WORKSTATION DESIGN AND ANALYSIS ON STUDENT WORKING IN ELECTRICAL WIRING LAB AT POLITEKNIK TUANKU SYED SIRAJUDDIN

MUHAMMAD BIN JAMALUDDIN

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Field of Study: Occupational Health (Ergonomics)

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ABSTRACT

This study is conducted to investigate the workstation design and the analysis on the student working posture in electrical wiring lab at Politeknik Tuanku Syed Sirajuddin, Arau Perlis for any relation between manual tools handling and significant risk factors related to body postural perceived exertion. The study is focusing on six different activities of wiring task that are screwing and tightening the electrical cable to wall lamp module, ceiling lamp module, lower level power socket outlet, screwing of the socket box to wall wooden panel, screwing of the enclose power outlet at the lowest level and the middle level. All of these activities are manually carried out and investigation on postural position the injuries related to musculoskeletal disorder injuries will be avoided. The study also focusing on workstation environment that is not conducive to work because of high humidity and need a good air flow design. Begin with Borg's RPE Scale questionnaire to the 5 participants whose previously work with the task given. The Borg's RPE result is compared to the anthropometric data taken. For better result, RULA (Rapid Upper Limb Assessment) become main tools for ergonomics assessment on the student individual upper limb MSD. Evaluator will focus on the selected activities as mentioned earlier for the assessment. Result with very high-risk level and RULA Score of 7 will need immediate investigation. On top of that work task postural also need to be change with new postural position implemented. All of these assessments are using worksheet. Based on RULA the result, the activities above students shoulder required immediate change and new working procedure are been proposed and implemented.

ABSTRAK

Kajian ini dijalankan bagi menyiasat stesen kerja dan menganalisa postur kerja pelajar di Makmal Pendawaian Elektrik, Politeknik Tunaku Syed Sirajuddin, Arau Perlis. Kajian ini membandingkan pengunaan alatan tangan dan mengenalpasti risiko berkaitan tahap kepenatan postur badan. Kajian ini mengfokus kepada 6 aktiviti pendawaian elektrik seperti mengetatkan skrew kabel elektrik kepada modul lampu dinding, modul lampu siling, barisan bawah soket kuasa keluaran, memasang skrew kotak soket kepada dinding kayu, memasang skrew penutup soket kuasa keluaran barisan bawah dan baridan tengah. Semua aktiviti ini dijalanakan secara manual dan siasatan bagi posisi postur dan kecederaan pada *Musculoskeletal Disorder* dapat di elakkan. Kajian juga mengfokuskan kepada persekitaran stesen kerja yang tidak kondusif di mana kadar kelembapan yang tinggi dan memerlukan pengudaraan yang baik. Bermula dengan keputusan soal selidik *Borg RPE* yang diberikan kepada 5 orang peserta yang terlibat dengan setiap aktiviti ini. Keputusan data *Borg RPE* ini kemudiannya dibandingkan dengan data antropometrik. Untuk keputusan yang lebih baik, Penilaian RULA dijadikan sebagai alat ukur ergonomik yang utama bagi menilai MSD bahagian atas anggota badan. Penilai akan memilih aktiviti yang mempunyai risiko tinggi berpandukan keputusan RULA dengan nilai skor 7 untuk diambil tindakan segara. Ini dilakukan dengan membuat perubahan kepada posisi postur yang baru. Kesemua penilaian ini menggunakan lembaran kerja yang tersedia. Berdasarkan keputusan RULA, didapati semua aktiviti yang berada melebihi paras bahu pelajar haruslah segera dibuat perubahan dengan mencadangkan dan melaksanakan prosidur kerja yang baru.

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Finally I wish to one and all that, directly or indirectly have lent their helping hand in this study.

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LIST OF SYMBOLS AND ABBREVIATIONS

°	:	Degree of angle
cm	:	Centimeters
MSD	:	Musculoskeletal Disorder
PTSS	:	Politeknik Tuanku Syed Sirajuddin
RULA	:	Rapid Upper Limb Assessment
RPE	:	Rating of Perceived Exertion
WMSD	:	Work Musculoskeletal Disorder
WRULD	:	Work Related Upper Limb Disorder
AL	:	Action Level

CHAPTER 1:

INTRODUCTION

1.1 Overview of The Case Study

Electrical wiring installation is a core subject for all 1st semester student of Electrical Engineering Department at Politeknik Tuanku Syed Sirajuddin, Arau Perlis. This involved all students to perform their wiring installation practical task. In this course the students need to clearly understand all the electrical safety in their working environment and performed a good work practice. On top of that, all students must efficiently handle the basic electrical engineering equipment, electrical accessories and tools for wiring installation which are related to the manual procedure.

Figure 1-1 Electrical Wiring Lab at Politeknik Tuanku Syed Sirajuddin, Perlis

The students also need to conduct a single phase domestic wiring, the wiring inspection and testing the installation according to MS IEC 60364. This is Malaysia Standard of the International Electrotechnical Commission on electrical installation of

buildings. This standard is an attempt to harmonize the national wiring standard for an IEC standard. (Tenaga, 2008)

In this wiring installation task, students are also needed to identify correctly the types of wiring protection against following the MS IEC 60364 standards. The students are also needed to perform practical work as a team to ensure they are applying the good work ethics and follow proper work procedures. The students must also comply the electrical engineering practices and follow all the regulation within stipulated time frame.

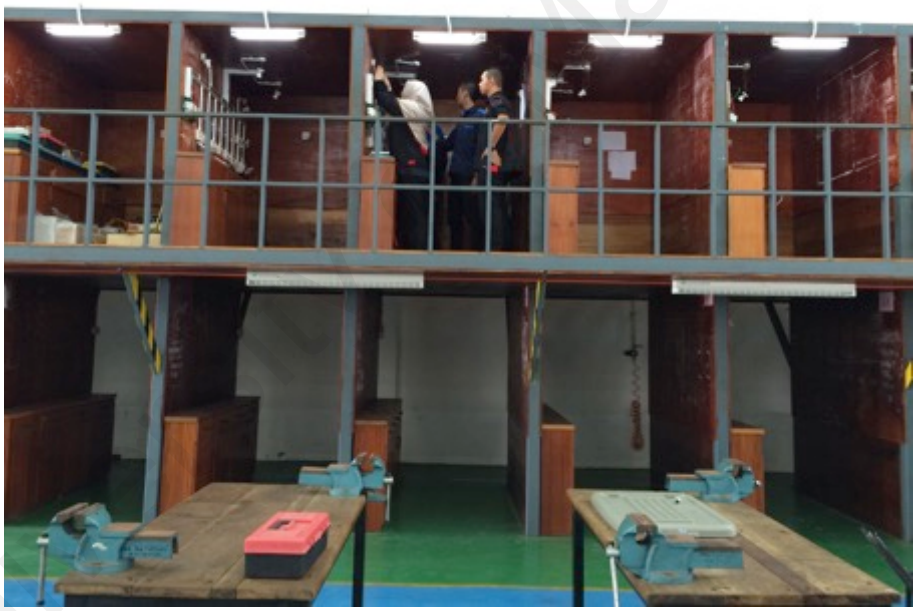

Figure 1-2 View of Double Deck Workstation

Ergonomics plays a vital role in improving productivity. Though, it is the fact that ergonomics itself does not produce anything. However, if wrong approach to body postural taken during performing wiring installation task. The subject might suffer musculoskeletal disorder and facing the bodies injury (Ansari & Sheikh, 2014).

The approach to this research is to study the body working postural and work place environment so that any related issue to musculoskeletal disorder can be identified and change immediately. There is no previous research work on the students body postural analysis done by the researcher focusing on electrical wiring lab at Malaysian Polytechnic's.

Figure 1-3 Halfway completed weekly practical work

1.2 Research Problem

During wiring practical work, The students divided into several groups. Each group to have within 2~4 students. The practical work will be conducted for 3 hours per week in 14 weeks. Based on observation it was found that the bay is congested during practical work.

Figure 1-4 Congested Workstation Occupied by 4 Students

Moreover the working postures, materials & tools handling, repetitive movements was their major activities during the wiring practical work. Therefore, a study of the ergonomics of the physical work is a must to identify any ergonomics issue regarding the students working in the wiring bay laboratory.

Figure 1-5 Wiring Equipment place at small cabinet

Figure 1-6 Hand tools such as multimeter, screw drivers, test pen and other tools are the common tools during work performance

Beside of the ergonomics studies of the student working on the wiring installation. The safety of the workstation also has to be focusing. In this lab, the workstations are placed at the left, right and the rear side of the lab. Figure 1-2 show the double deck

workstation located at the rear side of the lab and consists of 10 working bays on a single floor. In totals the rear side of wiring lab there are about 20 working bays.

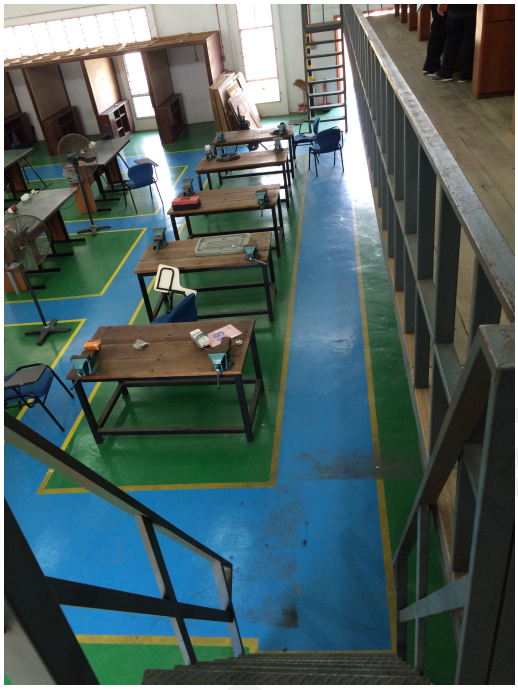

Figure 1-7 The Stairways As Seen From Upper Deck

Figure 1-8 The Corridor of the Upper Deck

1.3 Objectives

The objectives of the study are:

i. To determine the prevalence of the MSD and body perceived exertion among the students in the Electrical Wiring Lab Politeknik Tuanku Syed Sirajuddin (PTSS) through the Borg RPE Scale Assessment tools.

ii. To analyse the significant ergonomics risk factors among the student in their weekly practical wiring task through RULA assessment tools

iii. To proposed an improvement design of better new workstation environment in order to give the safe workstation and safe body posture during practical task in electrical wiring lab.

Figure 1-9 Workstation (1.4m width, 1.95m height, 1.95m long)

1.4 Scopes of the Study

The scope of study is to be focused on the Electrical Wiring Lab, Electrical Engineering Department, Politeknik Tuanku Syed Sirajuddin where the workstation for the student working to be study. This involved the 1st Semester students that are doing

their electrical wiring installation practical work or lab work. Study involved randomly of 5 students that are separately completing their weekly practical task in the different workstation. All students are male with the age from 18 and 19 years old and mainly focused their practical task on the wooden wall panel. The practical task need to be completed within a semester and their lecturer will give an evaluation for the completed, tested and safely to operate electrical circuit of the end of semester.

To complete the task till to the end of semester, students are required to use manual hand tools such as test pen, screwdrivers, hammer, cutter, pliers and etc. On top of that they are given material such as conduit, conduit holder, trucking, screws, based socket box, switch panel sockets, 3 pin power panel socket, lamp holder, lamp based socket and a complete set of distribution box.

The main purpose of this study are to examine the body perceived exertion and others work related postures that may cause injuries to manual handling processes of the electrical panel installation during this lab work.

1.5 Limitation of the Study

Although the study has met the objectives and carefully prepared, but there were some inevitable limitations. First, the location of the project lab has to be observed for any related ergonomics issue. This includes the lab environment such as walkways, stairways, table, chairs, whiteboards and etc. But the focused are only on the student that is performing their task inside their workstation only.

Any tools such as hand tools use by the student during the lab work also need to be considered. The study of the hand tools is a must, because during lab work student is needed to use these hand tools for preparation, during work and also during completion of work. The screwdrivers were used to insert the screw to the wooden wall as a part to

ensure the conduit holder, socket based box, trucking, and distribution board are attach to the wall and ceiling. Test pen were used to tighten the electrical cable to switching sockets, power sockets and lamp sockets holder. This indicates that during all 6 activities that were selected only these hand tools are to be used by the users.

CHAPTER 2:

LITERATURE REVIEW

2.1 Work-Related Neck and Upper Limb Disorders (WRULDs)

2.1.1 WRULDs Pathologies

Work Related Upper Limb Disorders (WRULDs) comprise a heterogeneous group of conditions that can affect any region of neck, shoulders, arms, forearms, wrists and hand (Walker-Bone, Palmer, Reading, & Cooper, 2003). Some of WRULDs, such as tendonitis, carpal tunnel syndrome, osteoarthritis, vibration white finger and symptoms, while others are less well defined, involving only pain, discomfort, numbness and tingling (Van Tulder, Malmivaara, & Koes, 2007). Other term can be related to this WRULD is the WMSDs (work related musculoskeletal disorder) that are related to repetitive movement in work activities. A study in a car manufacturing industries show that any task with repetitive movement can expose the worker to the risk of injuries in WMSD (Nur, Dawal, & Dahari, 2014). Wide range of inflammatory and degenerative decease and disorders are part of WRULD (Buckle & Devereux, 2002).

Many of the musculoskeletal conditions are non-specific indicating that a specific diagnosis or pathology cannot be determined by physical examination but pain and/or discomfort, numbness, tingling in the affected areas are reported. Other symptoms which can be exacerbated by cold or use of vibrating tools include swelling in the joints, decreased mobility or grip strength, changes in skin colour of the hands or fingers. These complaints can lead to physical impairment and even disability. Symptoms may take weeks, months or in some cases years to develop, so it is important to detect them and act at an early stage (Petreanu & Seracin, 2012) . The most common WRULDs are

- **Neck:** Tension Neck Syndrome, Cervical Spine Syndrome,
- **Shoulder**: Shoulder Tendonitis, Shoulder Bursitis, Thoracic Outlet

Syndrome,

- **Elbow**: Epicondylitis, Olecranon Bursitis, Radial Tunnel Syndrome, Cubital Tunnel Syndrome,
- **Wrist/Hand**: De Quervain Disease, Tenosynovitis Wrist / Hand, Synovial Cyst, Trigger Finger, Carpal Tunnel Syndrome, Guyon's Canal Syndrome, Hand-Arm Syndrome, Hypothenar Hammer Syndrome.

2.1.2 Prevalence of Upper Limb Disorder

Upper limb disorders are common in the general population. Data from (national) studies report a prevalence of 5% to 10% for non-specific complaints of strain that interferes with day-to-day activities, but rates could be as high as 40% in specific working populations (Van Tulder et al., 2007). For instance, for carpal tunnel syndrome studies have found prevalence rates of 7% to 14.5% (Walker-Bone et al., 2003). However disease labels and case definitions vary considerably between studies which might, in part, explain the differences between prevalence rates.

2.2 Ergonomics Risk Factor

Risk factor that is related to any work activities and ergonomics issue can be more difficult to maintain. The increases the probability that can make some individuals may develop a MSD. The major workplace ergonomics risk factors to consider are High Task Repetition, Forceful Exertions and Repetitive or Sustained Awkward Postures.

2.2.1 High Task Repetition in Electrical Installation

During work, the job task and cycles are considered repetitive in nature. They are frequently controlled by hourly or daily production target and work processes. High task repetition, when combined with other risk factors such as high force or awkward postures can contributes to the formation of MSD. A job is considered highly repetitive if the cycle time is 30 seconds or less (Van Tulder et al., 2007).

The repetitive strain injuries include the specific disorder such as carpal tunnel syndrome, cubital tunnel syndrome, guyon canal syndrome, lateral epicondylitis and tendonitis of wrist or hands (Van Tulder et al., 2007).

2.2.2 Forceful Exertion on Body Muscle

Many of the work task given requires high force loads on the human body. The muscle effort increases in response to high force requirements, increasing associated fatigue that can lead to MSD. This can also consider the amount of muscular effort expended to perform work. Exerting large amount of force can result in fatigue and contribute to injury (Armstrong et al., 2002). The worker who feel the high peak muscle loading, medium to high levels of hand repetition and extreme or awkward posture of the elbow and shoulder (Armstrong et al. 2002).

The amount of force exerted depends on a combination of factors, including:

- The effort with which one strikes an object (e.g. student hammering the nail at the wall).
- The shape and dimensions of an object student are working with.
- The hand grips an object or tool.
- The preciseness of motion required doing the task.
- Duration of force applied by the muscles (e.g., the amount of time spent without a muscle-relaxation break).
- Awkward postures (over-reaching).

2.2.3 Awkward Postures in Electricians Task

The awkward postures will show excessive force on joints and overload the muscles and tendons around the effected joint. Any joints of the body are most efficient when they operate closest to the mid-range motion of the joint. MSD risks are increased when

the joints are worked outside of this mid-range repetitively of sustained periods of time without adequate recovery of time. Awkward postures may lead to pain and injuries, the common postures are from trunk and neck in more than 70% of jobs (Keyserling, Brouwer, & Silverstein, 1992).

For the example of the wire-tying task, accomplished using pliers need repetitive forceful exertion and awkward wrist postures (Armstrong et al., 2002). The numbers of awkward wrist postures, including extension and ulnar deviation were also significantly decreased when using power driver-fixtures tools (Li, 2003). Head flexion and upper arm elevation show the higher degree in strenuous postures among this electrician comparing to other jobs (Moriguchi et al., 2013).

2.3 Electrical Hand Tools

Different kinds of hand tools give the different comfort to the user. Based on end user own word and the factor with the comfort experienced are calculated. It was found that the same factors are based on tools functionality, the interaction on physical adverse effect on user skin and also any contact between the skin and hand tools. On top of that the physical and it functionality are the most important factor in using hand screwdrivers (Kuijt-Evers, Vink, & de Looze, 2007).

Hand tools are the most primary user interface during electrical wiring installation. The screwdrivers, test pen, hammer, cutter, and etc. are the major hand tools use during the practical work (Kong, Lowe, Lee, & Krieg, 2008). Hand tools should be design to ensure user comfort with the design and the correct application. These hand tools should fit with hand and has a good force transmission and also has nice feeling handle (Kuijt-Evers et al., 2007).

The comfort in using screwdrivers must compromise with the ease of use, good feeling handle, low hand grip force supply, it own functionality and the cause of cramped muscle (Schulze, Congleton, Koppa, & Huchingson, 1995).

2.4 Psychophysical Scaling Method

The relationship between the physical qualities of a stimulus and the perception of those qualities is a study to a psychophysical (Stevens, 1974). Human are able to perceive the strain generated in the body by given work task and to make absolute and relative judgment about the perceived effort (Kroemer, Kroemer, & Kroemer-Elbert, 1994). Each of the individual need to relate their sensation to some of quantitative measure which are a subjective to each other (Noble & Robertson, 1996). This is a technique that allows participants to assign a numerical value to a certain subjective magnitude of an activity.

2.4.1 Borg's Scales for Perceived Exertion

In 1960, Borg developed a category scale for the rating of perceived exertion (RPE). The RPE scale was design according to the semantics quantitative principles (Noble & Robertson, 1996). The original RPE scale was design to be linear with heart rate. It also based on the subjective estimation, which scale the number of their activity. The scale ranges from 6 to 20 that are actually to match the heart rate from 60 to 200 pulses per minutes. Category scales are inter-individual subjective different studies and this cannot be study as parallel with conventional ratio scaling method. The term of "Perceived Exertion" can be described as how hard of the person experience during physical activities. On top of that Borg's RPE Scale is measured based on physical feeling of the worker during performing the task (Borg, 1982).

During activities the rates of breathing is increased together with heart rate then follow by body sweating and also muscle soreness. This method of scaling is totally an

individual's exertion score and the data may be helpful to represent the actual heart rate during physical activities (Borg 1982). The Borg's RPE scale is rated from 6 to 20, where the scale 6 define as "no exertion at all" and this level also can be refer to heart rate beat per minutes whereas the 6 which is match 60 beat per minutes in heart rate show the body in resting mode (Chen, Fan, & Moe, 2002).

In this assessment the participant need to select the rating that most described their feeling of the body perceived exertion level during the physical activity. For the perceived exertion rating from 12 to 14 on the Borg's RPE Scale show that the person is performing physical task at the moderate intensity (Callaghan, Khalil, Morres, & Carter, 2011). Any person who has the experience of monitoring the Borg's RPE scale may change the intensity level of their physical task either increase or decrease the physical movement.

For the body perceived exertion and the comparison with actual heart rate which has the relationship in the scale monitoring. The Borg's RPE scaling is one over ten (1/10) to the heart rate. As a conclusion any physical movement or the physical activity the Borg's scale number need to times 10 to get the actual heart rate values.

Therefore the Borg's RPE scale can be justify as a good data for estimation the individual body physical intensity comparing to the actual heart rate. For example a cyclist give the perceived body exertion rating as 12, with this data 12 X 10 = 120; then the heart rate supposed to be at the value of 120 beat per minutes. However this data is only the estimation of the involved participants. The actual heart rate result may differ to this data because the factor of physical condition of the person and the age.

In previous investigation, the Borg RPE scale has shown to be an accurate and reliable measurement for the perceived exertion. The activity such as bicycle ergometer,

stool stepping, walking treadmill, and normal walking has been validated by this Borg's scaling. Researchers also validate their research against the physical exertion from various physiological measures such as heart rate, blood and muscle lactate concentration, ventilation plus with respiration and also oxygen uptake are the criterions in validating the research (Chen et al., 2002; Noble & Robertson, 1996; Russell, 1997).

2.5 Rapid Upper Limb Assessment (RULA)

Work activity with prolonged standing can contributes with side effect in health such as spontaneous abortion, work related musculoskeletal disorder, insufficiency chronic venous, preterm birth, and carotid atherosclerosis. However with help from engineering application and administrative control, those injuries can be minimized (Halim, Omar, Saman, & Othman, 2012). In some of the activity required students to prolonged standing in their wiring task. Without proper posture of standing can affect discomfort and safety issue among the students. Standing with over than 90 minutes can developed fatigue in back muscle and lower limb muscle and as a consequences relates to low back pain (Sartika & Dawal, 2016).

Therefore the RULA (Rapid Upper Limb Assessment) is a good tool for upper body assessment for the exposure of worker to any risk of work musculoskeletal disorder (WMSD). Using this tool there is no special equipment needed during observation. RULA observation can be a fast technique and very rational for the researcher to assess the worker body postures. The part of body posture such as wrist, arm, upper arm, neck, shoulder, trunk and lower arm can be assess in a short time (McAtamney & Nigel Corlett, 1993). When longer time taken during work like the standing activities it will affect mental fatigue (Zadry, Dawal, & Taha, 2013).

The RULA concept of assessment is similar to REBA (Rapid Entire Body Assessment) method (Hignett & McAtamney, 2000). REBA is used in many countries

to assess the whole body postural analysis with response to the risk of musculoskeletal disorder. RULA also used the same technique of observation like REBA.

2.5.1 Application of RULA

Using RULA as assessment tools was very easy and quick to use. Practical users or assessor will find using RULA very useful when the concepts of musculoskeletal risk during work loading is presenting to the management. Managers will have a good data and can recognized or remember the actual problem in MSD at their work place. The report will be helpful for the management to decide the changes requirement on upper body postural working procedure.

After the modification in working postural and the workstation. Assessor has to reassessing the new modification postural. Then compare this new RULA assessment with previous RULA result. RULA should be useful in ergonomics research study and can cover the areas of physical, epidemiological, organizational factors, mental and environmental. It is also a complete tools for investigating the risk related to upper limb disorders (McAtamney & Nigel Corlett, 1993).

2.6 Summary

As summarized, based on the result obtained from the past research studies it definitely show that the Borg RPE Scale and RULA method are the best assessment tools for assessing the body postural and level of exertion among the student activities. The Borg RPE is a students or participant oriented assessing their own body perceived exertion. Meanwhile the RULA is the researcher or evaluator tools of assessing the body postural analysis.

CHAPTER 3:

METHODOLOGY

3.1 Introduction

The study is conducted to analyse the workstation design and the student body postural working in Electrical Wiring Lab at Politeknik Tuanku Syed Sirajuddin in Perlis. In this work the ergonomics risk is assessing to determine the MSD.

Working in electrical wiring installation needs to perform lots of screwing task. Electricians install electrical wiring systems in many areas such as industrial buildings, commercial, and domestic or residential infrastructure (Albers, Estill, & MacDonald, 2005). Activities such as conduit, trunking and wiring installation, electrical accessories fixtures, the control unit, and switches are the major work task among them. Electricians also completing all the above tasks using their hands and arms actively, for the examples of the screwing activities, inserting cable to conduit, placing cable into trucking and testing the connection. The neck discomfort are very common among the electricians (Hunting, Welch, Cuccherini, & Seiger, 1994).

The target participant in this study also being quantified using Borg Rating of Perceived Exertion (RPE) (Russell, 1997). The participant is giving the scale to access their discomfort, effort, strain and fatigue during their practical work performance. This Borg Rating scale data can be used as information of the control limit and the energy used for every task of wiring installation. On top of that it also provide the level of exertion that may lead the student at the risk of MSD. Borg RPE Scale is used to assess the effort, discomfort, fatigue experienced and strain during the physical task.

The scale gives the data as it able to control limited amount of energy for completing the tasks through maintaining a normal level of exertion. The result can also provide warning indicator when level of exertion that put students at the risk of injury.

The Rapid Upper Limb Assessment (RULA) is being carried out in this study to assess the postural analysis and also to find any activities that the students are performing above the secure limit (McAtamney & Nigel Corlett, 1993). It was found that most of the activities in this wiring lab required the students standing when they performing their task. On top of that the job task also required the students to manually used their hand tools and this activities may lead to work related musculoskeletal disorder (WMSD) (Entzel, Albers, & Welch, 2007).

In practice, RULA is used to investigate the ergonomics of these workstation activities. In other word is to find and reported any work related to upper limb disorders issue (Öztürk & Esin, 2011). Prolonged standing when performing job can contributes in various health problems such as work related musculoskeletal disorders, preterm birth and spontaneous abortion, carotid atherosclerosis and chronic venous insufficiency. With help of engineering and administrative controls those injuries related problem could be minimize.

Figure 3-1 Video Recording

A digital camera was use to captured images and video of the students while they performing their wiring task. The photos frame was taken from this video and was further analysed by using the RULA technique (Singh & Singh, 2014). It also can be a tool to identify the body segment that being exposed to the postural risks.

Finally after completing the investigation of any significant risk factor during manual handling task, recommendation are being proposed to reduce the MSD risk among the students. This is a must to ensure the future wiring work activities can minimized the MSD risk.

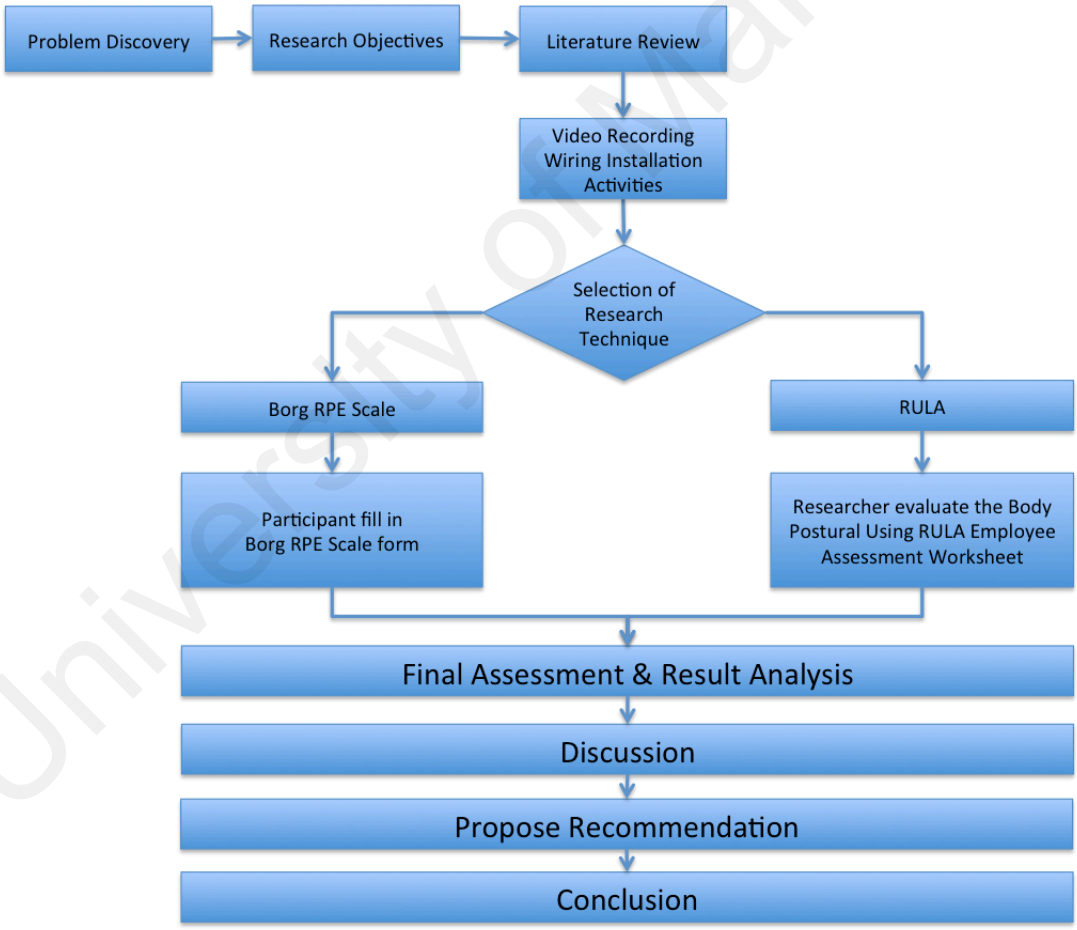

Figure 3-2 Process Flow of the Design Study

3.2 Design Study

Referring to Figure 3-2 the process design study begin with problem discovery related to workstation environment and together with body postural analysis of the students performing the electrical wiring installation. Then the research objectives are plan accordingly to cater any issues rise up from problem finding at early stage. Continue with previous research finding, the literature review will be a good reference for the result analysis.

The researcher will use video camera to record all the activities. Then each frame from the video recording been analyse and choose for RULA assessment. Researcher then evaluates the photos of selected body postural activities using RULA Employee Assessment Worksheet.

The selected activities in previous RULA assessment are then scale using Borg Rating Perceived Exertion. Questionnaire form (Refer appendix A) are distribute among the participant.

Results from RULA and Borg RPE Scale are compared and the highest score from RULA and High Rating in Borg RPE Scale will be selected for investigation and design change.

3.3 Using RULA for Postural Analysis Assessment Tools

For ergonomics investigation tool it was recommended to use the RULA assessment. Observer or auditor must go through some proper training in RULA step-by-step procedure. A RULA Employee Assessment Worksheet in Figure 3-3 is used to evaluate the body posture, force or repetition movement.

There are 2 different sections to be focus by the evaluator. Each section refers to certain body part. For Section A focus to the arm and wrist only. Follow by section B

that is the study of neck and trunk. Data to be collected first and scored accordingly to tables on the RULA forms.

Then the evaluator needs to compile the data and show which risk factor represent by the data. This result also indicates the level of MSD risk. RULA was designed without the need of any high technology equipment or high skills in ergonomic evaluation.

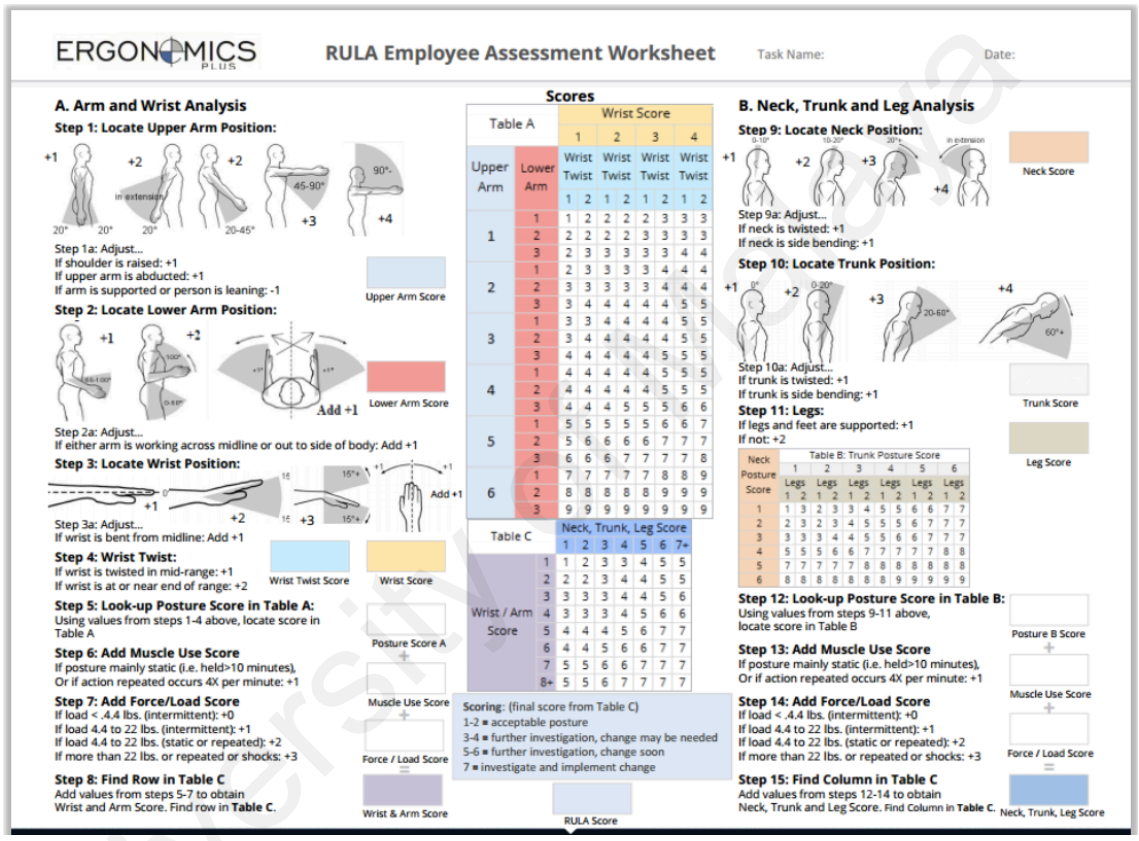

Figure 3-3 Example of RULA Employee Assessment Worksheet

By using the RULA worksheet in Figure 3-3, evaluator has to give score based on the body postures starting with upper arm then follow by the lower arm, wrist, then proceed to neck postures, trunk and lastly the legs.

Lastly for all data which was collected and scored, evaluator need to ensure table in the form are compile and the risk factor variable can be generate via a single score which indicates the MSD level of risk in Table 3-1.

Table 3-1 RULA Level Categorization

RULA Level	RULA Score	Risk Level	Action Required
0	1 - 2	Negligible	Acceptable
1	3 - 4	Low	Investigate Further
2	5 - 6	Medium	Investigate Further & Change Soon
3	7	High	Investigate Further & Change Immediately

Group A is a score for arm and wrist postures. When using this assessment evaluator can choose only the right or left side to be assessed at a time.

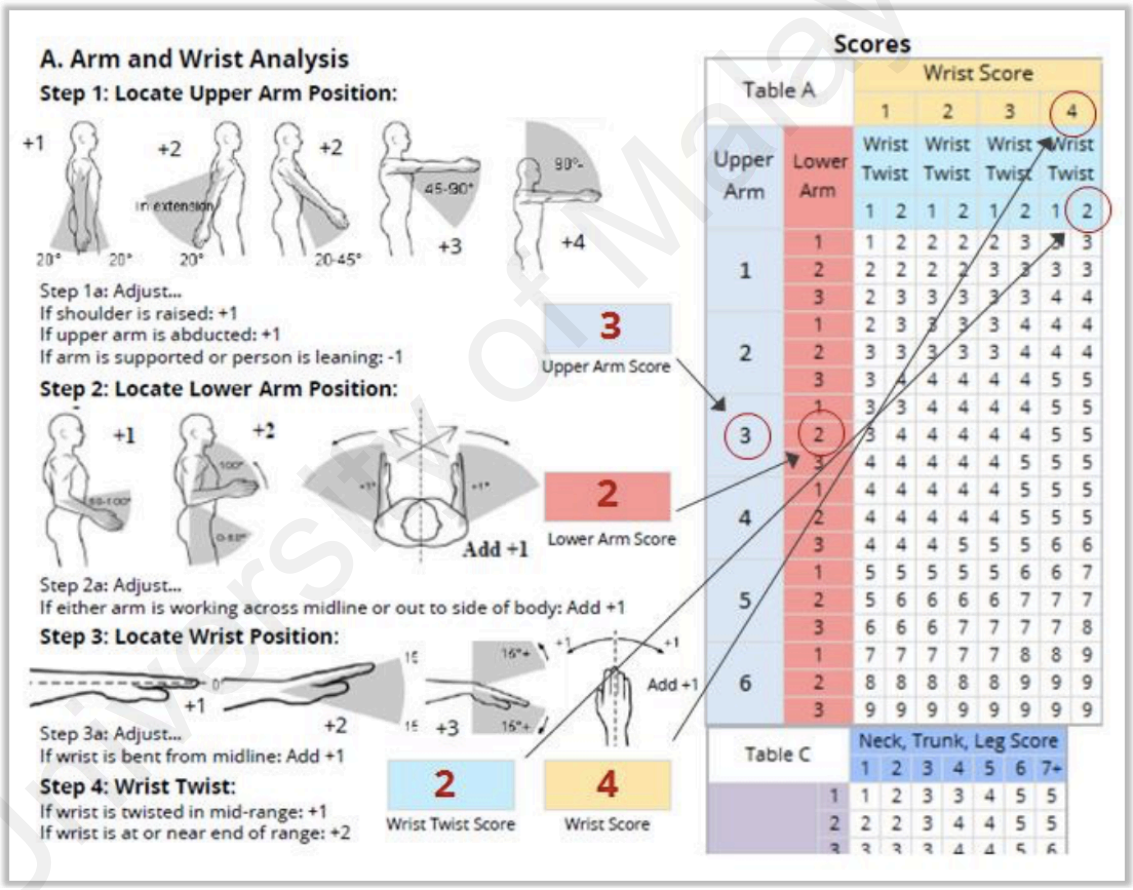

Figure 3-4 Section A – Example of Scoring for Arm and Wrist step 1-4

Refer to Figure 3-4 for the example; step 1 score +3 was given in the Upper Arm Position, which is at the angle of 45º. Then follow by step 2 which locate the lower arm position and the score +2 because the arm position < 60º. In step 3 the wrist flexion > 15º and scoring for this is +3, and +1 score was added for ulnar deviation. In step 4

wrists is twisted near the end range and score is +2. Finally each of the score has to be circle in the Table A.

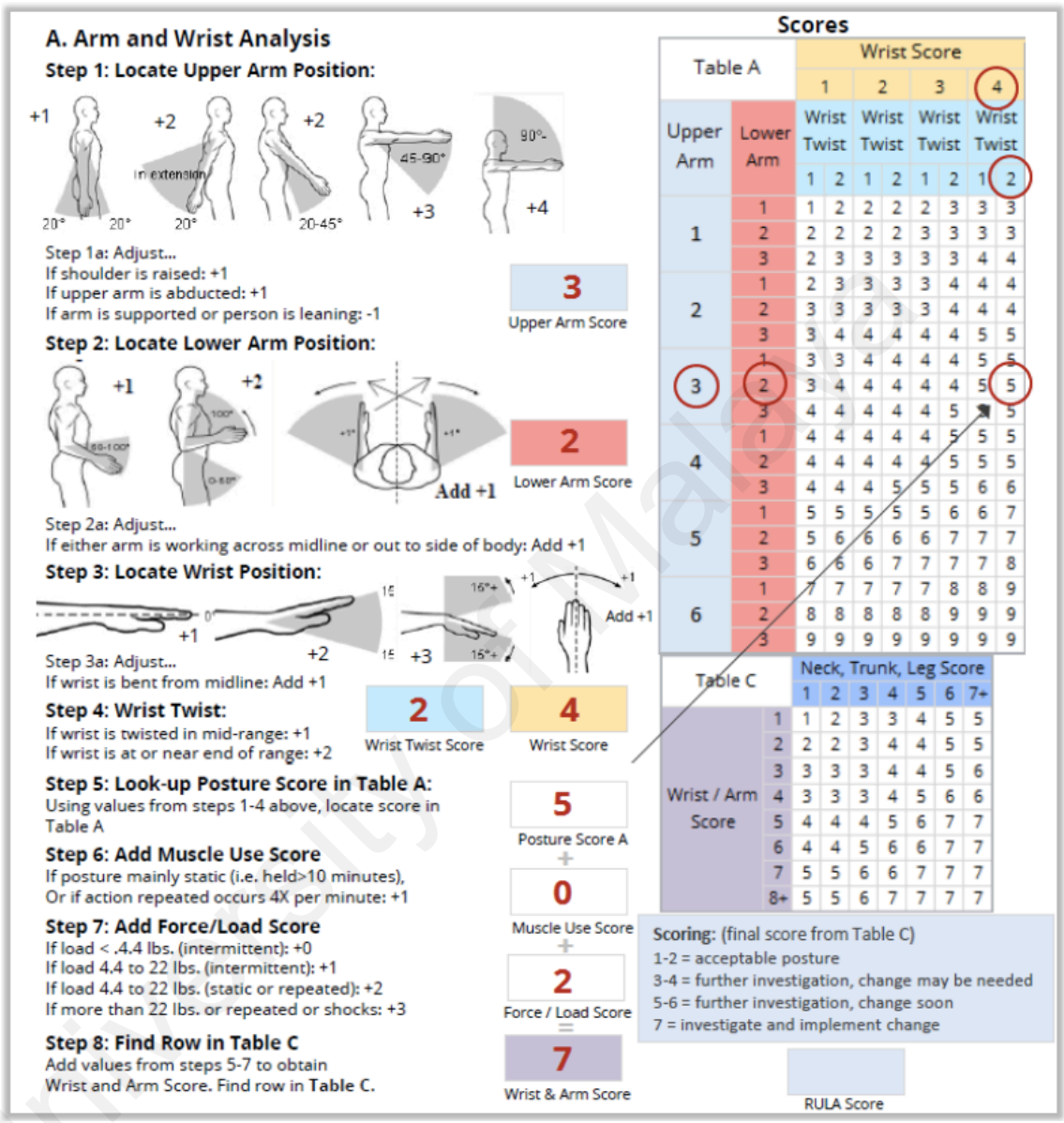

Figure 3-5 Section A – Example of Scoring for Arm and Wrist step 5-8

Next is to verify the score for step 5 refer to Figure 3-5, value from step 1-4 is use to locate the score in this step in Table A. Then step 6 is to add muscle score in this box. In this posture for the example, it is not sustained more than 10 minutes and the movement not repeated more than 4 times in a minutes. Therefore the score is given +0.

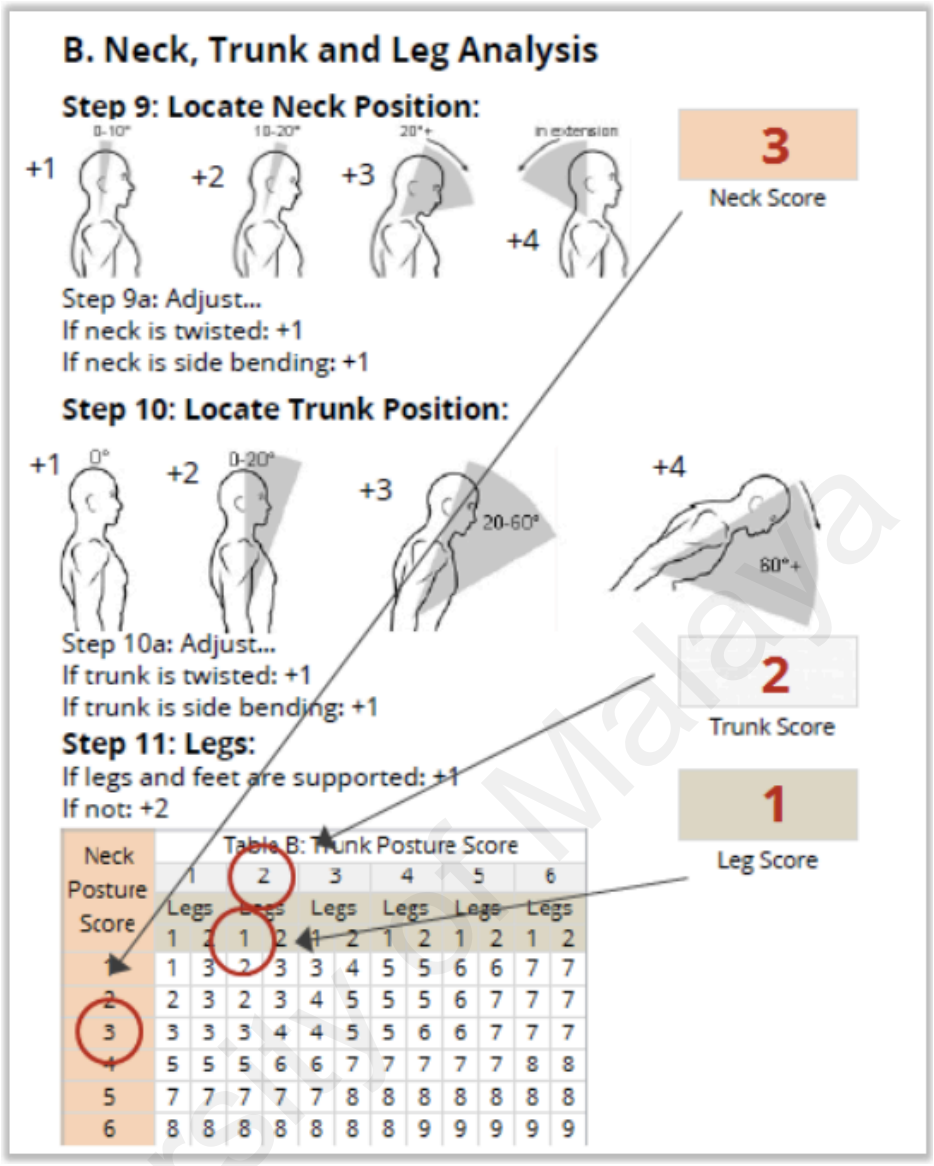

Figure 3-6 Section B – Example of Scoring for Neck, Trunk & Leg step 9-11

After that, this example shows the load weight are more than 4.4lbs and the process repeated. The score +2 is given. Lastly for step 8 is to add all values in step 5, step 6, and step 7 as to get the Wrist and Arm score.

Figure 3-6 shows the Section B process to locate and scoring the position of Neck, Trunk and Legs. Begin with step 9, a score of +3 was given for neck position which is > 20º. Then for the step 10, score +1 due to trunk position in between 0º to 20º. Each of

this score need to be circle on Table B. Step 12 using the values from step 9 to 11 and the score for this step can be refer to Table B in Figure 3-7.

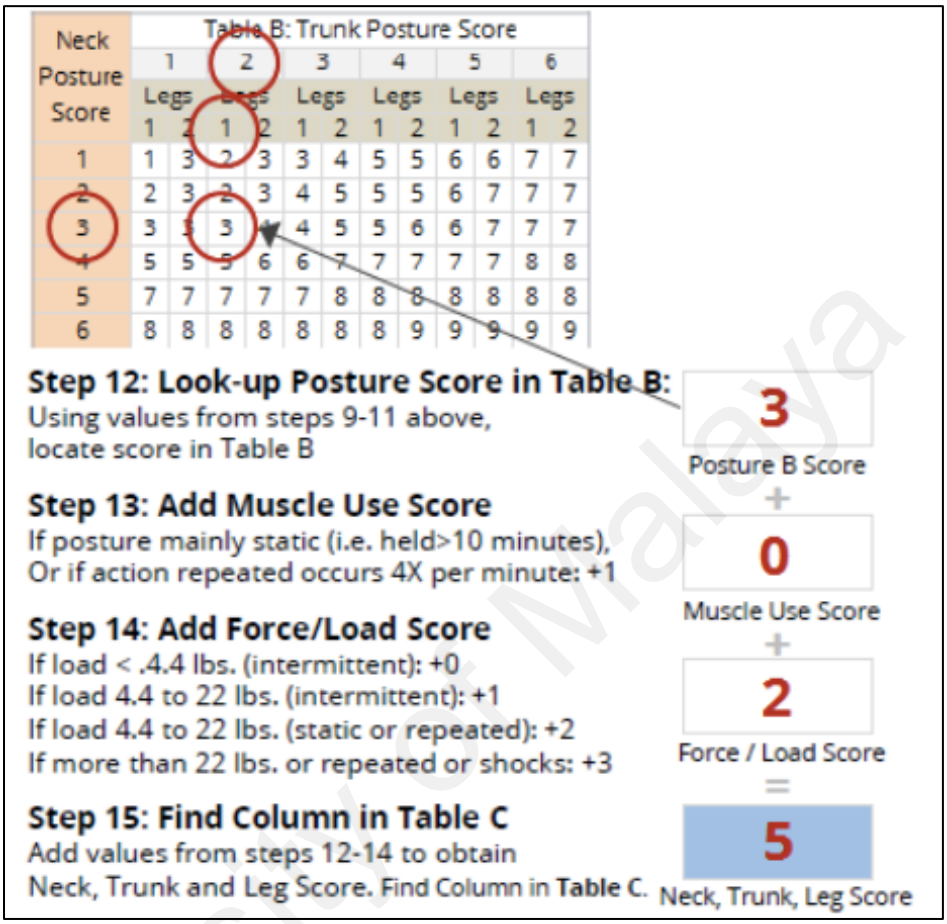

Figure 3-7 Section B - Example of Scoring for Neck, Trunk & Leg step 12-14

In the step 13, the muscle use to be given a score. In this example the posture is not sustained for more than 10 minutes and not repeated more than 4 times in a minute. Therefore the score is +0. Move to step 14 this example shows the load is greater than 4.4lbs and movement are repeated. Therefore the score is +2.

For this example the final RULA score can be determined from Table C as shown in Figure 3-8.

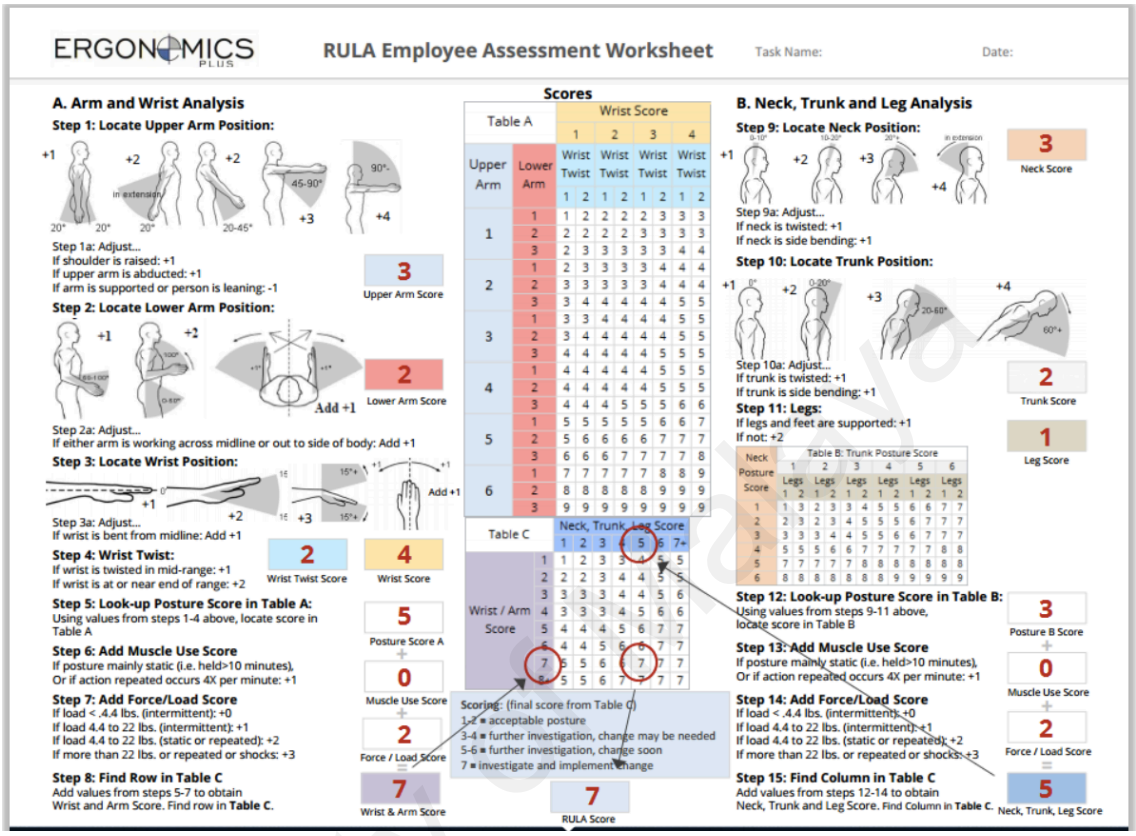

Figure 3-8 Example for Final RULA Score using Table C

3.4 Participants

There are 5 healthy students, males with age 18 and 19 years old. They were selected randomly to be participants or subject matter for involving in this RULA study. All of the students are well trained by their Lecturer during class.

Based on observation the students were found to be in a good health and no MSD history over the past of 24 months. The selected students are from the 1st semester in Diploma of Electronics Engineering. In this research study, those students need to complete their practical assignment from zero wall panels to complete and functional electrical wiring installation of power socket and lamp.

3.5 Description of the Task for Current Studies

During practical of electrical wiring installation, the students are divided to 10 different groups. Each group consists of minimum 3 students working to complete their task in a semester. Their assignment is to complete the electrical installation from zero to functional operation of listed below: -

- Conduit installation
- Trucking installation
- Cable routing for life, neutral and earth to each power socket and switch socket.
- Ceiling lamp socket installation
- Wall lamp socket installation
- Switch socket installation
- Power socket installation
- Distribution Board installation
- Testing

Only certain activities above were select for this RULA studies. For each of this installation, the main job tasks are screwing the socket box to wood panel and the next step is to attach with either switch panel or power outlet panel according to the electrical schematic which has been drawn earlier.

Figure 3-9 The Completed Electrical Wiring Installation awaiting Lecturer verify and testing

Each of these socket box need to be attach with screws. Students are needed to use screwdrivers as their hand tools. Table 3-2 shows the wall wood screw attachment quantities. There are about 62 units of screws need to be tighten to wall wood. Table 3-3 show only 20 screws for socket panel to socket based unit.

Lastly for Table 3-4 about 46 small screws to be tighten together with wiring cable. This is crucial part where cable need to interface with the switching panel or power outlet panel.

Without proper screws tighten the wiring cable might disconnected after the panel been attach to the based box. Based on these total screws quantities we can assume the most of the activities are about manual tools handling of using hand screwdrivers as hand tools.

Table 3-2 Wall Wooden Panel Screw Requirement Quantities

No	Items	Quantity	Screw Quantity	Total Screw
1	Socket box	10	2	20
2	Lamp socket holder	4	2	8
3	Lamp base	4	1	4
4	Trucking	1	8	8
5	Conduit holder	18	1	18
6	Distribution Board	1	4	4

Table 3-3 Switch and Power Socket Screws Quantities

No	Items	Quantity	Screw Quantity	Total Screw
1	Switch panel	6	2	12
2	Power Outlet panel	4	2	8

Table 3-4 Cable to Switch And Power Socket Screws Quantities

No	Items	Quantity	Screw Quantity	Total Screw
1	Lamp socket holder	4	2	8
2	Power Outlet Panel	4	3	12
3	Switch Panel 2 way	4	2	8
4	Switch Panel 3 way	2	3	6
5	Distribution Board	1	12	12

3.6 Outcomes Survey

A survey of the student postural in their practical work was done to find out any MSD's issue due to wrong postures during their manual tools handling. Therefore the techniques of electrical installation by the students were analysed. On top of that the observation and simple question were asked to the students regarding which activities they felt most difficult task. The Borg RPE Scale form is given to the participants and

this is an easy data retrieved. Participant will provide the scale according to the selected activities.

Then the next step is performing video recording from different angles. Each video recording frame was further analysed by using RULA techniques. Body postures such as arm, wrist, neck, trunk and leg analysis have been focus to ensure the photos frame is match with the RULA Assessment Worksheet.

3.6.1 Physical Exertion Assessment Tools: Borg's RPE Scale

The Borg's RPE Scale is considering the easiest part in this research method. There are total of 6 participants that are the students from the courses of DET1022 Electrical Wiring are selected. They were given a form to fill the scale of the selected activities. Borg's RPE Scale is very easy to use. Neither special equipment nor skill is needed to perform the scale rating.

When the student carrying out their activities, they will estimates the level of body perceived exertion and also their feel toward the task given. The activities photos are shown in the Borg's RPE Scale Survey form for better understanding.

Intensity level of the activities is measured during process. The factor such as breathing difficulty, leg swelling and the tough of task is not included. Students only estimate their exertion with concentrating on the feeling. On top of that, they were also asks to be honest in giving the answer in the Borg's RPE Scale Survey form.

Table 3-5 show the Borg RPE Scale. There are 15 scales to be measured from the level of body perceived exertion. The scale ranging from 6 to 20 and the minimum level 6 stand for "lightest activities" or no exertion at all. While the maximum level 20 indicates the "heaviest task" or maximal exertion.

Any physical activity during task given that is like short and slow walk with the walking pace in average of 5 to 10 minutes can be rate as 9. For the rating of 12 to 13 where the student can still think in the "OK" to carry on.

Table 3-5 The Borg's RPE Scale of the Body Perceived Exertion

Borg RPE Rating	Intensity
6	Lightest
7	Extremely light
8	Very Light
9	Very Light
10	Light
11	Light
12	Somewhat Heavy
13	Somewhat Heavy
14	Heavy
15	Heavy
16	Very Heavy
17	Very Heavy
18	Extremely Heavy
19	Extremely Heavy
20	Heaviest

In the rating of 16 to 17 is more to very tiring and tough enough for the student to perform their task. At this point student should feel "Very Heavy" upon performing the task and quickly become tired. They need to push themselves to continue the activities.

Begin with rating of 18 and 19 this is "Extremely Heavy" activity. Performing task at this level is the most exhausted comparing to all activities. Lastly for the rating of 20 is the maximal point whereas the student cannot performing the task because of the heaviest task among the others.

3.7 Summary

The research was found to involve few processes starting with data collection of participating student such as demographic data of anthropometric and ended with the new working procedure requirement during the task. This changes applicable to all students in each of the workstation. The student themselves have to assessed their Borg's RPE Scaling. Follow by RULA assessment to selected body postural activities is focused on student working in electrical wiring workstation. For the students anthropometric data are refers to means ± standard deviation. Referring to RULA's scoring result of assessment the corrective action must promptly attend and necessary changes has to be taken when high score result obtain.

CHAPTER 4:

RESULT AND DISCUSSION

4.1 The Electrical Wiring Workstation

Figure 4-1 presents the workstation dimensions with 195cm in length, 140cm in width and 195cm height. That means the space is about 5.3235 m^3. There is only one open space for the student to enter and exit. The duration for each group to perform their task will take at least 3 hours. It was found that the only air ventilation is from the open wall that also their entering door.

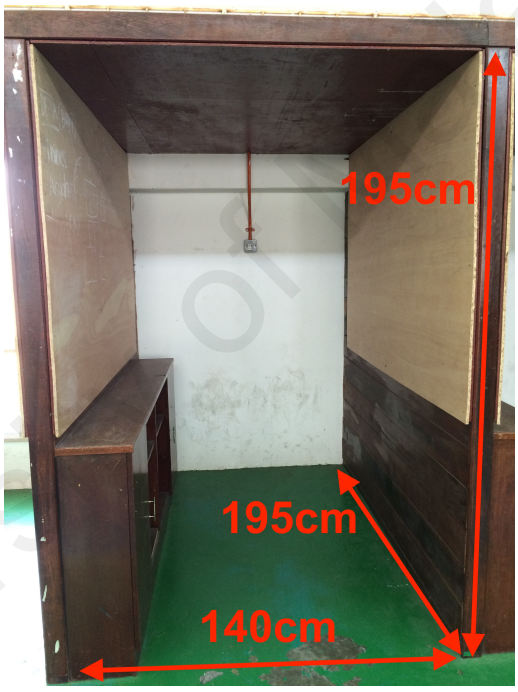

Figure 4-1 Standard workstation dimensions

Without any ventilation fan at the workstation, students claim the hot environment in the workstation. The environment of the lab itself which is no ceiling fan or stand fan provide when they performing their task is hot. The morning session class of the wiring will start at 9am and finish at 12pm and for afternoon session the class will begin at 2pm and finish at 5pm.

Between 10.30am to 3.30pm, the lab environment will be hot. The rooftops of the lab build up from zinc metal. It was found that the rooftop is without any heat insulation. Direct sun light will heat up to the zinc rooftop and this will lead the lab temperature to be hot during the mentioned hours.

When the students work inside the workstation, the hot temperature environment leads them to discomfort condition. It is observe that there is no air circulation inside the workstation.

4.2 Participant Background Information and Anthropometric Data

There are 5 male students sample out from group of 27 students. The data taken to be demographic such as the mean and standard deviation of the participant's age, weight, height, and experience are tabulated in Table 4-1.

Table 4-1 Participants Data by Age, Weight, Height and Experience

No	Participant	Age	Weight	Height	Experience
1	Student 1	18	70	165	2
2	Student 2	19	73	175	0
3	Student 3	18	65	167	0
4	Student 4	18	68	169	2
5	Student 5	18	71	171	0
Total		91	347	847	4
Mean		18.2	69.4	169.4	0.8
Std Deviation		0.40	2.73	3.44	0.98

The average age of the participants is 18.2±0.4 years, while the average weight is 69.4±2.73kg. From the total 5 students participate in this study, 2 of them have an experience at technique or vocational school. As a consequence the average experience 0.8±0.98 years. These conclude their average experience is less than 1-year in electrical wiring task. All the participant are right hand dominant and none of them were reported injuries of musculoskeletal disorder that might effect the practical task.

Table 4-2 Participants Anthropometric Data in Centimetres (cm)

Student	Student 1	Student 2	Student 3	Student 4	Student 5	Mean	Std Deviation
Stature	165	175	167	169	171	169.40	3.44
Eye heigth, standing	153	165	155	157	160	158.00	4.20
Shoulder height, standing	136	143	138	140	139	139.20	2.32
Elbow-height, standing	102	109	102	104	107	104.80	2.79
Span	170	179	171	173	175	173.60	3.20
Forearm length	29	34	30	31	32	31.20	1.72

The most important data in this study are the anthropometric data of the students involved in each of activity. The student's anthropometric data are shown in Table 4-2. The anthropometric data are mainly observed on standing of the participants. Follow by the anthropometric data of participants hand span and also the forearm measurement. All data were taken in the unit of centimetres.

Begin with the stature or height of the participants; the average height of the student is 169.40±3.44cm. Following with the eye height during standing with an average of 158.00±4.20cm. Next is the shoulder height with means of 139.20±2.32cm.

Elbow height during standing give the average of 104.80±2.79cm. While the hand span give the values of 173.60±3.20cm. For the last anthropometry data are the forearm length average that is 31.20±1.72cm.

4.3 Result of Borg RPE Scale

Survey form of Borg RPE Scale were distribute among the participants. They were asked about their task and compile as Activity 1 to Activity 6. Participant to fill in the scale of body perceived exertion for each of activities. Table 4-3 define the activities numbering to the actual task and Table 4-4 represent the Borg RPE Scale result fill in by participants in this studies.

Table 4-3 Activities Numbering and Task

Activity Number	Task
Act 1	Screwing and tigthening the electrical cable to wall lamp module
Act 2	Screwing and tigthening the electrical cable to ceiling lamp module
Act 3	Screwing and tigthening the electrical cable to lower power outlet
Act 4	Manual screwing the socket box to wood wall
Act 5	Screwing to enclosed the power outlet (lowest line)
Act 6	Screwing to enclosed the power outlet (middle line)

Table 4-4 Borg RPE Scale Result fill in by Participants

No	Participant	Act 1	Act 2	Act 3	Act 4	Act 5	Act 6
1	Student 1	16	17	14	15	12	11
2	Student 2	14	14	14	16	12	11
3	Student 3	17	18	12	16	13	10
4	Student 4	16	16	13	15	10	9
5	Student 5	14	14	12	17	12	11
Total		77	79	65	79	59	52
Mean		15.4	15.8	13.0	15.8	11.8	10.4
Std Deviation		1.3	1.8	1.0	0.8	1.1	0.9

Comparing with the Table 4-2 and Table 4-4, student with height above 175cm will not facing any issue with the task given relate to ceiling lamp installation. Referring to Table 4-4, Activity 6 shows the lowest mean 10.4±0.9, the scale confirm that at the middle line of the installation will not occurs any MSD injuries. Activity 1, Activity 2 and Activity 3 show the Borg RPE Scale more than 15. The highest scale is Activity 2

with mean result of 15.8±1.8, at this point student is required to attach the based socket to ceiling workstation follow by screwing and tightening electrical cable.

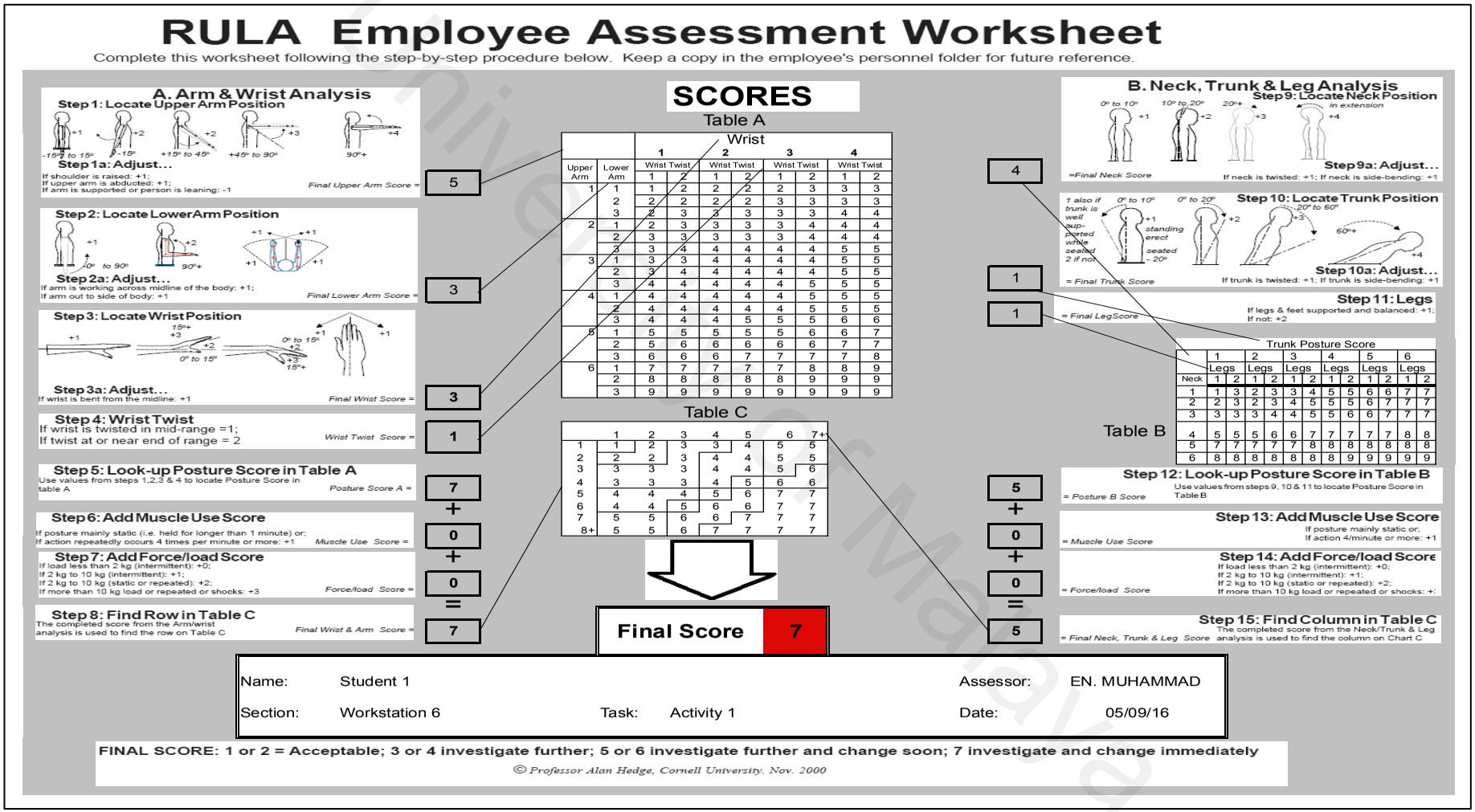

Figure 4-2 RULA Employee Assessment Worksheet for Activity 1

4.4 RULA Postural Score of Each Activity

Referring to activities list in Table-4.3, RULA scores are obtain for each of this activity respectively.

4.4.1 RULA Postural Score for Activity 1

Figures 4-2 present the RULA Employee Worksheet for Activity 1 that evaluate from Figure 4-3 of the actual Activity 1. The student mounts the electrical wiring cable from the based wall unit to the wall lamp socket module. Anthropometric data from Table 4-2 show that student height is 165cm and the wall units locate at the height of 180cm from the workstation floor.

Figure 4-3 Activity 1 – Wall Lamp Module Installation

At this level, student must raised their shoulder and his upper arm position will be at 90° above his shoulder. Section A to be completed first. RULA Step 1 is to *Locate Upper Arm Position*. Based on the Figure 4-2 the score is given at +4. An additional

step 1a is required, because the shoulder is raised up and the scores to be added with +1 more point. As a result the final score for step 1 is +5.

Then *Locate Lower Arm Position,* we can see that the lower arm is raised up above 100° and the arm is crossing the middle line. Therefore the Lower Arm Score at this step 2 is +2 and step 2a is +1. So the final score for Lower arm is +3.

For the step 3 in this assessment is to *Locate Wrist Position*, based on Figure 4-2 the wrist is between angle of 15° given the score +2 and for score in step 3a is +0. Therefore the final score for this remain at +2. Step 4 is to define the score for *Wrist Twist.* It was found that the wrist is twisted in the mid range. This gives the score +1 only.

Step 5 is referring to Table A and *Look-up Posture Score* RULA Employee Assessment Worksheet using all values from step 1 to 4 above and the posture score A is +7. Follow by Step 6 to give a score on *Muscle Use* and the student posture not mainly static less than 10 minutes and the action not repeated less than 4 times in a minute. The score result for Muscle Use is +0. In step 7 the student on hold a test pen screwdrivers to tighten the screw that holding the power cable. The weight of the test pen screwdrivers and socket module is less than 4.4lbs or 1.99kg. This will indicate the score for *Force/Load* at +0.

Last step for part A is step 8, at this point all score from Step 5, step 6 and step 7 to be total up. As a result the new score is +7 and this can be concluded as *Wrist and Arm Score*. With this value find the row of Wrist/Arm Score in Table C of the RULA Employee Assessment worksheet.

Section B used to define the score for Neck, Trunk and Leg Analysis. Begin with Step 9 to *Locate the Neck Position*. From the Figure 4-2 student's neck is in the

extension side which need him to look the at the module assembly at the above of his head. This will give the score of +4. Step 9a not to be considered because the neck is not in twisted or side bend.

Step 10 to *Locate Trunk Position*, at this point student's trunk in straight up position at 0°. Score for this step is +1. For step 10a the trunk is not twisted or side bend so there is no score. In addition Step 11 is to see the Legs and feet either supported or not. It is observed that both students' legs are supported at the working platform. The score is +1.

Together with Step 12 is to look up the Posture Score in table B. Using the value obtain from step 9, step 10 and step 11 above, the score locate from table B is +5. Then Step 13 is to Add Muscle Use score, the posture mainly static less than 10 minutes and no action found repeated occurs more than 4 times in a minutes. Therefore the score remain +0. In step 14 is to *Add Force or Load Score* if any. Load hold less than 4.4lbs and intermittent in this posture as a result the score is +0.

Step 15 is adding up all values from step 12, step 13 and step 14 with total score of +5. After getting this values to matched the column in table C.

Finally is to determine *Final RULA Score* by using the Table C in Figure 4-3. From the Wrist/Arm Score Column score +7 to be matched with Neck, Trunk, and Leg Row score of +5. From this matched point the Final RULA Score of +7 indicates high risk and calls for engineering and/or work method changes to reduce or eliminate MSD risk.

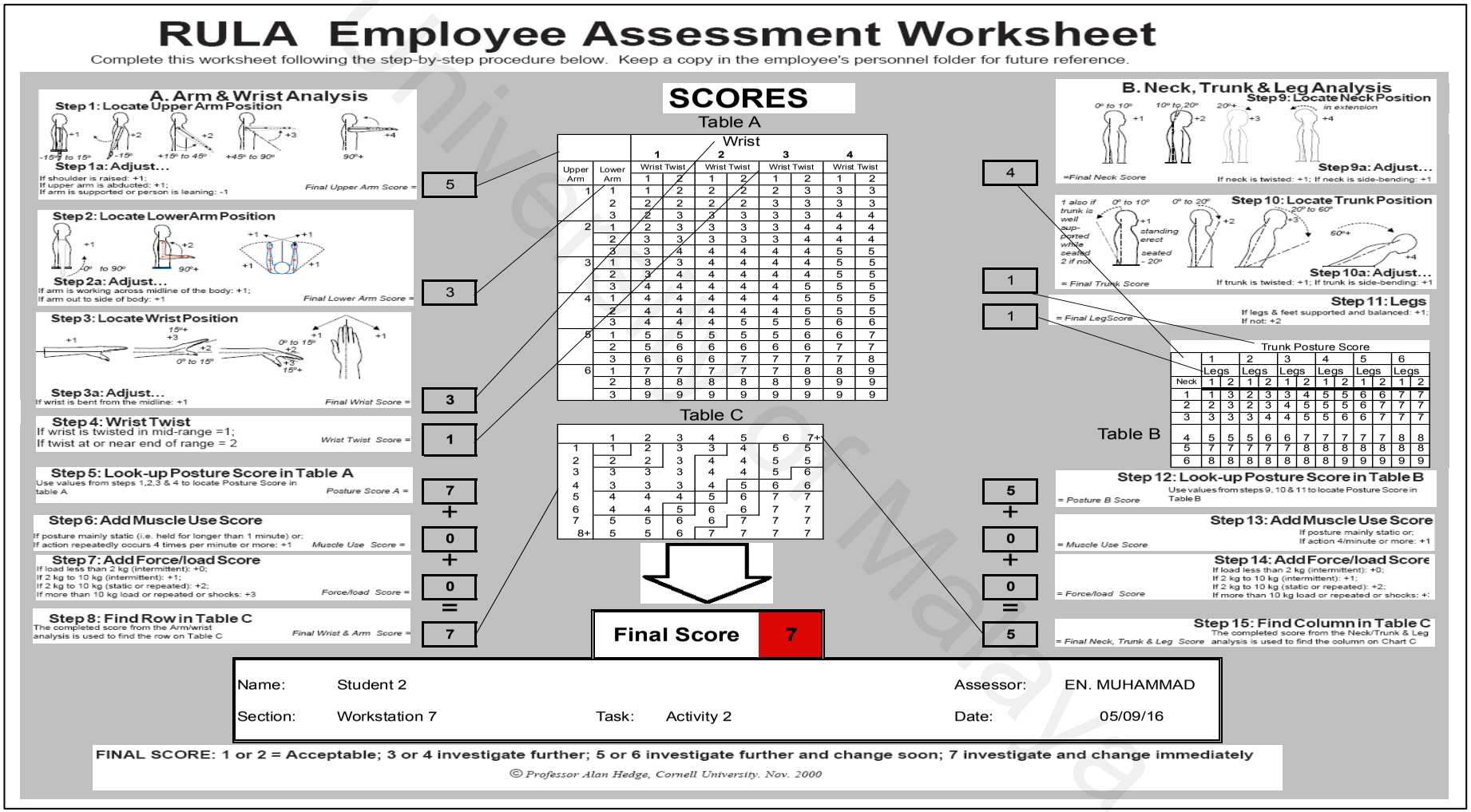

Figure 4-4 RULA Employee Assessment Worksheet for Activity 2

4.4.2 RULA Postural Score for Activity 2

Activity 2 required student to perform task of mounting the ceiling lamp module. Activity includes tighten the electrical cable to lamp module and finish with closing the lamp module to based unit attach at the ceiling. Figure 4-4 shows the ceiling lamp module installation.

Figure 4-5 Activity 2 - Ceiling Lamp Module Installation

In this activity student must raised their shoulder and his upper arm position 90° above his shoulder. Section A in RULA step 1 is to *Locate Upper Arm Position*. Based on the Figure 4-4 the score is given +4. An additional step 1a is required, because the shoulder is raised up and the scores to be added with +1 more point. As a result the final score for step 1 is +5.

Then to *Locate Lower Arm Position* and we can see that the lower arm is raised up above 100° and the arm is crossing the middle line. Therefore the Lower Arm Score at this step 2 is +2 and step 2a is +1. So the final score for Lower arm is +3.

For the step 3 in this assessment is to *Locate Wrist Position*, based on Figure 4-4 the wrist is over the angle of 15° given the score +3 and for score in step 3a is +0 be. Therefore the final score for this is +3.

Step 4 is to define the score for *Wrist Twist.* It was found that the wrist is twisted in the mid range. This gives the score +1.

Step 5 is referring to Table A in Figure 4-3 and *Look-up Posture Score* RULA Employee Assessment Worksheet using all values from step 1 to 4 above and the posture score A is +7.

Step 6 to give a score on *Muscle Use* and the student posture is mainly static less than 10 minutes and the action not repeated less than 4 times in a minute. The score result for Muscle Use is +0.

In step 7 the student on hold a test pen screwdrivers to tighten the screw that holding the power cable at the ceiling lamp module. The weight of the test pen screwdrivers and socket module is less than 4.4lbs or 1.99kg. This will indicate the score for *Force/Load* at +0.

Step 8 is the last for part A, at this point all score from Step 5, step 6 and step 7 to be total up. As a result the new score is +7 for *Wrist and Arm Score*. With this value find the row of Wrist/Arm Score in Table C of the RULA Employee Assessment worksheet in Figure 4-5.

The Neck, Trunk and Leg Analysis score are in Section. Begin with Step 9 to *Locate the Neck Position*. From the Figure 4-4 student's neck is in the extension mode which need him to look the at the module assembly at the ceiling. The score should be at +4.

Step 9a not to be considered because the neck is not in twisted or side bend. So the score for step 9a is +0.

Step 10 to *Locate Trunk Position*, at this point student's trunk in the standing straight up position of the angle 0°. The score +1 is given. For step 10a the trunk is not twisted or side bend so there is no score.

Step 11 is to see the Legs and feet either supported or not. It is observed that both students' legs are supported at the working platform. The score is +1.

Step 12 is to look up the Posture Score in table B. Using the value obtain from step 9, step 10 and step 11 above, the score locate from table B is +5.

Step 13 is to Add Muscle Use score, the posture mainly static less than 10 minutes and no action found repeated occurs more than 4 times in a minutes. Therefore the score remain +0.

In step 14 is to *Add Force or Load Score* if any. Students only hold the hand screwdrivers with weight of load less than 4.4lbs. He is intermittent position in this posture so the score is +0.

Step 15 is adding up all values from step 12, step 13 and step 14 with total score of +5. Values to be matched at the column in table C.

Finally is to determine *Final RULA Score* by using the Table C in Figure 4-4. From the Wrist/Arm Score Column score +7 to be matched with Neck, Trunk, and Leg Row score of +5. From the results the Final RULA Score of +7 indicates high risk and calls for engineering and/or work method changes to reduce or eliminate MSD risk.

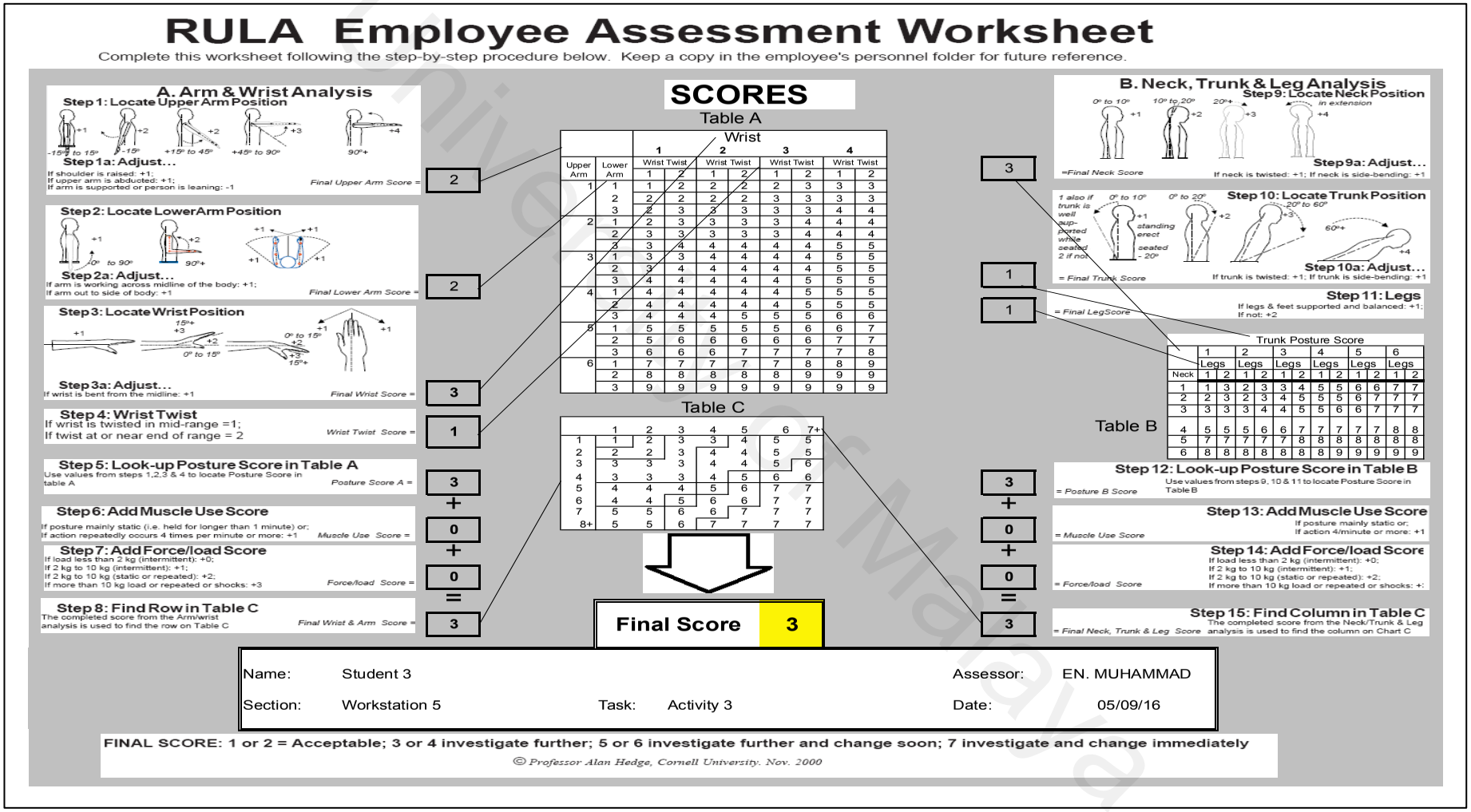

Figure 4-6 RULA Employee Assessment Worksheet for Activity 3

4.4.3 RULA Postural Score for Activity 3

During activity 3 students are required to use the test pen as a hand tools to tighten the electrical cables to the switching socket. The process needs 5 switching socket modules to be install and set up. For each of the process there are 3 screws to be tightened with the cables. After tighten the cables, all switching socket need to closed the based unit with 2 long screws. Figure 4-6 shows RULA result in worksheet and Figure 4-7 is the installation of switch socket.

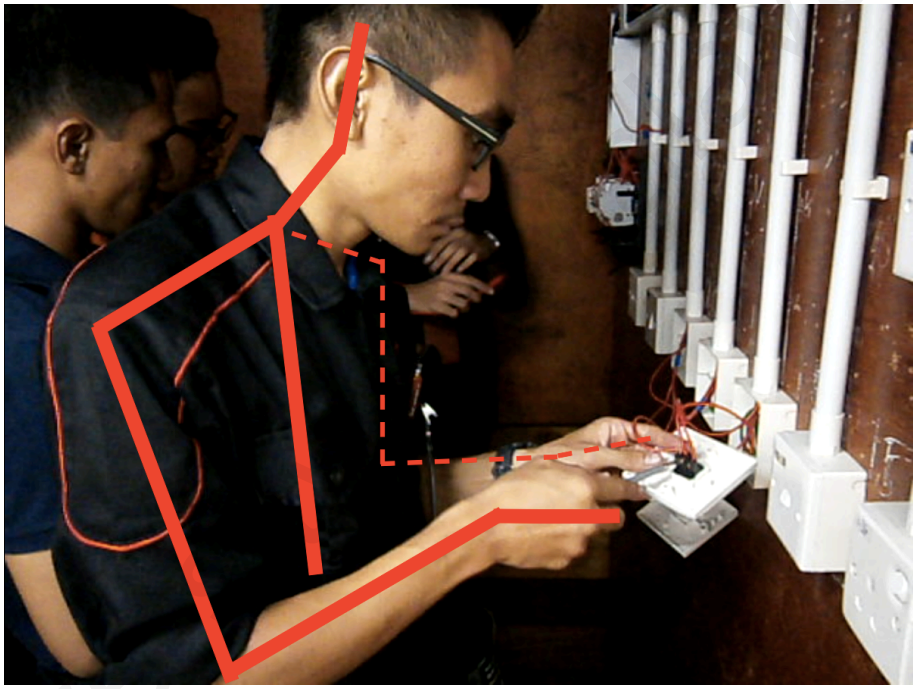

Figure 4-7 Activity 3 - Switch Socket Installation

This activity was conducted at workstation 5. Begin with Section A of Arm and Wrist Analysis. The first RULA step is to give score of the Upper Arm Position. The arm position is between 20° to 45°. There is no adjustment in this upper arm position because the shoulder is not raised up and upper should also is not abducted. The arm also not supported with any hand rest or the body also not leaning on any wall. The best score for this step 1 is +2.

In second step, lower arm position to be locate. The lower arm angle is more than 100° and the suitable score for this is +2. The lower arm is not across midline during the activity, so the score for step 2a is +0.

For the wrist position was found to be in the angle of -15° to 15° give the score for step 3 is +2. Moreover the wrist sometimes is bend from midline and additional +1 score is given in step 3a. The total score for this step is +3. However Step 4 show the Wrist Twist score give the value +1 because the wrist was in twisted in mid range.

Looking up to the Score Posture Table A in Figure 4-7 for the step 1, step 2, step3 and step 4 will give the Posture Score +3. Also Step 6 is adding any muscle use will indicates score +0 because the student remain static but less than 10 minutes and the action not repeated more than 4 times in a minutes. Together with Step 7 also gives the score +0 because the load weight is less than 4.4lbs (less than 1.99kg).

Lastly in step 8, all the values from step 5, step 6 and step 7 to be total up and then the Wrist And Arm Score obtained from the row in Table C in Figure 4-7. As a result the Final Score for Wrist and Arm are +3.

Moving toward to the next section is to analyse the Neck, Trunk and Leg. At this step 9 the neck position is bend down 20° angle. The neck is not twisted nor side bending. Therefore the score for this step is +3. Following next Step 10 show the trunk posture in a straight up position which is 0° angle. As a result the adjustment scores is +0 because neither trunk is twisted nor side bending. The score to be given is +1.

During this activity both of the student legs a well supported to the working platform. The step 11 for legs score is +1. It is observed the next Step 12 is to look up the Posture Score in table B in Figure 4-7. Using the value obtain from step 9, step 10 and step 11 above, the score locate from table B is +3.

In addition the Step 13 is to Add Muscle Use score, the posture mainly static less than 10 minutes and no action found repeated occurs more than 4 times in a minutes. Therefore the score remain +0.

In step 14 is to *Add Force or Load Score* if any. Students only hold the hand screwdrivers with weight of load less than 4.4lbs. He is intermittent position in this posture so the score is +0.

Later the Step 15 is adding up all values from step 12, step 13 and step 14 with total score of +3. Values to be matched at the column in table C.

Finally is to determine *Final RULA Score* by using the Table C in Figure 4-6. As a result the RULA score is +3 for this Activity 3 and only further investigation and change may be needed.

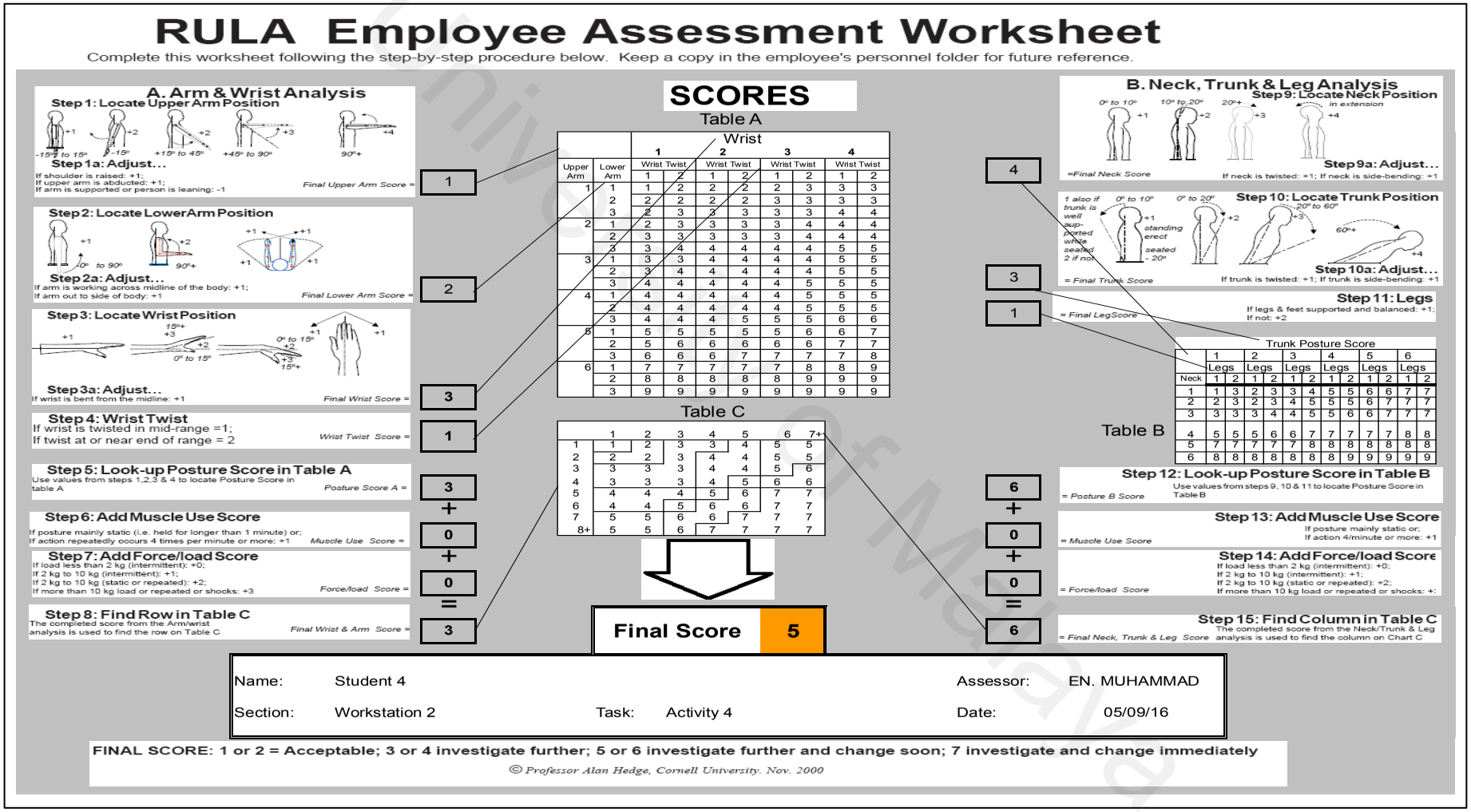

Figure 4-8 RULA Employee Assessment Worksheet for Activity 4

4.4.4 RULA Postural Score for Activity 4

Activity 4 required the student to attach the based socket box to the wood wall. This activity required the student to screw the based box. Figure 4-8 shows the actual socket box based unit attached with 2 screws to the wood wall panel.

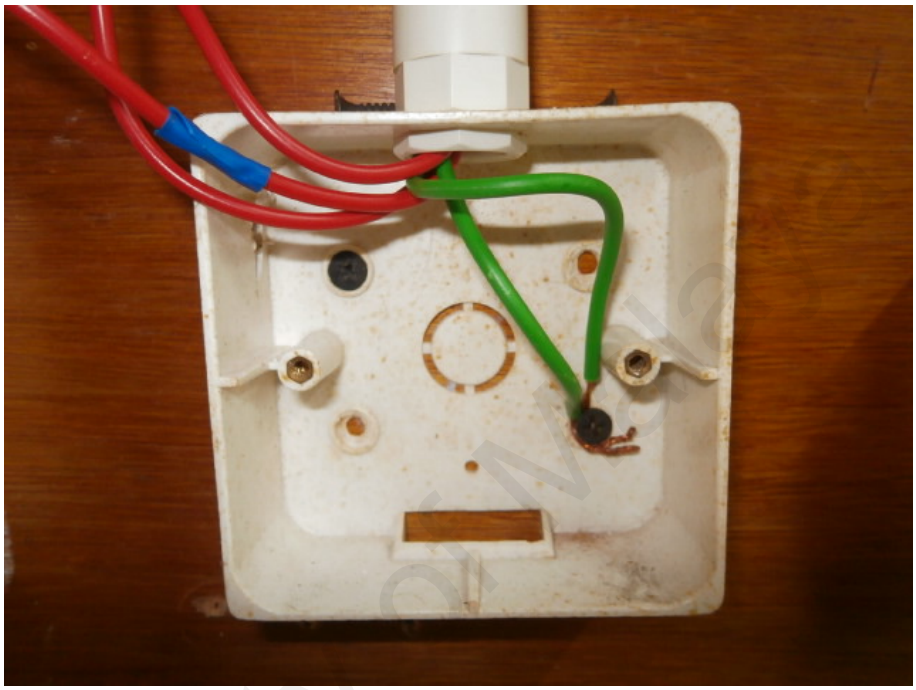

Figure 4-9 Socket Box attach to Wood Wall Panel

Referring to Figure 4-9 the activity was conducted at workstation 2. Begin with Section A of Arm and Wrist Analysis. The first RULA step is to give score of the Upper Arm Position. The upper arm position is at 0°. There is no adjustment in this upper arm position because the shoulder is not raised up and upper should also is not abducted. The arm also not supported with any hand rest or the body also not leaning on any wall. The best score for this step 1 is +1.

In second step, lower arm position to be locate. The lower arm angle is more than 100° and the suitable score for this is +2. The lower arm is not across midline during the activity, so the score for step 2a is +0.

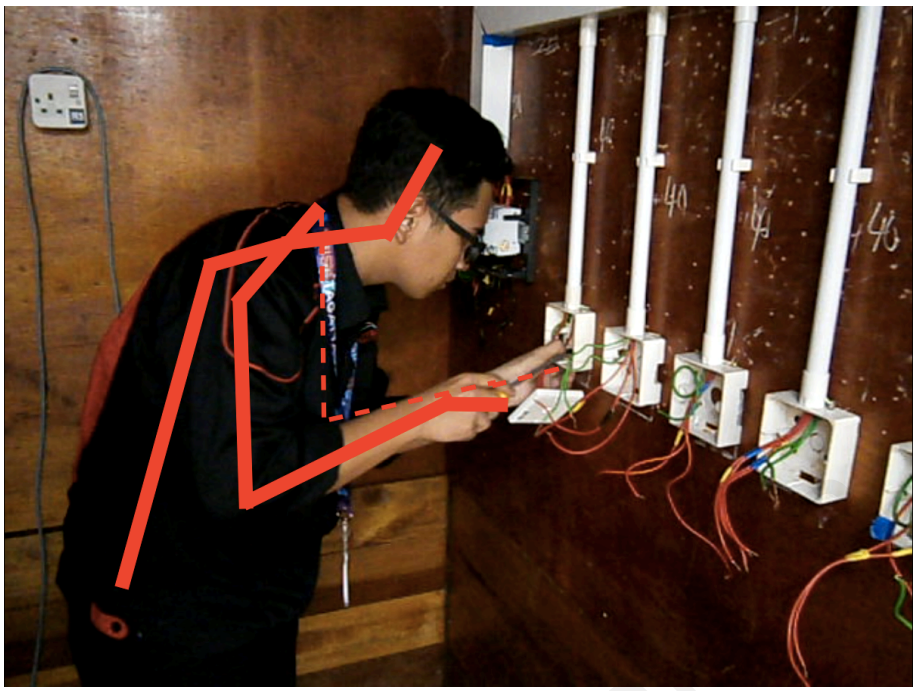

Figure 4-10 Activity 4 - Student tighten the screw of Socket Box to wood wall panel

For the wrist position was found to be in the angle of -15° to 15° give the score for step 3 is +2. Moreover the wrist sometimes is bend from midline and additional +1 score is given in step 3a. The total score for this step is +3.

Move forward to Step 4 in Wrist Twist score give the value +1 because the wrist was in twisted in mid range. Looking up to the Score Posture Table A in Figure 4-10 for the step 1, step 2, step3 and step 4 will give the Posture Score +3.

In addition Step 6 for adding any muscle use will indicates score +0 because the student remain static but less than 10 minutes and the action not repeated more than 4 times in a minutes.

Next is Step 7 also gives the score +0 because the load weight is less than 4.4lbs (less than 1.99kg).

Lastly in step 8, all the values from step 5, step 6 and step 7 to be total up and then the Wrist And Arm Score obtained from the row in Table C of Figure 4-10. As a result the Final Score for Wrist and Arm are +3.

Moving toward to the next section is to analyse the Neck, Trunk and Leg. At this step 9 the neck position is in extension mode but neither twisted nor side bending. Therefore the score for this step is +4.

It seems to be in Step 10 show the trunk posture between 20° to 60° angle. For adjustment scores is +0 because neither trunk is twisted nor side bending. Therefore the total score for this step 10 is +3. Student legs are well supported to the working platform. The step 11 for legs score is +1.

In other hand, the Step 12 is to look up the Posture Score in Table B of Figure 4-10. Using the value obtain from step 9, step 10 and step 11 above, the score locate from Table B is +6.

Step 13 is to Add Muscle Use score, the posture mainly static less than 10 minutes and no action found repeated occurs more than 4 times in a minutes. Therefore the score remain +0. In step 14 is to *Add Force or Load Score* if any. Students only hold the hand screwdrivers with weight of load less than 4.4lbs. He is intermittent position in this posture so the score is +0. Step 15 is adding up all values from step 12, step 13 and step 14 with total score of +6. Values to be matched at the column in table C. Finally is to determine *Final RULA Score* by using the Table C in Figure 4-8. As a result the RULA score is +5 for this Activity 4 and need further investigation and change soon.

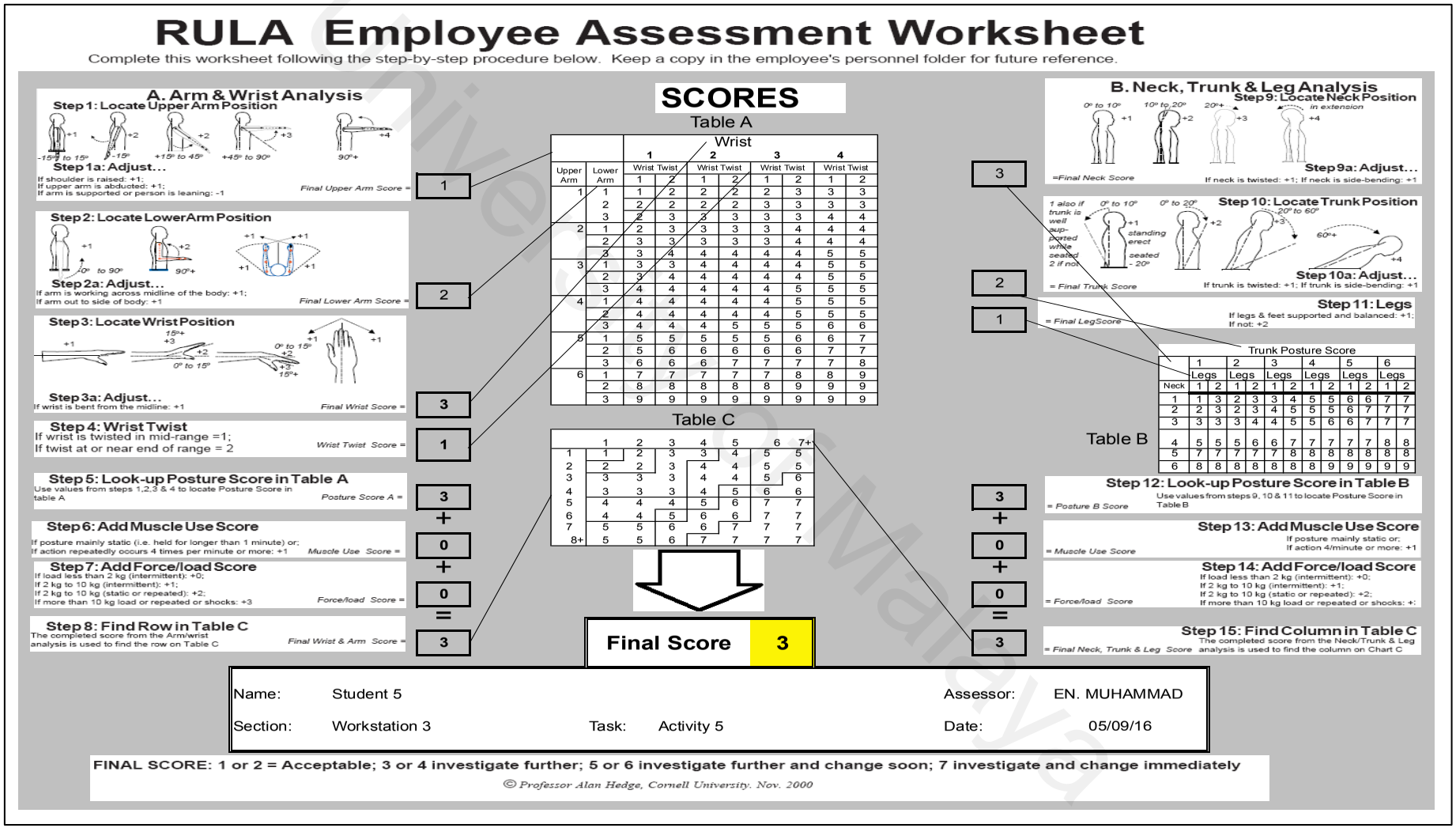

Figure 4-11 RULA Employee Assessment Worksheet for Activity 5

4.4.5 RULA Postural Score for Activity 5

Moving toward workstation 3, the student in the process of attaching the power socket modules. The power sockets locate at the same level of previous switching installation in activity 3 and activity 4. The task required student to attach the electrical cable to the power socket and then complete the installation by closing the based box with this power socket modules. Figure 4-12 show the power socket modules attach to base box and Figure 4-13 show that Activity 5 in progress of the power socket installation.

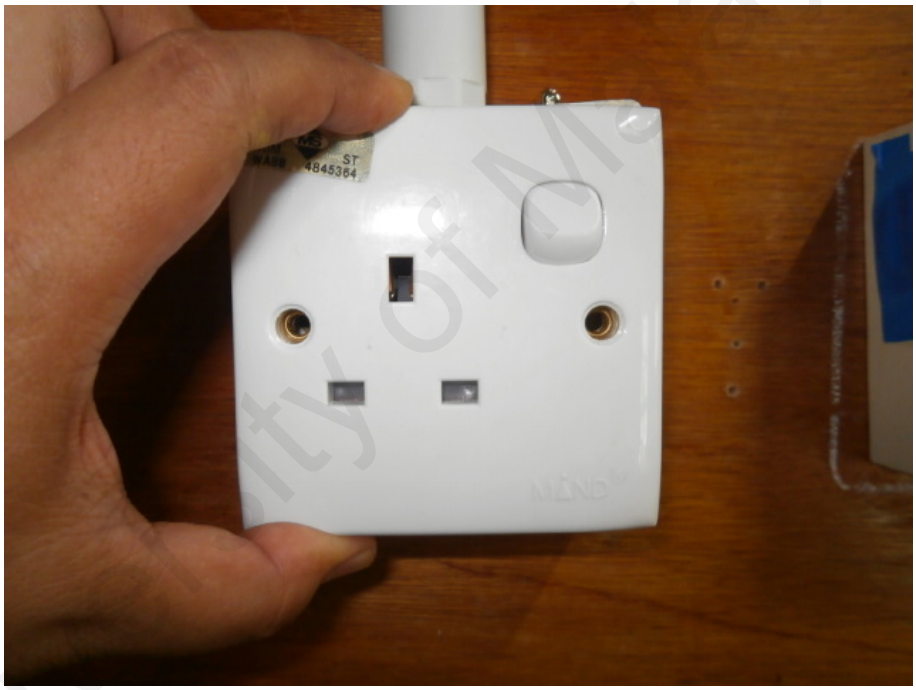

Figure 4-12 Power socket module ready for final closure and screwing

Referring to Figure 4-11 RULA Employee Assessment Worksheet for Activity 5, the Arm and Wrist Analysis in Section A to be analyse first. As usual Step 1 is to locate the upper arm position and we can see that the angle of the upper arm is between 20° to -20° in standing position. The student body in this standing position is 0° reference line. The score for this position is +1. The shoulder not raise up and the upper arm are not abducted. Student arm also not supported to any armrest. This gives the score for Step

1a +0. Next is to locate the lower arm position. From the Figure 4-13 we can see that the lower arm position at above 100° angle. Neither left nor right arm is working across the midline. The arm also not out to any side of the body. So Step 2 for Lower Arm total score is +2. For the wrist position in Step 3 it was bend over 15° angle and wrist not bent from midline. The score at this step is +3. Wrist Twist score in Step 4 give the value +1 because the wrist was in twisted in mid range.

Figure 4-13 Activity 5 - Student attaching the power socket module to the based box (lower level of the overall work task)

Referring to the Score Posture Table A in Figure 4-11 for the step 1, step 2, step3 and step 4 will give the Posture Score +3. In Step 6 for adding any muscle use will indicates score +0 because the student remain static but less than 10 minutes and the action not repeated more than 4 times in a minutes. Step 7 also gives the score +0 because the load weight is less than 4.4lbs (less than 1.99kg).

Lastly in step 8, all the values from step 5, step 6 and step 7 to be total up and then the Wrist And Arm Score obtained from the row in Table C in Figure 4-13. As a result the Final Score for Wrist and Arm are +3.

The next section is to analyse the Neck, Trunk and Leg. At this step 9 the neck position is bend down 20° angle. The neck is not twisted nor side bending. Therefore the score for this step is +3.

In Step 10 is to locate the Trunk Position. It shows that the body in straight up standing position and this give the score +1. The adjustment for the score in step 10a is given +1 because the trunk is side bend but not twisted. Overall score for Trunk Position is +2. Step 11 is to see the Legs and feet either supported or not. It is observed that both students' legs are supported at the working platform. The score is +1.

Step 12 is to look up the Posture Score in table B. Using the value obtain from step 9, step 10 and step 11 above, the score locate from table B is +3. Step 13 is to Add Muscle Use score, the posture mainly static less than 10 minutes and no action found repeated occurs more than 4 times in a minutes. Therefore the score remain +0.

In step 14 is to *Add Force or Load Score* if any. Students only hold the hand screwdrivers with weight of load less than 4.4lbs. He is intermittent position in this posture so the score is +0. Step 15 is adding up all values from step 12, step 13 and step 14 with total score of +3. Values to be matched at the column in Table C in Figure 4-11.

Finally is to determine *Final RULA Score* by using the Table C. As a result the RULA score is +3 for this Activity 5. Therefore only further investigation and change may be needed.

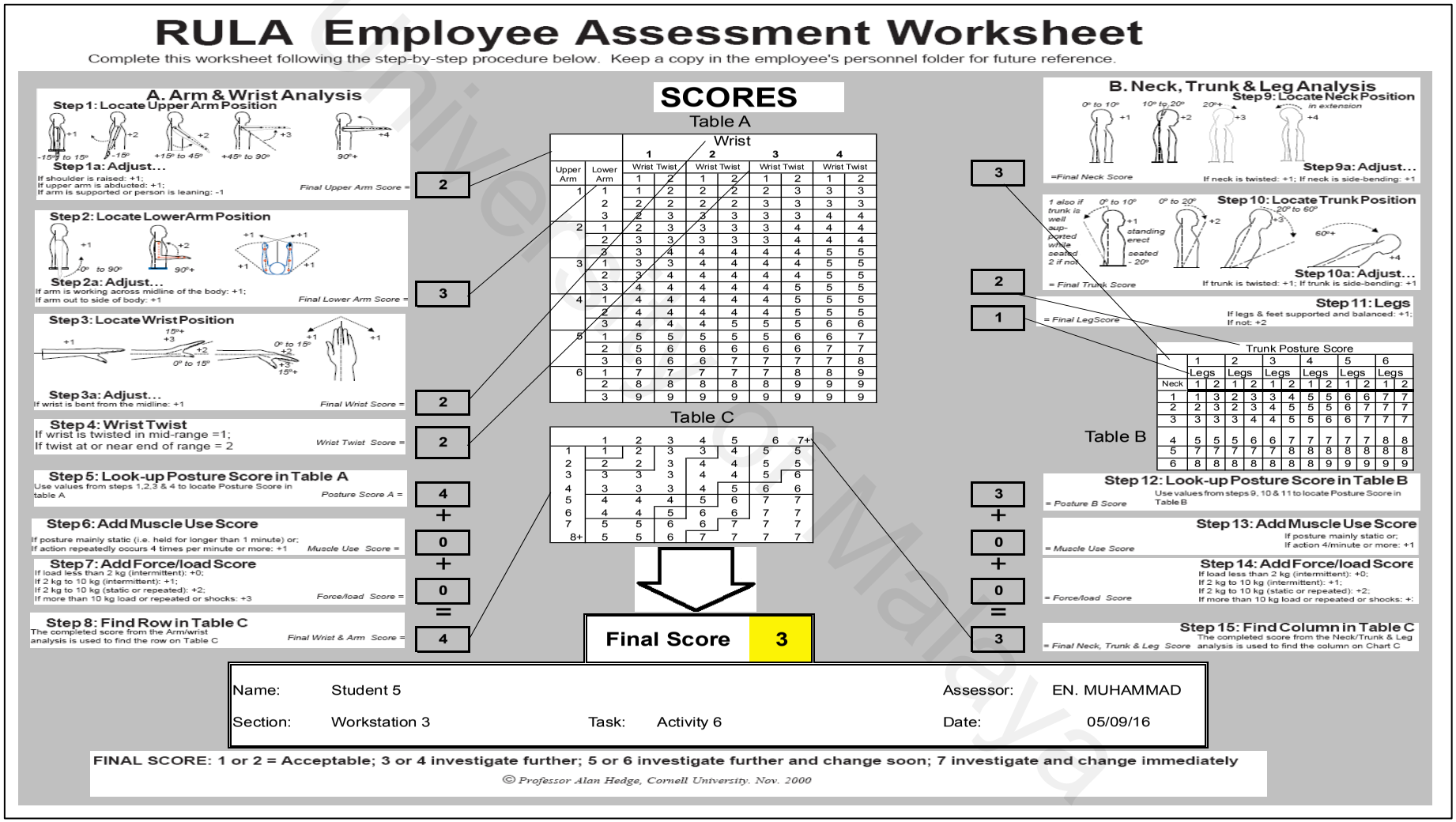

Figure 4-14 RULA Employee Assessment Worksheet for Activity 6

4.4.6 RULA Postural Score for Activity 6

Activity 6 has the same task with Activity 5 but the different is the location of the based electrical box. The based box is at the center level of the overall work task. Figure 4-15 shows the student screwing the power socket modules to the based unit.

Figure 4-15 Student screwing the power socket modules to the based box

Figure 4-15 describes the postural of the centre power socket installation to the based box unit. The task required student to attach the electrical cable to the power socket and then complete the installation by closing the based box with this power socket modules.

As for the Scoring result in Figure 4-14 of RULA Employee Assessment Worksheet, Step 1 is to locate the upper arm position and we can see that the angle of the upper arm is between 20° to 45° in standing position. The student body position is 0° and is set as reference line. The score for this position is +2 and for Step 1a +0 because the shoulder not raise up and the upper arm are not abducted. Student arm also not supported to any armrest. The Final Upper Arm Score is +2.

Move next to Step 2 is locating the Lower Arm Position which is 100° above from body referring line. Score is set at +2. The arm is also working across the midline but not out to side of body and this give the step 2a score of +1. Therefore the total score for Lower Arm is +3.

Figure 4-16 Activity 6 - Centre Level Power Socket Installation

Next Step 3 is to locate the Wrist Position. The angle position of the wrist is between 15° downside to 15° upside. This gives the score for step 3 is +2. Wrist is not bend from midline and step 3a score is +0. Combination of this score is +2.

Also for the Step 4 wrist twist score is +2 because of wrist is twist near end of range. In Step 5 we need to refer the Score Posture Table A in Figure 4-16 for the step 1, step 2, step3 and step 4 will give the Posture Score +4.

Yet the Step 6 is adding any muscle use will indicates score +0 because the student remain static but less than 10 minutes and the action not repeated more than 4 times in a minutes. Step 7 also gives the score +0 because the load weight of the test pen is less

than 4.4lbs (less than 1.99kg). Last step is Step 8, from all the values of step 5, step 6 and step 7 to be total up and then the Wrist And Arm Score obtained from the row in Table C. As a result the Final Score for Wrist and Arm are +4.

Furthermore in the Section B is to analyse the neck, trunk and leg scoring values. Begin with step 9 student neck was in angle of 10° to 20° in give the score of +2. But for step 9a the neck was twisted and additional score +1. As a result the neck score is +3.

Moving forward to Step 10, the trunk position is between 0° to 20° angle with score +2. The trunk not twisted and also not in side bending position. This indicates the step 10a with score +0. Final trunk score is +2. Both of the student legs are well supported on the working platform during observation. Therefore the step 11 score result gives +1. In step 12 is to look up at Table B for the posture score. Matching all score from step 9, step 10 and step 11 will give the Posture B score at +3.

Step 13 is to Add Muscle Use score, the posture mainly static less than 10 minutes and no action found repeated occurs more than 4 times in a minutes. Therefore the score remain +0. In step 14 is to *Add Force or Load Score* if any. Students only hold the hand screwdrivers with weight of load less than 4.4lbs. He is intermittent position in this posture so the score is +0. Step 15 is adding up all values from step 12, step 13 and step 14 with total score of +3. Values are matched at the column in Table C. Finally is to determine *Final RULA Score* by using the Table C in Figure 4-14. As a result the RULA score is +3. Therefore further investigation and change may be needed.

4.5 RULA Action Level

The results of RULA assessment show of the body current postural condition. RULA Action Level (AL) stands for the need and urgency of changes on the person who is dealing with the degree of MSD risk injuries. Based on RULA compilation in Table 4-5 the scoring postures for all activities are summarized (McAtamney & Nigel Corlett, 1993).

It is clearly show that the Activity 1 and Activity 2 has Final RULA Score of 7. This is considered very high level of exposure to MSD risk where immediate changes are required. Therefore Activity 1 and Activity 2 are considered as Action Level 4 (AL 4) and need to be focused in next chapter.

Only single activity that is Activity 4 has Action Level 3 (AL 3) with the RULA Final Score result 5. At this AL 3 person is consider working in a poor posture with a risk of injury in their work postures. The corrective action is needed sooner and to be discuss in near future to prevent any injury.

Action Level 2 (AL 2) refers to RULA Final Score of 3 and 4. At this AL 2 the person is believed to work in a postures that could represent some risk of injuries in their work task. In other word the AL 2 only represent the result of awkward position or only one part of body being deviated. In this case it only need of investigation and corrected in near future. Table 4-5 show 3 activities were reported to have this issues that are Activity 3, Activity 5 and Activity 6.

It was observed that among the entire 6 activities observed, none of them has Action Level 1 (AL 1). This refers to RULA Final Score of 1 and 2 where the students are working in best postures with no risk of injury from their work postures.

Table 4-5 Compilation of Score in RULA Employee Assessment Worksheet

No	Activity	Upper Arm	Upper Arm Adjust	Lower Arm	Lower Arm Adjust	Wrist	Wrist Adjust	Wrist Twist	**Posture Score in TABLE A**	Muscle Use	Force/Load	**ROW in TABLE C**	Neck Position	Neck Position Adjust	Trunk Position	Trunk Position Adjust	Legs	**Posture Score in TABLE B**	Muscle Use Score	Force/Load	**COLOUM in TABLE C**	**Final RULA SCORE**
		Step 1	Step 1a	Step 2	Step 2a	Step 3	Step 3a	Step 4	**Step 5**	Step 6	Step 7	**Step 8**	Step 9	Step 9a	Step 10	Step 10a	Step 11	**Step 12**	Step 13	Step 14	**Step 15**	
1	Screwing and tightening the electrical cable to wall lamp module	4	1	2	1	2	0	1	7	0	0	7	4	0	1	0	1	5	0	0	5	7
2	Screwing and tightening the electrical cable to ceiling lamp module	4	1	2	1	3	0	1	7	0	0	7	4	0	1	0	1	5	0	0	5	7
3	Screwing and tightening the electrical cable to lower power outlet	2	0	2	0	3	0	1	3	0	0	3	3	0	1	0	1	3	0	0	3	3
4	Manual screwing the socket box to wood wall	1	0	2	0	2	1	1	3	0	0	3	4	0	3	0	1	6	0	0	6	5
5	Screwing to enclosed the power outlet (lowest line)	1	0	2	0	1	0	1	3	0	0	3	3	0	1	1	1	3	0	0	3	3
6	Screwing to enclosed the power outlet (middle line)	2	0	2	1	2	0	2	4	0	0	4	2	1	2	0	1	3	0	0	3	3

4.6 Summary

Borg's RPE Scale result shows that the means values that more than 15 are from Activity 1 (15.4±1.3), Activity 2 (15.8±1.8) and Activity 4 (15.4±0.5). Comparing to RULA Assessment Final Scoring also show that Activity 1 (RULA Final Score 7), Activity 2 (RULA Final Score 7) and Activity 4 (RULA Final Score 5) are significant with Borg RPE scale rated by the student. The researcher evaluates RULA results and the participants themselves evaluate Borg's RPE Scale through the questionnaire (refer Appendix A.1). This is a good comparison and future design proposed on selected activities would be focus based on that result.

It is confirmed that the task above the shoulder will give obvious RULA scoring result. The wall lamp module from Activity 1 and ceiling lamp module from Activity 2 are both located above the students shoulder. The reason of the high RULA Final result is because of the postural stresses from manual activities and wrong standard operation procedure of their task. Therefore to reduce the MSD risk factor certain postural position must be corrected.

CHAPTER 5:

DESIGN PROPOSED

Based on the results in Chapter 4 there is need of modification to current workstation. The work environment of the workstation and the working postures has to be change. The proposed designs are targeted to reduce the risk factor of work fatigue and MSD risk among the student in this Wiring Lab at Politeknik Tuanku Syed Sirajuddin. For that reason below design proposed need to be taken for improvement.

I. Proposed New Installation of Ventilation Fan to the Workstation

II. Proposed Using Stepladder for Any Task Above Shoulder

5.1 Proposed for New Installation of Ventilation Fan

Without a proper air circulation the workstation is found to be in hot environment. The main purpose for having a ventilation fan to the workstation is to remove the uncirculated air or hot air out from the workstation.

The fan will also control to help eliminate the odours. It will work as a function to deodorizing the workstation. This is the effective way to rule out the smell.

Figure 5-1 shows that ventilation fan install at the back wall of the workstation. The new fresh air intake will suck into the entrance of the workstation with help of ventilation fan. Then hot air, which is previously inside the workstation, will be removed through the ventilation fan to the back of the workstation. This can lower the temperature by drive away the indoor workstation heat exchange into the cool outdoor air of the workstation. As a result the indoor workstation temperature will keep cool and comfortable.

On top of this, the change of air will increase oxygen in the workstation. The air remains unpolluted with the new fresh air coming in to the workstation.

Instead of new air circulation, the ventilation fan will help to remove the dust. During the activities the dust will floating in the workstation and this may accompanied by many invisible bacteria. Proper ventilation will help remove dust.

Human body will also release moisture during activities. Therefore the humidity of the workstation will increase. The workstation indoor humidity will also reduce if the air circulated in the workstation through the ventilation fan.

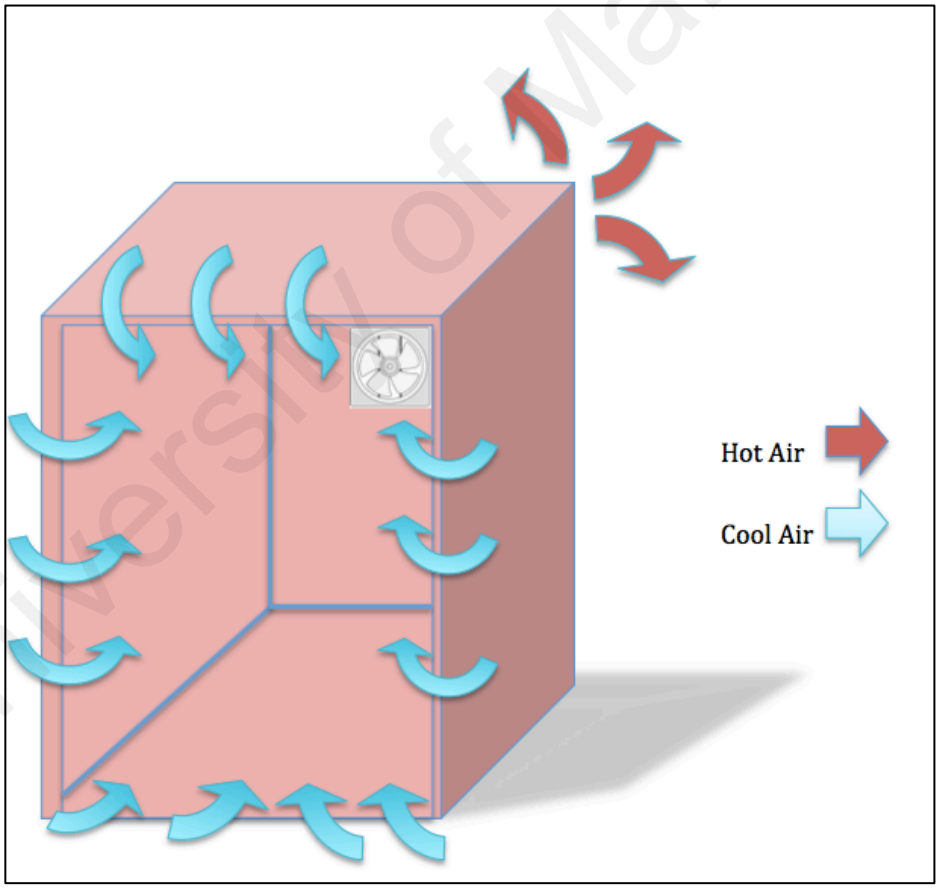

Figure 5-1 Air Circulation Model with the Installation of Ventilation Fan

5.2 Proposed of Using Stepladder for Any Task Above Shoulder

It appears that the RULA Employee Assessment Worksheet for Activity 1 and Activity 2 both gives the Final RULA Score 7. The score indicate the need of "Investigation and Immediate Change". Both of the activities show high score at the Step 1 that is +5. Step 1 focusing Upper Arm Position whereas at the beginning of assessment the upper arm position is above 90º and the shoulder also rose up. The score is more obvious when match all the values in Table A of the RULA Employee Assessment Worksheet. The score at this Table A is +7.

On top of that, both activities also show the neck position in extension mode. This will give high score for step 9 that is +4. When the look up score obtains in Table B the score at step 12 will give value +5.

This suggest that the need to reduce score in both Step 1 for Upper Arm Position and Step 9 for the Neck bending Position.

5.2.1 Analysis After Proposing the Stepladder for Activity 1

Figure 5-2 illustrate the 3 Dimension of manikin current position and proposed new position for Activity 1. To reduce the score for any electrical task above the shoulder, students are encouraged to use stepladder provided.

The participant's anthropometric data in Table 4-2 show that participants eye height during standing are in the average of 158.00±4.20cm. The task for activity 1 locates at 170cm from the working platform. It seems to be the use of stepladder will help the eye in straight position to the wall socket module. Approximately with the climb of 1 or 2 step of the ladder, student can have a good working postures. This will improve the postures of upper arm, lower arm and also the neck and trunk position.

Figure 5-2 “3D” view of Activity 1 High Wall Task Postures Improvement – The Posture Comparison between Manikin "A" (bad practice) and Manikin "B" (good practice)

Manikin “A” represents the current position with the overall RULA score of 7. Manikin “B” is new posture with the use of stepladder during activity or task.

It seem to be the Manikin “B” will have the Upper Arm position between 45º to 90º angles. The shoulder is not rising up and will give zero score in Step 1a. It is believed that the score is reducing from +5 to +3.

With the help of stepladder, the student can climb to the best position whereas the neck position is set between 0º to 10º angles. It appears that the score for Step 9 will reduce from +4 to +1. The score for trunk and legs will remain the same with previous score.

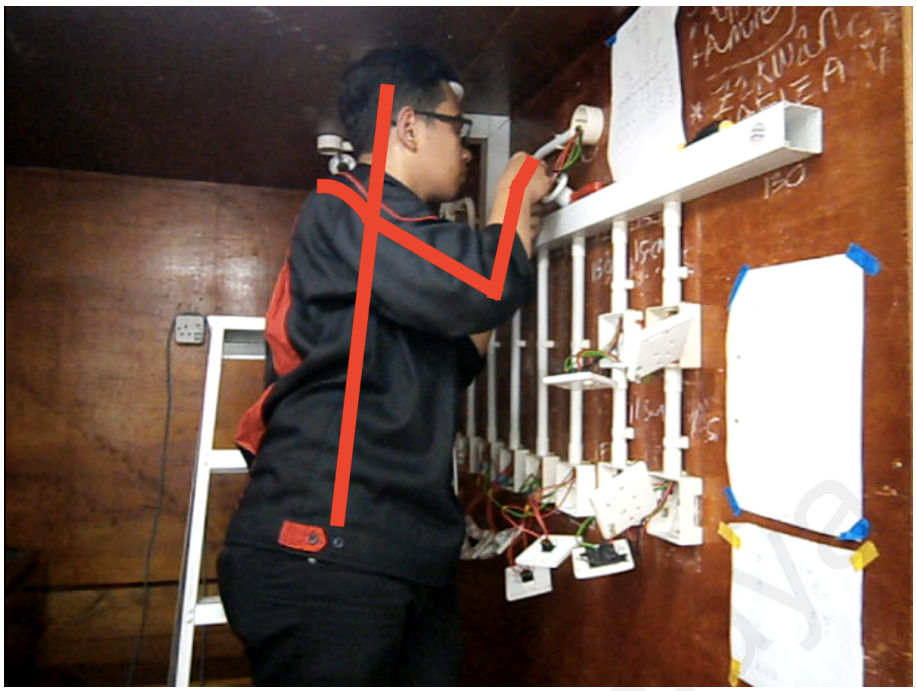

Figure 5-3 Actual Analysis of Activity 1 with Proposed Stepladder

It appears that that in Figure 5-3 when the students use the stepladder in their task. Moving to Step 12 there will be new score comparing to previous result. The score obviously reduce to +1 from +5 when match the step 9, step 10 and step 11 scores in Table B of the RULA Employee Worksheet Assessment. The new RULA Final Score after for this new requirement of task can be refer to Figure 5.4. Table C will adjust the previous Final RULA Score from 7 to 3 and at this point only need of further investigation.

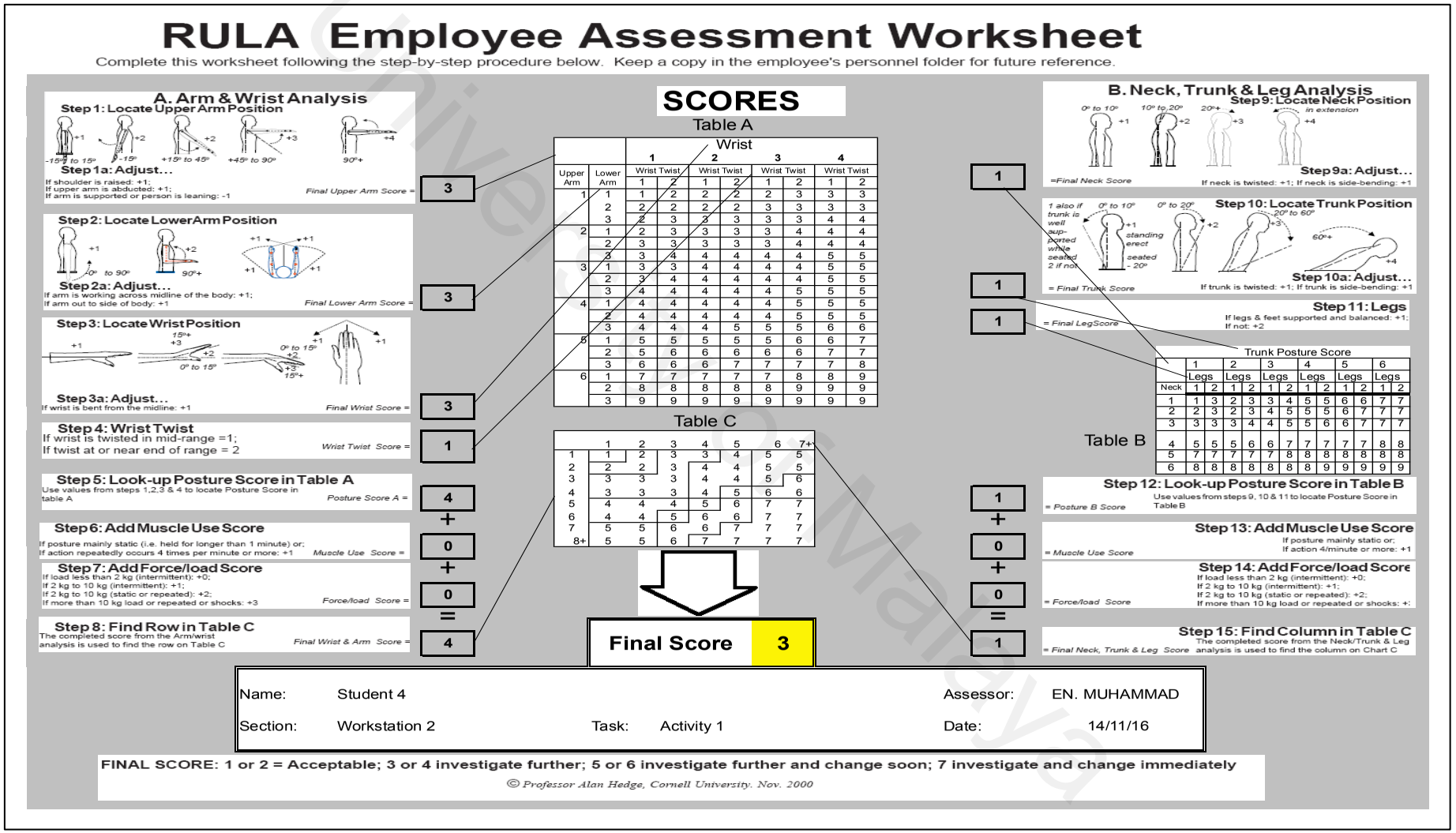

Figure 5-4 Activity 1 RULA New Final Score Reduce from 7 to 3 with the use of Stepladder

5.2.2 Analysis After Proposing the Stepladder for Activity 2

Referring to Figure 5-5 for the side view of Activity 2. Manikin "A" shows the current bad practice by the student that is without of using stepladder as their working aid during high-rise task like ceiling lamp socket attachment. Otherwise Manikin "B" shows good practice when stepladder is used to perform this task.

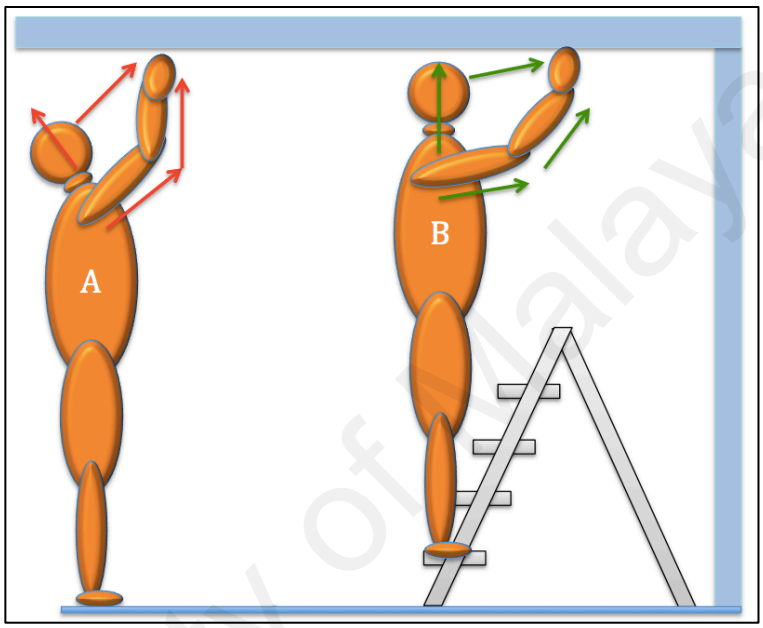

Figure 5-5 Side View of Activity 2 Ceiling Task Posture Improvement – Manikin "A" (bad practice) and Manikin "B" (good practice)

Furthermore the upper arm and the neck position can reduce the score in RULA Employee Assessment Worksheet. Figure 5-6 show the actual photo of the student using the stepladder for Activity 2. It is observe that the upper arm position score is reduced from +5 to +3 and at this position the shoulder is neither raised up nor abducted.

The lower arm score also reduce from +3 to +2 follow by wrist position score to +2 from previous +3. As can be seen from the reduce of the score in Section A (Arm and Wrist Analysis), the new projection score in Table A by using the values from step 1 to

step 4 will give the Posture Score A as +4. Soon the final Wrist and Arm Score will have +4.

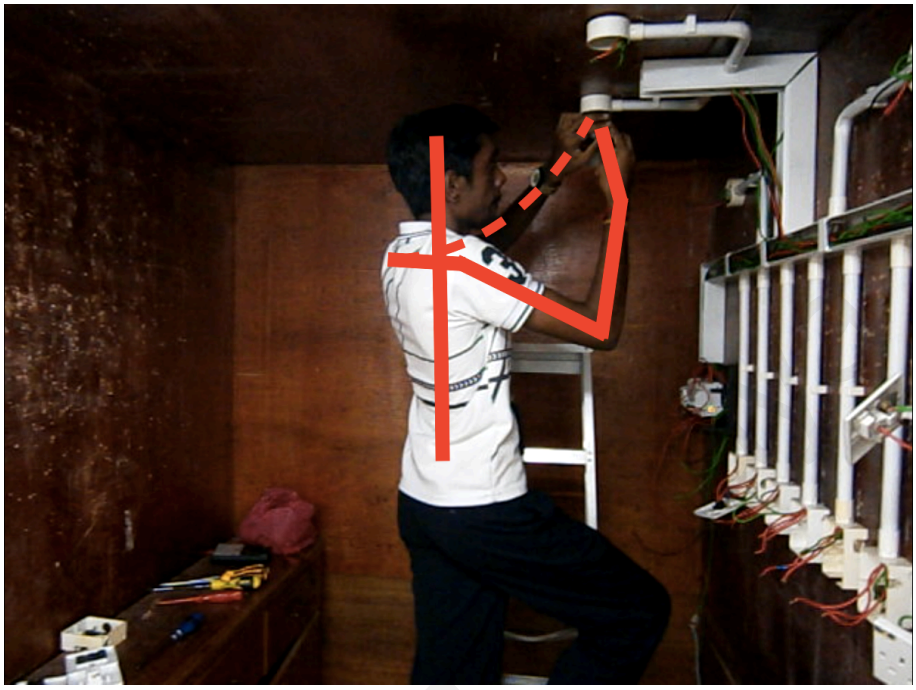

Figure 5-6 Actual Analysis of Activity 2 with Proposed Stepladder

Furthermore the neck position will be improved. The score for Step 9 manage to be reducing from +4 to +1. Others score for trunk position and legs will remain the same as previous finding. Using all values from step 9 to step 11 the final Posture B Score will obviously change from +5 to +1.

With refer to Table C in RULA Employee Assessment Worksheet in Figure 5-7, the new RULA Score for activity 2 after using the stepladder will show the previous score 7 reduce to 3. This means the stepladder will help better working postures for this activity. As a conclusion the final scoring only need further investigation, and change may be needed.

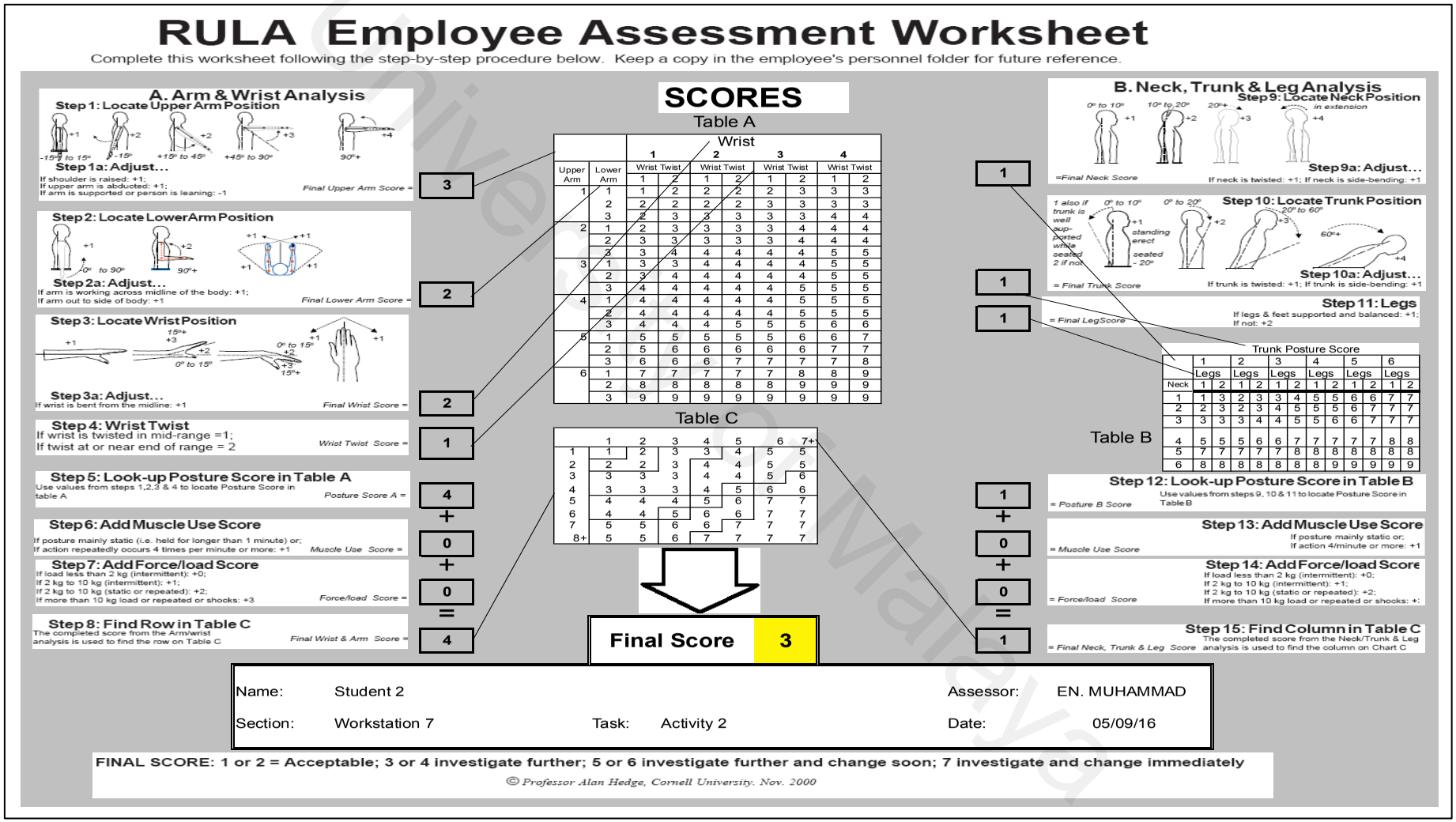

Figure 5-7 Activity 2 RULA New Final Score Reduce from 7 to 3 with the use of Stepladder

CHAPTER 6:

CONCLUSION

6.1 Conclusions

As a conclusion, this research reveals any electrical wiring installation activities above the shoulder may lead to high risk and potential MSD injuries. Thus further postural activities investigation is needed to reduce or avoid any MSD injuries. The Borg's RPE Scale and RULA Employee Assessment Worksheet are the tools that have been used in this study. The results obtain from Borg's RPE Scale and RULA's worksheets provided a good data relationship between them.

Borg's RPE Scale give score between 10 to 16 and students reveals that certain activities are light and some are heavy. The results from Borg RPE Scale conclude that the above shoulder activities are Heavy. RULA's scoring results also indicates that the above shoulder activities will give maximum Score of "7".

If the current practices still continue with the wrong body postural tasks, students might feel painful after their lab work. This is because the students and lecturers are lack of ergonomics knowledge and no awareness regarding the bad postural working practice.

Good recommendation and design proposed to current working practice, the previous body postural is corrected with a simple requirement of using the stepladder during the any task above the shoulder. The lecturers also need to emphasize the use of stepladder in any above shoulder activities.

On the other hand, the workstation environment also can be improved with the installation of ventilation fan. The humidity of the workstation will reduce with the help of air circulation.

6.2 Significant of the Finding

The significance of finding of these study are: -

i. Provide ergonomics information and knowledge together with the awareness to the students and lecturers on the current bad body postural that could seriously lead to MSD injury.

ii. A good Standard Operation Procedure especially related to ergonomics work postures has to be published and set up. This information can be a very useful to the students who are performing the task above their shoulder. On top of that the MSD risk level can be reduce among the students.

iii. The assessment result of current and proposed activity can be presented to the Safety Team of PTSS.

6.3 Future Research Study

For a better working posture in future activities study, it highly recommended that the RULA assessment to use software of CATIA V5. The manikins can be postures according to actual body postures for the RULA assessment score can be auto retrieve by the software. The body postures from manikin in CATIA V5 software are an overall body measurement. It not just only side body postural assessment like current RULA Employee Assessment Worksheet. The results from CATIA V5 RULA Assessment are more accurate because of the whole body assessment for the left and right side of the body.

The Electrical Department Management (Department Head), the Lecturers and the team of Occupational Health and Safety from PTSS must ensure all the students that

working in the Electrical Wiring Lab will use the stepladder when dealing with the task above their shoulder.

In future research study detail of Standard Operation Procedure (SOP) can be proposed. For example implementation of new Ergonomics-SOP (E-SOP) has to be place at the Wiring Lab for viewing. A good E-SOP must include photos of DO's and DON'Ts. For a better result the student can be charge with penalties of their Wiring Practical marks deduction if not follow the E-SOP. The lecturers have to be pro active observing their student during lab work.

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APPENDIX A QUESTIONAIRE

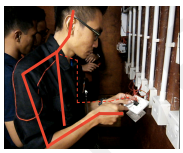
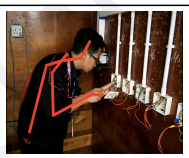
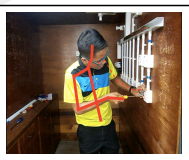
A.1 The Borg's RPE Scale Survey Form

BORG RPE SCALE SURVEY FORM

Borang Penilaian Skala "Borg RPE"

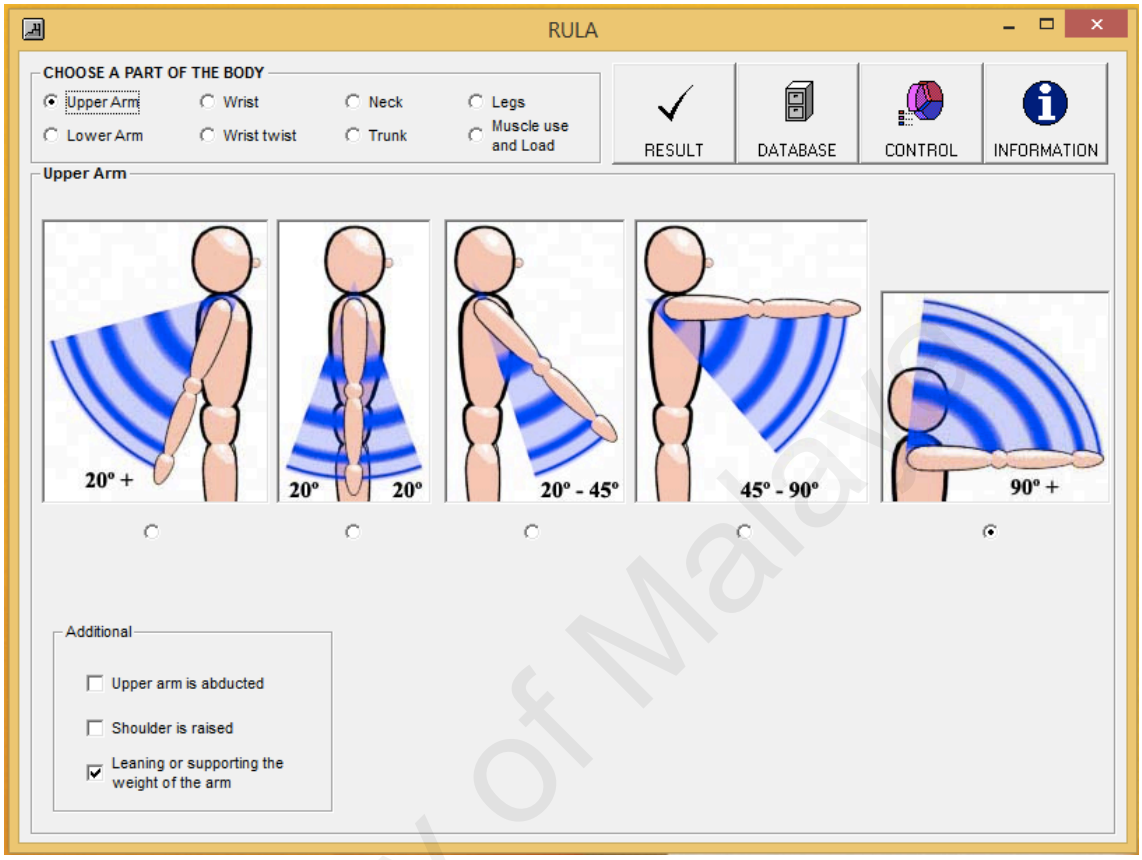
Name / *Nama*	
Age / *Umur*	
Weight / *Berat*	
Height / *Tinggi*	
Experience / *Pengalaman*	
Health status / *Status Kesihatan*	
Programme / *Program*	

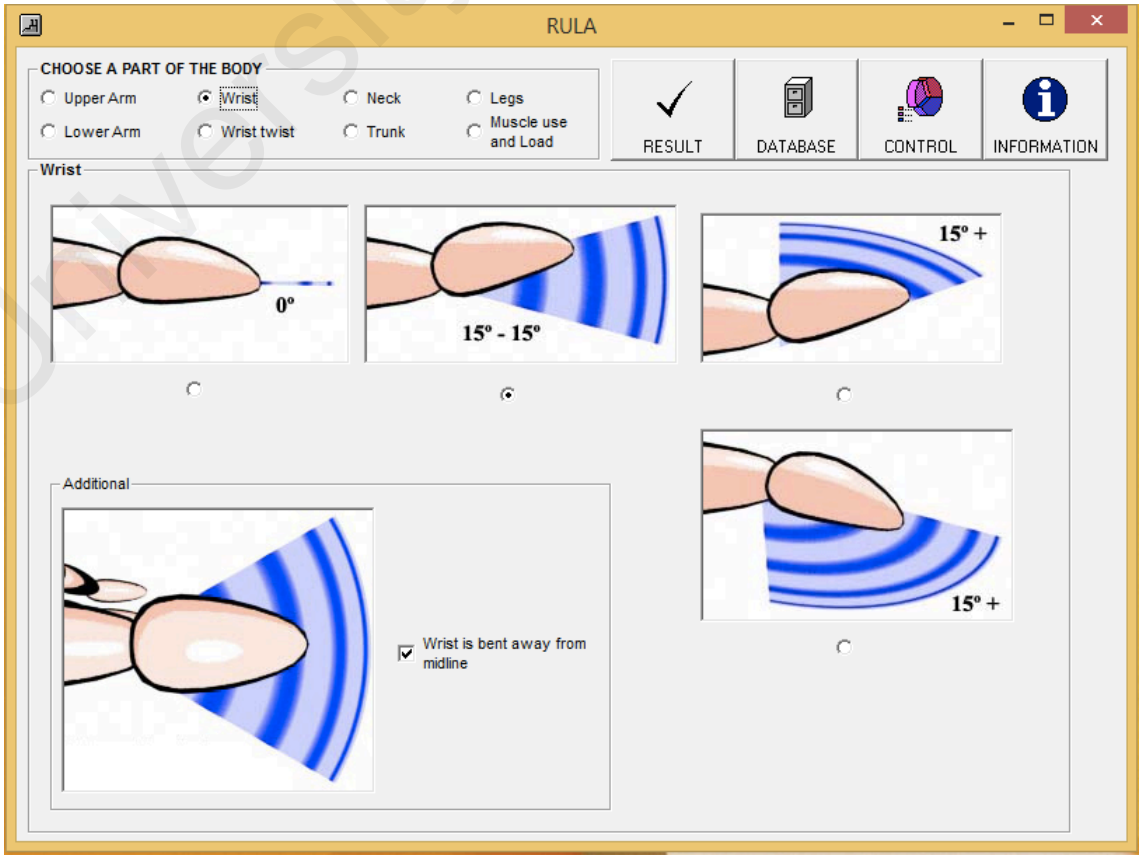
Please rate your scale (tick X) / *Sila nilaikan skala anda (tandakan X)*

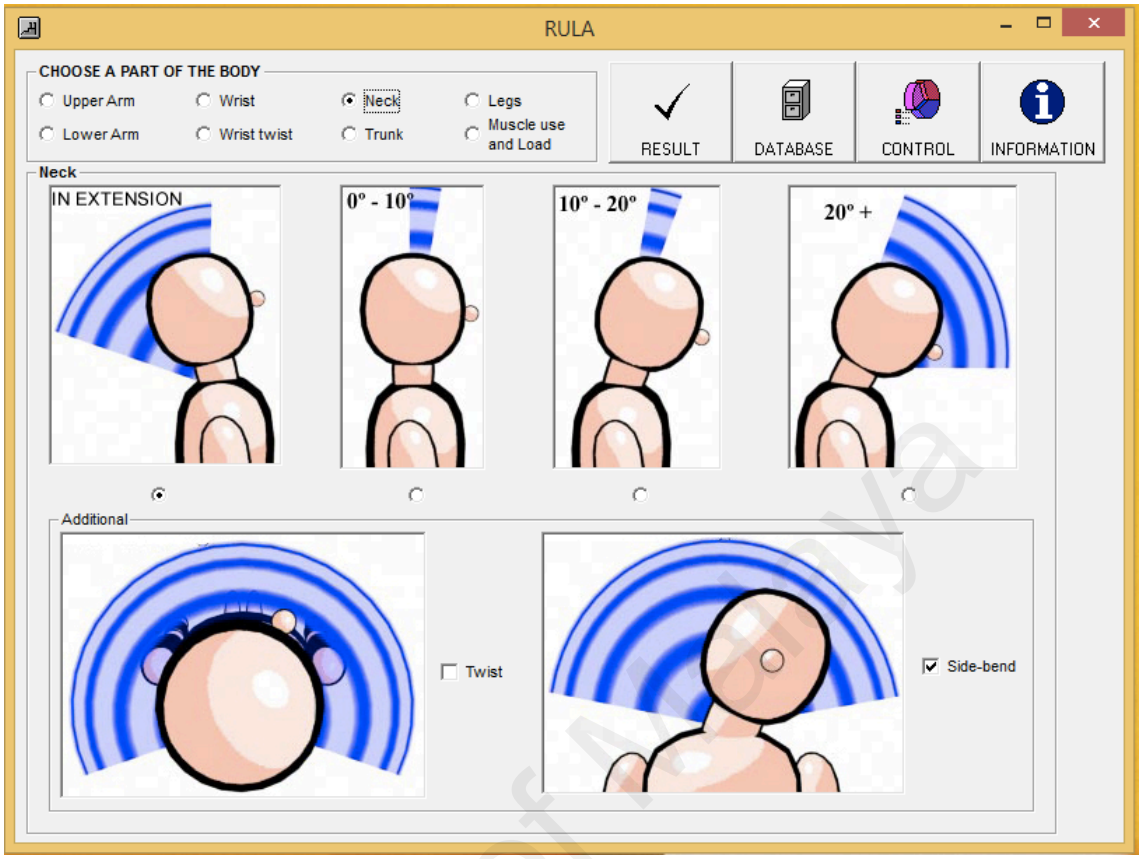
	Rating Number / *Nombor Kadar*	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	Description / *Keterangan*	Lightest / *Paling Ringan*	Extremely light / *Amat ringan*	Very Light / *Sangat ringan*	Very Light / *Sangat ringan*	Light / *Ringan*	Light / *Ringan*	Somewhat Heavy / *Agak Berat*	Somewhat Heavy / *Agak Berat*	Heavy / *Berat*	Heavy / *Berat*	Very Heavy / *Sangat Berat*	Very Heavy / *Sangat Berat*	Extremely Heavy / Amat *Berat*	Extremely Heavy / Amat *Berat*	Heaviest / *Paling Berat*
Activity 1																
Activity 2																
Activity 3																
Activity 4																
Activity 5																
Activity 6																

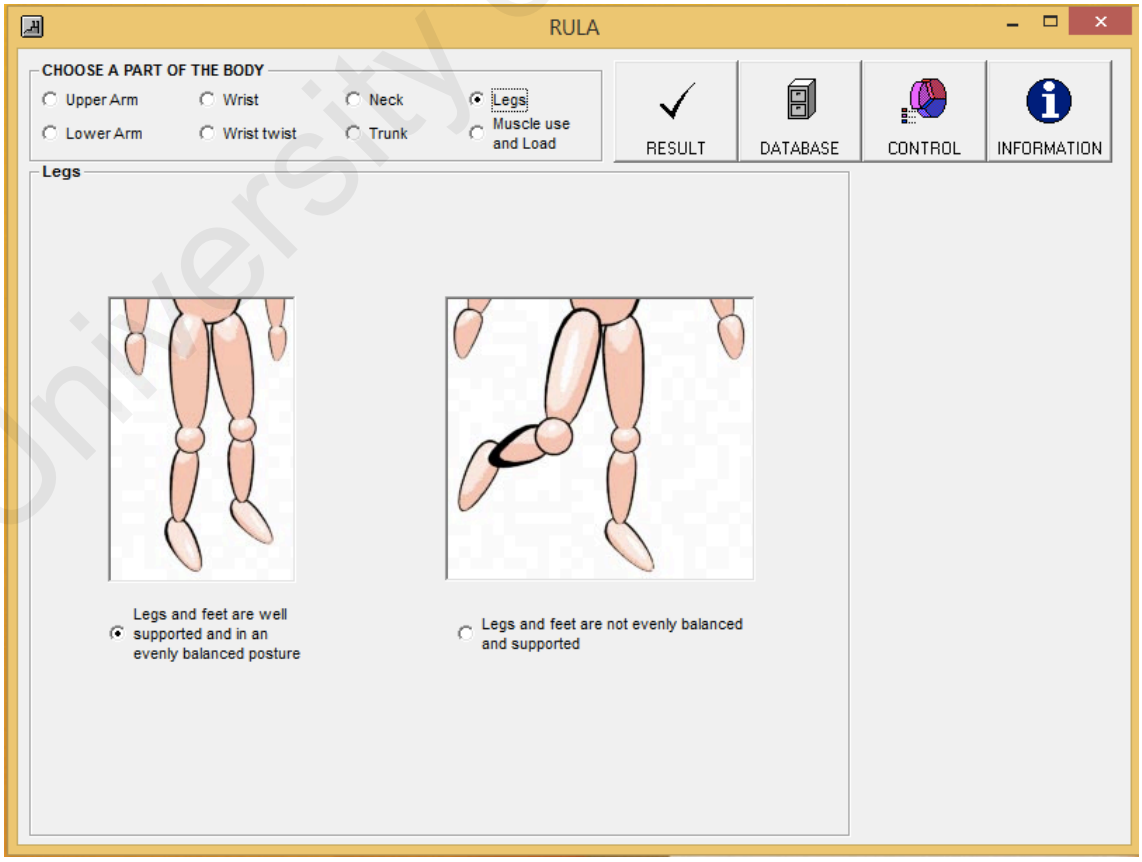
APPENDIX B THE SOFTWARE

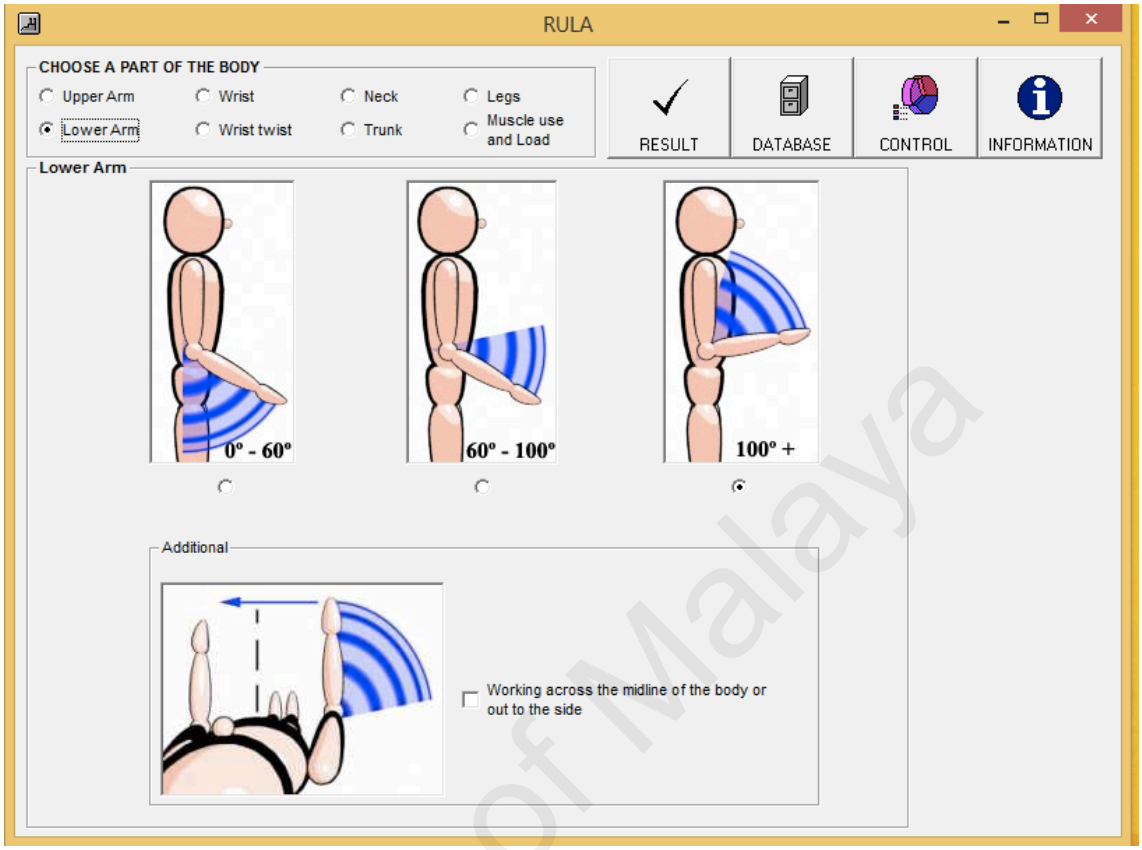
B.2 RULA free trial software

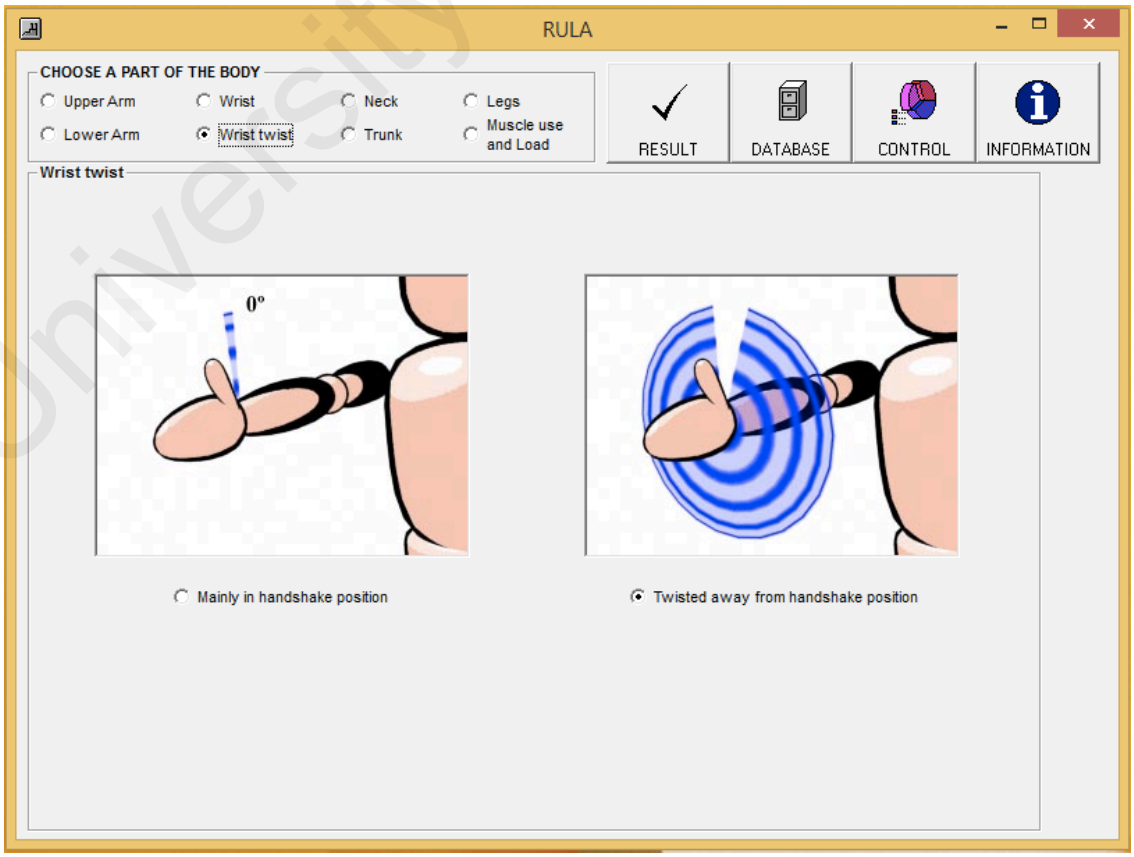


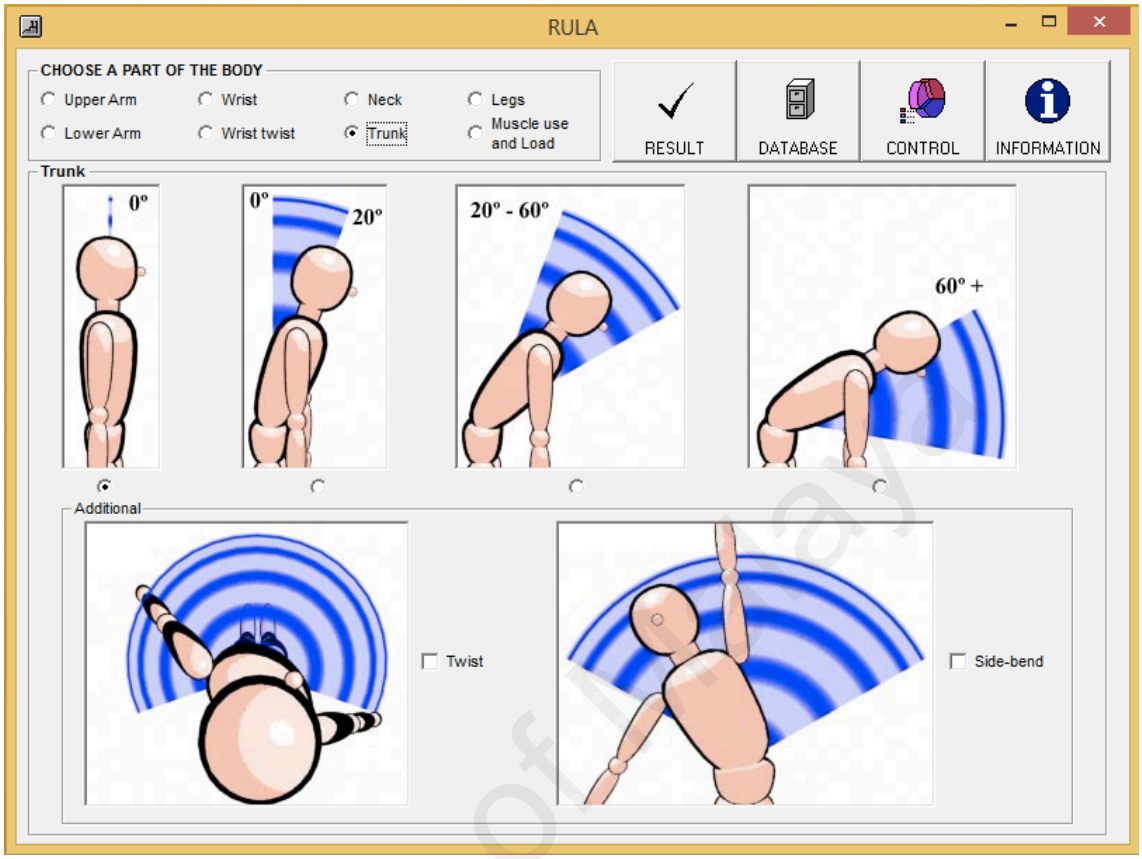


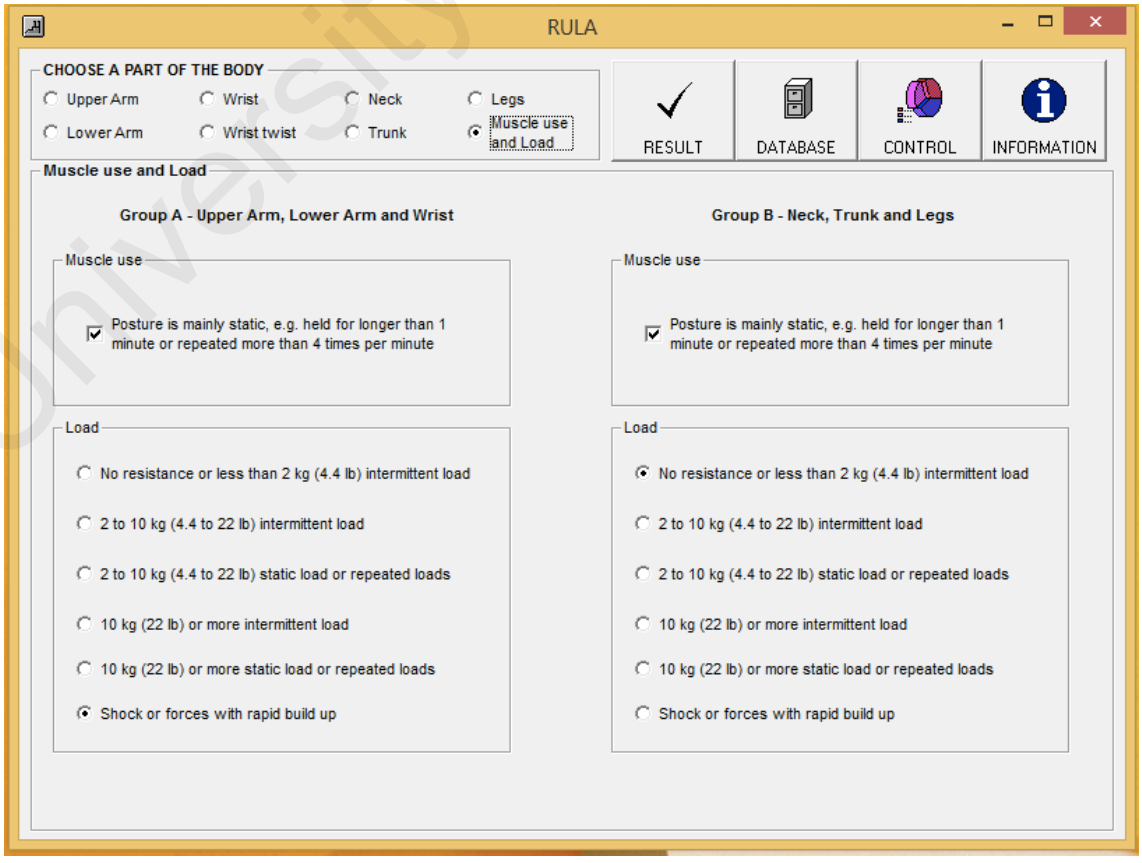


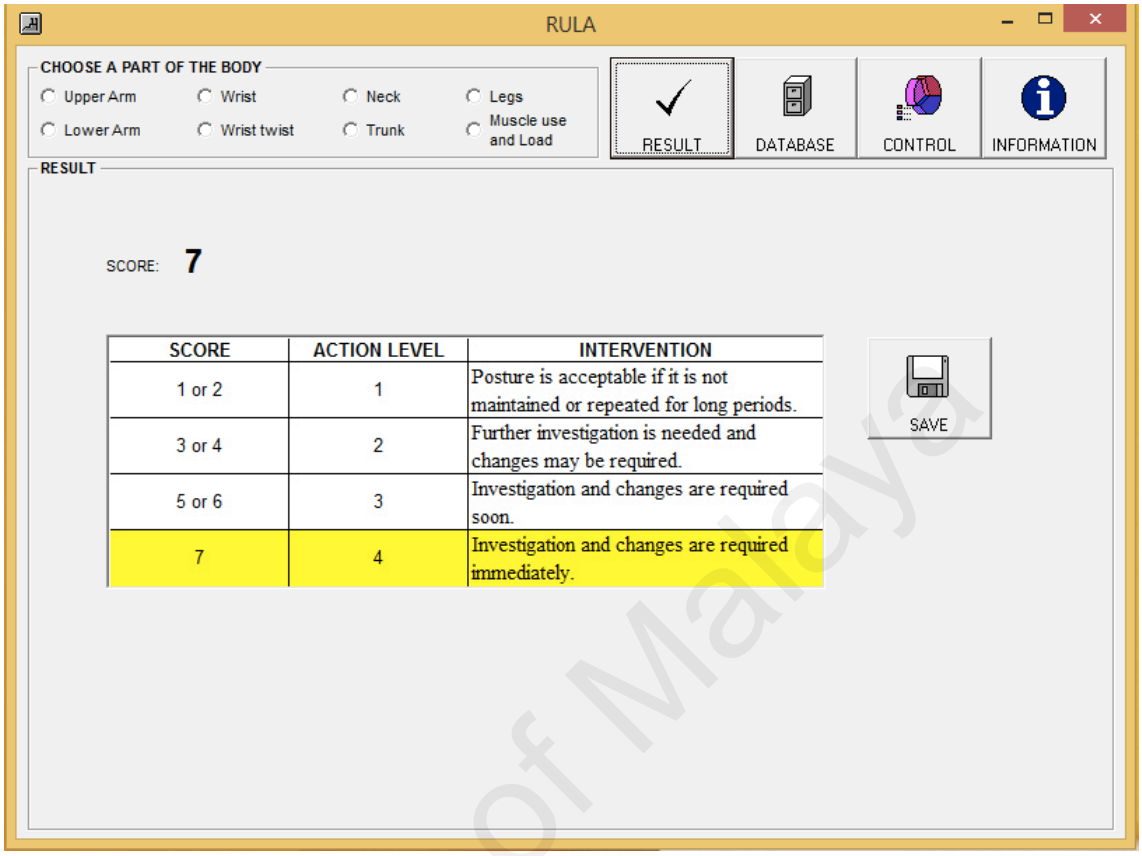












B.3 Microsoft Excel RULA Worksheet