิทยาลัย มหาวิทยาลัยมหิดล

ขอมอบประกาศนียบัตรนี้ เพื่อแสดงว่า

ธัญญารัตน์ ฤกษ์ใหญ่

ได้เข้าอบรมเรื่อง จริยธรรมการวิจัยในคน

วันศุกร์ที่ ๓๑ กรกฎาคม พ.ศ. ๒๕๕๒

ณ อาคารภาษาและวัฒนธรรมสยามบรมราชกุมารี มหาวิทยาลัยมหิดล ศาลายา

ขอให้นำความรู้และประสบการณ์ที่ได้รับไปใช้เป็นหลักในการปฏิบัติเพื่อให้เกิดประโยชน์สูงสุด

รองศาสตราจารย์ ทพญ.อารยา พงษ์หาญยุทธ
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ศาสตราจารย์ นพ.บรรจง มไหสวริยะ
คณบดีบัณฑิตวิทยาลัย

Certificate of Approval
Ethical Review Committee for Human Research
Faculty of Public Health, Mahidol University

COA. No. MUPH 2011-224

Protocol Title :	TORCH DESIGN TO REDUCE FATIGUE ASSOCIATED WITH ARM AND SHOULDER MUSCULARS IN WELDING PROCESS OF AIR CONDITIONNING PRODUCTION FACTORY
Protocol No. :	168/2554
Principal Investigator :	Miss Thunyarat Rerkyai
Affiliation :	Master of Science Program in Industrial Hygiene and Safety Faculty of Public Health, Mahidol University
Approval Includes :	1. Project proposal 2. Information sheet 3. Informed consent form 4. Data collection form/Program or Activity plan
Date of Approval :	23 November 2011
Date of Expiration :	22 November 2012

The aforementioned project have been reviewed and approved according to the Declaration of Helsinki by Ethical Review Committee for Human Research, Faculty of Public Health, Mahidol University.

S. Nantt

(Assoc. Prof. Sutham Nanthamongkolchai)
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