INTEGRATING USER REQUIREMENTS AND ERGONOMICS IN DESIGNING A SCHOOL WORKSHOP WORKSTATION

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ABSTRACT

Many studies showed that schoolchildren and adolescent faced risk of musculoskeletal disorder due to furniture mismatch in school. However, very few studies evaluate the extend of a possible mismatch between school workshop furniture to schoolchildren's body postures. It may be due to variety of furniture design in school workshop. Furniture mismatch and inappropriate workstation design may contribute to early symptoms of muskuloskeletal disorder and back pain among schoolchildren.

The purpose of this study was to evaluate students' working postures when using the school workshop's workstation and recommended an ergonomically workstation design for future school workshop furniture guidelines. This study was carried out at a suburb secondary school in Klang district of Selangor, Malaysia. A total of 320 students aged 13 to 15 years old participated for questionnaire survey. 6 students were randomly selected for physical posture evaluation when using the current workstation. Each student was represented for each age and gender. 260 and 205 students were selected for Kano model and User importance survey respectively to discover user requirement. 145 students participated in anthropometry data measurement using manual and 3 dimension body scanning methods for a new designed workstation. Finally, the Jack simulation software was used to evaluate students' working postures when interact with the proposed workstation.

Results showed that short students faced higher risks of developing musculoskeletal disorder when using the current workstation regardless the age and gender. Short students has higher scores in physical assessment methods. Kano model and Quality Function Deployment integration analysis indicated that safety application and broad working surface were important requirements for the students. In addition, technical requirement result suggested that design stardard and comfort element were the important features for the proposed design. Finally, the simulation analysis indicated that shorter students have reduced the scores in RULA method significantly. The risk level also changed to lower level when using the proposed workstation.

In conclusion, this study provides some significant insights on the need of workstations evaluation for technical and vocational classroom of secondary schools in Malaysia.

ABSTRAK

Banyak kajian menunjukkan kanak-kanak sekolah dan remaja yang menghadapi risiko disebabkan masalah perabot sekolah yang tidak sepadan. Tetapi, sangat kurang kajian yang membuat penilaian terhadap kemungkinan masalah perabot bengkel sekolah tidak bersesuaian dengan postur tubuh pelajar. Ini berkemungkinan kerana pelbagai rekabentuk perabot yang digunakan di dalam bengkel sekolah. Ketidakpadanan perabot dan ketidaksesuaian ruang kerja boleh menyebabkan simptom awal kepada masalah muskuloskeletal dan sakit belakang di kalangan pelajar sekolah..

Tujuan kajian ini adalah untuk menilai postur kerja pelajar semasa menggunakan ruang kerja bengkel sekolah dan mencadangkan rekabentuk ruang kerja yang ergonomik sebagai garis panduan untuk perabot bengkel sekolah. Kajian ini telah dijalankan di sebuah sekolah luar bandar di daerah Klang, Selangor, Malaysia. Sejumlah 320 orang pelajar berumur antara 13 hingga 15 tahuan telah menyertai untuk kajian soal-selidik. 6 orang pelajar telah dipilih secara rawak untuk penilaian postur fizikal semasa menggunakan ruang kerja sedia ada. Setiap pelajar tersebut mewakili setiap umur dan jantina. 260 dan 205 orang pelajar telah dipilih secara rawak untuk kajian Kano Model dan kepentingan pengguna bagi mengenalpasti keperluan pengguna. 145 orang pelajar telah menyertai pengukuran data antropometri menggunakan kaedah manual dan imbasan badan tiga dimensi untuk merekabentuk ruang kerja yang baru. Kaedah terakhir adalah menggunakan perisian simulasi Jack untuk menilai postur kerja pelajar semasa menggunakan ruang kerja yang dijalankan.

Hasil kajian menunjukkan pelajar rendah menghadapi risiko lebih tinggi terhadap masalah muskuloskeletal semasa menggunakan ruang kerja sedia ada tanpa mengira umur dan jantina. Daripada analisis Integrasi Kano Model dan QFD, aplikasi keselamatan dan permukaan ruang kerja yang luas menjadi keutamaan pelajar. Daripada keperluan teknikal, piawaian rekabentuk dan unsur keselesaan adalah ciri-ciri utama untuk rekabentuk ruang kerja baru yang dicadangkan. Daripada analisis simulasi, pelajar rendah berjaya mengurangkan nilai skor dengan ketara. Aras risiko juga berubah kepada rendah semasa menggunakan ruang kerja yang dicadangkan.

Kesimpulannya, kajian ini telah menghasilkan pandangan yang penting tentang keperluan penilaian ruang kerja untuk kelas teknik dan vokasional untuk sekolah menengah di Malaysia

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ABBREVIATIONS

2D	Two-dimensional
3D	Three-dimensional
3DSSPP	3 Dimension Static Strength Prediction Program
ANSUR	Army Natick Survey User Requirements
BMI	Body Mass Index
BSF	Building Schools for the Future
CAD	Computer Aided Design
CAD/CAM	Computer Aided Design/ Computer Aided Manufacturing
CATIA	Computer Aided Three-dimensional Interactive Application
CD	Customer Dissatisfaction
CS	Customer Satisfaction
CTD	Cumulative Trauma Disorder
Cm	centimeter
DELMIA	Digital Enterprise Lean Manufacturing Interactive Application
DHM	Digital Human Modeling
DMQ	Dutch Musculoskeletal Questionnaire
GHQ	General Health Questionnaire
HME	Human machine environment
HoQ	House of Quality
JSI	Job Strain Index
Kg	kilogram
LBA	Low Back Analysis
MDF	Medium density fiberboard
MP	Musculoskeletal pain

MS	Malaysian Standard
MSD	Musculoskeletal disorder
N	Newton
NIOSH	National Institute of Occupational Safety and Health
NMQ	Nordic Musculoskeletal Questionnaire
OCRA	Occupational Repetitive Actions
OOS	Occupational Overuse Syndrome
OPT	Occupant Packaging Toolkit
OSH	Occupational Safety and Health
OWAS	Ovako Work Assessment System
QFD	Quality Function Deployment
REBA	Rapid Entire Body Assessment
RSI	Repetitive Strain Injury
RULA	Rapid Upper Limb Assessment
SD	Standard Deviation
SPSS	Statistical Package for the Social Sciences
SSI	Small Scale Industries
TAT	Task Analysis Toolkit
TQM	Total Quality Management
TSB	Task Simulation Builder
VDT	Video Display Terminal
WMSDs	Work-related musculoskeletal disorders
WHSW	Workplace Health, Safety and Welfare

Chapter 1

INTRODUCTION

1.1 Importance of the study

In recent years, students in Malaysia have been suffering from musculoskeletal disorder symptoms because of furniture mismatch in school (Ahmad Nazif Noor Kamar et al., 2011; Syazwan Aizat Ismail et al., 2010). Mohd Azuan et al., (2010) also indicated that school related factors which have to do with backpack and school furniture have been identified as a common risk of back pain. There is still lacking in ergonomic intervention in school environment and facilities. Murphy et al., (2003) revealed that characteristics of school furniture have the highest prevalence of relationship with pain. Conventional workstations that are currently used in school have often described as incompatible for students.

It is agreed by many researchers that school furniture is among several factors that may contribute to musculoskeletal pain to students (Aagaard & Storr-Paulsen, 1995; Adekunle Ibrahim Musa, 2011; Agha, 2010). Furniture with fixed dimension is likely not to accommodate majority of students. In fact, female students are less likely to fit into chairs compared to male students (Parcells et al., 1999; Castellucci et al., 2010; Murphy et al., 2003; Syazwan Aizat Ismail et al., 2009). Castellucci et al., (2010) indicated that sitting in the same posture for long time may cause strains related to back pain. Thus, extra size marks for school furniture are needed to fit with different body dimensions of students. Hänninen & Koskelo (2003); Koskelo et al., (2007); Oyewole et al., (2010) also claimed that ergonomically designed school furniture especially adjustable furniture might reduce the risks of early symptoms of musculoskeletal disorder problem. Therefore, Hänninen & Koskelo (2003) proposed a better design furniture with adjustable height. They showed that adjustable furniture has significant influence in obtaining better grades at the end of high school. In most cases, improper combination of chair and desk dimensions is the reason of discomfort. Besides ergonomic furniture in classrooms, other class locations such as science laboratories and workshops should be considered in designing ergonomic furniture as they may also involve in the mismatch problems.

Pain and musculoskeletal disorder symptoms among students have received particular increasing interest in ergonomic field. A study done by Troup et al., (1987); Watson et al., (2002) specified that musculoskeletal disorder and back pain problems in adult are contributed by having such symptoms during their previous history of pain. It is important to understand the symptoms of low back pain in children and design early interventions to reduce chronic symptoms that they may possibly experience when they are adult. Musculoskeletal disorder and back pain problems in children and adolescent may give great implications in future workforce.

Secondary students spend at least five hours in school and their activities circulated in classrooms, laboratories, workshops, and sports lesson as part of their learning processes. School furniture gives high impact on their posture habit. They can develop musculoskeletal disorder and back pain problems if mismatch occurred (Brewer et al., 2009; Savanur et al., 2007). Bad posture is among the risk factors associated to feeling of discomfort while doing activities. Pain regularly related with static posture, sitting arrangement and loads carried. Students tend to show variation of postures while seated and performing tasks regardless of the furniture (Maslen & Straker, 2009). Different postures may contribute to different sites of discomfort. On the other hand, they are prone to adopt flexed postures when working at the desk. To conclude, it is important to investigate all relevant risk factors in order to identify the postural stress among students (Murphy et al., 2004).

Technical and vocational subject has gained so much interest in Malaysian Education. The main reason is to give better chances for those who are not keen in academic stream and prepared the industries for necessary skilled workers (Maizatul Ranai, 2011). Integrated Living Skills subject was introduced to Malaysian Education. The aim is to produce creative and knowledgeable students in technology-know-how in facing the rapid changes of technology in everyday lives. It is a practical subject as an exposure to the real working world. The subject is an initial step of vocational skills for our future workers. It develops students experience and creativity in design and manual handling tasks and skills. Besides introducing basic design and technology subject, other skills such as home economic, basic commerce and agriculture also being taught to all lower secondary forms (Malaysia Ministry of Education, 2002).

Mazlena Mazlan (2012) highlighted that the Malaysian Education Minister has launched the vocation education transformation. It is an intervention program for lower academic achievers at lower secondary level starting at 13 years old. The objectives are to provide an alternative option for them and at the same time, rising to twenty per cent of the industry's requirement in vocational education (Chen, 2012). In point of fact, the aspiration has been started earlier when many vocational and skill classes are offered to form four students such as machine shop practice, furniture making and domestic construction (Kementerian Pelajaran Malaysia, 2007). These students are spending more time in workshop compare to the classroom. It is important that the furniture in school workshop must be treated the same as in classroom. Moreover, technical and vocational education is planned for younger students starting 2012. The size of the furniture must match accordingly with the users' body measurements to prevent body pain and postural stress.

Thus, this study takes the initiative to develop an optimum workstation model for Integrated Living Skill's workshop for secondary schools in Malaysia as to reduce the ergonomic risk factor. It is hoped that the new designed workstation would be able to maintain correct working postures and establish good working habits in the future.

1.2 Problem Statement

Integrated Living Skill is a technological based subject for 13 to 15 years old students. Most of the time, this subject is conducted in the school workshop. In Design and Technology topic, students need to produce a product as part of coursework requirement. The reason is to give practical experience to students of performing basic hands-on machining and fabricating work. Therefore, workshops are provided by school administration to carry out these practical lessons. For the coursework project, students are required to design and produce a product consists of wood and composite materials. There are two main tasks that need to be carried out, which are materials cutting and assembly task. Examples of materials for cutting task are wood, Medium Density Fiber (MDF) board, and Polyvinyl chloride (PVC) pipe. The usual cutting equipment is jigsaw machine and handsaw. The workstation is used by four to five students at a time and they share some of the tools like jigsaw, rasps, and clamps. Therefore, they need to organize their work methods to save time and increase work performance and quality.

There are three steps to complete the project which are measuring, cutting and assembling materials. This is shown in figure 1.1.

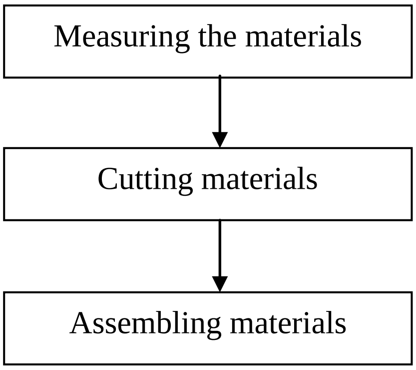


Figure 1.1. Work tasks flow cart

Initial observations on the workstation are explained below:

1. **Awkward working postures**

Most students perform measuring task in sitting posture, cutting task in standing posture and assembling task in sit-stand posture. Figure 1.2 shows students work in sitting and standing positions. The first picture showed that the student needs to bend her back while sitting. Obviously because there is no leg room and the stool is too high for her.

2. **Safety awareness**

Most students do not apply safety equipment and follow safety regulation even though they were already being taught about safety guidelines in the workshop. From the second picture, the student is not using any holding tools like clamp or vice to grip materials to be cut while performing cutting task, therefore this action may endanger his safety. It was told that G-clamps were provided but most students are too unconcerned and ignored to use them. As an alternative, it is necessary to provide vice bench or toggle clamp which is fixed at the workbench.

Figure 1.2. Students perform working tasks

3. **Improper work organization**

The size of the workbench is too small. Four students are sharing the same workbench at a time made the work performance less efficiently. Tools and materials were scattered on the workbench because there are no proper storage compartments for materials handling.

As a conclusion, a poor designed workstation gives negative impact to students' health, safety and production time. Work-related musculoskeletal disorder should be prevented at early stage of their working development. A correct working posture should be put into practice so they will adapt a good body posture while working in the future environment (Education and Training Unit, 1999).

1.3 Scope of the study

Workshops are built as facilities in all public schools in Malaysia. Students perform practical knowledge and complete coursework projects in the workshop. All lower form students aged between 13 to 15 years old are required of producing a wood prototype using manufacturing process. It is a compulsory coursework for Integrated Living Skills subject. They will be taught about design process and types of materials and fasteners before the project begins. All equipment and tools to build the product are prepared by school administrative. Duration of study for Integrated Living Skills subject is approximately two hours per week which is the total time for students to complete their project. But most of the students are incompetent to complete the work within the time given where usually they took several weeks to finish the work. Figure 1.3 shows an example of student's wood project and the current workstation.

Figure 1.3. a) An example of student's wood project   b) Current workstation

This study was focused on assessing the work-related factors which are associated with risks of musculoskeletal disorders. It also suggests a recommendation of an ergonomically workstation design for future school workshop furniture guidelines. Working environment and psychology factors are not discussed in this research even though they are also in relation with work performance (Occupational Safety and Health Administration, 2002). Further research may include an evaluation on these factors to workplace layout for secondary school's workshop.

1.4 Research Rationale and Hypotheses

The main contribution of this project is to provide the guidelines of designing a safe and ergonomic workstation for secondary school workshop in Malaysia. A safe workstation can avoid unexpected accidents and incidents as well as an ergonomic workstation can reduce factors which lead to musculoskeletal disorders problems. This study will provide both characteristics in the workstation modification process. A good working posture should be developed at early stage of their age to generate a good working habit in their future life (Korkmaz, 2008).

Cutting and assembling tasks were chosen to represent the workstation functions and to demonstrate user performance. Each hypothesis was developed to describe students' postural stress properly. The hypotheses of the present study are as follows:

1. Younger students face higher risk exposure than older students.
2. Female students tend to complain more about body pain than male students.
3. Younger students have higher scores in both Rapid Upper Limb Assessment and Rapid Entire Body Assessment postural evaluation.
4. There are significant improvements of postural scores for students when using the new ergonomically designed workstation.

1.5 Aim and objectives of the study

The aim of this study is to provide significant guidelines for designing school workshop's workstation. In order to accomplish the aim, several objectives shall be achieved which are

1. To determine the students' working posture comfort level at the current workstation.
2. To identify user and technical requirements through the integration of Kano Model and Quality function deployment approach.
3. To develop and evaluate an ergonomic design workstation for school workshop by using Jack ergonomic software.

1.6 Research outline

The followings are the summary of each chapter on this study. This dissertation contains eight chapters as follows:

1. Chapter 1 : **Introduction**

The first chapter of this dissertation began with the background of the study. It also comprises of problem statements, scope of study and its limitation, research rationale and hypotheses, objectives, and the research outline.

2. Chapter 2 : **Literature Review**

This chapter is based on literature reviews of the related topic and foundation for this study. Mainly the literature reviews are constructed from books, journals, articles, magazines, and Internet. Initially, the topic discussed is the overview of workstation mismatch and its significant relationship with working postures. Then, it is followed by the importance of anthropometry data gathering in order to fit the workstation for the user and avoiding mismatch problems. Next, the application of total quality management in design development stage, which is the overview of Kano Model and Quality Function Deployment method integration approach. Finally, the chapter ended with a brief review about virtual ergonomic simulation and its advantages.

3. Chapter 3 : **Methodology**

This chapter concentrates on the methodologies used to carry out the study. Methods involved are physical posture evaluation, questionnaires and surveys for Kano Model and House of Quality utilization. Besides that, methods include data collection of anthropometry data and virtual ergonomics analysis.

4. Chapter 4 : **Pilot study**

This chapter highlights the importance of this study and finalizes the questionnaire. The purpose of this stage is to clarify the language and layout setting of the questionnaire. On the other hand, physical posture evaluation was done to narrow the number of subjects for easier observation process.

5. Chapter 5: **Working posture evaluation**

This chapter focuses on results and discussion of data analyses from physical posture evaluation, questionnaire and survey on body pain and comfort rating by using SPSS program. Statistical analyses are performed to examine the differences among age and gender.

6. Chapter 6: **Workstation design development**

This chapter discusses about results and discussion on Kano Model classification and user satisfaction coefficient value. House of Quality matrix development and result finding from virtual human modeling simulation are also analyzed.

7. Chapter 7 : **Digital human simulation**

This chapter focuses on discussing the findings in Digital Human Modeling simulation. Analysis and discussion in this chapter are carried out with regard to fulfill the objectives of the research.

8. Chapter 8 : **Conclusion**

This chapter is constructed to describe the contribution and limitation of the study. There are also several recommendations discussed in this chapter regarding the study.

Chapter 2

LITERATURE REVIEW

2.1 Introduction

Lately, there is a growing interest among ergonomic researchers on the prevalence of musculoskeletal disorder and back pain in schoolchildren. The findings of most studies indicated serious musculoskeletal disorder and back pain problems among students (Legg et al., 2003; Mohd Azuan et al., 2010; Prendeville & Dockrell, 1998).

Students spend at least five hours in school everyday. Their activities are mostly in classroom, laboratory and workshop. Their interactions with furniture in these places were proved as among the risk factors of contributing to musculoskeletal disorder and back pain symptoms (Breen et al., 2007; Khanam et al., 2006; Milanese & Grimmer, 2004). The results of the above are due to the mismatch problems of school furniture to students' body dimensions.

2.2 Mismatch in School furniture

Furniture mismatch occurs among school children when school furniture does not match or fit with their body dimension and may develop pain on the body due to awkward sitting and standing postures. Tackling this problem at the initial stage in schools would be of great importance (Whittfield et al., 2005). According to Raja Ariffin Raja Ghazilla et al. (2010), the design of chairs and desks for the workplace has been studied with great interest. And yet, little interest of workplace assessment for students still has been shown in schools. Under the Malaysian Occupational Safety and

Health Act constitutes, schools are part of the workplace and because of that, students must be given the same attention.

A study done by Parcells et al. (1999) revealed that less than 20% of students were fit to three types of school chair. These chairs were found as too high and too deep for them which did not fit to the popliteal height and buttock-popliteal length of their body dimensions. Due to too deep and high of chairs type, children need to sit forward on the seat edge, away from the backrest when reading and writing. This condition causes kyphotic postures. Milanese & Grimmer, (2004) stated more furniture mismatch cases are involved in adolescent as their physical characteristics are growing fast along age increasing. Their human machine environment system is affected significantly by the development stages. Taller students have higher chances of facing risks of developing spinal and neck pain when using low seat and desk in school. To minimize possible mismatch problems, workstation dimensions shall focus in the design to match at least the 50^{th} percentile of anthropometric characteristics of user population (Milanese & Grimmer, 2004). As anthropometry measurement for certain age groups may change rapidly, an alternative is to create different sizes of furniture for each group (Adekunle Ibrahim Musa, 2011). The best practice possible is to let students choose from all existing sizes of furniture to fit their own body dimension. Therefore, the percentage of mismatch can be successfully reduced (Gouvali & Boudolos, 2006; Kane et al., 2006).

Gender differences should be considered in the design. Mohd Nasrull Abd Rahman et al., (2011) has carried out an observation with school children of different gender. They emphasized the stature, Body Mass Index (BMI) and other body dimensions have a significant impact on the anthropometric results of the study. Thus, furniture design must be able to fit both genders. Saarni et al. (2007) revealed that girls sit in bad postures more often than boys as they try to fit themselves into the furniture. Even though they have the same height but their body development are different as majority of girls already entered puberty during 10 to 14 years old.

Based on various studies, mismatch cases may vary, depending on the furniture used in certain populations. Most case studies in primary school which include students of age range between 7 to 12 years old were having large furniture problems that adapt well only to older age group (Panagiotopoulou et al., 2004; Yanto et al., 2008). On the other hand, case studies in secondary school which include students of ranging from age between 12 to 17 years old were having small furniture problems. Most mismatch problems were related to chairs that are too shallow which suitable only for small size students (Brewer, 2006; Adekunle Ibrahim Musa, 2011). According to Castellucci et al. (2010), the starting point to design matching school furniture to students' body characteristics should refer from the seat height. However, recommendation by many researchers, adjustable furniture is most preferable (Koskelo et al., 2007; Hänninen & Koskelo, 2003; Oyewole et al., 2010).

Mismatch problem has given great impact to students' feeling of comfort. However, the consequence of this problem may possibly encourage awkward postures among students. Possibly students will adapt unhealthy postures as a habit when they grow up and significantly affect their life in the future (Grimes & Legg, 2004).

2.2.1 *Postural stress and discomfort*

Workstations and tasks should be designed to avoid strain and damage to any part of the body such as the tendons, muscles, ligaments, and especially the back. While performing the task, people unconsciously accept and adapt to unsatisfactory working conditions. They may not realize that their body is under strain until they sense a pain and even then, they may not understand the causes either (Pehkonen, 2010). The most usual musculoskeletal problems are back pain and muscular fatigue of the upper extremities. Back pain sufferers were identified as people involves in repetitive lifting, carrying heavy weights, leaning forward, and bad sitting posture. While muscular fatigue involves in the upper extremities including shoulders, elbows, upper and lower arms, hands and wrists and fingers. Some cases that cause muscular fatigue in this region are repetitive movement of hands, force application like using hammer and jigsaw machine (Rongo, 2005).

Adolescents may face the same threats as adults when involve in woodworking task. A study by Neumann et al. (1997) considered body posture and manual material-handling activities in the wood industry. The study evaluated the biomechanics of the manual materials handling tasks; which were repetitive lifting, awkward postures, static muscle loads and high external loads. There are critical components to consider in ergonomic intervention development. Rongo (2005) also stated workers in small-scale industries, such as garages, woodworking, carpentry and metalwork, reported ergonomics-related injuries. Usually, the illnesses range from eye strain and headaches and musculoskeletal ailments such as chronic backache, neck and shoulder pain. Thus, the above risks should be eliminated and reduced postural stress and discomfort in woodworking tasks.

Physical evaluation methods can be used to identify the risk factors in limited time (Barriera-Viruet et al., 2006; Dartt, 2010; David, 2005; Kesson et al., 2001).

2.2.2 Physical evaluation tools

There are several tools to evaluate risk factors related to postures and muscle strain. Methods like OWAS (Ovako Work Assessment System), RULA (Rapid Upper Limb Assessment) , REBA (Rapid Entire Body Assessment), OCRA (Occupational Repetitive Actions) and JSI (Job Strain Index) are widely used in assessing how the work is being done (Norman et al., 2006). These tools are capable to identify awkward posture and well define the criterions of the analysis demand. Selection of the suitable method for risk analysis is defined by the demand's characteristics. A bad selection of methods may provide unnecessary results that do not reflect the actual risks (Sá et al., 2006).

Discomfort feeling can be recognized by using a survey. Questionnaire is a set of planned questions for data collection purposes. Subjects need to fill the questionnaire by self-administrative to identify the workstation problems that lead to musculoskeletal disorder problems and discomfort. There are many validated questionnaires that can be used such as Nordic Musculoskeletal Questionnaire (NMQ) (Crawford, 2007; Dickinson et al., 1992; Kuorinka et al., 1987), Dutch Musculoskeletal Questionnaire (DMQ) (Bos et al., 2007; Engels et al., 1996; Hildebrandt, 1995; Hildebrandt et al., 2001) and General Health Questionnaire (GHQ) (Banks et al., 1980; Goldberg & Hillier, 1979; Tennant, 1977). However, some items in the questionnaires can be modified to be used in certain situation based on the conducted study (Bos et al., 2007; Eltayeb et al., 2007).

Rapid Upper Limb Assessment (RULA) is a method to identify postural stress of upper limbs that was originally developed by McAtamney & Corlett, (1993). The risk is calculated into scores and classified into four action levels. A RULA sheet consists of body posture diagrams and scoring tables. Based on the RULA method, the human body is divided into two parts, which are part A for Arm and Wrist analysis while part B for Neck, Trunk and Leg Analysis. A scoring system is used to assign scores at every step, depends on the body position, pointing to higher scores for more awkward postures. RULA method is widely used in ergonomic field and a version of RULA tool can be achieved on the Internet at http://www.rula.co.uk/.

A study was conducted by Dockrell et al., (2012) to implement RULA assessment to young people. The result highlighted that RULA was more reliable for assessing older children (age 8 to 12 years old) compared to younger children (age 4 to 7 years old). It was found that older children have closer stature to an adult and their computing behaviors are also similar. A study on postures problem of Iranian worker in a communication company was carried out by Choobineh et al., (2007). The aim of the study was to find out Work-related Musculoskeletal Disorders prevalence and assessing the exposure level. They discovered that 88.1% of the workers were exposed to levels 3 and 4 which showed the working conditions in the company tend to develop Work-related Musculoskeletal Disorders.

Hignett & McAtamney, (2000) developed the Rapid Entire Body Assessment (REBA) method. Unlike RULA method that focused for sedentary task, REBA method assesses the whole body. The risk calculates into the score with five action levels. A REBA sheet consists of body posture diagrams and three scoring tables. The human body is divided into two parts, which are part A is for Neck, Trunk and Leg analysis while part B is for Arm and Wrist Analysis. A scoring system is used to assign scores at every step. The process depends on the specific body position, showing higher scores for more awkward postures.

A study was conducted using REBA as the assessment tool. The aim of the study was to determine the effectiveness of ergonomic intervention in Video display terminal operators by Ashraf Shikdar et al., (2011). The result highlighted the significant increase in the participants' productivity performance which was about 43% higher on the smart assembly workstation compared with the existing assembly workstation. Baba Md Deros et al., (2009) compared the design of four types of mountain rescue stretchers using REBA assessment method. They concluded that none of the stretchers fulfilled ergonomic requirements because all scores in REBA assessment were above 4 but benefits of some features in every stretcher were selected as design features for the future mountain rescue stretcher.

The above methods showed almost similar procedure and can give a quick and easy calculation of body posture, force and actions used (Hignett & McAtamney, 2000; Lueder, 1996; McAtamney & Corlett, 1993). The identification of risk factors are important in determining the new ergonomics design workstation that will possibly lessen both postural scores and corrects the working condition and improve safety.

2.3 Workstation modification process

Kano model and Quality function deployment methods are usually used as evaluation tools in a product development process. These methods are selected because of their ability to ensure the proposed design will fulfill users' needs. Few models are discussed below.

2.3.1 Kano Model

Kano Model is an effective method to explore user requirement and ideas so they can be clearly defined and emerged (Furlan & Corradetti, 2010). The model is widely used in product improvement or development and service sector. It can decide user requirement and exceed their expectation. Kano Model was developed by Kano, et al., (1984) which proposed two-dimensional quality model. The Kano Model lists six types of quality categories which are One dimension (O), Must-be (M), Attractive (A), Indifferent (I), Reversal (R) and Questionable result (Q). Figure 2.1 shows the Kano Model diagram to identify the qualities distribution.

According to Sauerwein et al., (1996), it is not enough to ask only about user needs because usually the answers are already known. User's problems while using current products need to be expressed. Many studies use Kano model as assessment tool such as in service and product improvement. A study done by Chen & Chuan, (2010) demonstrated an extended Kano model procedure for a mobile phone design improvement. The results proved that the procedure is able to identify the objective and subjective attributes for better understanding of customer satisfaction. Kano model method was also used in a study to investigate customer perception on packaging quality and design. Results showed that quality attributes of packaging like recyclable material and resealability are attractive and influence customers' buying decision (Lofgren & Witell, 2005).

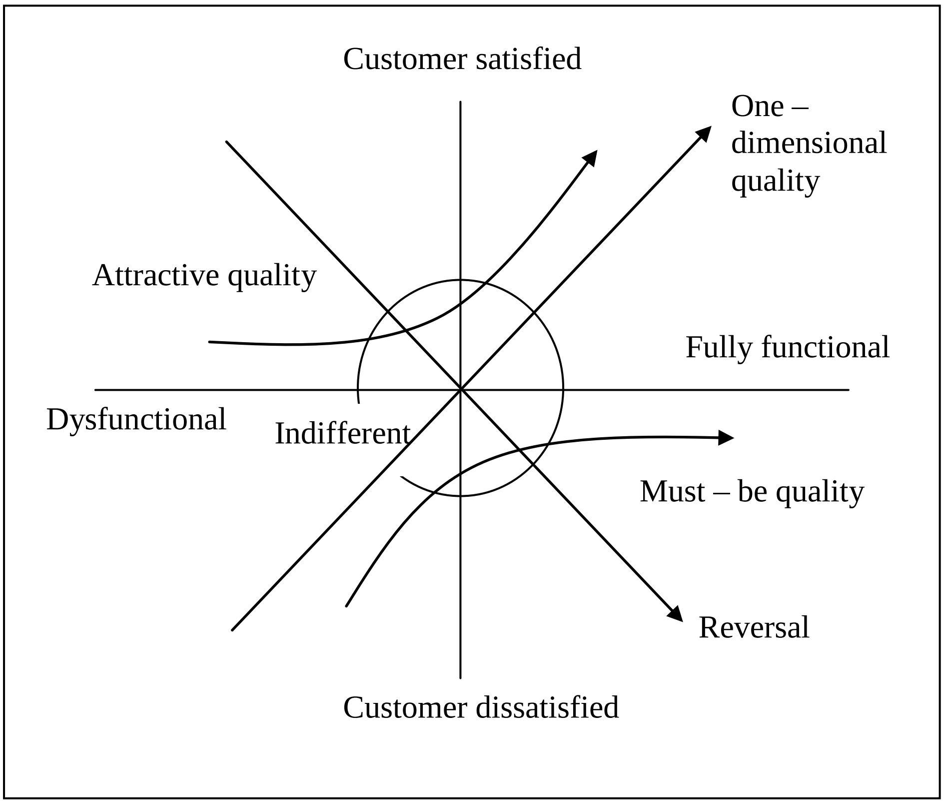


Figure 2.1. Kano model diagram (Lofgren & Witell, 2005)

2.3.2 Quality Function Deployment (QFD)

One of the powerful methods in new product development under the Total Quality Management is the Quality Function Deployment. Akao (1997) developed the Quality Function Deployment method in 1960s and made popular in 1970s by Toyota Auto Body when they created the House of quality matrix (Chen & Chen, 2001). It is a great tool in product development to translate the voice of customer in engineering design quality that fulfills customer satisfaction. Sireli et al., (2007) also stated Quality

Function Deployment can help to evaluate the impact values of design requirement characteristics on meeting customer requirement expectations by prioritizing the design requirement based on their important values. To identify these requirements, the House of Quality was built to integrate user requirement and technical capability. Figure 2.2 shows the main parts of the House of Quality matrix (Lin et al., 2004).

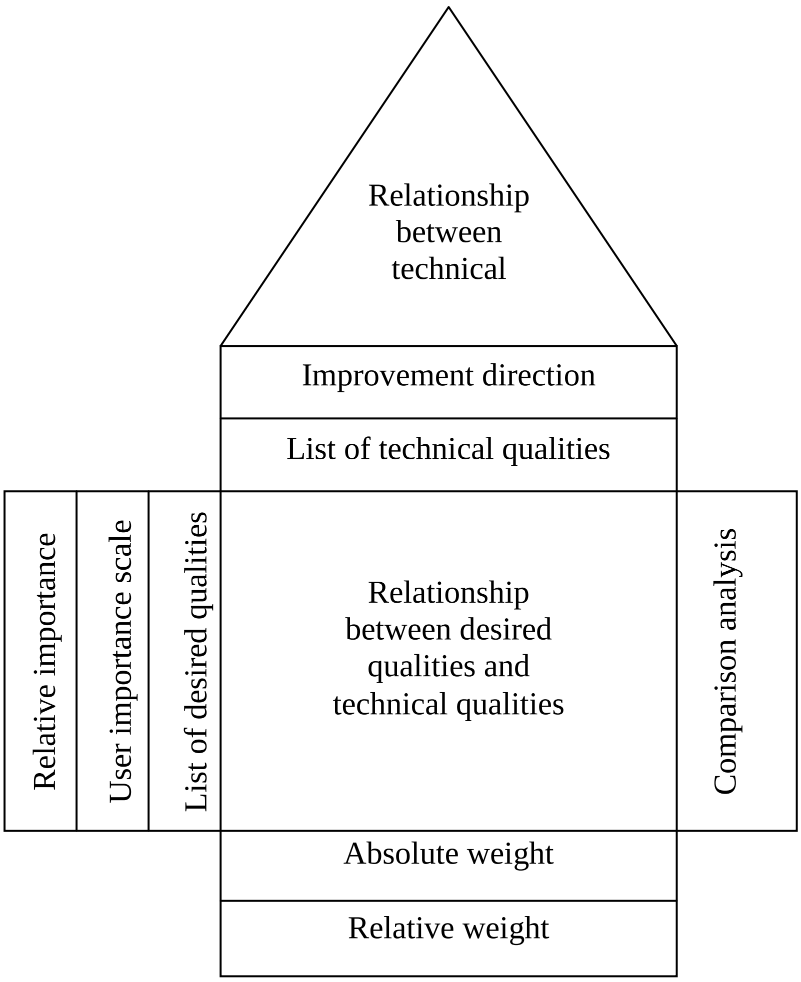


Figure 2.2. Main parts of the House of Quality matrix

However, some constraints such as space limitation to fit the workstation and cost may change the design in which some of requirement features cannot be implemented. One should try to maximize user satisfaction and apply ergonomic and safety features to make sure the workstation design would be positively acceptable.

According to Lai et al. (2004), higher quality is defined by meeting the customer requirement. However, because of some constraints, such as financial and manpower limitation, Quality Function Deployment as optimization method is needed to exploit the use of resources available.

Mas Alina Mohd Alia et al., (2010) has done a research on facility layout redesign of a metal stamping factory in Shah Alam, Selangor. They demonstrated an improved design that successfully overcome the production flow problems derived from the integration of Quality Function Deployment and simulation modeling using QUEST analysis software. A study in ergonomic design of a boning knife by Marsot (2005) also showed that Quality Function Deployment has been applied to identify the best solution to ergonomics-related expectations. From both studies above, it can be concluded that Quality Function Deployment is a valid tool in design improvement and linking user expectations with relevant technical requirements.

2.3.3 Ergonomic design

Most companies always concentrate on developing and improving product design to fulfill customer satisfaction. Sometimes, the design is not capable to satisfy every possible user's expectations and ergonomics in the design process. Overall stages of product development usually are handled by engineering specialist. The absence of ergonomist for example may result in undesirable product design (Marsot, 2005). Ergonomic design is made to ensure it is within users' capability and limitation while handling the products, workstations and machineries (Helander & Lin, 2002). Ergonomic design knowledge is focused on the relationship of designed objects and environmental with reference to human factors. This knowledge is important for design engineers when making crucial decisions about ergonomic parameters for product and layout design (Kaljun & Dolsak, 2012). In human – workstation interaction, it is important that the workstation is designed to adjust to the task and to fit the purpose. As such, ergonomic design of workstation and furniture must basically based on the anthropometry and biomechanics of a human body (Oyewole et al., 2010).

Several studies that implemented the ergonomic oriented-designs were done by ergonomic researchers (Liu et al., 2008; Park et al., 2000; Paschoarelli et al., 2008). Park et al. (2000) demonstrated a new workstation's chair to minimize physical discomfort and the risk of Cumulative Trauma Disorder in Video Display Terminal workstation. The ergonomically designed chair attached with keyboard-mouse support was proven to be more suitable for computer work because it was able to decrease muscle activity. In safety issue, a helmet design suggested by Liu et al., (2008) based on head shape has successfully improved the helmet's stability and reduced its weight. Ergonomic aspects were important to be considered with the integration of helmet and human head modeling. Using three dimensional human head anthropometry measurement as reference, preliminary design has shown improvement in efficiency and fitting comfort. An example of ergonomic design in health industry was presented by Paschoarelli et al. (2008) to evaluate the redesign of ultrasound transducers. This study was defined that an organized methodology procedures of recording and analyzing movement and perception in product development phase were able to generate important information for more effective products' improvement.

Ergonomic is closely related to human factors and their interaction with works which involve machineries, products and workstations. It is well known that the objective of ergonomic is focusing in design to fit the users. Therefore, the users' opinions and recommendations should be considered in design process.

2.3.4 User participatory method

User participatory design is a growing interest over the last decade. It is a user centered approach to speed up the product development and to overcome some problems in the design phase based on user's view (Kreifeldt, 2001). Participatory design also indicates that the end users are considered as field experts in identifying problems and requirements from their personal experience (Han et al., 2010). However, according to Lahti & Seitamaa-Hakkarainen (2005), it was a challenge to meet some contradictory requirement of some users and create the optimal design solutions. Moreover, young users often have different views and may generate interesting and creative ideas towards the design. Young users have been involved in some participatory design program in previous studies such as usability evaluation of children website by Kumar et al. (2009) and learning environment in education by Choi & Mark (2004). Students also play their important roles in intervention programs such as Academy Schools and Building Schools for the Future which was initiated by the United Kingdom government in 2002. It was agreed that school environment design affects the teaching and learning activities (Woodcock & Newman, 2010). Students spend at least five hours per day in school and it is important to involve them in the design of spaces they inhabit (Woolner, 2009). Building Schools for the Future project emphasized that student participants are crucial in order to balance the needs of different users and make sure their demands are fulfilled (Horton, 2007; Horton et al., 2009).

2.4 Anthropometric data

Anthropometric data are used in ergonomics to specify the physical dimensions of work spaces, equipment, furniture, clothing and other products (Jeong & Park, 1990). The use of poorly designed furniture, especially school desks and tables, that fails to account for the anthropometric characteristics of its users has a negative influence on human health (Tunay & Melemez, 2008). A surprising number of grade school children and adolescents were reported to have regular back, neck, and headache pain due to furniture mismatch in school (Parcells et al., 1999). A case study done by Agha (2010) revealed the mismatches in seat height, seat depth and desk height of classroom furniture occurred to 99% of students in five primary schools in Gaza Strip. 600 male students whose ages were between 6 and 11 years old were unable to fit themselves into the furniture provided by the schools' administration.

Anthropometry dimensions collected are necessary for the workstation design which includes the height and area of workbench, seat height and depth and the distance of reachable racks. There are two types of anthropometrical techniques to measure the human body:

- Direct measurement, also known as manual measurement technique.
- Indirect measurement, usually using three dimensional image scanning or two dimensional image photo.

However, according to Christine Franke-Gromberg et al. (2010), both techniques are similarly valid and can be replaced each other.

Despite of its accuracy and fast measurement, there are still some weaknesses in three dimensional scanning methods. According to Kouchi & Mochimaru (2011), the most serious problem in this method is land marking. Position of landmarks on bones usually is detected by palpation during manual measurement method. In contrast for scanning method, most software uses automated land marking extraction where the geometry of human body is analysed (Lu & Wang, 2008; Sims et al., 2012). A study done by Han et al. (2010) indicated that scanning measurement is generally larger than manual measurement. The same study also showed that circumferences measurement were larger than lengths and heights measurement as well. However, scanning method is still needed for large number of samples.

A study done by Karmegam et al. (2011) verified the difference of body dimension among three main ethnics in Malaysia, which are Malay, Chinese and Indian. From overall measurements, Chinese people have the biggest body size, based on 300 samples aged between 18 to 24 years old. A database consists of 40 anthropometric body dimensions was successfully developed by Gonza´lez et al. (2003), which collected 1007 samples of 516 and 491 Malaysian males and females aged between 15 to 80 years old. The database is useful for product design development in order to minimize mismatch of man-machine interface.

As summary, anthropometry data is able to discover mismatch elements in workstation and furniture of certain groups and populations. In order to ensure the workstation and furniture match the intended users, some guideline should be considered in design stage.

2.5 Workstation design guideline

The workstation is the smallest basic unit which a worker has to work with necessary tools and materials to carry out some stages of the production process (Górska, 2001). The workstation should be designed in a form that the workers can perform their work in an efficient manner. The work performed by the worker, the materials, equipment, tools, and the worker movements and anatomical measurements are taken into consideration. That is why the ergonomic design should be implemented in designing a workstation supporting the fact that ergonomic workstation encourages good postures (Bridger, 2003). Several other physical design principles that also need to be considered are light, color, angles, surface, shape, height, distance, sound, and storage.

According to Fogliatto & Guimaraes (2004), workstation design is assigned into two forms. They are Functional and Environmental design. Functional design is related to physical interaction to the worker such as worktable and seat. Environmental design is related to psychological interaction to them such as climate and lighting. The study discussed about functional workstation, which is a work seat of tollbooth workstation in order to decide the best alternatives in its design development (Fogliatto & Guimaraes, 2004). At the end of the study, they proposed a method to prioritize features on the work seat based on users' demands.

Ergonomics can influence the interaction of man-machine in workplace. Therefore, all designs must be able to accommodate man itself to reduce risk factors that may contribute to musculoskeletal disorder and cumulative trauma disorder symptoms. Ergonomics in product design has been implemented since several decades ago (Buesen, 1984; Sagot et al., 2003). Consumers nowadays are conscious about their right of safety and healthy lifestyle (Page, 1997). The implementation of ergonomic elements has given major benefit to industries and companies in increasing their products' sale.

Ergonomic workstation design based on engineering anthropometry and occupational biomechanics can play a major role in the reduction of many risk factors of occupational injury (Grandjean, 1982). Anthropometry and biomechanics are closely related because occupational biomechanics provide the bases for the use of engineering anthropometry to the problems of workstation design (Pheasant, 2003).

The most important thing in designing a good workstation is to prevent problems related to poor working condition (Pheasant, 2003). Each workstation should be designed with both the workers and the tasks as top priority so that work can be performed comfortably, smoothly and efficiently. A proper designed workstation ensures the workers to maintain a correct body posture while performing the tasks (Bridger & Whistance, 2001).

Ergonomic workstation design needs to consider the match in man-workstation interaction. The importance of human physical characteristics and physical dimensions of workstation integration is to ensure the task assigned is fit to the worker (Baba Md Deros et al., 2009). According to Shikdar et al. (2011) a 'smart workstation' can be defined as a workstation that could be used by any individual in any posture.

Baba Md Deros et al. (2011) found that there was a mismatch between workers physical dimensions to the assembly line workstation in an automotive industry. A recommended workstation design was also suggested to overcome the problem. Another study related to workstation mismatch was done by Choobineh et al. (2004). According to them, the workstation needs to be adjusted to 20 cm above elbow height and the seat high to 10º forward-sloping. At the end of the study, they proposed a specific guideline for a carpet hand-weaving workstation modification.

According to Openshaw & Taylor, (2006), there are four common postures to be considered in workstation design. These postures include sitting, standing, manual handling for moving task and workspace for reaching task.

2.5.1 Sitting posture

A good sitting posture guarantees a straight back and relaxes shoulders. Appropriate anthropometric measurement should consider for seat, work surface, legroom and clearance for getting in and out from the workstation (Khanam et al., 2006). A good seated posture is one that is comfortable and does not put a lot of stress or strain on the user's buttocks, feet, back and arm muscles (Openshaw & Taylor, 2006). Precision tasks are usually performed in sitting position because the amount of forces for the body to exert is small. The parts of the body commonly involved are the forearm and hand. Moreover, chair height should be matched to workbench height.

Measurement and assemble task require a worker to bend closer to the materials and the position involved during these tasks is more to forward-leaning postures. Consequently, the workers' neck and back will bend lower to the worktop and can cause strain to both muscles. To overcome the problem, a tilt seat surface is preferable so the strain on the neck and shoulder can be eliminated. Tilt surface is able to support the student leaning forward while working on the table or workbench (Aagaard & Storr-Paulsen, 1995; Kane et al., 2006).

2.5.2 Standing posture

Standing work can be categorized based on leg movements such as dynamic activity (with leg movements), static activity (with less or no leg movements), and a combination of dynamic and static actions. To exert greater forces, the body must use the bigger muscles of the body that are located on the shoulders, back and thighs (Ministry Of Human Resources, 2002). A standing posture allows greater flexibility to exert such force. Desk height for a standing operator can range from 28 to 43 inches depending on whether the desk is for precision, light, or heavy work. The heavier work is the lower the worktop. An over-height worktop will put a lot of strain on upper extremist of the body while a worktop that is too low will put stress on the lower back and neck. A footrest should be provided to help reduce the strain on the back and to allow the worker to change positions (Pheasant, 2003).

Material cutting task is a common task in woodworking job. Usually, the task is performed in standing position. The task can be performed using machineries or manual tools. Generally, machines used for material cutting are jigsaw machine or circular saw. If the job is done manually, usually a hacksaw or backsaw is used. Cutting task is categorized as heavy and manipulative work (Bridger, 2003). Therefore, the work should be performed around 60 to 100 mm in front of the body. While the worktop should be around 50 to 100 mm below elbow height.

2.5.3 Manual handling

Manual handling covers a wide range of activities including lifting, pushing, pulling, holding, throwing and carrying. It includes repetitive tasks such as packing, typing, assembling, cleaning and sorting, manually or using hand-tools such as machineries and special equipment (Jung & Jung, 2010). These activities are common among occupational groups in which repetitive movement and prolonged strain are put on the spine. Mostly, occupational groups involved are farmers, nurses, machine operators, miners, maintenance staff and delivery personnel.

According to Carrivick et al. (2005), one over third cases of occupational disorders is involved with manual handling. Unsafe and improper designed of workstation can lead to some conditions like repetitive strain injury (RSI), occupational overuse syndrome (OOS), cumulative trauma disorder (CTD) and work-related musculoskeletal disorders (WMSDs). Body twisting and bending should be avoided by designing proper workstation with adequate workspace for tasks and body movement and postures.

Reaching, grasping and frequent body movement will be involved while handling tools and materials in working environment. Minimize the distance for grasping and reaching within reach limit can help reduce strain to the body. For easier materials and tools handling, the workstation should be provided with proper racks and storage facilities. In designing workstation, keep in mind that the worker should minimize bending or twisting movement to search or reach for tools and materials on the worktop (Cheung et al., 2007).

2.5.4 Working space

Workspace is referring as normal working area, which is defined as comfortable of the upper limb movement (Pheasant, 2003). Ideal working space depends on within reach area of users who able to work without muscle stress and awkward postures. Kumar et al. (2009) conducted a study of a tractor's control layout. It was found that controls location which is out of workspace envelops results the operator need to stretch his limits of normal reach to operate the controls. Moreover, adjustment of seat location was also unable to locate those controls in workspace envelope of the operator. Reaching activity is an action in our daily life. According to Choi & Mark, (2004), reaching action is a goal-directed activity that we have to scale the object's distance and weight to decide the effective reach actions. They indicated that the actor's strength and environment and the object's distance and weight have a significant relationship, which determine the affordability of reaching.

Figure 2.3 shows an ideal workspace envelops. According to Workplace Health, Safety and Welfare (WHSW) Regulations (2007), the recommended space for a person is 3.7 m^2. The size of an adolescent is usually smaller than an average adult. Thus, the recommended size of a workspace for adolescent can be approximately 3.0 to 3.5 m^2 (Kroemer, 2006). It is important to design a workstation based on the anthropometric measurement of the intended users.

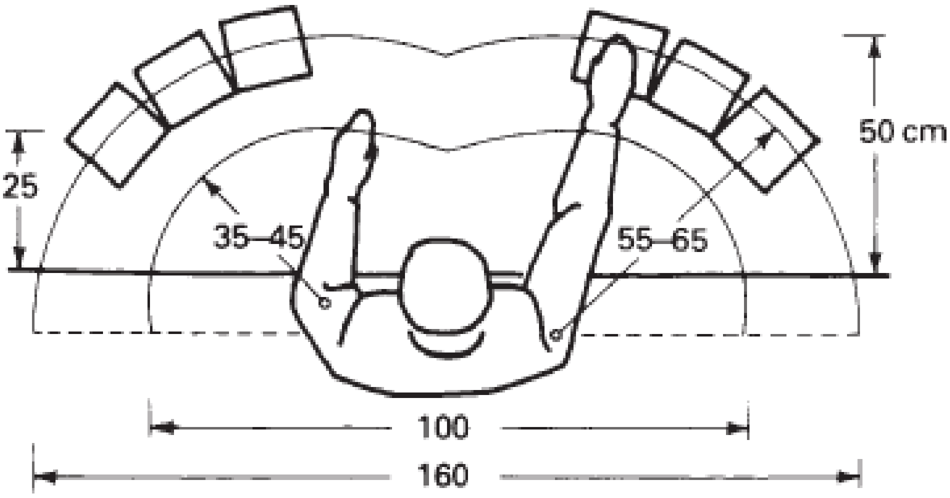


Fig 2.3. Ideal Measurements of a Workspace Envelop (Pheasant, 2003)

2.5.5 Design for children and adolescent

During growing years from birth to adulthood, human go through major changes in body dimensions, skills and strength. Early adolescent who ranges from 12 to 18 years old poses highly design challenge due to variety in body sizes among boys and girls (Kroemer, 2006). Changes in body size during childhood may vary among individuals. Ergonomic data should be properly used to ensure the final product will fit to intended users. These data includes anthropometric dimensions, muscle strength and motor skills (Steenbekkers, 1993).

Children's postures have been a concern since the 18th century. In 1888, Lorenz recommended a furniture design especially for adolescent. It was a combination of seat and writing desk. It has a tall backrest and curved back support. The desk is elevated around chest height and supports the forearms when writing. In 1890, Schindler proposed a school furniture design with adjustment features of seat and footrest to support different body sizes in schoolchildren (Kroemer, 2006). According to Zacharkow (1988) sitting upright position apparently provides discomfort and insufficient support for children's back. The reclined – sitting position with back support at all times and inclined seat surface of 10 to 15 degrees is recommended.

As a summary, workstation design process should be based on the anthropometric measurement of the intended users. Classification of children and adolescent according to body sizes should be carefully considered. Furniture design for children and adolescent is totally different from an average adult.

2.6 Ergonomic Simulation Analysis

2.6.1 Digital Human Modeling (DHM)

Digital human modeling was invented in late 70s, since then the technology is rapidly growing throughout the years. It is a development process that includes simulation that can support the design of an ergonomic workplace through early assessment of ergonomic conditions. This calls for an established work method for ergonomics simulation (Backstrand et al., 2007). Until today, some virtual analysis software has been developed such as Jack, RAMSIS and Delmia. These tools are commonly used by designers to perform occupational ergonomic analysis on a virtual mock-up, by immersing a virtual human controlled by direct or inverse kinematics. Within the above applications, the human's models cover about 90% of the population (Aubry et al., 2009).

Digital Human Modeling tools are used for faster result in design process. They can perform as pre evaluation of virtual builds for product or machine – human interface before the solid prototype is developed (Lamkull et al., 2008). Digital Human Modeling tools have been used in many industries especially automotive. Shengfeng et al. (2011) have carried out a study of assessing real task motion using three dimensional body scanning with Jack simulation software integration. This study successfully provided useful evaluation on human postures and work design without using Computer Aided Design-based virtual product. Xinhua et al. (2011) have conducted a study to perform an assembly simulation of vibration sieve. Result outcome showed the efficiency of assembly has improved and the production cost is reduced. Moreover, this method was able to identify relevant problems in assembly planning.

In designing process workstations such as assembly task, several Computer Aided Design (CAD) prototypes need to be built for the verification of human related factors. In complex manual tasks, the human involvement is very critical as it influences the feasibility, the cycle time, the working comfort and the safety of an operation. The use of these techniques provides a fast and flexible way of creating realistic virtual representations of complete assembly workspaces (Ben-Gal & Bukchin, 2002). It was done by integrating the human presence and intervention into the form of digital mannequins as well as by supporting the optimization of the human-product-process relationship. These techniques have been explored during the last few years for industrial processes verification (Pappas et al., 2006).

Several ergonomic simulation tools that are widely used in industries are Delmia, Jack, RAMSIS, SAMMIE, Santos and 3DSSPP. Table 2.1 presents the comparison between available Digital Human Modeling software in the market.

Table 2.1. Ergonomic software comparison

Software	Company	Input device	Analysis provided
DELMIA	Dassault Systemes	Cyberglove Spaceball Fakespace	Human activity analysis Material handling analysis Vision and reach envelop
JACK	Siemens Technomatix	Cyberglove Vicon Flock of Birds	Task analysis tools Occupant packaging tools Vision and reach envelop
RAMSIS	Tecmath	Body scanning Motion tracking	Posture prediction Strength model Fatigue and comfort assessment Mainly for automotive industries.
SAMMIE	Nottingham University	Motion tracking	Comfort assessment Focus on people with disabilities and elderly.
Santos	University of Iowa	Motion capture	Posture prediction Clothing modeling Fatigue assessment
3DSSPP	University of Michigan	iDrive	Material handling tasks Biomechanical analysis

An investigation of ergonomics with human modeling was done in automotive assembly line using Jack simulation to improve the ergonomic situation of assembly workers. The result indicated that physiology workload of workers and assembly time was improved by redesigning the work process and workplace layout (Niu et al., 2010). Another study that used Jack as simulation tool was done by Colombo & Cugini, (2005). They analyzed the ergonomic design of a riveting system. They emphasized that virtual humans are important to improve virtual prototyping functionalities and safety.

Digital prototypes nowadays are significantly useful not only in big industry, but also in small to medium industry. Thus, they play more important role in product and work layout development. Digital prototypes are able to perform tests of man – machine interaction by using simulation techniques. Moreover, they can identify critical aspect of design and evaluate human motions while dealing with machines or workstations (Colombo & Cugini, 2005).

As a summary, it is important to perform ergonomic simulation to evaluate man – machine interaction to a new digital prototype design. This technique is the fastest and cheapest rather than a built – up prototype which costly affects time and labor cost.

2.6 Summary

In conclusion, physical evaluation tools which are RULA and REBA methods can be used to identify posture problems in school workshop's workstation. This study make used of Quality Management approach via Kano Model and Quality Function Deployment methods. These methods are proven to be reliable to discover users' needs. It is important to identify user requirement in design and ergonomic aspect to increase the product value in the market and fulfil users' satisfaction. Digital human modelling simulation is a well- known method during design development process. This method is preferred because of its cost and time saving. Furthermore, it is validated and able to obtain desirable results.

Chapter 3

METHODOLOGY

3.1 Introduction

This study was conducted at Sekolah Menengah Kebangsaan Meru, a rural secondary school in Klang district in Selangor, Malaysia. Samples were among students aged between 13 to 15 years old. Integrated Living Skills is a subject that is only taught to lower secondary student. Permission was granted from the Ministry of Education Malaysia to conduct the study (Appendix A). The state education department of Selangor, the district education office of Klang and the school administrative have also been informed about the proposed research (Appendices B and C).

This was a cross-sectional study conducted in nine months beginning of March 2011 until November 2011. All subjects were chosen on voluntary basis and have been notified about the purpose of the study. All of them have the experience of using the school workshop's workstation at least five hours to complete the woodworking project.

The chapter is divided into three stages which are according to three objectives stated.

I. Evaluation process

The first objective is to investigate students' working postures of the current workstation. This stage explains about how questionnaire was conducted to discover students' perception towards the current workstation. Then, the evaluation of students’ working postures was assessed to get the postural assessment score and identify risk factors of the current workstation.

II. Design process

The second objective is to identify user and technical requirements through the integration of Kano Model and Quality function deployment approach. This stage highlights on how the design process was performed in two steps. First, the Kano model was used to clarify user requirement for a workstation. Then, results from the Kano Model were integrated to the House of Quality to prioritize the desirable qualities and technical characteristics. The results simplify the relevant qualities to be implemented in the improved workstation. Anthropometry data was collected for the design development process.

III. Simulation process

The third objective is to develop and evaluate an ergonomic design workstation for school workshop by using Jack ergonomic software.The final design was validated using Jack ergonomic software. This stage demonstrated how the software is able to evaluate students’ working postures while interacting with the new proposed designed workstation. Rapid Upper Limb Assessment evaluation tool was used in the analysis process. Lower Back Analysis evaluation method was used as a supporting tool for lower limb analysis. Simulation of Human – workstation interaction was used to assess for two main tasks which were material cutting and assembly process.

3.2 Subjects

In the evaluation stage, 320 students were randomly selected for questionnaire survey. The sample size was based on a confidence level of 95% and a degree of accuracy of 5%. While for workstation validation, a total of 6 students, from each age category for both genders were assessed while performing the woodworking project in their school workshop. Their work postures were evaluated using RULA and REBA methods. Age and gender of students were taken into consideration in the evaluation stages.

After the first stage was completed, 260 and 205 students were randomly selected for Kano model and User importance survey respectively. User importance survey is needed for House of Quality importance scale. 145 students participated in anthropometry data measurement using manual and 3D body scanning methods. The anthropometry measurement were used to determine whether the proposed workstation matched the students' body dimensions through simulation.

3.3 Workstation characteristics

The school furniture used in this study will be defined as workstation. According to Fulder et al. (2005), a workstation is a person's work area including furniture, appliances etc. It can also be defined as the place where this equipment is properly positioned so users can perform their job appropriately.

Work study was made during actual work in 4 school workshops. The workstations used by every students is almost similar. The project's tools and materials were provided by the school administrative. The workshop is usually occupied by 25 to

28 students for each class session. Most of the workshops have six workstations and each workstation will be shared by 4 to 5 students. Each workstation consists of a workbench with bottom storage and stools for each student. Figure 3.1 show the current workstation in Computer Aided Design (CAD) drawing. The height, width and depth of the workbench are 78 cm, 143 cm and 84 cm, respectively. Whereas, the height and diameter of the stool are 58 cm and 30 cm, respectively (Orthographic view in Appendix D).

Some students performed the cutting task on different workstations such as desks and wooden stools. The duration for each student spent in the workshop was about two hours per week. The workshop is used for both as a classroom and practical classes.

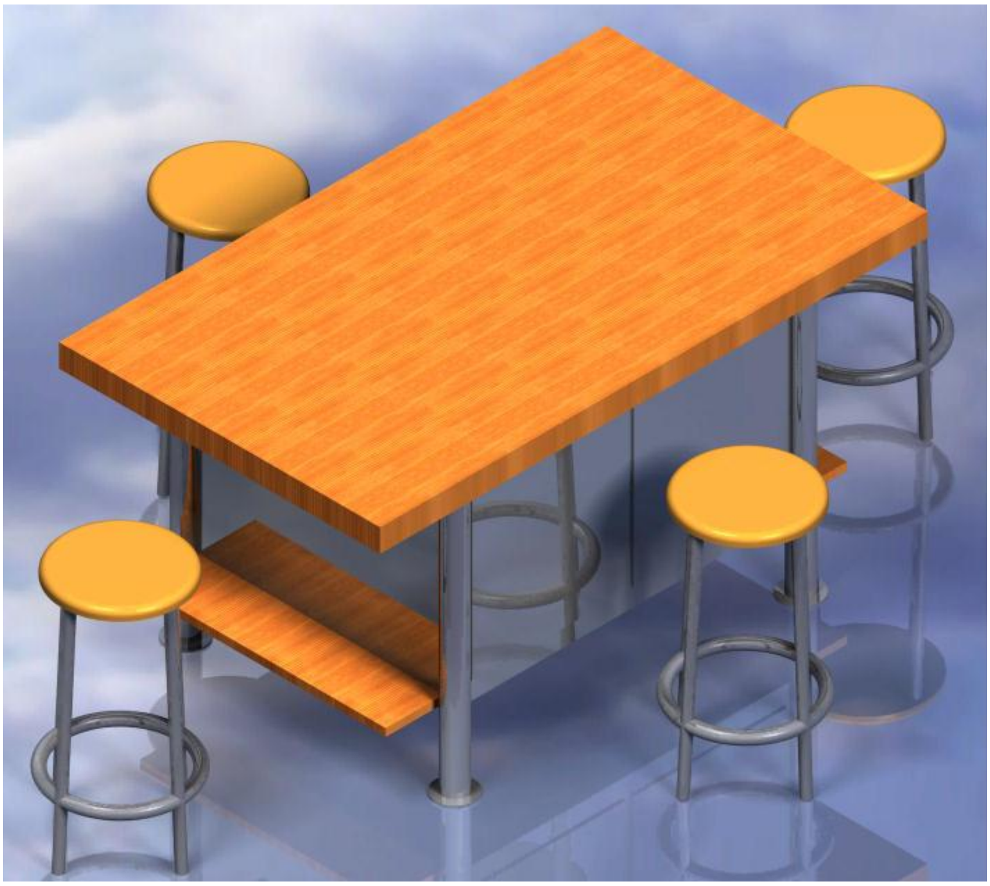


Figure 3.1. Current workstation in CAD drawing.

STAGE I

3.4 Evaluation of working postures

3.4.1 Questionnaire and comfort rating

The questionnaire used in this study was based on Dutch Musculoskeletal Questionnaire (DMQ), developed by Hildebrandt (2001). The questionnaire consists of 22 questions. These questions were categorized into four factors, dynamic workload (cutting task), dynamic workload (assembly task), workspace condition and force exertion. The dynamic loads questions covered awkward postures while performing the tasks, both in sitting and standing positions. The workspace condition included the comfort area and the force exertion in evaluating how they felt while performing cutting task. Appendix E shows the self – administrative questionnaire.

Data coding for the questionnaire is 1 = Yes and 2 = No. Workstation comfort rating to define subjects' perception towards the current workstation is included in the questionnaire. Likert scale of five levels, 1: Very discomfort; 2: Discomfort; 3: Medium comfort; 4: Comfortable; 5: Very comfortable were used to measure the comfort rating. A physical discomfort survey by using a body map indicator to identify pain and discomfort feeling on the body regions is included at the end of the questionnaire.

3.4.2 Physical posture assessment

Working postures for this study were analyzed by the following methods:

- RULA method is used to analyze the upper section of the body. It is best for sedentary and seated works. There are four levels of actions to indicate the obtained scores. Table 3.1 shows the actions level for RULA scores.

- REBA method is suitable for the whole body evaluation and best for both static and dynamic works. There are five levels of actions to indicate the obtained scores. Table 3.2 shows the actions level for REBA scores.

Table 3.1. RULA indication

Score	Indication
1 – 2	Posture is acceptable.
3 – 4	Investigation is needed and changes may be required.
5 – 6	Investigation and changes are required soon.
7 <	Investigation and changes are required immediately.

Table 3.2. REBA indication

Score	Risk level	Actions
1	Acceptable	Unnecessary
2 – 3	Low	May be necessary
4 – 7	Medium	Necessary
8 – 10	High	Necessary soon
11 – 15	Very high	Immediately

This study needed both methods because the tasks which were being analyzed require students to be in sitting and standing positions. Both methods will undergo statistical correlation test to identify their significant relationship. Appendix F shows both RULA and REBA evaluation sheets.

A total of 117 most happened working postures were used assessment analysis. The significant postures for each task were recorded using a JVC HD Everio camcorder while students performing the materials cutting and assembly tasks. The posture scores for both methods were calculated using programs from Ergonomic Ireland webpage. The data from RULA and REBA methods was further analyzed using SPSS 17.0 statistical software.

Figure 3.2. Cutting task

Figure 3.3. Assembly task

Figures 3.2 and 3.3 show how assembly and cutting tasks are performed in school workshop. Students used the workshop to complete a wood project for 1 hour and 45 minutes. Besides the coursework project, the workshop is also used as a classroom for Integrated Living Skills subject.

It was less fortunate for 13 year old students because they are only allowed to use conventional handsaw for cutting task instead of jigsaw machine unlike older students. Syllabus for machines application was only taught for 14 years old and above.

STAGE II

3.5 Workstation modification process

3.5.1 Kano model survey

In this study, students are viewed as the users (customers) because they are the target group in this study. They highlighted their problems and needs based on their experience with the current workstation. To reduce musculoskeletal disorder problems, it is necessary to change the work condition or the workstation itself. All students who participated in this study have the experience of using the current workstation for at least five hours.

The Kano questionnaire was constructed by direct users contact through interview and researcher personal observation (Appendix G). All relevant comments, suggestions and possible solutions of ergonomic consideration were included in the questionnaire. Table 3.3 shows each element classification and description. All elements are referred to Ergonomic Checkpoints by International Labour Office (2010).

The Kano Model lists six types of quality categories which are One dimension (O), Must-be (M), Attractive (A), Indifferent (I), Reversal (R) and Questionable result (Q). These qualities are determined by Kano questionnaires.

Table 3.3. The description of the Kano Model elements (International Labour Office, 2010)

No	Elements	Description
1	Broad work surface.	Size of the working table to be shared by four to five people at a time.
2	Workbench height.	Suitable to use by all students.
3	Stool and chair height.	Suitable to work with a fixed working table height.
4	Adjustable furniture.	Suitable for variety of body sizes.
5	Temporary storage.	Temporary place or container to put materials and tools.
6	Additional tools.	Advanced tools for better working performance.
7	Leg room.	Enough space for leg position and proper feet rest.
8	Back rest.	A proper back support for sitting work.
9	Stable workstation.	The workstation must be sturdy and robust in design.
10	Smooth working surface.	Avoiding damage to materials.
11	Safety design and application.	Secure electrical wiring, no sharp edges, and additional safety devices such as clamps and vices.

The qualities were examined by pairs of functional and dysfunctional questions of a same feature / element. The answer is given in five different ways: *I like it, I am expecting it, I am neutral, I can accept it and I dislike it*. A functional question asks about costumer's reaction if the product has the referred element. While a dysfunctional question asks about costumer's reaction if the product does not have the referred element (Guimaraes, 2005). These two types of questions were combined and analyzed using a Kano evaluation table (Appendix H), which results in a quality classification of each element (Kano et al., 1984).

According to Berger et al. (1993), Kano method is simplified and reduced into two values which are a positive and negative numbers named Customer Satisfaction Coefficient. These values are able to show on how each element can influence customer satisfaction if the element is provided and dissatisfaction if the element is not provided (Sims et al., 2012). The positive and negative values are relative with customer satisfaction and customer dissatisfaction respectively (Lu & Wang, 2008; Kouchi & Mochimaru, 2011). A study done by Lee et al., (2006) suggested the situation of customer satisfaction, where satisfaction will increase if the element was provided. However, in customer dissatisfaction case, satisfaction will decrease if the element was not included.

The customer satisfaction value specifies if the number is closer to 1, indicates the influence on customer satisfaction. While the customer dissatisfaction value specifies if the number is closer to -1, the influence on customer dissatisfaction is higher if the quality is unavailable (Matzler & Hinterhuber, 1998).

$$\textit{Customer Satisfaction} = (A + O) / (A + O + M + I) \qquad (1)$$

$$\textit{Customer Dissatisfaction} = (O + M) / (A + O + M + I) \qquad (2)$$

Data gathered from Kano questionnaire was analyzed using Kano evaluation table. By using the table, the total number of quality categories of each element can be determined. Appendix H explains how to analyze questionnaire data into Kano evaluation table.

Values for each quality categories are used in customer satisfaction and dissatisfaction equations. The final values of customer satisfaction and customer dissatisfaction are able to prioritize elements that are important to students. Customer satisfaction and customer dissatisfaction values for each quality element are used in the House of Quality matrix to classify important elements to be implemented in the new workstation design.

3.5.2 House of Quality

Quality Function Deployment approach is widely used to decide design characteristics of a new or improved product (Abd. Rahman Abdul Rahim & Mohd. Shariff Nabi Baksh, 2003). Most important phase in Quality Function Deployment is the House of Quality development. House of Quality completing stage is a critical phase to prioritize certain characteristics to be implemented into a product.

The initial phase of House of Quality development is to list all the elements expected by the users. Figure 3.4 shows the initial structure of the House of Quality matrix. Elements listed are the same as in Kano model questionnaire. To identify some particular elements to be prioritized, a set of user importance survey is distributed to 205 students. Five level of Likert scale are used in the survey: (Unimportant = 1, Most important = 5).

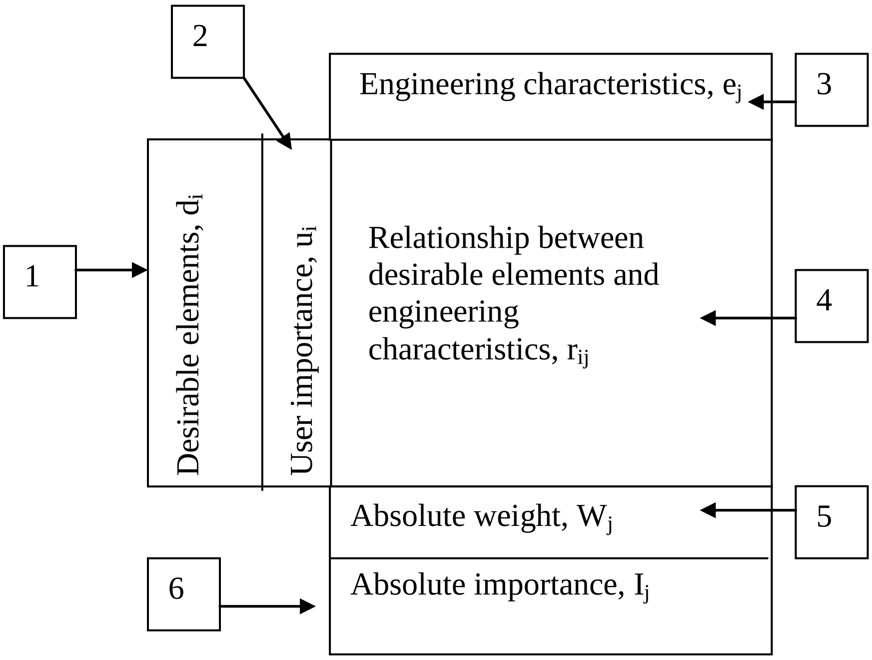


Figure 3.4. House of Quality initial structure (Lin et al., 2004)

Area 1 represents the desirable elements (d_i) which are the same with Kano Model elements. These elements are sorted into importance level (u_i), range qualitatively from 1 (unimportant) to 5 (most importance), which are included in area 2. Area 3 represents the engineering characteristics (e_j) of the workstation design. Area 4 analyses the interaction between the desirable elements and the engineering characteristics (r_{ij}) that takes value (strong = 5, moderate = 3, weak = 1) depending on the strength relationship between both of them. Area 5 reports the weight (W_j) that user assigns to each characteristic, calculated by adding all the scale numbers in the relationship matrix and multiplied by its importance scale (Chen & Chen, 2001). Area 6 shows the absolute weight in percentage values and named as Absolute importance (I_j).

$$\textbf{Absolute weight, } W_j = \sum_j \sum_i u_i r_{ij} \qquad (3)$$

where

u_i = user importance

r_{ij} = Relationship between desirable elements and engineering characteristics

3.5.3 *Kano model and Quality Function Deployment integration*

Data obtained from Kano Model method and user importance survey were integrated into the House of Quality matrix. The purposes of combining these methods are to maximize customer satisfaction and easily prioritize potential user requirements (Gupta & Srivastava, 2011; Yadav & Goel, 2008). Figure 3.5 shows a diagram of the House of Quality and Kano Model integration elements (Garibay et al., 2010).

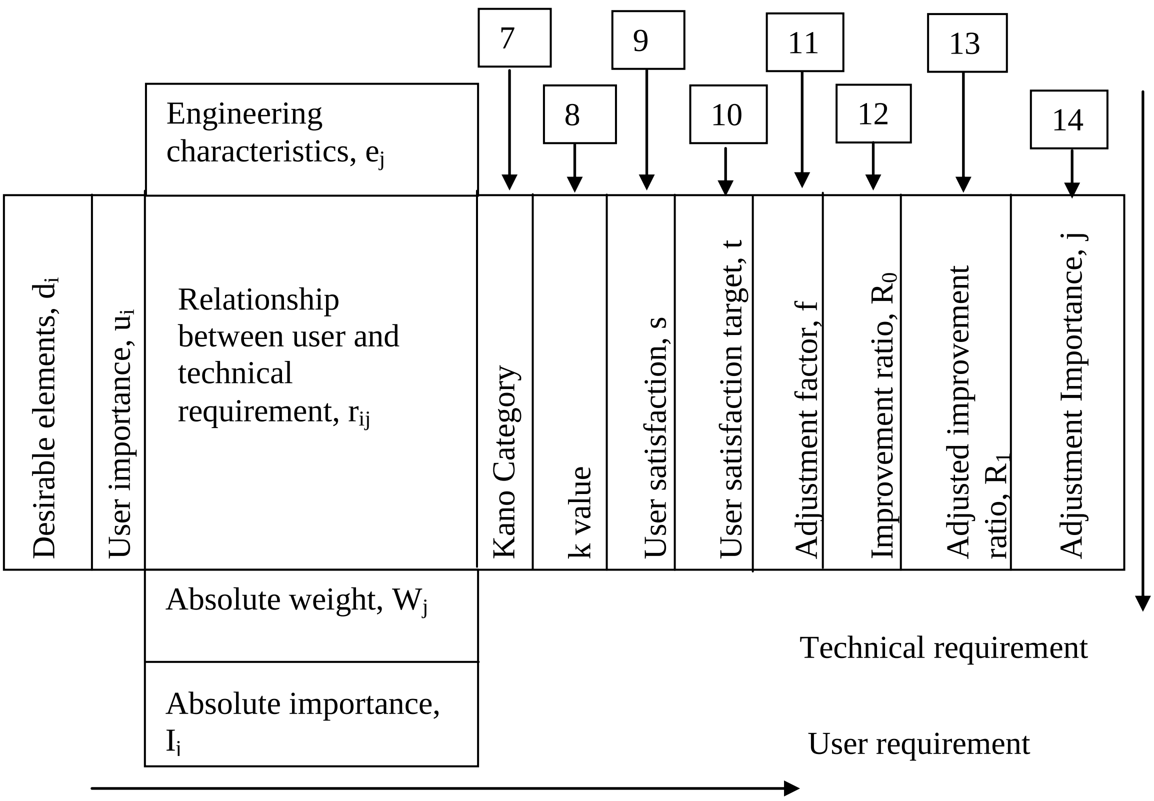


Figure 3.5. House of Quality and Kano Model integration elements

Area 7 and area 8 are the Kano category and its k values. The k value is decided accordingly to extended options by Chaudha et al. (2011). The value of k is defined as 0, 0.5, 1 and 1.5 for Indifferent (I), Must-be (M), One-dimensional (O) and Attractive (A), respectively. Area 9 is the user satisfaction, s. The value is the mean calculated for each element from the user importance survey.

Area 10 is the target expectation for each element, reported by the users from the user importance survey. Area 11 is the adjustment factor. It is proposed by Tontini (2007) to be used directly in the Quality Function Deployment matrix.

Adjustment factor, f = max ([CS], [CD]) ***(4)***

where

CS = Customer satisfaction

CD = Customer dissatisfaction

Area 12 is the improvement ratio. The ratio is to measure user satisfaction degree for each user attribute to each element listed. Tan & Shen (2000) suggested a calculation to describe the user satisfaction improvement ratio.

Improvement ratio, $R_0 = t / u$ ***(5)***

where

t = User satisfaction target

u = User importance

The adjusted improvement ratio, R_1 in area 13 is recommended by Chaudha et al. (2011) which used important parameters from Kano method to contribute into Quality Function Deployment matrix.

Adjusted improvement ratio, $R_1 = (1 + f)^k \times R_0$ ***(6)***

where

f = Adjustment factor

k = Kano Category

R_0 = Improvement ratio

Area 14 is the adjustment importance, j which is obtained from multiplying the adjusted improvement ratio to the user importance. This value indicates clear understanding of prioritizing the elements expected by target users.

3.6 Anthropometric measurement and data collection

In this study, manual and scanning methods are used for data collection. Manual measurement method is used for seated position. While for standing position, the scanner used for data collection was the *[TC]*^{2} *NX-16* body measurement system. The system was successfully able to capture the body image within 6 seconds and extracted the relevant anthropometry data into ergonomic software such as Jack and Delmia (Zwane et al, 2010; Shengfeng et al., 2011). The implementation of 3D body measurement system was able to save time and labour cost.

Anthropometry data of 13 to 15 years old students were needed for modification purpose. Thus, their body sizes would matched perfectly to the new workstation design.

In this study, collection of anthropometry data uses combination methods of indirect measurement technique which are three dimensional image-based and manual methods for some selected postures.

146 subjects of 12 measurements were collected by trained researchers. Students' sizes of 5th percentile and 95th percentile of both genders were used in the design stage. 146 students were involved in the anthropometric measurements.

The scanner used for data collection was the *$[TC]^2$ NX-16* body measurement system. A study done by Sims et al. (2012) approved the validity of the method with no significant difference between body scanner and traditional methods for easily-identifiable bony landmarks. They also ensured that the scanner method is theoretically capable of yielding accurate results.

Manual method is used to measure anthropometry data focusing in sitting position and some measurements in standing position. The measurements taken were:

- Stature
- Elbow height
- Shoulder - elbow height
- Elbow – wrist length
- Forward reach
- Buttock – popliteal length
- Tight thickness
- Popliteal height
- Hip breath

Next, design development process is conducted using Computer Aided Design (CAD) software. Computer Aided Three-dimensional Interactive Application (CATIA) by Dassault Systems is used as computer aided design tool.

STAGE III

3.7 Ergonomic simulation

Digital human modeling simulation is the final analysis which can be used to validate the results of this study. The simulation is needed to validate the new workstation and to approve its efficiency. Digital Human Modeling is able in creating realistic environment just like the real process. In order to cut cost of a real prototype workstation and human presence, this method gives the best result to achieve the objective. A digital environment has been developed by simulating a real life workstation for wood and composite materials product tasks of a coursework project for lower secondary students in Malaysia. Videos from the cutting and assembly tasks performed by real students are used to identify the critical body postures. Then, ergonomic evaluation of these postures is performed with the use of digital manikins.

3.7.1 Jack 7.1

Jack 7.1 simulation software is an ergonomics evaluation program to evaluate and improve the ergonomics of product / workstation design to fit with human body. Jack software is capable in analyzing physical ergonomics issues such as lower back risk, fatigue prediction, and metabolic energy expenditure. These analysis tools can be achieved in Task Analysis Toolkit (TAT) which is focused to analyze industrial tasks (Siemens PLM software, 2011b). It is useful to determine a worker performance and identify potential risks that expose the worker to injury. Besides, its' capability of positioning the virtual human into various postures enable users to conduct ergonomic assessment in virtual workplace (Shengfeng et al., 2011).

Besides Task Analysis Toolkit, Jack software also provides the Occupant Packaging Toolkit (OPT) which is focused to help in designing vehicle interiors for maximum comfort and performance (Siemens PLM software, 2011a). Another advantage of using Jack is the Task Simulation Builder (TSB) application. Task Simulation Builder provides a high-level simulation standard which is very flexible to tackle 'what – if' scenarios including changing environment and varying human models (Siemens PLM software, 2011c).

This study utilized Rapid Upper Limb Assessment (RULA) and Low Back Analysis (LBA) as its evaluation tool. In this study, material cutting and assembly tasks were evaluated separately using virtual humans. The humans' sizes used are the demographic data of six subjects from physical posture assessment and also the 5th percentile, 50th percentile and 95th percentile of both male and female anthropometry data. There are 12 manikins to be created for simulation. From the analysis, the risk exposure level can be determined whether the proposed design workstation is able to reduce ergonomic risks to the students.

Six manikins were created based from the 5th percentile, 50th percentile and 95th percentile of the anthropometric collection. Six manikins were also created for comparison of six samples from physical posture assessment. Their height and weight were used for human model set up. Results obtained will be compared to determine whether the proposed workstation is able to improve the RULA and Low Back Analysis scores. Reviews of these analysis tools used in this study are discussed below.

3.7.2 Rapid Upper Limb Assessment (RULA) method.

RULA is used to reveal awkward postures and the risk of upper limb disorder when performing task at the new designed workstation. This study uses the RULA tool to evaluate postures of the upper limb and decide whether the proposed workstation is able to reduce the assessment score compare to the current workstation.

3.7.3 Low back analysis (LBA) method.

Low Back Analysis is used to evaluate spinal force acting on the lower back while performing a task. It can be accessed in any posture and loading condition. This tool is used as a supporting result to evaluate postures of the lower limb. It is as the replacement of REBA method from the ergonomic evaluation stage. This method can provide information of compression, shear forces and axial spinal reaction (torques) on the L4 / L5 vertebral disc joint. It shows the compression forces compared to National Institute of Occupational Safety and Health (NIOSH) recommended force limit (Siemens PLM software, 2011b). Table 3.4 shows the three levels of risk identified for manual task evaluation according to National Institute of Occupational Safety and Health (1981) Guide:

Table 3.4. Work Practice Guide for Manual Task

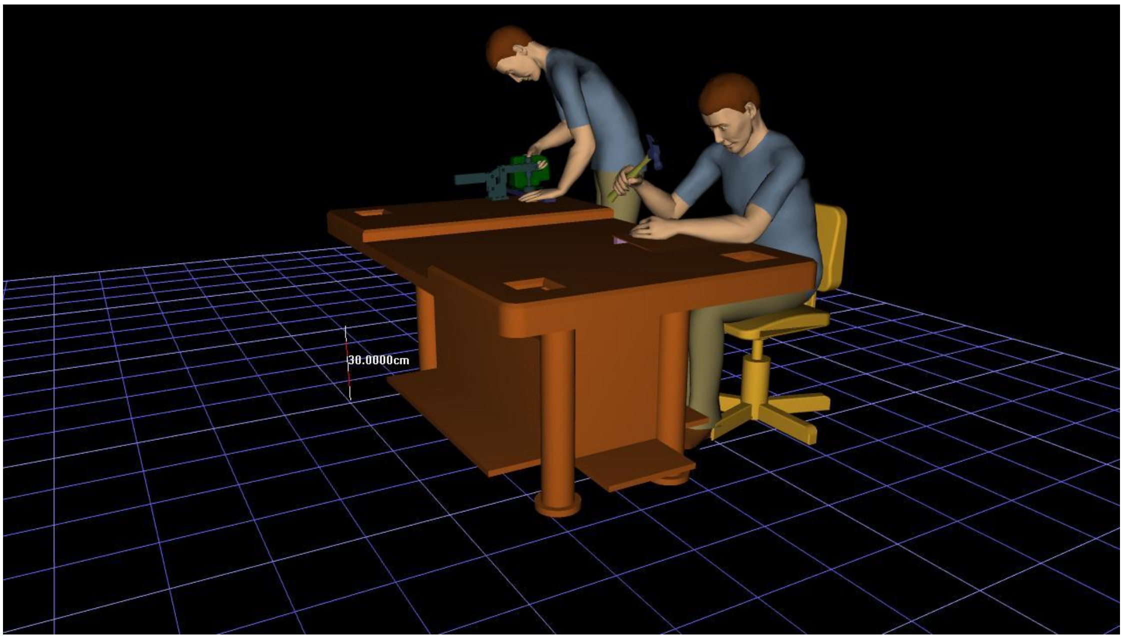
Manual task evaluation	**Compression force (N)**
Below the Action Limit	< 3400
Above the action limit	3400 - 6400
Above the maximum Permissible Limit	> 6400

The main digital items in this study are the workbench and chair. Other items are additional tools and materials to perform the work tasks. These items are jigsaw machine, hammer, handsaw, toggle clamp, Medium Density Fiber board and dressed timbers. These items can be loaded from Jack 7.1 library. The main digital items are imported from CATIA V5 Computer Aided Design (CAD) software, after the files are converted into *.igs* files format using the CAD software. Figure 3.8 demonstrates the working environment of cutting and assembly tasks.

3.8 Summary

The methodology proposed in this study is able to obtain desirable results in improving students' working postures in the school workshop. These methods include questionnaire design, physical posture assessment, interview and observation, Kano model method and House of Quality integration matrix analysis and human modeling simulation in Jack 7.1 ergonomic software.

This study has identified a number of tools to analyze the working postures. The tools include questionnaire and body map survey, Rapid Upper Limb Assessment (RULA) and Rapid Entire Body Assessment (REBA). By not dealing with the risk factors, students may experience back pain and muscle strain while using the school furniture. This study will recommend an ergonomic intervention to the furniture design to improve the students' working postures. The intervention process will use two methods to redesign the workstation and at the same time will fulfill user requirement and satisfaction. The methods are Kano model and Quality Function Deployment. In order to validate the proposed design, digital human modeling simulation will be used to compare the postures' scores.



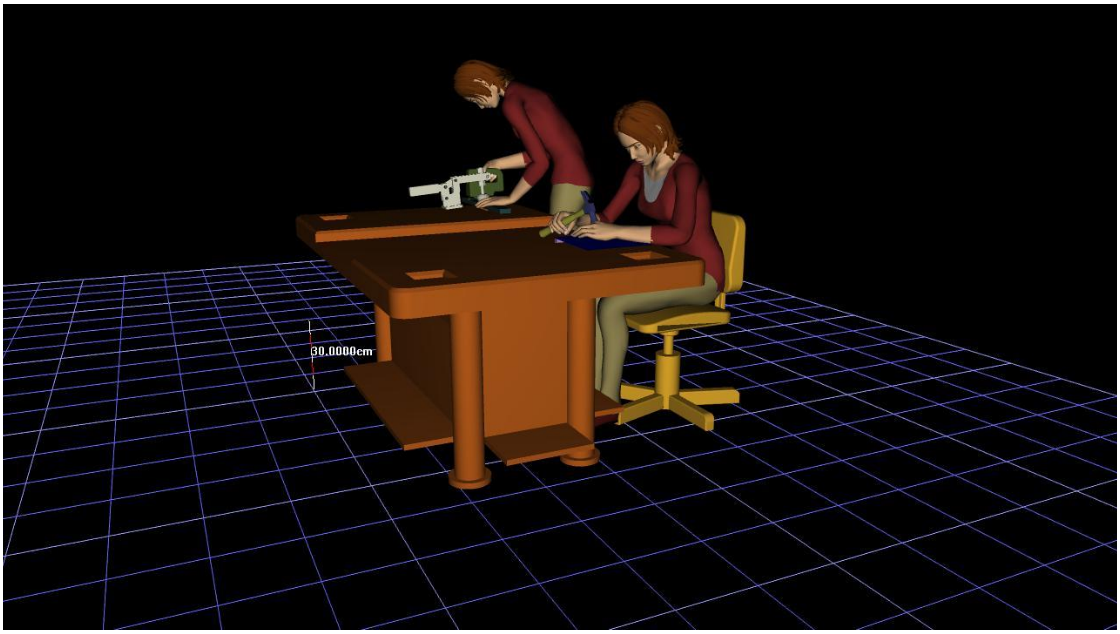


Figure 3.6: Working environment

Chapter 4

PILOT STUDY

4.1 Introduction

Two pilot studies were conducted prior to testing. The purpose of a pilot study was to avoid unnecessary questions and reduce the number of subjects for physical posture assessment. The evaluation was conducted using two methods which were:

1. Perception views: Based on the Dutch Musculoskeletal Questionnaire survey, comfort rating and body map. The body map was used to assess the discomfort feeling and pain when performing their tasks.
2. Physical posture assessment: RULA and REBA methods were used to evaluate awkward postures.

Factors that need to be considered were the questionnaire content and layout. As for posture assessment, selection criteria for the chosen postures to be evaluated were based on their common occurrences while performing the tasks.

4.2 Questionnaire result

Pilot study was performed to clarify whether the terminology and content of the questionnaire would be interpreted correctly. This was necessary as some of the languages used could be misunderstood and confused the participants.

The first section of the questionnaire were comfort rating for the workstation and students' opinion on the workstation. There were 27 questions consist in the questionnaire. Subjects were randomly selected: eight teachers and 10 students for the pilot study survey. All the teachers taught Integrated Living Skill subject. The questionnaire was given at the end of the Integrated Living Skills class and collected the next day.

Figures 4.1 until 4.4 showed the percentage of risk exposure for each factor: dynamic workload (cutting), dynamic workload (assembly), workspace's condition and force exertion.

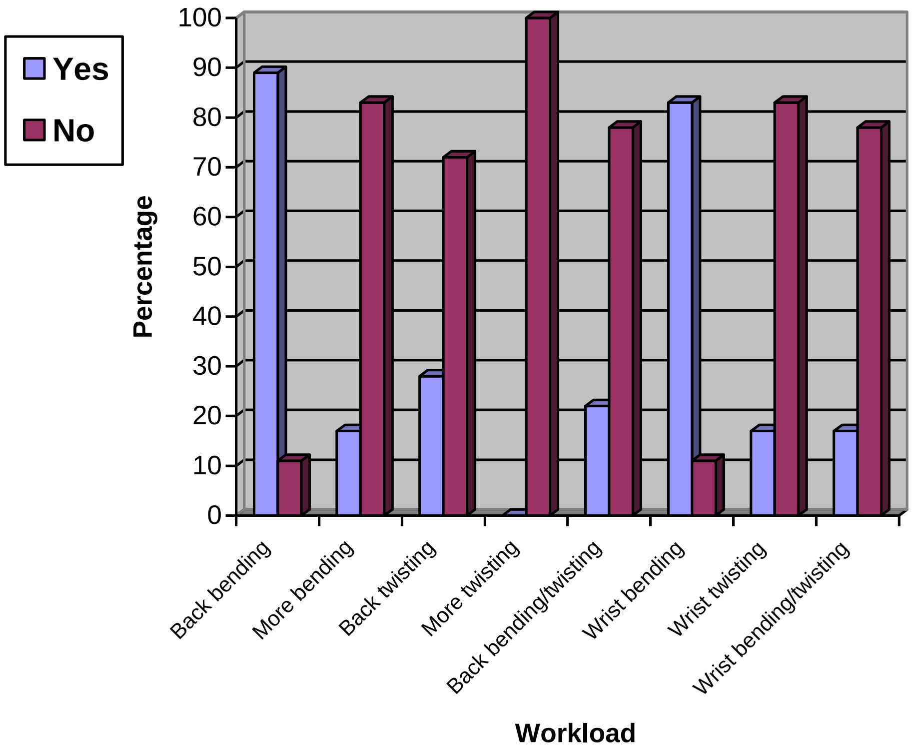


Figure 4.1. Percentages of dynamic workload (cutting)

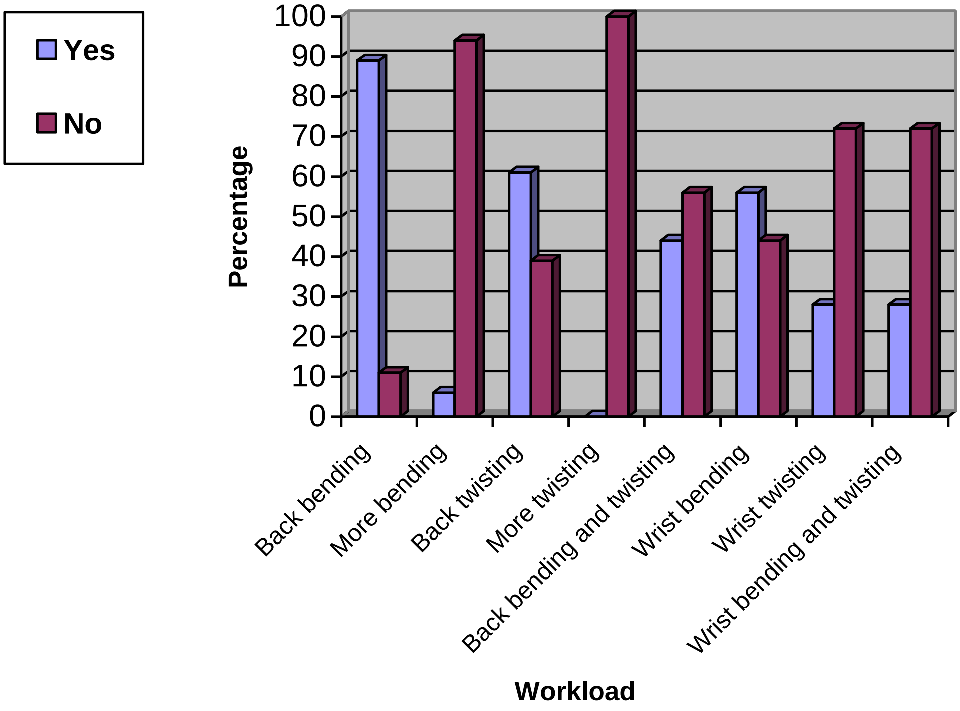


Figure 4.2. Percentages of dynamic workload (assembly)

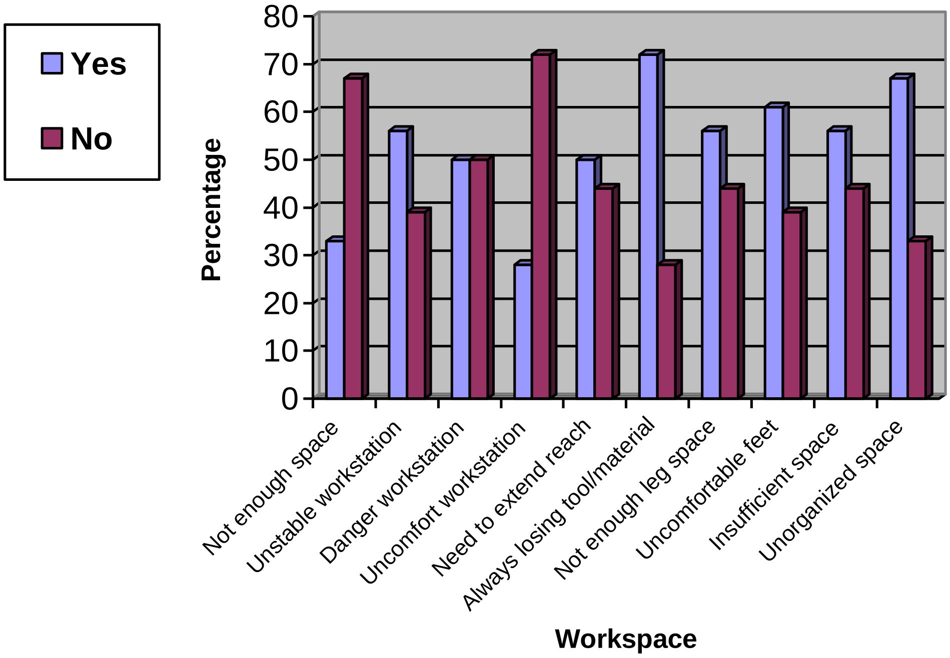


Figure 4.3. Percentages of workspace condition

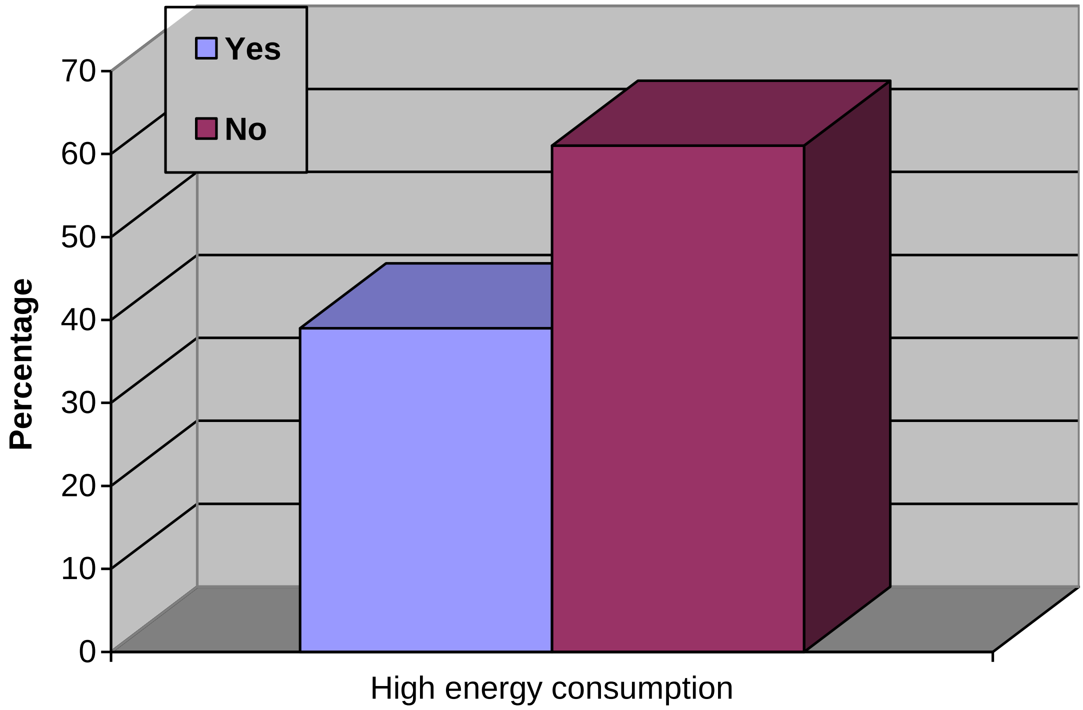


Figure 4.4. Percentages of force exertion

The results highlighted that all subjects were bending their back for cutting and assembly tasks. Most subjects had to twist their back when performing assembly task. In addition, most subjects reported on lack of legroom and their feet felt uncomfortable. The results also indicated that the workspace was insufficient and unorganized for more than half of the subjects.

The results of the pilot study indicated that the students had no experience of major bending and twisting their back for both dynamic workloads (cutting and assembly tasks). Therefore, some questions related to major bending and twisting need to be discarded. Some questions in workspace condition factor which were too general and confusing were also removed from the questionnaire.

As for comfort rating and body map evaluation, 44% of subjects rated the workstation as moderate in comfort and 39% of subjects rated as discomfort. 67% and

72% of subjects experienced back and neck pain respectively. These results indicated that there were risk factors in the school workshop that could lead to musculoskeletal disorder.

4.3 Physical posture assessment

Pilot study was also conducted on 60 students to determine whether the RULA and REBA methods were reliable to be used in this study. 104 most happened working postures were assessed using evaluation sheets. Scores among age and gender were measured to assess working postures' differences.

Figures 4.5 and 4.6 showed the percentage of RULA and REBA evaluation scores among age. The results showed that 13 year old students had the greatest scores for both methods. RULA mean values were 5.4 (SD 1.13), 5.1 (SD 1.14) and 4.52 (SD 0.82) while REBA mean values were 6.0 (SD 1.54), 5.5 (SD 1.50) and 4.8 (SD 1.43) for 13, 14 and 15 year old respectively. Figures 4.7 and 4.8 showed the percentage of RULA and REBA evaluation scores among gender. The results showed that the male students had greater score for RULA while the female students had greater score for REBA. RULA mean values were 5.12 (SD 1.14) and 5.00 (SD 1.08) while REBA mean values were 5.52 (SD 1.68) and 5.54 (SD 1.34) for male and female students, respectively.

A score of 5 in RULA required changes soon whereas score 4, changes may be required. On the other hand, for REBA method, the range of score is from 4 to 7 which were in medium level. The medium level indicated as actions are necessary to be taken.

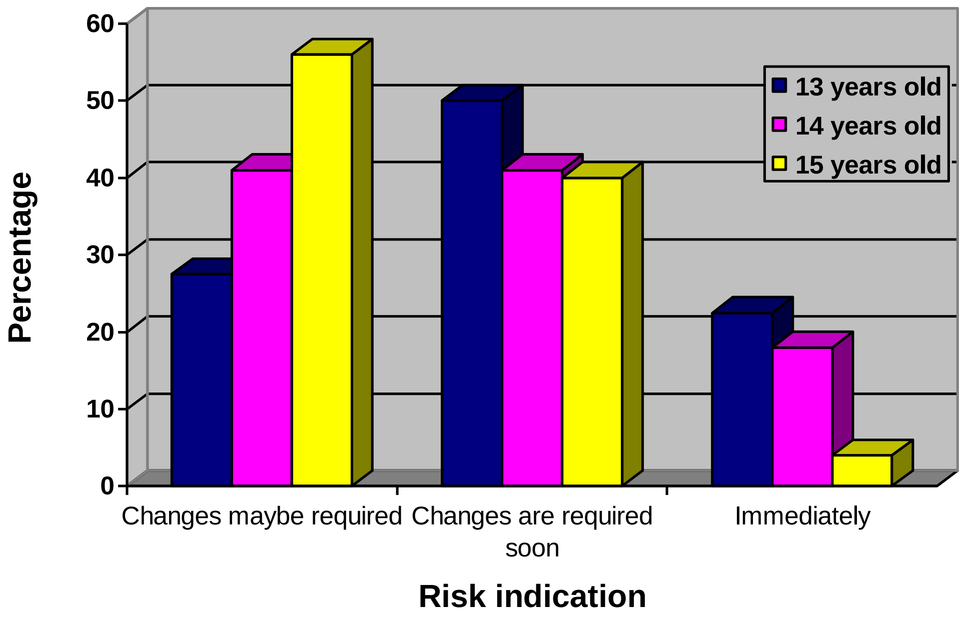


Figure 4.5. RULA analysis between ages

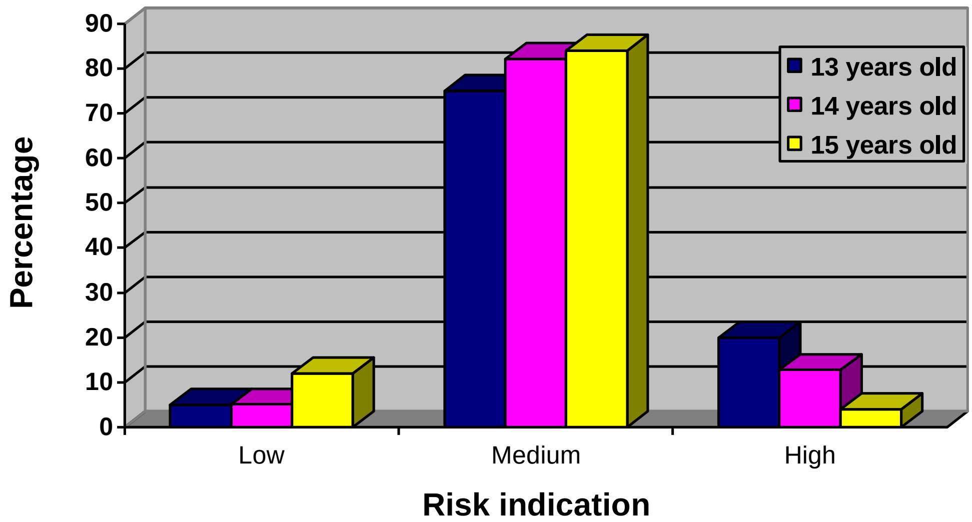


Figure 4.6. REBA analysis between ages

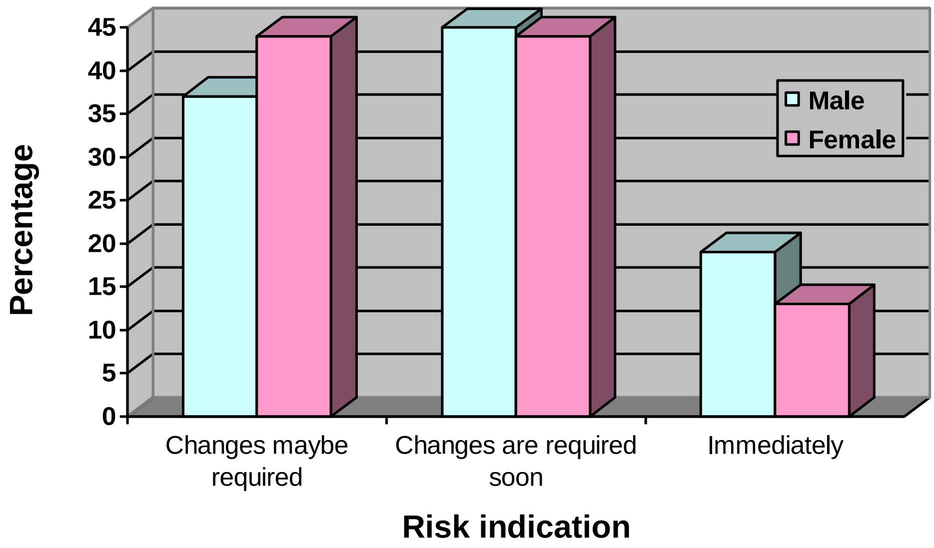


Figure 4.7. RULA analysis between genders

Based on RULA and REBA scores, it can be determined that older students and female students were more compatible with the current workstation. The results from the physical posture assessment described that 13 year old male students had higher average scores for both RULA and REBA methods.

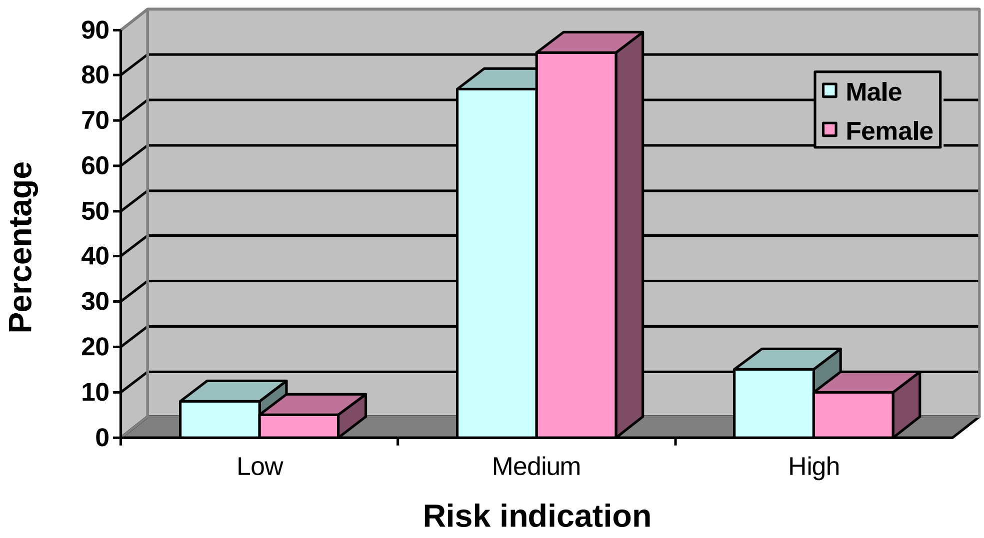


Figure 4.8. REBA analysis between genders

4.4 Summary

After conducting pilot tests, revisions on the questionnaire were made. Some feedbacks from the teachers were taken into consideration in order to improve the content of the questionnaire. Some of the questionnaires with predicted answers and redundant questions were taken out and left 22 questions remain. The layout of the questionnaire was rearranged with the comfort rating was placed before the body map so students could rate the workstation in general before going into detail of specific body parts. Subjects' problems and suggestions were placed at the end of the questionnaire. The number of subjects was reduced into 6 students which represent for each age and gender to clarify whether age and gender have significant correlation with the postures' scores.

Chapter 5

ERGONOMIC EVALUATION ANALYSIS

5.1 Introduction

This chapter presented the results and discussion of the ergonomic evaluation on students' working postures while performing tasks using the current workstation. Nonparametric tests were carried out to determine the differences among age using Kruskal-Wallis test while genders were determined using Mann-Whitney test. The relationship between RULA and REBA methods were determined using correlation analysis. The objective of this chapter was to investigate students' working postures of the current workstation.

5.2 Questionnaire

5.2.1 Dutch Musculoskeletal Questionnaire (DMQ)

Instruments used to investigate students' working condition and risks factors were the Dutch Musculoskeletal questionnaire, body map and comfort rating. These instruments were given to subjects after they finished their coursework project. Questionnaire validity was measured by using SPSS 17.0. Table 5.1 showed the questionnaire validity test.

Table 5.1. Validity test of questionnaire

Factor	**Content**	**No. of question**	**Cronbach's alpha**
Dynamic workload (cutting task)	Bending and twisting of neck, trunk and wrist.	9	0.669
Dynamic workload (assembly task)	Bending and twisting of neck, trunk and wrist.	9	0.768
Working space	Leg room, footrest and work area.	3	0.685
Independent factor	Force exertion in cutting task.	1	-

Table 5.2 and 5.3 showed the demographic data and the age distribution of the subjects. The demographic data as seen in Table 5.2 showed that the height of the students is increased with their age. The data indicated that younger students are shorter than older students. Based on Body Mass Index (BMI) value, all subjects can be categorized as in normal weight category.

Table 5.2. Demographic data of subjects

Gender	**Age**	**Mean (Standard Deviation)**		
		Height (m)	Weight (kg)	BMI
Male	13 year old	1.52 (0.07)	41.1 (14.1)	18
	14 year old	1.58 (0.08)	48.8 (13.1)	20
	15 year old	1.62 (0.06)	54.7 (12.5)	21
Female	13 year old	1.53 (0.08)	49.8 (15.9)	21
	14 year old	1.54 (0.06)	45.4 (9.6)	19
	15 year old	1.55 (0.05)	45.9 (8.9)	19

The age distribution shows that half of the subjects are 14 year old students and the number of female subjects that are participated in the survey is higher than male subjects.

Table 5.3. Age distribution of subjects

Gender	**Age**	**N**	**%**	**Gender**	**Age**	**N**	**%**
Male	13 year old	46	27.4	Female	13 year old	31	14.9
	14 year old	70	44.6		14 year old	98	58.3
	15 year old	47	28.0		15 year old	44	26.8
	Total	163	100		Total	173	100

The questionnaire results were presented in mean values. Table 5.4 showed the mean range for each factor. The lower mean means the more risk exposure.

Table 5.4. Mean range for each factor

Number of questions	**Factor**	**Range**	
		Minimum	Maximum
9	Dynamic workload (Cutting)	9	18
9	Dynamic workload (Assembly)	9	18
3	Workspace condition	3	6
1	Force exertion	1	2

Tables 5.5 and 5.6 showed the comparison of four factors among ages and genders, respectively. Figures 5.1 and 5.2 showed the mean of each factor for clearer comparison.

Table 5.5. Mean scores between ages

Age	Mean (SD)			
	Dynamic workload (Cutting)	Dynamic workload (Assembly)	Workspace condition	Force exertion
13 years old	13.77 (1.9)	13.04 (2.3)	4.84 (1.0)	1.23 (0.4)
14 years old	14.45 (1.4)	13.74 (2.1)	4.52 (1.1)	1.55 (0.5)
15 years old	14.25 (1.4)	13.51 (1.8)	4.07 (1.2)	1.58 (0.5)

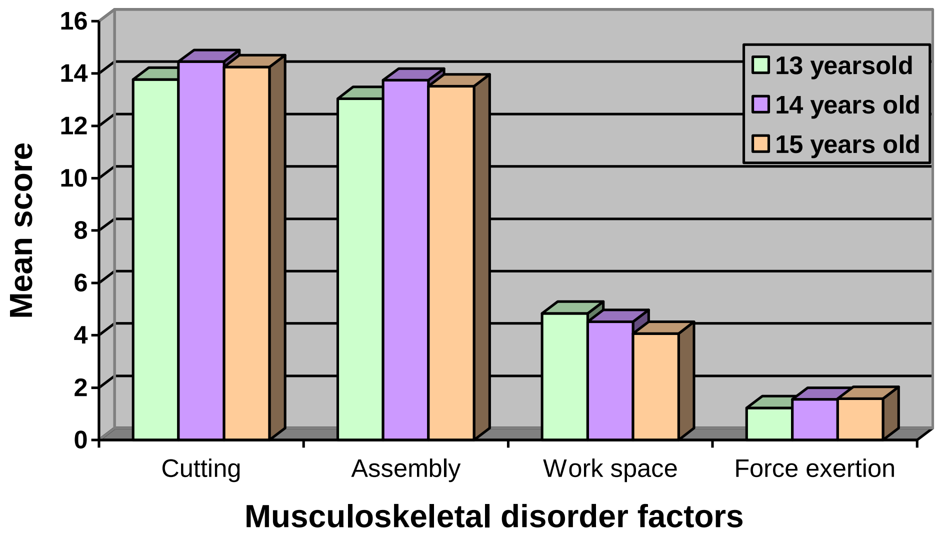


Figure 5.1. Mean scores between ages

The results indicated that 13 year old students had more difficulties in fitting themselves to the current workstation, both for cutting and assembly task. Most 13 year old students have smaller body sizes compared to 14 and 15 year old students. A study by Castellucci et al., (2010) indicated that standard school furniture did not accommodate younger students and suggested to define an additional lower size mark compared to the existing ones. All students also had more difficulties while performing assembly task. Based from the result, 50.3% of students answered ‘yes’ for bending and twisting their back at the same time when performing assembly task by using the current workstation.

Table 5.6. Mean scores between genders

Gender	**Mean (SD)**			
	Dynamic workload (Cutting)	Dynamic workload (Assembly)	Workspace condition	Force exertion
Male	14.24 (1.6)	13.50 (2.0)	4.38 (1.1)	1.50 (0.5)
Female	14.24 (1.5)	13.54 (2.1)	4.55 (1.2)	1.47 (0.5)

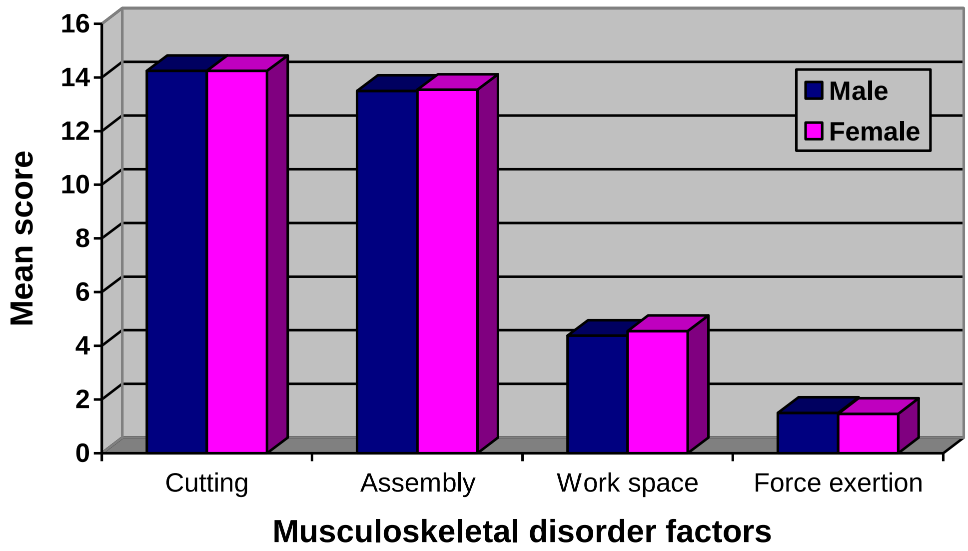


Figure 5.2: Mean scores between genders

The results showed that male students faced higher risks for dynamic workload (assembly task) and workspace condition while for dynamic workload (cutting task), the number was equally the same for male and female students. On the other hand, the female students faced higher risks for force exertion factor.

A Kruskal-Wallis and a Mann-Whitney test were performed to determine differences among ages and genders in tables 5.7 and 5.8, respectively. The Kruskal-Wallis test showed a significant difference of risk exposure among ages for all factors. Table 5.3 showed that 13 year old students tended to face higher risk exposure in cutting task (χ^2 = 8.08, $p < 0.05$), assembly task (χ^2 = 6.39, $p < 0.05$) and force exertion (χ^2 = 25.98, $p < 0.01$) factors compared to older students. However, there were no significant differences of all factors among gender ($p > 0.005$). Statistical analysis carried out is shown in Appendix J.

Table 5.7. Kruskal-Wallis test for comparison of risk exposure

	Factor	Age	Mean Rank	P value
Score for risk exposure	Dynamic workload (Cutting)	13 year old	145.64	0.018
		14 year old	180.55	
		15 year old	163.88	
	Dynamic workload (Assembly)	13 year old	146.03	0.041
		14 year old	179.45	
		15 year old	167.30	
	Workplace	13 year old	199.39	0.000
		14 year old	172.29	
		15 year old	133.86	
	Force exertion	13 year old	125.77	0.000
		14 year old	179.50	
		15 year old	184.35	

Table 5.8. Mann-Whitney test for comparison of risk exposure

	Factor	Gender	Mean Rank	P value
Score for risk exposure	Cutting	Male	169.44	0.779
		Female	166.66	
	Assembly	Male	167.16	0.804
		Female	169.77	
	Workplace	Male	161.33	0.207
		Female	174.25	
	Force exertion	Male	171.02	0.595
		Female	166.13	

5.2.2 Comfort rating

The purpose of the comfort rating was to rate students' overall perception on the workstation. Likert scale of five levels, 1: Very discomfort; 2: Discomfort; 3: Medium comfort; 4: Comfortable; 5: Very comfortable were used to measure the comfort rating. Table 5.9 and 5.10 showed the comparison of the workstation's comfort level among students' age and gender.

Table 5.9. Comfort rating between ages

Comfort rating	**Age**		
	13 year old	14 year old	15 year old
Very discomfort	-	6	9
Discomfort	2	16	29
Moderate comfort	44	107	41
Comfortable	22	30	11
Very comfortable	5	2	-

Table 5.10. Comfort rating between genders

Comfort rating	**Gender**	
	Male	Female
Very discomfort	6	9
Discomfort	20	27
Moderate comfort	84	108
Comfortable	38	25
Very comfortable	7	-

The results showed that older students and female students tended to rate the current workstation as uncomfortable. The current workstation was rated as very comfortable by 5 (13 year old) and 2 (14 years old) male students. However, there were no 15 year old students and female students rated the current workstation as very comfortable.

Statistical tests were carried out to determine the difference among ages and genders associated to comfort rating. A Kruskal – Walllis test indicated a strong significant difference of comfort rating among ages. Table 5.11 showed that older students tended to rate the current workstation as discomfort compared to younger students (χ = 2, p = 0.00). A Mann – Whitney test indicated a significant difference of comfort rating among genders. Table 5.12 showed that female students tended to rate the current workstation as discomfort compared to male students (Z = -2.78, p = 0.005). Statistical analysis carried out is showed in Appendix K.

Table 5.11. Kruskal-Wallis test for comparison of comfort rating

	Age	Mean Rank	P value
Score for comfort rating	13 year old	204.78	0.000
	14 year old	166.79	
	15 year old	120.53	

Table 5.12. Mann-Whitney test for comparison of comfort rating

	Gender	Mean Rank	P value
Score for comfort rating	Male	175.85	0.005
	Female	150.25	

2.6.1 Body map

Discomfort survey was determined by a body map. Students were told to mark the body areas that felt pain or uncomfortable while using or after using the current workstation. Tables 5.13 and 5.14 showed the pain on body regions associated with age and gender.

Table 5.13. Pain on body region between ages

	Percentage (%)				
Age	**Neck**	**Shoulder**	**Elbow**	**Wrist**	**Upper back**
13 years old	58.0	40.6	18.8	49.3	30.4
14 years old	65.6	43.7	19.9	43.0	64.9
15 years old	59.3	47.7	19.8	45.3	75.6
Age	**Waist**	**Lower back**	**Hip**	**Knee**	**Ankle**
13 years old	13.0	7.2	11.6	13.0	21.7
14 years old	35.8	31.1	20.5	21.9	17.9
15 years old	61.6	27.9	30.2	23.3	36.0

Table 5.14. Pain on body region between genders

	Percentage (%)				
Gender	**Neck**	**Shoulder**	**Elbow**	**Wrist**	**Upper back**
Male	58.7	38.5	23.1	41.3	57.3
Female	65.0	49.1	16.6	48.5	62.6
Gender	**Waist**	**Lower back**	**Hip**	**Knee**	**Ankle**
Male	42.0	24.5	21.0	21.0	23.8
Female	34.4	25.2	21.5	19.6	23.9

The results indicated that older students and female students complained more frequently for most body regions. These results agreed with the results of the studies conducted by Grimmer & Williams, (2000); Taimela et al., (1997); Tsang et al., (2008).

Table 5.15. Kruskal-Wallis test for comparison of body pain

	Factor	Age	Mean Rank	P value
Score for body pain	Neck	13 year old	176.23	0.590
		14 year old	164.50	
		15 year old	169.35	
	Shoulder	13 year old	174.91	0.492
		14 year old	170.00	
		15 year old	160.31	
	Elbow	13 year old	170.14	0.955
		14 year old	168.50	
		15 year old	167.12	
	Wrist	13 year old	163.32	0.666
		14 year old	172.50	
		15 year old	165.50	
	Upper back*	13 year old	214.68	0.000
		14 year old	162.50	
		15 year old	140.50	
	Lower back*	13 year old	206.86	0.000
		14 year old	172.50	
		15 year old	128.65	
	Buttock*	13 year old	195.59	0.001
		14 year old	159.50	
		15 year old	162.19	
	Hip*	13 year old	183.55	0.011
		14 year old	170.00	
		15 year old	153.00	
	Knee	13 year old	179.86	0.198
		14 year old	166.50	
		15 year old	162.58	
	Ankle*	13 year old	172.27	0.003
		14 year old	178.00	
		15 year old	147.77	

Statistical tests were carried out to determine the difference between ages and genders associated with body pain. A Kruskal – Walllis test indicated significant differences of body pain in five body parts as shown in table 5.15. Pain on upper back (χ = 34.5, p = 0.00), lower back (χ = 40.7, p = 0.00), buttock (χ = 14.9, p = 0.001), hip (χ = 9.0, p = 0.011) and ankle (χ = 11.5, p = 0.003) were complained most by 15 year old students. A Mann – Whitney test indicated no significant differences in all body parts except for shoulder between genders as shown in table 5.16. Statistical analysis carried out is shown in Appendix L.

Table 5.16. Mann-Whitney test for comparison of body pain

	Factor	Gender	Mean Rank	P value
Score for body pain	Neck	Male	176.92	0.072
		Female	160.56	
	Shoulder*	Male	179.31	0.020
		Female	158.31	
	Elbow	Male	164.49	0.268
		Female	172.28	
	Wrist	Male	176.69	0.078
		Female	160.78	
	Upper back	Male	175.98	0.112
		Female	161.45	
	Lower back	Male	164.66	0.393
		Female	172.12	
	Buttock	Male	170.43	0.626
		Female	166.68	
	Hip	Male	170.08	0.672
		Female	167.01	
	Knee	Male	168.58	0.983
		Female	168.42	
	Ankle	Male	169.96	0.709
		Female	167.13	

5.3 Physical posture assessment

Assessment methods used for this evaluation were Rapid Upper Limb analysis (RULA) and Rapid Entire Body Analysis (REBA). Both methods were used due to the tasks involved with sitting and standing postures. There were 6 students participated in the assessment represented for each age and gender. The mean height of the subjects was 1.55 m (SD 0.09), weight was 47.5 kg (SD 5.75), and Body Mass Index (BMI) was 19.85 kg / m2 (SD 2.25).

Table 5.17 showed the mean scores obtained from the RULA and REBA evaluation. A total of 117 most happened working postures were evaluated by using both methods. There were 49 postures of cutting task and 55 postures of assembly task. All postures scores were combined to find the mean scores of RULA and REBA. The analysis results revealed that risk level for students' postural condition was in medium range, which indicated changes should be applied the soonest possible.

Table 5.17. Mean scores of RULA and REBA methods

	RULA	**REBA**
Mean	5.17	6.08

Tables 5.18 and 5.19 showed the results of percentage distribution of RULA and REBA indication. Figures 5.3 and 5.4 illustrated the results in charts for clearer comparison. The results have found out that changes were needed and necessary to improve students' working postures.

Table 5.18. Percentage distribution of RULA indication

RULA Indication	**Percentage (%)**
Changes can be required	33
Changes are soon required	57
Changes are immediately required	11

Table 5.19. Percentage distribution of REBA indication

REBA Indication	**Percentage (%)**
Changes can be necessary	7
Changes are necessary	70
Changes are fast necessary	23

Figures 5.5 and 5.6 showed the percentage distribution of RULA and REBA scores between age and gender. The results indicated that students' posture scores in RULA was in medium to low risk. Students' did not faced high difficulties on their upper extremist. However, posture scores in REBA indicated that students faced medium to high risk. The result showed that students' tended to use awkward postures on their entire body while performing the tasks.

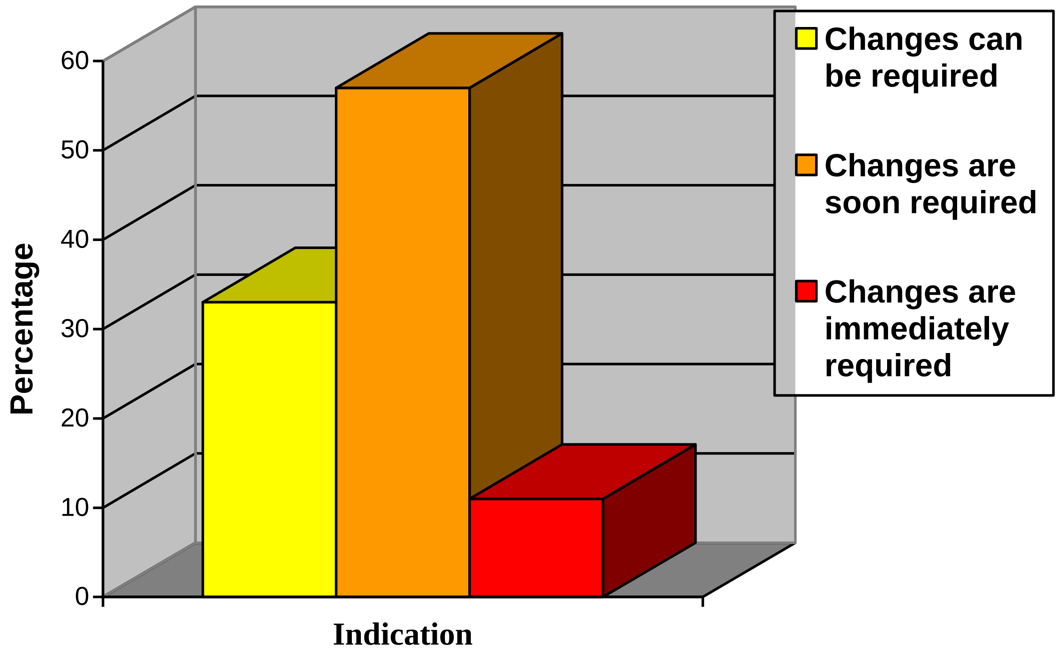


Figure 5.3. RULA percentages distribution

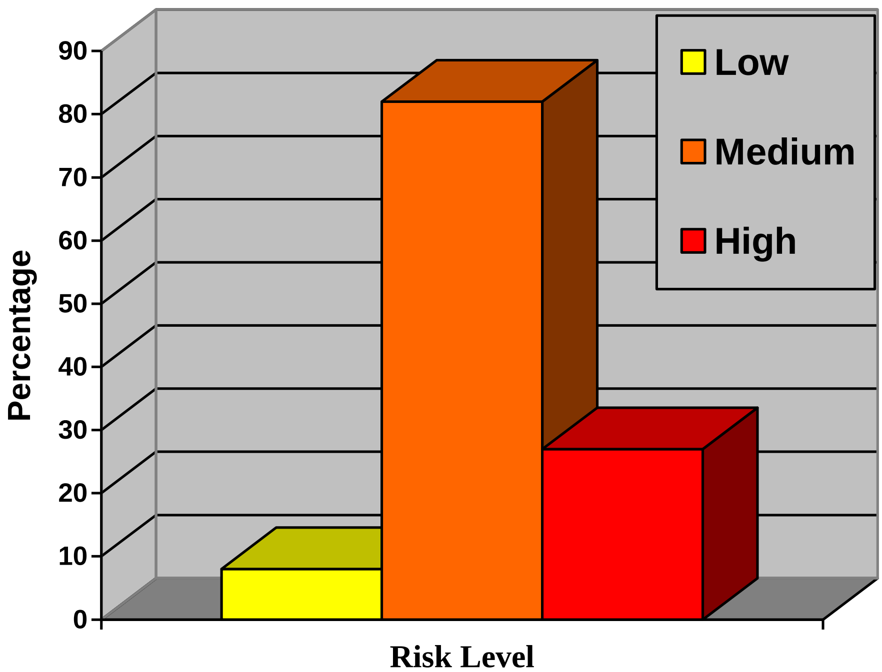


Figure 5.4. REBA percentages distribution

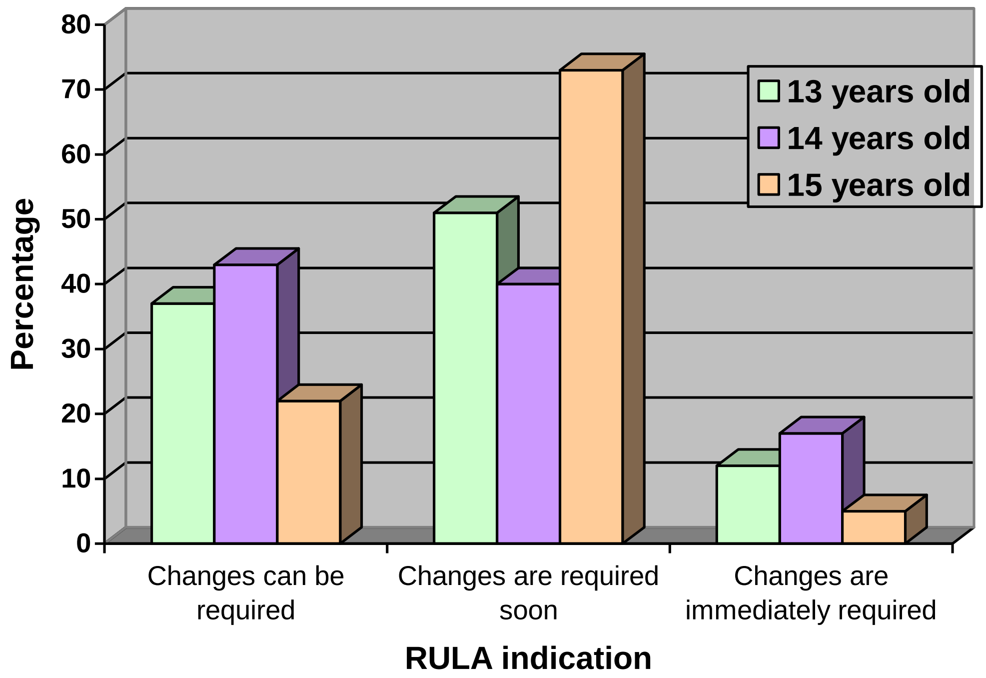


Figure 5.5 (a). Percentages of RULA analysis between ages

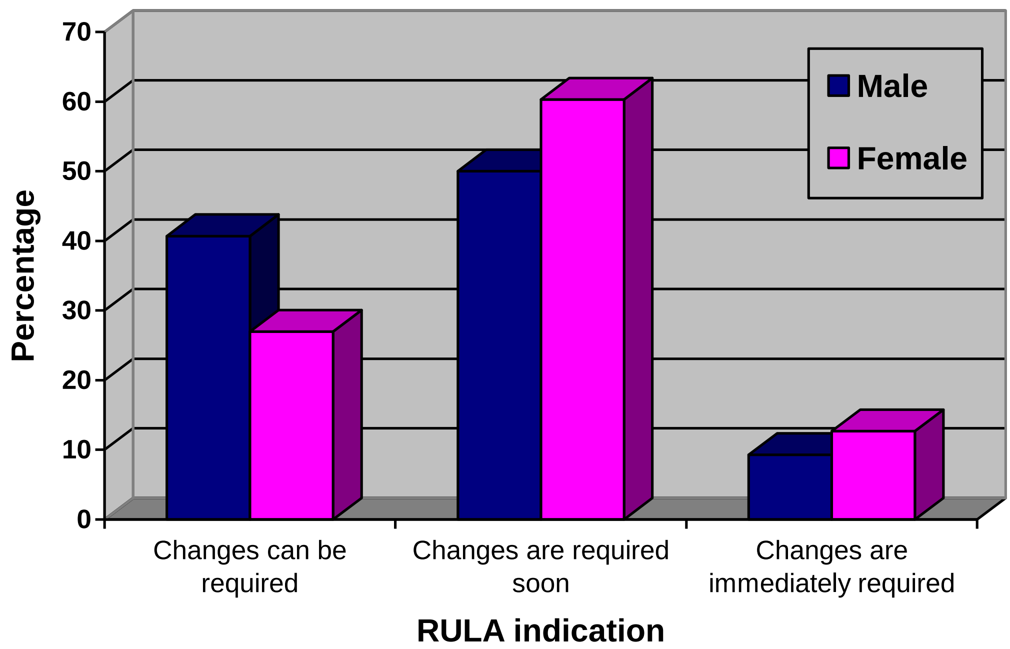


Figure 5.5 (b). Percentages of RULA analysis between genders

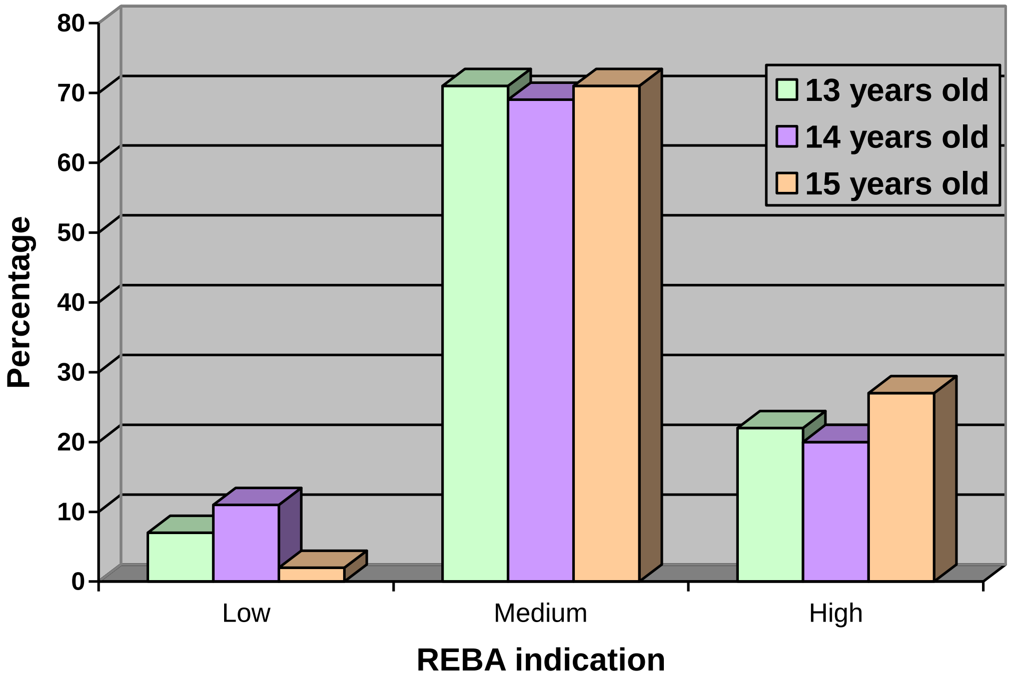


Figure 5.6 (a). Percentages of REBA analysis between ages

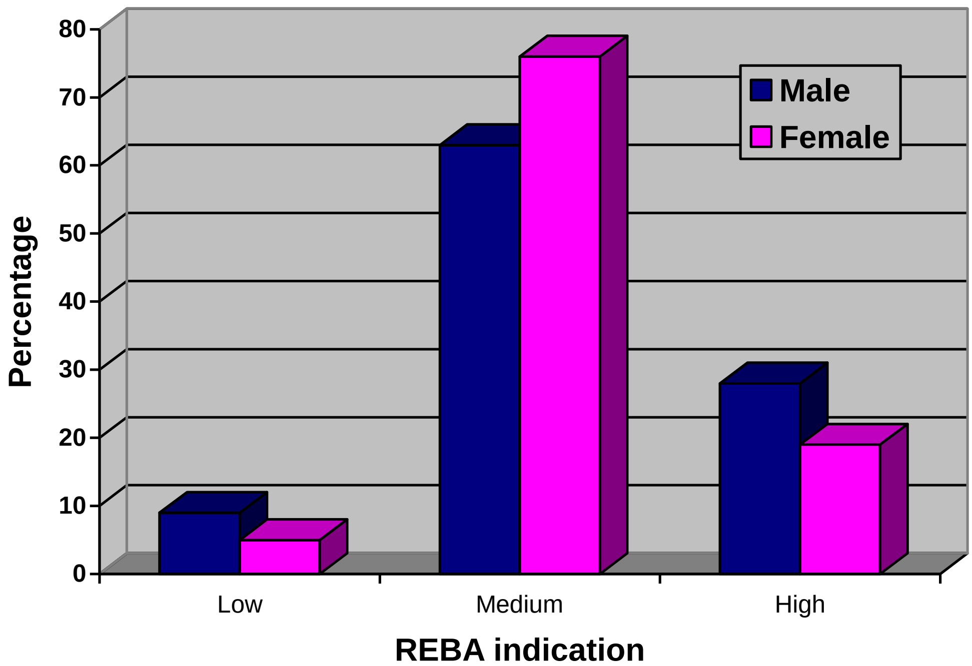


Figure 5.6 (b). Percentages of REBA analysis between genders

The results from RULA analysis showed that the mean values for 13 year old students were 5.12 (SD 1.1), 14 year old students were 5.03 (SD 1.12) and 15 year old students were 5.34 (SD 0.88). In gender category, the mean values were 5.00 (SD 1.05) for male students and 5.32 (SD 1.01) for female students.

On the other hand, the results from REBA analysis showed that the mean values were 5.88 (SD 1.91), 5.94 (SD 1.75) and 6.39 (SD 1.52) for 13, 14 and 15 years old students, respectively. While for gender, the mean values were 6.02 (SD 1.82) for male students and 6.13 (SD 1.67) for female students.

Table 5.20. Mean score of each sample

Age	Gender	Height (cm)	RULA	REBA
13 year old	Male	166	5.00	6.06
	Female	160	5.22	5.74
14 year old	Male	156	4.59	5.00
	Female	140	5.44	6.83
15 year old	Male	150	5.37	6.89
	Female	157	5.32	5.95

Table 5.20 revealed that the highest RULA and REBA scores were 5.44 and 6.83 of 14 year old female students and 5.37 and 6.89 of 15 year old male students. These scores were the highest among subjects. The height of 14 year old female students and 15 year old male students were 140 cm and 150 cm, which were the shortest among the subjects. This result indicated that the current workstation was unsuitable for short students regardless of the age and gender.

Table 5.21 showed the RULA and REBA standardized indications which is adapted from a study done by Sá et al., (2006). The study has categorized both scores of RULA and REBA methods into similar scale to standardize the indications. These categories were easier to identify the correct indication based on analysis that has been combined together and to achieve the proper action to be taken.

Table 5.21. Standardization of RULA and REBA scores

Category	Scores		Risk level
	RULA	REBA	
A	1 – 2	1	Safe
B	3 – 4	2 – 5	Low
C	5 – 6	6 - 9	Medium
D	7 <	10 <	High

Table 5.21 simplified scores from RULA and REBA methods and classified them into category C. This category was in the medium risk level and need actions for changes. Actions were required to prevent future back pain and upper extremity disorders.

A statistical test was carried out to determine the relationship of both methods to students' working postures. Table 5.22 showed correlation test between RULA and REBA scores were medium correlated by $r = 0.45$ and $p < 0.001$. This result agreed with studies conducted by Saraji et al., (2006), Sullivan et al., (2005) which indicated that final scores and action level of RULA and REBA methods were correlated to evaluate WMSDs risk factor and poor working postures in workplaces. Correlation analyses were also carried out to determine the relationship of age and gender to the postures being evaluated. Table 5.23 showed that age and gender are not correlated to RULA and REBA scores. The result in physical posture assessment has found out that shorter students have higher RULA and REBA scores regardless of age and gender. The detail of the analysis is depicted in Appendix M.

Table 5.22. Correlation test between RULA and REBA scores

	Correlation test	**RULA**	**REBA**
RULA	Pearson correlation, r	1	0.449
	Significant, p		0.000
REBA	Pearson correlation, r	0.449	1
	Significant, p	0.000	

Table 5.23. Correlation test between RULA and REBA scores among age and gender

	Correlation test	RULA	REBA
Age	Pearson correlation, r	0.089	0.124
	Significant, p	0.34	0.182
Gender	Pearson correlation, r	0.153	0.031
	Significant, p	0.099	0.737

5.4 Discussion

The results showed that 13 year old students have the lowest mean of 13.77 which indicated that they faced the highest risk level compared to 14 year old students with 14.45 and 15 years old students with 14.25. This result indicated that older students which generally have bigger body sizes have less difficulty when using the current workstation. According to Khaspuri et al., (2007), younger students (13 year old) have smaller body sizes compared to 14 and 15 year old students. On the other hand, 53% of the students have difficulties when performing assembly task because they needed to bend and twist their waist at the same time due to insufficient legroom.

61% of 15 year old students rated the current workstation as uncomfortable and very uncomfortable compared to 36% of 14 year old students and 3% of 13 year old students. On the other hand, 58% of female students rated the current workstation as uncomfortable and very uncomfortable compared to 42% of male students. It was revealed that female students were prone to complain more often than male students and the prevalence was increased with age. This result agreed with Hakala et al., (2010); Watson et al., (2002) which indicated that girls and older students reported more health complaints. Moreover, female students tended to display erect sitting posture with lumbar lordosis and thoracic extension. This position may create higher risk of musculoskeletal disorder to them compared to male students (Straker, et al., 2008).

Statistical analyses for questionnaire revealed significant differences among 13 to 15 year old students for all factors. However, there were no differences among gender. Statistical analyses for comfort rating and body map indicated that there were significant differences among age and gender in comfort rating. However, there were no differences among age and gender in body pain.

However, according to Geldhof et al., (2006), feeling of pain is a subjective phenomenon and the results can be questioned by others. Under certain situations, mostly in limited time, the answers can be overestimated (Kesson et al., 2001). Therefore, evaluation from direct observation using postural score is needed to evaluate students' awkward working postures that can lead to body pain and MSD problem. According to David (2005), observation based assessments are the best methods for limited time and a basis for establishing priorities for intervention. Spielholz et al., (2001) also emphasized that self-reports questionnaire were the least precise assessment method due to over-estimated exposures compared to observational video analysis and direct measurement.

The results of physical posture assessment indicated that shorter students have more difficulties while using the workstation, regardless the age and gender. Two students with less than 150 cm height have higher postural scores of 5.44 and 5.37 for RULA method while REBA method was 6.83 and 6.89. School administrative may have equipped the school workshop according to adult size furniture that was incompatible for growing up adolescent. The size of school workstation should be based on their stature, rather than any other body segments (Molenbroek et al., 2003).

Statistical analyses for physical posture evaluation indicated that both RULA and REBA methods are correlated to each other with correlation value, $r = 0.45$ (medium strength) and correlation significant at $p < 0.01$. The result proved that both methods were reliable to get the same results of working postures evaluation. On the other hand, correlation analysis result found no relationship between postural scores with age and gender.

5.5 Summary

In surveillance context of physical risk exposure activities, the questionnaire analysis indicated that 13 year old students have the highest risk exposure with the current workstation. Both dynamic workloads for cutting and assembly tasks have identified that the younger students could not fit themselves to the current workstation. Generally, the younger students have smaller body size~~s~~ with shorter stature. The results also highlighted that shorter students have difficulties when using the current workstation. Postural score results suggested that most likely the workshop furniture tends to suit bigger size students. The school's management may have equipped the school workshop with adult size furniture that is unsuitable for small size students.

Participatory ergonomic action was suggested to reduce the students' postural stress as indicated in physical posture assessment. Two types of intervention~~s~~ recommended are workstation modification and ergonomic education for good posture. Workstation modification may involve suitable furniture size to tailor with students' variety of sizes. In this case, the chair or stool used by students can be adjustable in height to collaborate with different body dimensions since the workbench were shared by a group of students. Other aspects of comfort like leg space, footrest and workspace envelope should be considered in redesigning of workstation. According to Linton et al., (1994), workstation modification cannot totally improve students' posture. Additionally, a study done by Shinn et al., (2002) suggested that promotion of correct body mechanics and ergonomic education can reduce the risks of musculoskeletal injuries (Geldhof et al., 2006).

Chapter 6

DESIGN DEVELOPMENT ANALYSIS

6.1 Introduction

This chapter presented the results of the design process development. The process was based on the methodology described in Chapter 3. This chapter was divided into three subtopics which are Kano model, Kano model and QFD integration and workstation design development. Data analysis was done using SPSS 17.0 software. Results from the HoQ matrix were combined with anthropometry data collection of the students' population in design process. Design development was created in CATIA V5 CAD software. The objective of this chapter was to identify user and technical requirements through the integration of Kano Model and Quality function deployment (QFD) approach which will be implemented in design stage.

6.2 Kano Model method

A total of 260 sets of questionnaire were distributed to the subjects and 255 complete answered forms were returned. The effective questionnaires response rate was 98%. The respondent's age distribution is shown in Table 6.1. Cronbach alpha values for the questionnaire are 0.705 and 0.726 which mean the questionnaire is reliable to be used in this study. This study applied SPSS 17.0 software as the analysis tool.

Table 6.1. Age distribution of subjects for Kano Model survey

Gender	Age	Frequency	Percentage (%)
Male	14 years old	102	78.5
	15 years old	28	21.5
	Total	130	51
Female	14 years old	76	60.8
	15 years old	49	39.2
	Total	125	49

The analyses were based on the Kano evaluation table to identify their quality categories. Then, each element was calculated using customer satisfaction and dissatisfaction equations. The results revealed that the students selected four elements as Must-be quality, one element as One-dimensional and six elements as Indifferent quality. Table 6.2 showed the Kano category classification, Customer Satisfaction and Customer Dissatisfaction values for each element. Figure 6.1 shows the quality elements in a graph. The plotting analysis was carried out based on a study done by (Meng & Jiang, 2011). The study proposed a quantitative Kano Model of the express service industries and used it to finalize customer requirements in quality function deployment.

Customer satisfaction (CS) analysis indicated that broad workspace was the top requirement by students (blue box). The feedback from the students and observation has found out that the current workstation needs to be shared by three to four students at a time. The following requirement needed was back rest for chair. This element was mostly highlighted in student's problem statements.

Table 6.2. Kano category classification, Customer Satisfaction and Customer Dissatisfaction values for each element

Elements	CS	CD	Quality
Workbench size	0.48	0.58	O
Stool height	0.33	0.43	I
Workbench height	0.23	0.43	I
Adjustable furniture	0.38	0.16	I
Temporary storage	0.24	0.19	I
Additional tools	0.45	0.47	I
Leg room	0.32	0.52	M
Back rest	0.47	0.47	I
Stable workstation	0.33	0.62	M
Smooth work surface	0.39	0.60	M
Safety design and application	0.27	0.73	M

Customer dissatisfaction (CD) analysis indicated that safety elements should be provided to prevent student's dissatisfaction (blue box). The second element should be included was stability. These results proved students intense of safety awareness in workshop. Even though worktop height, chair height and backrest were included in indifferent quality, these elements were needed in the new design to improve student's working postures. All elements included in one dimension and must-be categories were added in the new designed workstation.

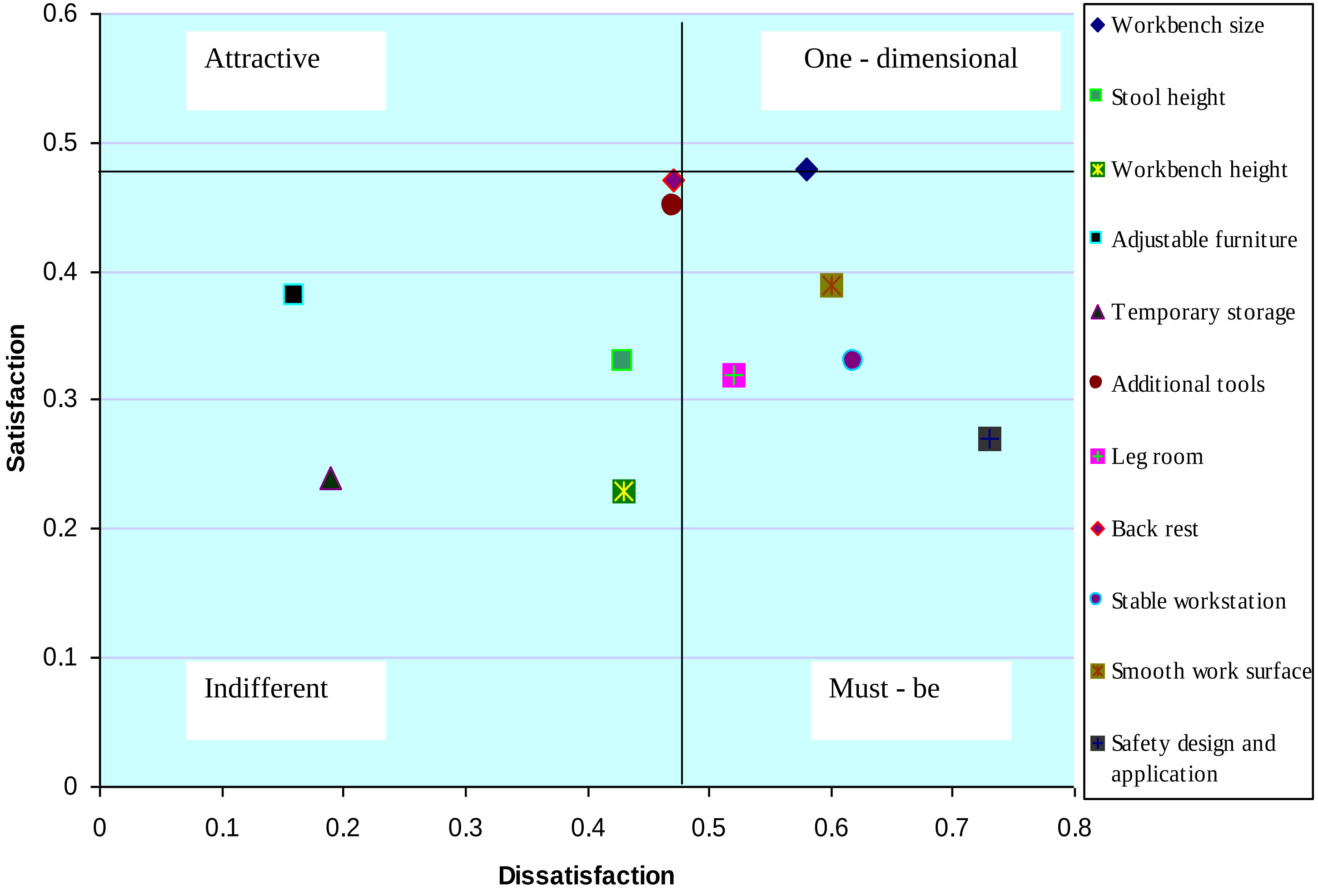


Figure 6.1. Kano classification of each element

The Kano Model results indicated that user was expecting for safety elements and decided it as a must-be category. This element must be included in the design as user perceived safety as a basic requirement for a workstation. While broad working space was classified as one-dimensional category and user would be discouraged if it is not presented in the workstation based on customer dissatisfaction value. Back rest for chair also had almost the same value as broad work surface even though it was classified in Indifferent category. Results emphasized that students were expecting for safety elements and will satisfy if they were fulfilled which were safety design and stable workstation. While elements which will dissatisfy the user if not present were broad working space and chair back rest which were more in comfort category.

6.3 Kano Model and QFD integration

The user requirements of the HoQ matrix were reapplied from previous Kano model classification. While the technical requirements lists were referred to studies about furniture design by Gonza´lez et al., (2003); Nurcahyanie et al., (2009). Some suggestions by technical expert were also considered.

User importance survey was analyzed using SPSS 17.0 software. The rating was based on Likert scale of 1 as less important to 5 as most important. The validity of the user importance survey was 0.734 (Cronbach alpha value). Appendix I shows the user importance scale survey.

Table 6.3 showed the rating of each element which was listed in the survey. Figure 6.2 showed the House of Quality matrix with Kano model integration.

Table 6.3. User importance rating

Element	User importance	User satisfaction	User satisfaction target
Workbench size	3	3.94	5
Stool height	3	4.19	5
Workbench height	3	4.17	4
Adjustable furniture	1	3.67	4
Temporary storage	1	3.66	5
Additional tools	3	4.00	5
Leg room	4	4.29	5
Back rest	2	3.97	5
Stable workstation	4	4.25	5
Smooth work surface	4	4.37	5
Safety design and application	5	4.47	5

Figure 6.2. House of Quality matrix of Kano model and QFD integration

Desirable qualities \ Engineering characteristics		User importance, i	Design: Malaysian Standards	Design: Material thickness	Design: Joining methods	Material: Materials type	Material: Finishing	Material: Weight	Ergonomic: Comfort	Ergonomic: Dimension	Ergonomic: Cost	Kano Category	k value	User satisfaction, u	User satisfaction target, t	Adjustment factor, f	Improvement ratio, R_0	Adjusted improvement ratio, R_1	Adjustment Importance, j
Size	Broad work space	3	5		1			5	3	5	5	O	1	3.94	5	0.58	1.27	2.01	6.03
	Workbench height.	3	5		1			3	5	5	1	I	0	4.17	4	0.43	0.96	0.96	2.88
	Stool/chair height.	3	5		1			3	5	5	1	I	0	4.19	5	0.43	1.19	1.19	3.57
Design	Adjustable furniture.	1	3					3	5	1	5	I	0	3.67	4	0.38	1.09	1.09	1.09
	Additional tools.	3						3			5	I	0	4.00	5	0.47	1.25	1.25	3.75
	Temporary storage	1	1		1			3	3	1	3	I	0	3.66	5	0.24	1.37	1.37	1.37
Comfort	Leg room.	4	5		1				5	5		M	0.5	4.29	5	0.52	1.17	1.44	5.76
	Back rest.	2							5		3	I	0	3.97	5	0.47	1.26	1.26	2.52
Safety	Stable workstation.	4	5	5	5	5	1	5	1	5	3	M	0.5	4.25	5	0.62	1.18	1.50	6
	Smooth working surface.	4	1			5	5		3		1	M	0.5	4.37	5	0.60	1.14	1.44	5.76
	Safety design and application.	5	5	3	3	3	3	3	5	1	5	M	0.5	4.47	5	0.73	1.12	1.47	7.35
	Absolute weight, AW		118	35	49	55	39	83	118	92	91								
	Absolute importance, AI		168.4	52.1	71.7	80.9	56.9	120.2	161.3	131	133								

Importance scale: 1=less to 5=most importance
Relationship: 1=Weak 3=Moderate 5=Strong

6.4 Anthropometry data collection

Anthropometric measurements were collected from a hundred and forty five students aged 13 to 15 years old. Table 6.4 shows subjects' demographic data. Both manual and three-dimensional scanning measurement methods were used in this process. The manual measurement method was used mostly for sitting posture. The three-dimensional scanning measurement method was used for standing posture by using the *[TC]^2 NX-16* body measurement system. The anthropometric data was analyzed to calculate the 5th percentile, 50th percentile and 95th percentile for design purposes.

Table 6.4. Age distribution for anthropometric data collection

Age	**Gender**	**Frequency**	**Percentage (%)**
13 year old	Male	22	15
	Female	10	7
14 year old	Male	22	15
	Female	35	24
15 year old	Male	22	15
	Female	35	24

Table 6.5 showed the measurements used for design development process of the workstation. Dimension values of the workstation that were used in the design process shown in table 6.6 and appendix N showed the anthropometric data measurements of all samples.

Table 6.5. Workstation measurements based on anthropometrics (Openshaw & Taylor, 2006)

Design	Measurement	Description
Workbench	Worktop height	Elbow height
	Workspace envelop	Forward reach
	Leg room	Buttock – popliteal length, popliteal height and foot depth
	Under table clearance	Tight clearance
	Feet rest	Foot depth
Chair	Seat height	Popliteal height
	Seat depth	Buttock – popliteal length
	Seat width	Hip breath

Table 6.6. Percentile values of anthropometric dimensions of students for workstation design in school workshop

Anthropometric measurements in cm	**Mean (n = 145)**	**Standard deviation**	**5th percentile**	**50th percentile**	**95th percentile**
Stature	156.83	7.73	146.03	155.90	172.57
Elbow height	97.49	7.70	90.04	96.50	106.93
Shoulder breath	32.43	3.86	27.01	32.20	39.26
Buttock – popliteal length	42.92	2.80	38.64	42.35	47.97
Popliteal height	36.43	2.82	31.84	36.50	41.17
Tight clearance	11.65	2.32	8.27	11.1	15.97
Hip breath	30.01	3.44	25.50	29.55	36.61
Foot depth	21.27	1.69	18.83	21.10	24.58
Forward reach	63.52	5.66	57.17	62.70	73.66

50^{th} percentile measurement was used for leg room, under table clearance, foot depth and seat height. The 50th percentile was used as most closely representing for the entire population of the target group. 5^{th} percentile measurement of forward reach was used for workspace envelop. 5^{th} percentile of elbow height was added with 18 cm lower measurement for worktop height. The workstation was classified for the purpose of heavy manipulative task (Pheasant, 2003). The 5^{th} percentile was used to ensure no extended reach and uncomfortable working condition. The design process was created using CATIA V5 design software.

6.5 New design development

Elements in one – dimensional and must – be categories which were workbench size, leg room, stable workstation, smooth work surface and safety were included in the proposed workstation. Some elements in indifferent category were implemented because of ergonomic considerations which were workbench height, chair height and backrest. Safety elements were fully implemented to make sure student's requirement toward safety design and application were fulfilled.

Malaysian Standard series such as dimensions of office chair (Malaysian Standard, 2003), specification for school furniture (Malaysian Standard, 2005b), mechanical safety requirement for office table (Malaysian Standard, 2005a) and general safety in woodworking machinery (Malaysian Standard, 2011) were used for guidelines. The design standard requirements that were included in the proposed design were dimensions determination and basic safety design.

6.6 Design guidelines and specifications.

The proposed workstation recommended some design features in order to provide support to the existing workstation. As mentioned earlier, design guidelines that were presented in this study were safety design and dimension determination.

6.6.1 Additional features

Some features equipped in the proposed design were legroom, footrest and an open storage under the worktop. The legroom feature in the proposed workstation was measured based on buttock-popliteal length of 95^{th} percentile at a neutral posture. As for footrest, the depth was based on 50^{th} percentile of anthropometric measurement of the target population. The open storage was 16 cm height. The storage was proposed for a temporary place of hand tools and materials.

6.6.2 Safety design

The workstation safety feature must be capable of avoiding unexpected accident and incident. Parts which may come into contact with the user should be designed to avoid injuries. This includes edges and corners which should be made rounded. The top of the workbench should be smoothed to avoid damage to materials and personal injury. The diameter of the workbench frame was increased from 6 mm to 10 mm for stability improvement. Two vise benches were mounted on both sides of the workbench. Four square holes on the worktop were provided. The purpose of these holes was as a temporary storage for small parts like nails and hooks.

6.6.3 Dimension determination

The dimensions of the workstation were referred to anthropometric measurement of the target population. Specifically, the design specifications required for two items as followed:

1. **Workbench**

   The range in height of the workbench should extend from normal sitting to standing heights. Figure 6.3 illustrated the dimension determination of the proposed workbench. The workbench used the 50^{th} percentile elbow height as the reference height. To minimize possible mismatch problems, workstation dimensions shall focus in the design to match at least the 50^{th} percentile of anthropometric characteristics of user population (Milanese & Grimmer, 2004). The dimension was lowered to 15 – 30 cm to match for heavy manipulated tasks in woodworking (Bridger, 2003). The workbench too, must be able to provide a reachable area over the entire range of sitting and standing postures. The required dimension was the 5^{th} percentile forward reach of the user population. The worktop area shall be able to fit four users at a time.

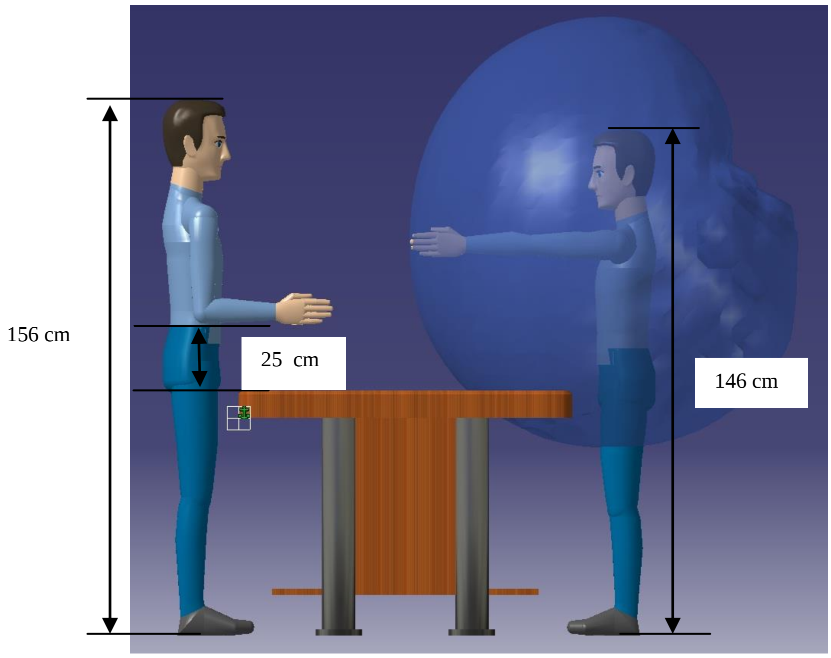


Figure 6.3. Dimension determination of proposed workbench

2. Chair

The chair height is based on 50th percentile of students' popliteal height. The 50th percentile value was used as most closely representing for the entire population of the target group. As discussed in Chapter Two, a good chair design should have appropriate measurement of these features. (Bendix & Biering-Sorensen, 1983) indicated that preferred tilted seat is from 15-degrees backwards to 35-degrees forwards. Therefore, the proposed seat-pan design is tilted 20-degrees forward. The seat pan is based on 95th percentile of students' hip breath. It was designed wide enough to accommodate the biggest hip size. The backrest dimension is referred to office chair standard design and (Department Of Occupational Safety and Health, 2002) document (MS 1711: Part 1: 2003). The height, width and thickness of the backrest were 28 mm x 30 mm x 5 mm. Figure 6.4 illustrated the dimension determination of the proposed chair.

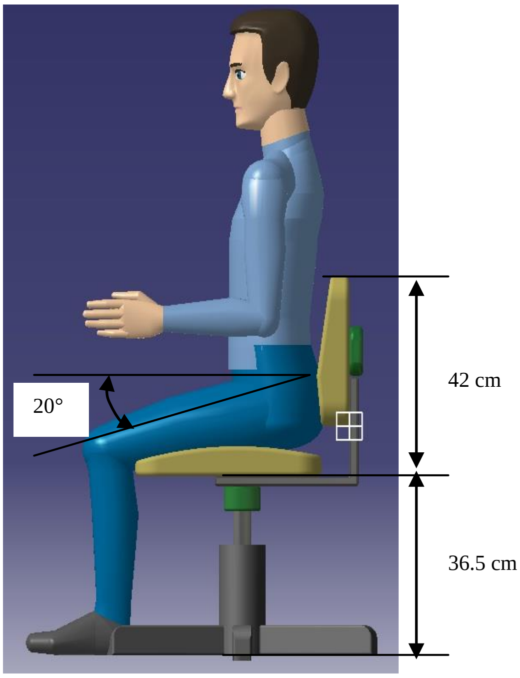


Figure 6.4. Dimension determination of proposed chair

The measurement of height, width and depth of the workstation are totally modified. The reasons are to match with appropriate working height for cutting task and fit to normal working envelop. Design features are implemented as the following:

- The height of the workbench was lowered to 72 cm.
- The worktop size was made broader to 160 cm x 100 cm.
- The chair was adjusted to 40 cm height and equipped with backrest.
- The seat pan was 40 x 40 cm in dimension.
- The seat pan was tilted forward to 20-degrees.
- The workstation frame was made bigger to 10 cm in diameter for stability.

- All corners were made to be rounding edges for safety purposes.
- Four pockets for nails' temporary storage were provided on the worktop.
- Beneath of the worktop, an open storage of 16 cm height was provided.
- Foot rest of 20 cm depth was provided at all sides of the workbench.
- Leg room of 30 cm depth was provided at all sides of the workbench.

Figure 6.5 presented the new proposed workstation. Appendix O provided the orthographic projection of the proposed workstation.

Figure 6.5. Proposed workstation

6.7 Discussion

Kano Model and Quality function deployment integration method have successfully prioritized user requirement. It was discovered from the house of quality matrix that Malaysian design standard and comfort criteria were the most important characteristics in technical requirement. Less important criteria in technical requirement were material thickness and finishing work. This result was able to guarantee user satisfaction by identifying potential elements to be implemented in the proposed workstation design.

Safety application was the most important element for user satisfaction and followed by broad working space element. On the other hand, adjustable furniture and temporary storage were not as important preference in user's desirable elements.

The results from HoQ and Kano Model integration process indicated that those important elements to be implemented in the proposed workstation are grouped into two categories:

- User requirements: Safety design and application and size of the worktop.
- Technical requirement: Design standard and comfort element.

Ergonomic was one of the main factors in engineering characteristics. This factor must be included in design phase of a new or modified product as users nowadays were aware with the importance of safety and ergonomic design. Students were interested on safety caution and care about their working condition issue. However, adjustable furniture was not favorable by users. Most likely they have never been informed about the importance of correct postures and how to gain benefits from adjustable furniture. A study done by Gerr et al., (2000) indicated that there was no significant difference on body pain between those who were using adjustable chair than nonadjustable. It was possible that they may have different postures or they were not given proper instruction on using chair.

From user satisfaction values, it was found that users were tended to rate all qualities close to neutral satisfaction but more towards important based on user satisfaction target values. The result was similar to studies by Chaudha et al., (2011); Tontini (2007).

6.8 Summary

To summarize, the HoQ matrix indicated that students' top requirements for the workstation is safety design and application. In Kano method, it was classified as a must – be quality category. It was top in Customer Dissatisfaction (CD) value, which if the element is not presented, user will be highly dissatisfied. While for adjustable furniture element, it was classified as indifferent quality in Kano method and has the smallest value in CD. It was also rated as the least important in the HoQ matrix. It can be concluded that the results in HoQ matrix is based on the CD values of Kano model method. The design development process was carried out based on the results of the Kano Model and HoQ integration. The results were able to determine which elements should be included in the proposed workstation design. This result showed that students are conscious with their safety and comfort when using the workstation. Therefore, all elements that are associated to safety and comfort design need to be implemented in the proposed workstation.

Chapter 7

DIGITAL HUMAN MODELING ANALYSIS

7.1 Introduction

This chapter presented the results of the Digital Human Modeling (DHM) simulation. The process was based on the methodology described in Chapter 3. The objective of this chapter was to develop and evaluate the proposed ergonomic design workstation for school workshop using simulation process. This chapter was divided into two subtopics which were Rapid Upper Limb Assessment (RULA) and Low Back Analysis (LBA) methods. Rapid Entire Body Assessment (REBA) method was not available in Jack 7.1 activity toolkit, so LBA method was used as supporting result for lower limb analysis. Human models for analysis were presented in two sections:

1. **Manikins based on physical posture assessment subjects**: Six human models based on statures and weights of subjects in physical posture analysis were used for comparison of RULA scores of before and after workstation modification. LBA method was conducted to analyze the lower back force among subjects.

2. **Manikins based on percentile**: 5^{th} percentile, 50^{th} percentile and 95^{th} percentile anthropometric measurement of both male and female students were used to evaluate the proposed workstation design using RULA and LBA methods.

7.2 Digital human model specification

There were two groups of digital humans which were subjects and percentile group. Figure 7.1 shows the human models based on percentile for the simulation. Figure 7.2 showed the human models based on subjects for the comparison. Table 7.1 and 7.2 showed the height and weight for each human model.

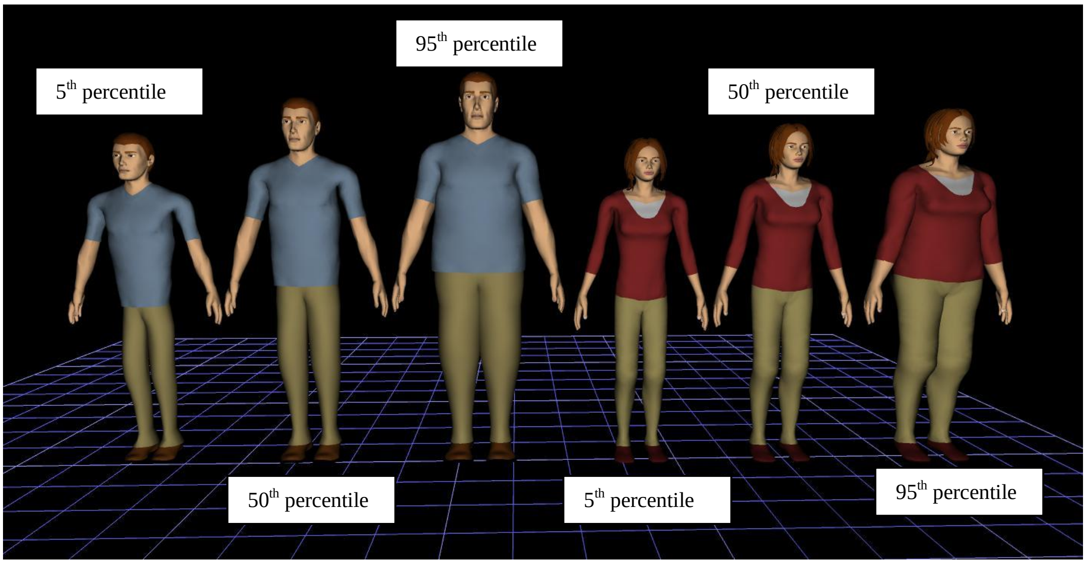


Figure 7.1. Human model based on percentile of both genders

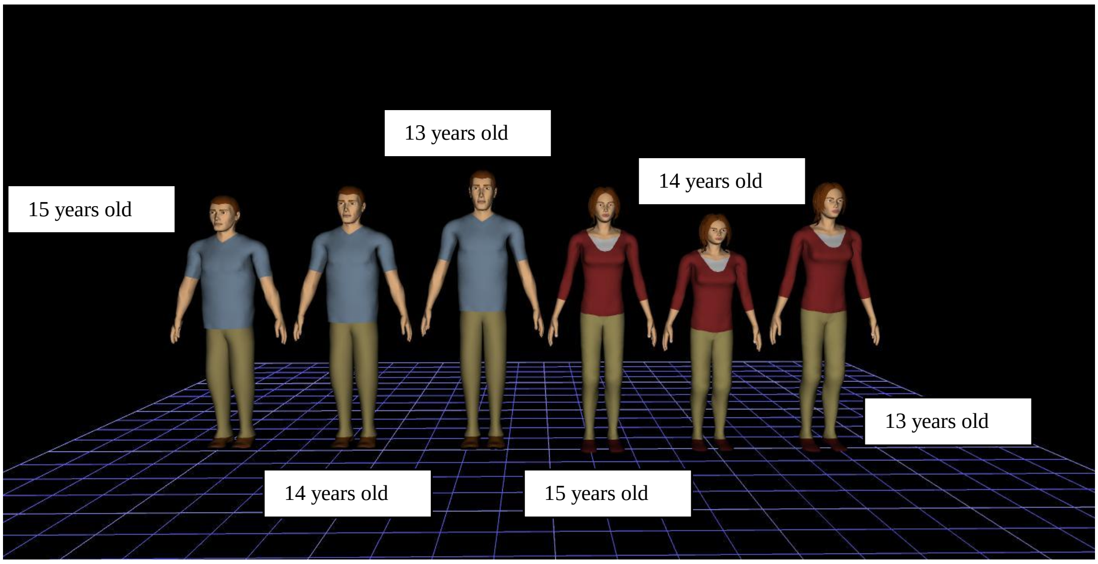


Figure 7.2. Human model based on subjects of physical evaluation analysis

Table 7.1. Subjects group body sizes

Age	Gender	Height (cm)	Weight (kg)	BMI
13 year old	Male	166	52	18.87
	Female	160	45	17.58
14 year old	Male	156	55	22.6
	Female	140	40	20.41
15 year old	Male	150	50	22.22
	Female	157	43	17.44

7.2.1 Assumption

In this study, any error in the posture parameters between all the digital humans was assumed negligible. For example, the 5th percentile male may have the exact same posture as the 95th percentile female. As for the workstation environment, the virtual environment in the Jack 7.1 software was created based on the same design as the actual school workshop in the place where this study was conducted.

Table 7.2. Percentile group body measurement

	Male					Female				
	Mean	**Standard Deviation**	**5th percentile**	**50th percentile**	**95th percentile**	**Mean**	**Standard Deviation**	**5th percentile**	**50th percentile**	**95th percentile**
Stature (cm)	161.46	8.42	146.35	162.70	174.85	153.01	4.31	146.01	153.00	160.50
Weight (kg)	54.25	17.15	32.37	51.10	94.34	50.18	12.77	36.44	46.10	87.88
BMI	20.65		15.15	19.47	30.79	21.44		17.08	19.69	33.91

7.3 Rapid Upper Limb Assessment (RULA) analysis

7.3.1 Manikins based on physical posture assessment subjects

The results of physical evaluation assessment for the current workstation indicated that shorter students have difficulties to fit themselves into the current workstation, regardless of age and gender. Table 7.3 showed the average RULA scores for each subject in physical posture assessment.

Table 7.3. Average RULA scores of each subject

Age	**Gender**	**Stature (cm)**	**RULA**
13 year old	Male	166	5.00
	Female	160	5.22
14 year old	Male	156	4.59
	Female	140	5.44
15 year old	Male	150	5.37
	Female	157	5.32

RULA scores were obtained from the mean scores of both standing (cutting task) and sitting (assembly task) positions. Appendix P provided results of RULA analysis summary of each subject for cutting and assembly tasks using the proposed workstation. Table 7.4 showed the RULA scores for the proposed workstation design. Figures 7.3 illustrated the RULA scores before and after workstation modification intervention.

Table 7.4. RULA analysis summary of each sample

Age	Stature (cm)	Gender	RULA scores		
			Cutting	Assembly	Mean
13 year old	166	Male	4	3	3.50
	160	Female	4	3	3.50
14 year old	156	Male	4	3	3.50
	140	Female	3	3	3.00
15 year old	150	Male	3	3	3.00
	157	Female	3	3	3.00

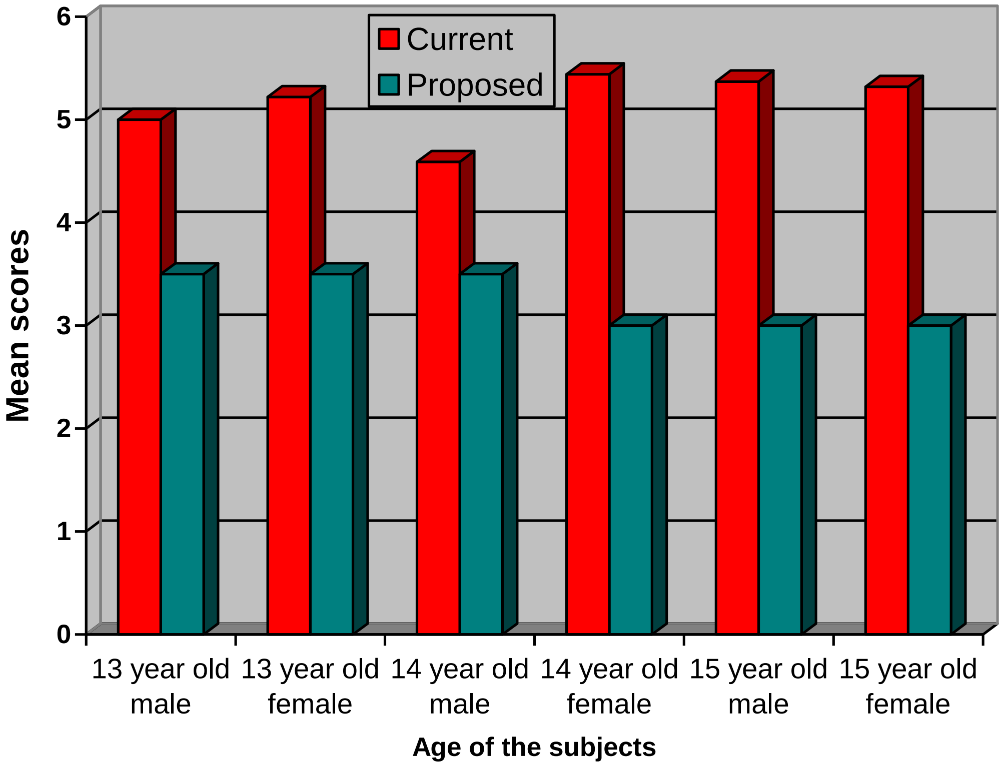


Figure 7.3. RULA scores before and after the workstation modification between subjects

7.3.2 Manikins based on percentile

There were three percentile values used: 5th percentile, 50th percentile and 95th percentile of anthropometric measurement. There were six manikins which represented each gender. RULA scores were obtained from the mean scores of both standing (cutting task) and sitting (assembly task) positions. Appendix Q provided the results of RULA analysis summary of each percentile for cutting and assembly tasks. Table 7.5 showed the RULA analysis summary of each percentile.

Table 7.5. RULA analysis summary of each percentile

Percentile	**Gender**	**RULA scores**		
		Cutting	Assembly	Mean
5th	Male	3	3	3.0
	Female	3	3	3.0
50th	Male	3	3	3.0
	Female	4	3	3.5
95th	Male	4	3	3.5
	Female	4	3	3.5

The results have found out that the all manikins have low risk level of the proposed workstation. However, taller students have higher postural score values.

7.4 Low back analysis (LBA) method

The LBA method was used as a supporting result for lower limb part. This method analyzed the low back compression force or spinal force acting on a lower back in Newton (N) in proposing the new designed workstation.

7.4.1 Manikins based on physical posture assessment subjects

Table 7.6 showed LBA method summary for each subject using Jack 7.1 Task analysis Toolkit. The mean values were compared to Body Mass Index (BMI) values for significant relationship. Appendix R provided the results for LBA assessment summary of each subject for cutting and assembly tasks.

Table 7.6. LBA summary of each subject

Age	**Gender**	**Stature (cm)**	**BMI**	**LBA method (N)**		
				Cutting	Assembly	Mean
13	Male	166	18.87	1265	940	1103
	Female	160	17.58	1036	710	873
14	Male	156	22.6	1214	978	1096
	Female	140	20.41	810	608	709
15	Male	150	22.22	1306	891	1099
	Female	157	17.44	993	707	850

The results have found out that the all subjects have risk level of the proposed workstation was below the NIOSH Back Compression Action Limit of 3400 N, representing minor risks of low back injury for most healthy workers.

7.4.2 Manikins based on percentile

In percentile analysis, LBA method was used to evaluate working postures of 5^{th} percentile, 50^{th} percentile and 95^{th} percentile anthropometric measurements of both genders. The result was showed in table 7.7. Appendix S provided the results for LBA assessment summary of each percentile for cutting and assembly tasks. Table 7.7 showed the result of each percentile.

Table 7.7. LBA summary of each percentile

Percentile	Gender	Stature (cm)	BMI	LBA method (N)		
				Cutting	Assembly	Mean
5	Male	146	15.15	1081	883	982
	Female	146	17.08	733	604	669
50	Male	163	19.47	1170	956	1063
	Female	153	19.69	1065	698	882
95	Male	175	30.79	1869	1356	1613
	Female	161	33.91	1617	1225	1421

7.5 Discussion

The results have found out that RULA scores of all subjects have reduced significantly. The risk level has also converted to low level. This result was applied to both subjects and percentile group. On the other hand, taller students with stature above 160 cm have higher RULA score; however the risk level was still acceptable and indicated as low level. The RULA mean scores indicated that the risk level of the proposed workstation was low. This result has proven that the proposed workstation was able to improve students' working postures for upper limb part when performing their tasks.

The mean score of lower back's compression force of all manikins showed the risk level of the proposed workstation was below the NIOSH Back Compression Action Limit of 3400 N, representing a nominal risk of low back injury for most healthy workers. Male students have higher compression force compared to female students even though they have almost the same BMI values as example 50th percentile male and female students have BMI of 19.47 and 19.69, respectively. As suggested by Gonzales et al., (2007), female experiences less compressive force and muscle fatigue compared to male because of differences in body mass and muscle metabolism (Hicks et al., 2001; Russ & Kent-Braun, 2003). Table 7.6 and 7.7 indicated that lower bending postures resulted in higher LBA score, which was referred to cutting task. According to Kumar, (2001), excessive bending of waist may create greater biomechanical loads on the lower back, which the muscle needs to work with higher forces against the center of gravity while bending. Students with greater BMI value have higher compression force. However, the risk level was still in the safe condition level. The result emphasized that the proposed workstation was able to improve students' working postures for lower limb part when performing their tasks.

7.6 Summary

Human-machine integration in simulation model has been developed to evaluate the human factor related engineering design of a prototype school workshop's workstation via ergonomic simulation approach. This chapter provided a summary of the results for ergonomic assessment in both subject and percentile groups.

- According to RULA assessment, shorter students have lower mean score compared to students with stature 160 cm and above. However, the risk level was still low for all students.
- According to Low Back Analysis, shorter and female students have lower low back force. However, the compression force for all students which the highest was 1613 N still far from NIOSH's back compression action limit of 3400 N.

Chapter 8

CONCLUSION

8.1 Conclusions

The first objective of this study was to determine the students' working posture comfort level at the current workstation. It was found that 13 year old students faced the highest risk level compared to 14 year old students and 15 year old students. . The result also highlighted that shorter students have difficulties when using the current workstation. It was suggested that most likely the workshop furniture tends to suit bigger size students.

The second objective was to identify user and technical requirements through the integration of Kano Model and Quality function deployment approach. The results have shown that Kano Model and Quality function deployment integration method have successfully prioritized user and technical requirement. It was found that Malaysian design standard and comfort criteria were the most important characteristics in technical requirement. On the other hand, safety application and broad working space were the most important characteristics in user requirement.

The third objective was to develop and evaluate an ergonomic designed workstation for school workshop by using Jack ergonomic software. The proposed workstation was able to reduce the RULA scores significantly compared to the current workstation. The result also emphasized that the proposed workstation was able to improve students' working postures for lower limb part when performing their tasks.

8.2 Contribution

This study gives significant insight of the need to provide design guidelines for furniture in school workshop. A need for an ergonomically designed workstation was shown through working postures assessment. A guideline for dimension determination and features was provided and a proposed design was presented. A comparable of the current and proposed design was also evaluated using Jack ergonomic simulation software. The proposed workstation was validated by the simulation program has able to improve students' working postures and working condition.

An ergonomically workstation in school workshop should present the following items:

1. Designed to match for sitting and standing working postures.
2. Designed to fit the anthropometrical range of the potential user's population.
3. Designed for woodworking tasks.
4. Allow for multitasking and easier movement.
5. Allow for comfortable and pleasant.

This study has successfully quantified postural stress faced by students aged 13 to 15 years old when using the school workshop's workstation. The prevalence of musculoskeletal disorder symptoms among age and gender was also successfully identified. The significance of this study can be attributed to the methodology adopted, which involved user requirement and digital human modeling software. The integration method of Kano Model and Quality function deployment has successfully prioritized the potential user requirements and at the same time, able to increase user satisfaction. The simulation analyses using digital human modeling presented quantitative results which are difficult to achieve in manual ergonomic assessment methods. The results obtained were easy to evaluate and have saved cost and time.

8.3 Limitation

The limitation of this study is the initial evaluation to assess students working posture and comfort is mainly based on cross-sectional studies. The survey was done without considering outside factors such as illness history and mental condition when data is being collected.

As stated earlier in this study, simulating the real workshop environment using digital human modeling might be a challenge. For example, assumption of posture parameters for all digital humans is the same. Furthermore, this study uses only the typical grasp posture for material and tool handling. The hand and finger postures are quite difficult to define and simulate.

8.4 Recommendation future study

In summary, this study is able to evaluate the ergonomic intervention process using an advanced methodology in order to improve students' working postures when using the school workshop's workstation. This study demonstrated the effectiveness of the DHM software to perform ergonomic assessment as accurate as traditional methods. However, this study focused only on posture parameters. Therefore, future work in this area should apply more ergonomic measurements such as environmental and physiological factors. Nevertheless, other factors should be considered to evaluate one working posture. Medical history and possible environmental factors such as thermal and lighting may influence the result of working comfort.

Besides, the age of population of subjects can be increased to 17 years old because technical and vocational classes are more focused to upper secondary student. They spend most of their time at school in the workshop. This could potentially assist in the efforts to develop an innovative woodworking workstation design that matches schoolchildren of all ages.

Further study in this area is important to reduce the impact of MSD and back pain among children and adolescent. Ensuring ergonomic and safe environment in school workshop would avoid early symptoms of ergonomic illness.

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APPENDICES

AND

INSTRUMENTS

Appendix A

Permission letter from Ministry of Education, Malaysia

BAHAGIAN PERANCANGAN DAN PENYELIDIKAN DASAR PENDIDIKAN
KEMENTERIAN PELAJARAN MALAYSIA
ARAS 1 - 4, BLOK E - 8,
KOMPLEKS KERAJAAN PARCEL E
PUSAT PENTADBIRAN KERAJAAN PERSEKUTUAN
62604 PUTRAJAYA

Telefon : 03-88846591
Faks : 03-88846579

Rujuk. kami : KP(BPPDP)603/5/JLD.2 (138)
Tarikh : 18 Feb 2011

Puan Adila bt. Md Hashim IC: 771110145506
No. 2 Jln Beruas 2D/KU8 Tmn Daya Maju Meru
41050 Klang
Selangor

Tuan/Puan,

Kelulusan Untuk Menjalankan Kajian Di Sekolah, Institut Perguruan, Jabatan Pelajaran Negeri dan Bahagian-Bahagian di Bawah Kementerian Pelajaran Malaysia

Adalah saya dengan hormatnya diarah memaklumkan bahawa permohonan tuan/puan untuk menjalankan kajian bertajuk:

Pembangunan Ruang Kerja KHB Yang Ergonomi Untuk Sekolah-Sekolah Menengah Di Malaysia

diluluskan.

2. Kelulusan ini adalah berdasarkan kepada cadangan penyelidikan dan instrumen kajian yang tuan/puan kemukakan ke Bahagian ini. Kebenaran bagi menggunakan sampel kajian perlu diperoleh dari Ketua Bahagian / Pengarah Pelajaran Negeri yang berkenaan.

3. Sila tuan/puan kemukakan ke Bahagian ini senaskah laporan akhir kajian setelah selesai kelak. Tuan/Puan juga diingatkan supaya mendapat kebenaran terlebih dahulu daripada Bahagian ini sekiranya sebahagian atau sepenuhnya dapatan kajian tersebut hendak dibentangkan di mana-mana forum atau seminar atau diumumkan kepada media

Sekian untuk makluman dan tindakan tuan/puan selanjutnya. Terima kasih.

"BERKHIDMAT UNTUK NEGARA"

Saya yang menurut perintah,

(DR. SOON SENG THAH)
Ketua Sektor,
Sektor Penyelidikan dan Penilaian
b.p. Pengarah
Bahagian Perancangan dan Penyelidikan Dasar Pendidikan
Kementerian Pelajaran Malaysia

Appendix B

Permission letter from state education department of Selangor

JABATAN PELAJARAN SELANGOR
Jalan Jambu Bol 4/3E, Seksyen 4, 40604 Shah Alam,
Selangor Darul Ehsan

JPS

Rujukan Tuan :
Rujukan Kami : JPNS.PPN 600-1/48/JLD.10(24)
Tarikh : 10/08/2011

ADILA BT. MD HASHIM
NO.2 JALAN BERUAS 2D/KU8
TAMAN DAYA MAJU MERU
41050 KLANG
SELANGOR

Tuan,

PEMBANGUNAN RUANG KERJA KHB YANG ERGONOMI UNTUK SEKOLAH-SEKOLAH MENENGAH DI MALAYSIA

Dengan segala hormatnya perkara di atas dirujuk.

2. Jabatan ini tiada halangan untuk pihak tuan menjalankan kajian/penyelidikan tersebut di sekolah-sekolah dalam Negeri Selangor seperti yang dinyatakan dalam surat permohonan.

3. Pihak tuan diingatkan agar mendapat persetujuan daripada Pengetua/Guru Besar supaya beliau dapat bekerjasama dan seterusnya memastikan bahawa penyelidikan dijalankan hanya bertujuan seperti yang dipohon. Kajian/Penyelidikan yang dijalankan juga tidak mengganggu perjalanan sekolah serta tiada sebarang unsur paksaan.

4. Tuan juga diminta menghantar senaskah hasil kajian ke Unit Perhubungan dan Pendaftaran Jabatan Pelajaran Selangor sebaik selesai penyelidikan/kajian.

Sekian, terima kasih.

"BERKHIDMAT UNTUK NEGARA"

Saya yang menurut perintah,

(JOHARI BIN MOHD NOH)
Penolong Pendaftar Institusi Pendidikan dan Guru,
Jabatan Pelajaran Selangor,
b.p. Ketua Pendaftar Institusi Pendidikan dan Guru,
Kementerian Pelajaran Malaysia.

s.k. 1. Fail

Kami mengamalkan Sistem Pengurusan Berkualiti Berasaskan MS ISO 9001: 2008

Certified to ISO 9001:2008 Cert No.AR3375

(Sila catatkan nombor rujukan apabila berurusan dengan kami)

JABATAN PELAJARAN SELANGOR - TERBILANG

No. Telefon: 03-55186500
No. Faksimili: 03-55102133
Email: jpn.selangor@moe.gov.my
Laman Web: http://www.moe.gov.my/jpnselangor

Appendix C

Permission letter from district education office of Klang

ڤجابت ڤلاجرن دائره كلڠ

PEJABAT PELAJARAN DAERAH KLANG
Jalan Meru, 41050 Klang
SELANGOR DARUL EHSAN
Tel : 03-3348 7100 Faks : 03-3341 2043 Web : http://www.ppdklg.gov.my

Ruj Tuan:
Ruj Kami: PPDK/PPS/PPN/04/06/013( )
Tarikh : 1 November 2011

ADILA BT MD. HASHIM
No.2, Jalan Beruas 2D/KUB,
Taman Daya Maju Meru,
41050 Klang,
Selangor

Tuan,

KEBENARAN MENGGUNAKAN PELAJAR SEBAGAI SUBJEK PENYELIDIKAN - RUANG KERJA KHB YANG ERGONOMIK UNTUK SEKOLAH-SEKOLAH MENENGAH DI MALAYSIA

Dengan segala hormatnya perkara di atas adalah dirujuk.

2 Sukacita dimaklumkan bahawa berdasarka surat Kementerian Pelajaran Malaysia (18 Februari 2011) dan surat Jabatan Pelajaran Negeri Selangor (10 Ogos 2011) **Pejabat Pelajaran Daerah Klang** tiada halangan untuk membenarkan **Adila bt Md Hashim** membuat kajian dan menggunakan pelajar daripada SMK Meru Klang sebagai subjek penyelidikan yang akan diadakan pada:

Tarikh	:	31.10.2011 – 31.11.2011
Masa	:	Sesi pagi - 9.00 pagi – 1.00 tengahari Sesi Petang – 2.00 petang – 6 petang
Tempat	:	Bangunan Bioinfomatik, Fakulti Sains, 50603 Kuala Lumpur

3. Oleh yang demikian tuan dikehendaki mematuhi syarat-syarat seperti berikut:

3.1.1 Mematuhi peraturan sedia ada di sekolah.

3.1.2 Mendapat kebenaran ibubapa dan kerjasama daripada pihak Guru Besar/Pengetua sekolah yang terbabit.

3.1.3 Tidak mengganggu jadual rasmi dan proses pengajaran dan pembelajaran di sekolah.

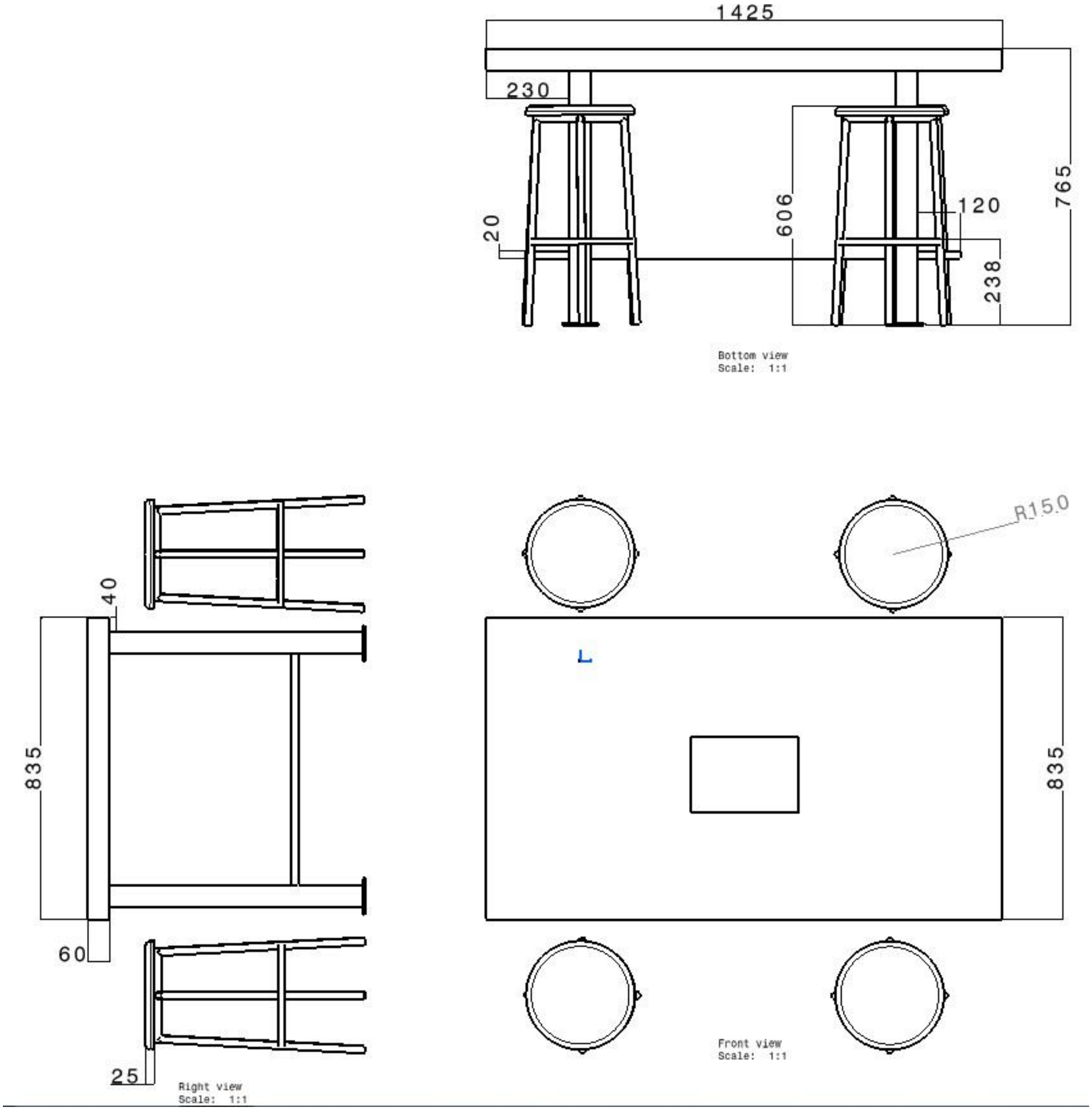
3.1.4 Tidak menjejaskan imej mana-mana Sekolah, Pejabat Pelajaran Daerah, Jabatan Pelajaran Negeri dan Kementerian Pelajaran Malaysia.

3.1.5 Penyertaan pelajar dan guru-guru adalah atas kerelaan sendiri dan mendapat kebenaran Pengetua/Guru Besar.

3.1.6 Keselamatan pelajar dan guru-guru wajib diutamakan dan menjadi tanggungjawab penganjur. Rujuk Surat Pekeliling Ikhtisas Bil.8/1999 : Keselamatan Pelajar Pergi Dan Balik Sekolah serta Penyertaan Pelajar Di Dalam Aktiviti Luar : Pekeliling Ikhtisas Bil 1/1995.

Appendix D

Orthographic view of current workstation in CAD drawing



Appendix E

Self – administrative questionnaire

No siri : Tarikh :

BORANG KAJI SELIDIK

Soal Selidik Untuk Mengenalpasti Postur Kerja Pelajar

Kelas :_____________ Jantina : Lelaki / Perempuan

Tinggi : _____________ Berat : ______________

Masalah kesihatan : Tiada / Ada Jika ada, nyatakan _____________________

BAHAGIAN 1 : Proses memotong bahan kerja

Arahan : Sila bulatkan pada jawapan yang berkenaan.

Semasa melakukan proses memotong bahan kerja, adakah anda perlu

1. Menunduk belakang anda? Ya / Tidak
2. Memusing badan anda? Ya / Tidak
3. Menunduk dan memusing badan anda? Ya / Tidak

Semasa melakukan proses memotong bahan kerja, adakah anda perlu

4. Menunduk leher anda? Ya / Tidak
5. Memusing leher anda? Ya / Tidak
6. Menunduk dan memusing leher anda? Ya / Tidak

Semasa melakukan proses memotong bahan kerja, adakah anda perlu

7. Membengkokkan pergelangan tangan anda? Ya / Tidak
8. Memusingkan pergelangan tangan anda? Ya / Tidak
9. Membengkok dan memusingkan pergelangan tangan anda? Ya / Tidak

Semasa melakukan proses memotong bahan kerja, adakah anda perlu

10. Menggunakan daya tenaga yang tinggi? Ya / Tidak

BAHAGIAN 2 : <u>Proses menanda, memasang dan mencantum bahan kerja</u>

Arahan : Sila bulatkan pada jawapan yang berkenaan.

Semasa melakukan proses menanda, memasang dan mencantum bahan kerja, adakah anda perlu

11. Menunduk belakang anda? Ya / Tidak
12. Memusing badan anda? Ya / Tidak
13. Menunduk dan memusing badan anda? Ya / Tidak

Semasa melakukan proses menanda, memasang dan mencantum bahan kerja, adakah anda perlu

14. Menunduk leher anda? Ya / Tidak
15. Memusing leher anda? Ya / Tidak
16. Menunduk dan memusing leher anda? Ya / Tidak

Semasa melakukan proses menanda, memasang dan mencantum bahan kerja, adakah anda perlu

17. Membengkokkan pergelangan tangan anda? Ya / Tidak
18. Memusingkan pergelangan tangan anda? Ya / Tidak
19. Membengkok dan memusingkan pergelangan tangan anda? Ya / Tidak

Semasa melakukan proses menanda, memasang dan mencantum bahan kerja, adakah

20. Anda mempunyai ruang kaki yang sempit? Ya / Tidak
21. Kedudukan kaki anda tidak selesa? Ya / Tidak
22. Ruang kerja terlalu sempit? Ya / Tidak

- Nyatakan masalah yang dihadapi ketika menggunakan ruang kerja ini.

____

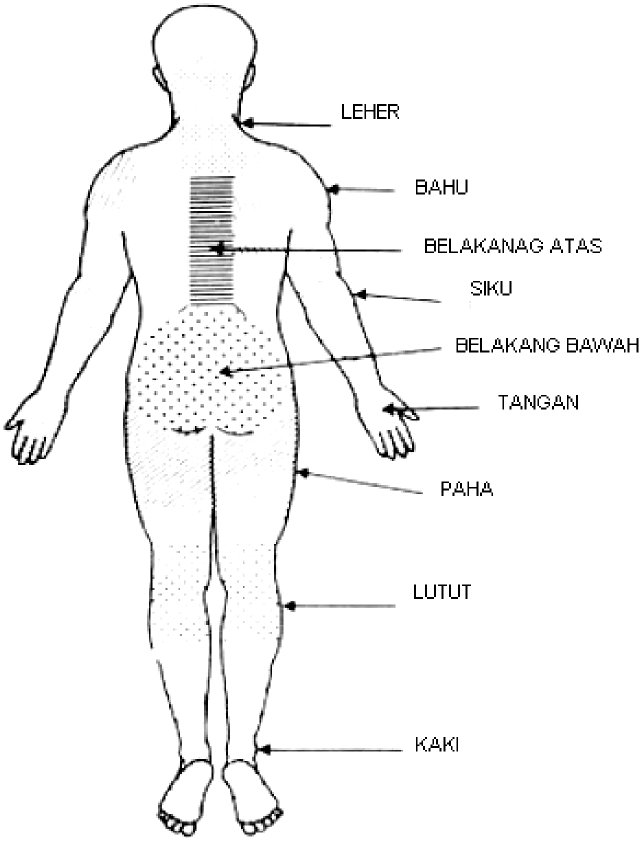
____

- Cadangan untuk penambahbaikan ruang kerja bengkel Kemahiran Hidup Bersepadu :

____

____

Arahan : Tanda / lorek bahagian badan yang bermasalah seperti SAKIT, SENGAL, KEJANG, TEGANG, KEBAS, LENGUH, TIDAK SELESA semasa melakukan projek kerja kayu



Arahan : Sila bulatkan pada jawapan yang berkenaan.

- Apa pendapat anda tentang ruang kerja yang anda gunakan?

Sangat tidak selesa / Tidak selesa / Sederhana / Selesa / Sangat selesa

~Terima kasih atas kerjasama yang diberikan~

Disediakan oleh
ADILA BINTI MD HASHIM

ENGLISH VERSION

Serial No: Date:

QUESTIONNAIRE FORM

Survey to identify Students' Working Postures

Class : ______________ Gender : Male / Female

Height : _____________ Weight : ____________

Health problems : No / Yes If yes, please state ______________________

PART 1: Material Cutting Task

Instruction : Please circle the relevant answer.

During cutting task, do you need to

1.	bend your back?	Yes /	No
2.	twist your body?	Yes /	No
3.	bend and twist your body?	Yes /	No

During cutting task, do you need to

4.	bend your neck?	Yes /	No
5.	twist your neck?	Yes /	No
6.	bend and twist your neck?	Yes /	No

During cutting task, do you need to

7.	bend your wrist?	Yes /	No
8.	twist your wrist?	Yes /	No
9.	bend and twist your wrist?	Yes /	No

During cutting task, do you need to

10.	use high force?	Yes /	No

PART 2 : Assembly Task

Instruction : Please circle the relevant answer.

During assembly task, do you need to

11. bend your back?	Yes	/	No
12. twist your body?	Yes	/	No
13. bend and twist your body?	Yes	/	No

During assembly task, do you need to

14. bend your neck?	Yes	/	No
15. twist your neck?	Yes	/	No
16. bend and twist your neck?	Yes	/	No

During assembly task, do you need to

17. bend your wrist?	Yes	/	No
18. twist your wrist?	Yes	/	No
19. bend and twist your wrist?	Yes	/	No

During assembly task, do you

20. have limit legroom?	Yes	/	No
21. have to put you feet uncomfortably?	Yes	/	No
22. have limited workspace?	Yes	/	No

- Please state any problem when using the workstation.

____

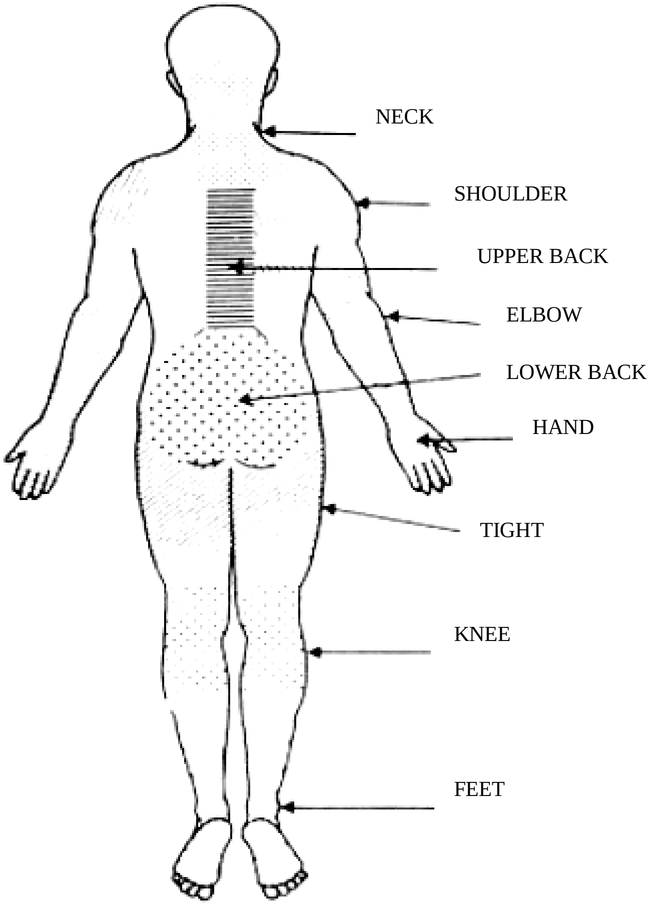
____

- Recommendation to improve Integrated Living Skills workshop's workstation.

____

____

Instruction : Mark body parts that feel PAIN, STRAIN, STIFF, NUMB, UNCOMFORTABLE when performing the woodworking project.



Instruction : Please circle the relevant answer.

- What is your rating for your current workstation?

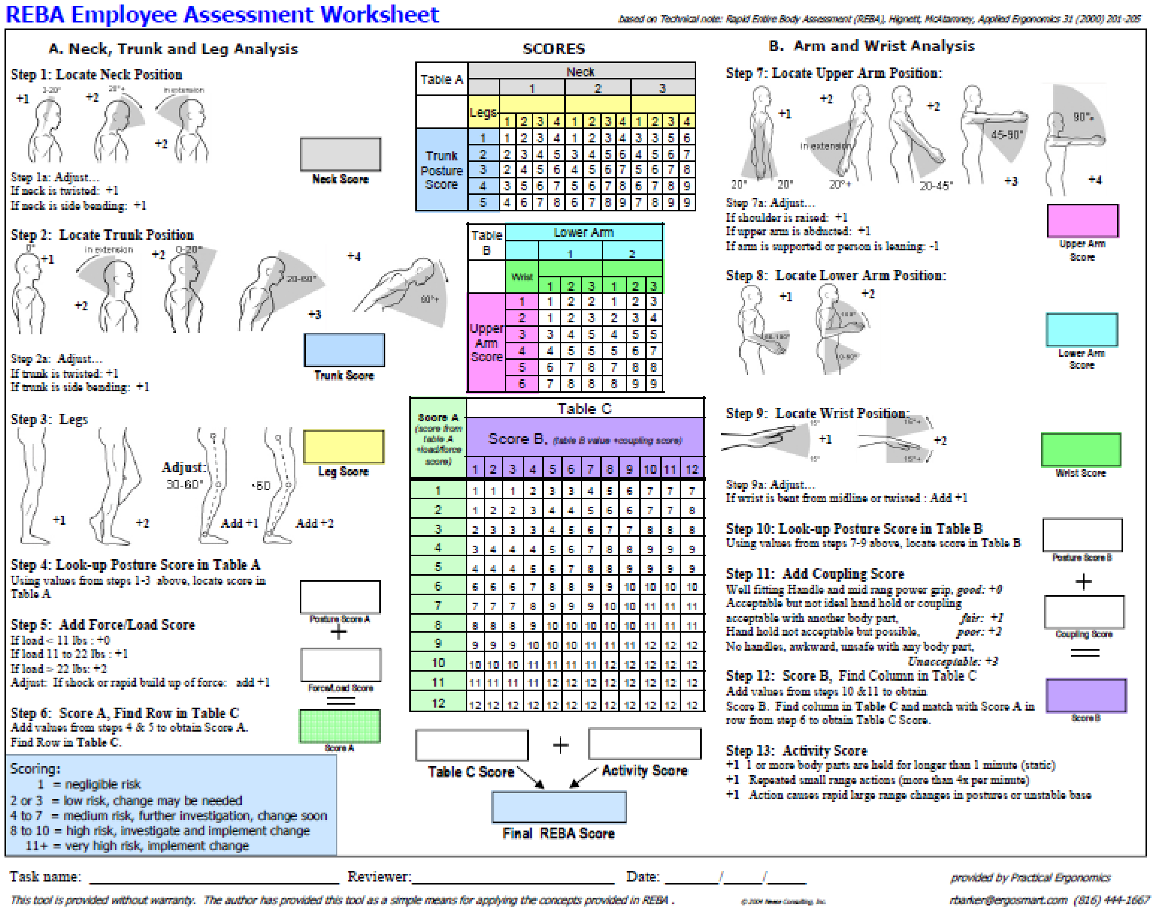
Very uncomfortable / Uncomfortable / Moderate / Comfortable / Very comfortable

~ Thank you for your cooperation~

Prepared by
ADILA BINTI MD HASHIM

Appendix F

RULA and REBA evaluation sheet



REBA Employee Assessment Worksheet

based on Technical note: Rapid Entire Body Assessment (REBA), Hignett, McAtamney, Applied Ergonomics 31 (2000) 201-205

A. Neck, Trunk and Leg Analysis

Step 1: Locate Neck Position

+1 (0-20°) +2 (20°+) +2 (in extension)

Step 1a: Adjust…
If neck is twisted: +1
If neck is side bending: +1

Neck Score

Step 2: Locate Trunk Position

+1 (0°) +2 (in extension) +2 (0-20°) +3 (20-60°) +4 (60°+)

Step 2a: Adjust…
If trunk is twisted: +1
If trunk is side bending: +1

Trunk Score

Step 3: Legs

+1 +2 Adjust: 30-60° Add +1, 60 Add +2

Leg Score

Step 4: Look-up Posture Score in Table A
Using values from steps 1-3 above, locate score in Table A

Posture Score A

+

Step 5: Add Force/Load Score
If load < 11 lbs : +0
If load 11 to 22 lbs : +1
If load > 22 lbs: +2
Adjust: If shock or rapid build up of force: add +1

Force/Load Score

=

Step 6: Score A, Find Row in Table C
Add values from steps 4 & 5 to obtain Score A.
Find Row in Table C.

Score A

Scoring:
1 = negligible risk
2 or 3 = low risk, change may be needed
4 to 7 = medium risk, further investigation, change soon
8 to 10 = high risk, investigate and implement change
11+ = very high risk, implement change

SCORES

Table A	Neck	1				2				3			
	Legs	1	2	3	4	1	2	3	4	1	2	3	4
Trunk Posture Score	1	1	2	3	4	1	2	3	4	3	3	5	6
	2	2	3	4	5	3	4	5	6	4	5	6	7
	3	2	4	5	6	4	5	6	7	5	6	7	8
	4	3	5	6	7	5	6	7	8	6	7	8	9
	5	4	6	7	8	6	7	8	9	7	8	9	9

Table B	Lower Arm	1			2		
	Wrist	1	2	3	1	2	3
Upper Arm Score	1	1	2	2	1	2	3
	2	1	2	3	2	3	4
	3	3	4	5	4	5	5
	4	4	5	5	5	6	7
	5	6	7	8	7	8	8
	6	7	8	8	8	9	9

Table C

Score A (score from table A +load/force score)	Score B, (table B value +coupling score) 1	2	3	4	5	6	7	8	9	10	11	12
1	1	1	1	2	3	3	4	5	6	7	7	7
2	1	2	2	3	4	4	5	6	6	7	7	8
3	2	3	3	3	4	5	6	7	7	8	8	8
4	3	4	4	4	5	6	7	8	8	9	9	9
5	4	4	4	5	6	7	8	8	9	9	9	9
6	6	6	6	7	8	8	9	9	10	10	10	10
7	7	7	7	8	9	9	9	10	10	11	11	11
8	8	8	8	9	10	10	10	10	10	11	11	11
9	9	9	9	10	10	10	11	11	11	12	12	12
10	10	10	10	11	11	11	11	12	12	12	12	12
11	11	11	11	11	12	12	12	12	12	12	12	12
12	12	12	12	12	12	12	12	12	12	12	12	12

Table C Score + Activity Score

Final REBA Score

B. Arm and Wrist Analysis

Step 7: Locate Upper Arm Position:

+1 (20° / 20°) +2 (in extension, 20°+) +2 (20-45°) +3 (45-90°) +4 (90°+)

Step 7a: Adjust…
If shoulder is raised: +1
If upper arm is abducted: +1
If arm is supported or person is leaning: -1

Upper Arm Score

Step 8: Locate Lower Arm Position:

+1 (60-100°) +2 (100°+, 0-60°)

Lower Arm Score

Step 9: Locate Wrist Position:

+1 (15°, 15°) +2 (15°+, 15°+)

Step 9a: Adjust…
If wrist is bent from midline or twisted : Add +1

Wrist Score

Step 10: Look-up Posture Score in Table B
Using values from steps 7-9 above, locate score in Table B

Posture Score B

+

Step 11: Add Coupling Score
Well fitting Handle and mid rang power grip, *good: +0*
Acceptable but not ideal hand hold or coupling acceptable with another body part, *fair: +1*
Hand hold not acceptable but possible, *poor: +2*
No handles, awkward, unsafe with any body part, *Unacceptable: +3*

Coupling Score

=

Step 12: Score B, Find Column in Table C
Add values from steps 10 &11 to obtain Score B. Find column in Table C and match with Score A in row from step 6 to obtain Table C Score.

Score B

Step 13: Activity Score
+1 1 or more body parts are held for longer than 1 minute (static)
+1 Repeated small range actions (more than 4x per minute)
+1 Action causes rapid large range changes in postures or unstable base

Task name: ____________________ Reviewer:____________________ Date: ____/____/____

provided by Practical Ergonomics

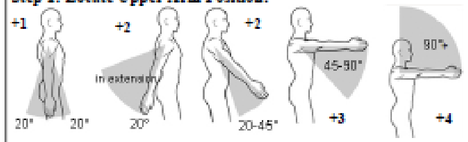
This tool is provided without warranty. The author has provided this tool as a simple means for applying the concepts provided in REBA .

rbarker@ergosmart.com (816) 444-1667

RULA Employee Assessment Worksheet *based on RULA: a survey method for the investigation of work-related upper limb disorders, McAtamney & Corlett, Applied Ergonomics 1993, 24(2), 91-99*

A. Arm and Wrist Analysis

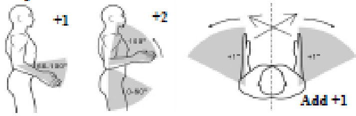
Step 1: Locate Upper Arm Position:



Step 1a: Adjust...
If shoulder is raised: +1
If upper arm is abducted: +1
If arm is supported or person is leaning: -1

Upper Arm Score

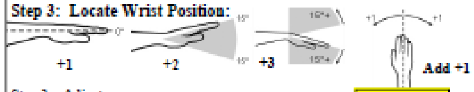
Step 2: Locate Lower Arm Position:



Lower Arm Score

Step 2a: Adjust...
If either arm is working across midline or out to side of body: Add +1

Step 3: Locate Wrist Position:



Step 3a: Adjust...
If wrist is bent from midline: Add +1

Wrist Score

Step 4: Wrist Twist:
If wrist is twisted in mid-range: +1
If wrist is at or near end of range: +2

Wrist Twist Score

Step 5: Look-up Posture Score in Table A:
Using values from steps 1-4 above, locate score in Table A

Posture Score A
+

Step 6: Add Muscle Use Score
If posture mainly static (i.e. held>10 minutes),
Or if action repeated occurs 4X per minute: +1

Muscle Use Score
+

Step 7: Add Force/Load Score
If load < 4.4 lbs (intermittent): +0
If load 4.4 to 22 lbs (intermittent): +1
If load 4.4 to 22 lbs (static or repeated): +2
If more than 22 lbs or repeated or shocks: +3

Force/Load Score
=

Step 8: Find Row in Table C
Add values from steps 5-7 to obtain
Wrist and Arm Score. Find row in Table C.

Wrist & Arm Score

SCORES

Table A: Wrist Posture Score

Upper Arm	Lower Arm	Wrist 1, Wrist Twist 1	Wrist 1, Wrist Twist 2	Wrist 2, Wrist Twist 1	Wrist 2, Wrist Twist 2	Wrist 3, Wrist Twist 1	Wrist 3, Wrist Twist 2	Wrist 4, Wrist Twist 1	Wrist 4, Wrist Twist 2
1	1	1	2	2	2	2	3	3	3
	2	2	2	2	2	3	3	3	3
	3	2	3	3	3	3	3	4	4
2	1	2	3	3	3	3	4	4	4
	2	3	3	3	3	3	4	4	4
	3	3	4	4	4	4	4	5	5
3	1	3	3	4	4	4	4	5	5
	2	3	4	4	4	4	4	5	5
	3	4	4	4	4	4	5	5	5
4	1	4	4	4	4	4	5	5	5
	2	4	4	4	4	4	5	5	5
	3	4	4	4	5	5	5	6	6
5	1	5	5	5	5	5	6	6	7
	2	5	6	6	6	6	7	7	7
	3	6	6	6	7	7	7	7	8
6	1	7	7	7	7	7	8	8	9
	2	8	8	8	8	8	9	9	9
	3	9	9	9	9	9	9	9	9

Table C: Neck, trunk and leg score

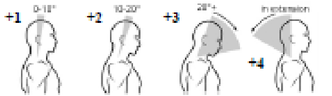
Wrist and Arm Score	1	2	3	4	5	6	7+
1	1	2	3	3	4	5	5
2	2	2	3	4	4	5	5
3	3	3	3	4	4	5	6
4	3	3	3	4	5	6	6
5	4	4	4	5	6	7	7
6	4	4	5	6	6	7	7
7	5	5	6	6	7	7	7
8+	5	5	6	7	7	7	7

Scoring: (final score from Table C)
1 or 2 = acceptable posture
3 or 4 = further investigation, change may be needed
5 or 6 = further investigation, change soon
7 = investigate and implement change

Final Score

B. Neck, Trunk and Leg Analysis

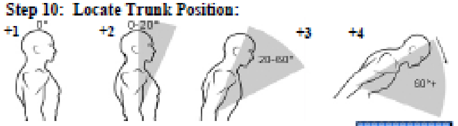
Step 9: Locate Neck Position:



Neck Score

Step 9a: Adjust...
If neck is twisted: +1
If neck is side bending: +1

Step 10: Locate Trunk Position:



Trunk Score

Step 10a: Adjust...
If trunk is twisted: +1
If trunk is side bending: +1

Step 11: Legs:
If legs and feet are supported: +1
If not: +2

Leg Score

Table B: Trunk Posture Score

Neck Posture Score	1, Legs 1	1, Legs 2	2, Legs 1	2, Legs 2	3, Legs 1	3, Legs 2	4, Legs 1	4, Legs 2	5, Legs 1	5, Legs 2	6, Legs 1	6, Legs 2
1	1	3	2	3	3	4	5	5	6	6	7	7
2	2	3	2	3	4	5	5	5	6	7	7	7
3	3	3	3	4	4	5	5	6	6	7	7	7
4	5	5	5	6	6	7	7	7	7	7	8	8
5	7	7	7	7	7	8	8	8	8	8	8	8
6	8	8	8	8	8	8	8	8	9	9	9	9

Step 12: Look-up Posture Score in Table B:
Using values from steps 9-11 above,
locate score in Table B

Posture Score B
+

Step 13: Add Muscle Use Score
If posture mainly static (i.e. held>10 minutes),
Or if action repeated occurs 4X per minute: +1

Muscle Use Score
+

Step 14: Add Force/Load Score
If load < 4.4 lbs (intermittent): +0
If load 4.4 to 22 lbs (intermittent): +1
If load 4.4 to 22 lbs (static or repeated): +2
If more than 22 lbs or repeated or shocks: +3

Force/Load Score
=

Step 15: Find Column in Table C
Add values from steps 12-14 to obtain
Neck, Trunk and Leg Score. Find Column in Table C.

Neck, Trunk & Leg Score

Task name: ______________________ Reviewer:__________________ Date: ____/____/____ *provided by Practical Ergonomics*

This tool is provided without warranty. The author has provided this tool as a simple means for applying the concepts provided in RULA.

rbarker@ergosmart.com (816) 444-1667

Appendix G

Kano questionnaire

No.siri: Tarikh:

Soal selidik Kano Model

Arahan : Sila bulatkan pada jawapan yang berkenaan.

1. Apa pendapat anda keperluan ruang kerja yang luas?

Saya Suka Memang Sepatutnya Tidak kisah Boleh terima Tidak suka

2. Apa pendapat anda tiada ruang kerja yang luas?

Saya Suka Memang Sepatutnya Tidak kisah Boleh terima Tidak suka

3. Apa pendapat anda keperluan ruang kaki yang cukup?

Saya Suka Memang Sepatutnya Tidak kisah Boleh terima Tidak suka

4. Apa pendapat anda tiada ruang kaki yang cukup?

Saya Suka Memang Sepatutnya Tidak kisah Boleh terima Tidak suka

5. Apa pendapat anda keperluan kerusi berketinggian sesuai

Saya Suka Memang Sepatutnya Tidak kisah Boleh terima Tidak suka

6. Apa pendapat anda tiada kerusi berketinggian sesuai

Saya Suka Memang Sepatutnya Tidak kisah Boleh terima Tidak suka

7. Apa pendapat anda keperluan kerusi dengan tempat sandar

Saya Suka Memang Sepatutnya Tidak kisah Boleh terima Tidak suka

8. Apa pendapat anda tiada kerusi dengan tempat sandar

Saya Suka Memang Sepatutnya Tidak kisah Boleh terima Tidak suka

9. Apa pendapat anda keperluan meja kerja berketinggian sesuai

Saya Suka Memang Sepatutnya Tidak kisah Boleh terima Tidak suka

10. Apa pendapat anda tiada meja kerja berketinggian sesuai

Saya Suka Memang Sepatutnya Tidak kisah Boleh terima Tidak suka

11. Apa pendapat anda keperluan ruang storan sementara di atas meja kerja

Saya Suka Memang Sepatutnya Tidak kisah Boleh terima Tidak suka

12. Apa pendapat anda tiada ruang storan sementara di atas meja kerja

Saya Suka Memang Sepatutnya Tidak kisah Boleh terima Tidak suka

13. Apa pendapat anda keperluan perabot boleh diubah aras ketinggian

Saya Suka Memang Sepatutnya Tidak kisah Boleh terima Tidak suka

14. Apa pendapat anda tiada perabot boleh diubah aras ketinggian

Saya Suka Memang Sepatutnya Tidak kisah Boleh terima Tidak suka

15. Apa pendapat anda keperluan ruang kerja lebih kukuh

Saya Suka Memang Sepatutnya Tidak kisah Boleh terima Tidak suka

16. Apa pendapat anda tiada ruang kerja lebih kukuh

Saya Suka Memang Sepatutnya Tidak kisah Boleh terima Tidak suka

17. Apa pendapat anda keperluan permukaan meja yang sekata, keras dan licin

Saya Suka Memang Sepatutnya Tidak kisah Boleh terima Tidak suka

18. Apa pendapat anda tiada permukaan meja yang sekata, keras dan licin

Saya Suka Memang Sepatutnya Tidak kisah Boleh terima Tidak suka

19. Apa pendapat anda keperluan peralatan keselamatan yang lengkap

Saya Suka Memang Sepatutnya Tidak kisah Boleh terima Tidak suka

20. Apa pendapat anda tiada peralatan keselamatan yang lengkap

Saya Suka Memang Sepatutnya Tidak kisah Boleh terima Tidak suka

21. Apa pendapat anda keperluan peralatan/jig yang mudah digunakan

Saya Suka Memang Sepatutnya Tidak kisah Boleh terima Tidak suka

22. Apa pendapat anda tiada peralatan/jig yang mudah digunakan

Saya Suka Memang Sepatutnya Tidak kisah Boleh terima Tidak suka

~Terima kasih atas kerjasama yang diberikan~

Disediakan oleh

ADILA BINTI MD HASHIM

ENGLISH VERSION

Serial No : Date :

Kano Model Questionnaire

Instruction : Please circle the relevant answer.

1. How do you feel if the workstation provides a broad workspace?

I like it *I am expecting it* *I am neutral* *I can accept it* *I dislike it*

2. How do you feel if the workstation provides no broad workspace?

I like it *I am expecting it* *I am neutral* *I can accept it* *I dislike it*

3. How do you feel if the workstation provides enough legroom?

I like it *I am expecting it* *I am neutral* *I can accept it* *I dislike it*

4. How do you feel if the workstation provides not enough legroom?

I like it *I am expecting it* *I am neutral* *I can accept it* *I dislike it*

5. How do you feel if the workstation provides a chair with suitable height?

I like it *I am expecting it* *I am neutral* *I can accept it* *I dislike it*

6. How do you feel if the workstation provides a chair with unsuitable height?

I like it *I am expecting it* *I am neutral* *I can accept it* *I dislike it*

7. How do you feel if the workstation provides a chair with backrest?

I like it *I am expecting it* *I am neutral* *I can accept it* *I dislike it*

8. How do you feel if the workstation provides a chair without backrest?

I like it *I am expecting it* *I am neutral* *I can accept it* *I dislike it*

9. How do you feel if the workstation provides a workbench with suitable height?

I like it *I am expecting it* *I am neutral* *I can accept it* *I dislike it*

10. How do you feel if the workstation provides a workbench with unsuitable height?

I like it *I am expecting it* *I am neutral* *I can accept it* *I dislike it*

11. How do you feel if the workstation provides temporary storages?

I like it *I am expecting it* *I am neutral* *I can accept it* *I dislike it*

12. How do you feel if the workstation provides no temporary storages?

I like it *I am expecting it* *I am neutral* *I can accept it* *I dislike it*

13. How do you feel if the workstation provides adjustable furniture?

I like it *I am expecting it* *I am neutral* *I can accept it* *I dislike it*

14. How do you feel if the workstation provides no adjustable furniture?

I like it *I am expecting it* *I am neutral* *I can accept it* *I dislike it*

15. How do you feel if the workstation provides a stable frame?

I like it *I am expecting it* *I am neutral* *I can accept it* *I dislike it*

16. How do you feel if the workstation provides unstable frame?

I like it *I am expecting it* *I am neutral* *I can accept it* *I dislike it*

17. How do you feel if the workstation provides smooth working surface?

I like it *I am expecting it* *I am neutral* *I can accept it* *I dislike it*

18. How do you feel if the workstation provides smooth working surface?

I like it *I am expecting it* *I am neutral* *I can accept it* *I dislike it*

19. How do you feel if the workstation provides complete safety tools?

I like it *I am expecting it* *I am neutral* *I can accept it* *I dislike it*

20. How do you feel if the workstation provides incomplete safety tools?

I like it *I am expecting it* *I am neutral* *I can accept it* *I dislike it*

21. How do you feel if the workstation provides additional tools?

I like it *I am expecting it* *I am neutral* *I can accept it* *I dislike it*

22. How do you feel if the workstation provides no additional tools?

I like it *I am expecting it* *I am neutral* *I can accept it* *I dislike it*

~ Thank you for your cooperation~

Prepared by

ADILA BINTI MD HASHIM

Appendix H

Looking up questionnaire answers in the evaluation table and tabulating the results (Löfgren & Witell, 2008).

Question	Answers
How do you feel if the workstation provides a chair with backrest? *(functional question)*	1. **<u>I like it.</u>** 2. I am expecting it. 3. I am neutral. 4. I can accept it. 5. I dislike it.
How do you feel if the workstation provides a chair without backrest? *(dysfunctional question)*	1. I like it. 2. I am expecting it. 3. I am neutral. 4. **<u>I can accept it.</u>** 5. I dislike it.

Costumer requirement (CR)		Dysfunctional question				
		Like	Expect	Neutral	Accept	Dislike
Functional question	Like	Q	A	A	A	O
	Expect	R	I	I	I	M
	Neutral	R	I	I	I	M
	Accept	R	I	I	I	M
	Dislike	R	R	R	R	Q

CR	A	M	O	R	I	Q	Total	Quality
1	1							
…..								

Appendix I

User importance scale

Skala Keutamaan Pengguna

Arahan : Sila isikan nombor 1 – 11 mengikut **keutamaan** keperluan pelajar dan **bulat**kan di ruang yang berkenaan.

No	Keperluan pelajar	Keutamaan	Kano Rating				
1	Ruang kerja yang luas		Sangat perlu	Perlu	Neutral	Kurang perlu	Tidak perlu
2	Ruang kaki yang cukup		Sangat perlu	Perlu	Neutral	Kurang perlu	Tidak perlu
3	Kerusi berketinggian sesuai		Sangat perlu	Perlu	Neutral	Kurang perlu	Tidak perlu
4	Kerusi dengan tempat sandar		Sangat perlu	Perlu	Neutral	Kurang perlu	Tidak perlu
5	Meja kerja berketinggian sesuai		Sangat perlu	Perlu	Neutral	Kurang perlu	Tidak perlu
6	Ruang storan sementara di atas meja kerja		Sangat perlu	Perlu	Neutral	Kurang perlu	Tidak perlu
7	Perabot boleh diubah aras ketinggian		Sangat perlu	Perlu	Neutral	Kurang perlu	Tidak perlu
8	Ruang kerja lebih kukuh		Sangat perlu	Perlu	Neutral	Kurang perlu	Tidak perlu
9	Permukaan meja yang sekata, keras dan licin		Sangat perlu	Perlu	Neutral	Kurang perlu	Tidak perlu
10	Peralatan keselamatan yang lengkap		Sangat perlu	Perlu	Neutral	Kurang perlu	Tidak perlu
11	Peralatan/Jig yang mudah digunakan		Sangat perlu	Perlu	Neutral	Kurang perlu	Tidak perlu

User importance scale

Instruction: Please fill in the numbers 1 – 11 according to the priority and circle for rating in the appropriate column.

No	Students' requirement.	Priority	Kano Rating				
1	Broad work surface.		Very important	Important	Neutral	Less important	Unimportant
2	Sufficient leg room.		Very important	Important	Neutral	Less important	Unimportant
3	Suitable chair or stool height.		Very important	Important	Neutral	Less important	Unimportant
4	Chair with backrest.		Very important	Important	Neutral	Less important	Unimportant
5	Suitable workbench height.		Very important	Important	Neutral	Less important	Unimportant
6	Temporary storage on the worktop.		Very important	Important	Neutral	Less important	Unimportant
7	Adjustable furniture.		Very important	Important	Neutral	Less important	Unimportant
8	Stable workstation.		Very important	Important	Neutral	Less important	Unimportant
9	Smooth and flat working surface.		Very important	Important	Neutral	Less important	Unimportant
10	Safety application.		Very important	Important	Neutral	Less important	Unimportant
11	Friendly-user tools.		Very important	Important	Neutral	Less important	Unimportant

Appendix J

Statistical test (risk exposure)

Test Statistics[a]

	bend back cut	twist back cut	bend/twist back cut	bend neck cut	twist neck cut	bend/twist neck cut	bend wrist cut	twist wrist cut	bend/twist wrist cut	high energy cut	bend back ass	twist back ass	bend/twist back ass	bend neck ass	twist neck ass	bend/twist neck ass	bend wrist assembly	twist wrist assembly	bend/twist wrist ass	leg space	comfort feet	insufficient space
Mann-Whitney U	13657.000	13447.000	13800.500	13164.500	13608.500	13450.500	12544.000	13439.000	13439.000	13689.500	13006.500	13859.000	12590.000	14098.000	13960.500	12761.000	12086.000	13267.500	12534.000	13726.000	13904.000	12255.000
Wilcoxon W	28708.000	26813.000	28851.500	28215.500	26974.500	26816.500	27595.000	26805.000	26805.000	28740.500	28057.500	27225.000	27641.000	27464.000	29011.500	27832.000	25452.000	26653.500	25900.000	27092.000	27270.000	25458.000
Z	-1.778	-.946	-.452	-1.915	-.821	-1.114	-2.813	-1.526	-1.526	-.532	-2.351	-.317	-1.959	-.003	-.182	-1.819	-2.613	-1.414	-2.745	-.487	-.254	-2.301
Asymp. Sig. (2-tailed)	.075	.344	.652	.055	.412	.265	.005	.127	.127	.595	.019	.751	.050	.997	.856	.069	.009	.157	.006	.627	.799	.021

a. Grouping Variable: GENDER

Test Statistics[a,b]

	bend back cut	twist back cut	bend/twist back cut	bend neck cut	twist neck cut	bend/twist neck cut	bend wrist cut	twist wrist cut	bend/twist wrist cut	high energy cut	bend back ass	twist back ass	bend/twist back ass	bend neck ass	twist neck ass	bend/twist neck ass	bend wrist assembly	twist wrist assembly	bend/twist wrist ass	leg space	comfort feet	insufficient space
Chi-Square	6.840	11.534	10.533	5.686	13.001	19.063	43.772	15.117	19.078	25.979	23.502	3.000	11.495	2.812	30.157	8.366	12.066	11.297	22.194	17.722	14.715	12.510
df	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Asymp. Sig.	.033	.003	.005	.058	.002	.000	.000	.001	.000	.000	.000	.223	.003	.245	.000	.015	.002	.004	.000	.000	.001	.002

Appendix K

Statistical test (comfort rating)

Test Statistics[a]

	COMFORTIBILITY
Mann-Whitney U	11028.000
Wilcoxon W	25393.000
Z	-2.780
Asymp. Sig. (2-tailed)	.005

Test Statistics[a,b]

	COMFORTIBILITY
Chi-Square	42.588
df	2
Asymp. Sig.	.000

Appendix L

Statistical test (body pain)

Test Statistics[a,b]

	NECK	SHOULDER	ELBOW	WRIST	UPPER BACK	LOWER BACK	BUTTOCK	HIP	KNEE	ANKLE
Chi-Square	1.057	1.418	.092	.814	34.453	40.709	14.883	8.982	3.241	11.501
df	2	2	2	2	2	2	2	2	2	2
Asymp. Sig.	.590	.492	.955	.666	.000	.000	.001	.011	.198	.003

Test Statistics[a]

	NECK	SHOULDER	ELBOW	WRIST	UPPER BACK	LOWER BACK	BUTTOCK	HIP	KNEE	ANKLE
Mann-Whitney U	12726.500	12337.000	13445.500	12764.500	12879.500	13473.500	13785.500	13842.000	14086.500	13862.000
Wilcoxon W	27777.500	27388.000	26811.500	27815.500	27930.500	26839.500	28836.500	28893.000	29137.500	28913.000
Z	-1.797	-2.332	-1.108	-1.761	-1.590	-.854	-.487	-.423	-.022	-.374
Asymp. Sig. (2-tailed)	.072	.020	.268	.078	.112	.393	.626	.672	.983	.709

Appendix M

Correlation test

Correlations

		RULA	Age
RULA	Pearson Correlation	1	.089
	Sig. (2-tailed)		.340
	N	117	117
Age	Pearson Correlation	.089	1
	Sig. (2-tailed)	.340	
	N	117	117

Correlations

		REBA	Age
REBA	Pearson Correlation	1	.124
	Sig. (2-tailed)		.182
	N	117	117
Age	Pearson Correlation	.124	1
	Sig. (2-tailed)	.182	
	N	117	117

Correlations

		RULA	Gender
RULA	Pearson Correlation	1	.153
	Sig. (2-tailed)		.099
	N	117	117
Gender	Pearson Correlation	.153	1
	Sig. (2-tailed)	.099	
	N	117	117

Correlations

		REBA	Gender
REBA	Pearson Correlation	1	.031
	Sig. (2-tailed)		.737
	N	117	117
Gender	Pearson Correlation	.031	1
	Sig. (2-tailed)	.737	
	N	117	117

	RULA	REBA
RULA	1	.449**
		.000
	117	117
REBA	.449**	1
	.000	
	117	117

Appendix N

Anthropometric data measurements of all samples

Statistics

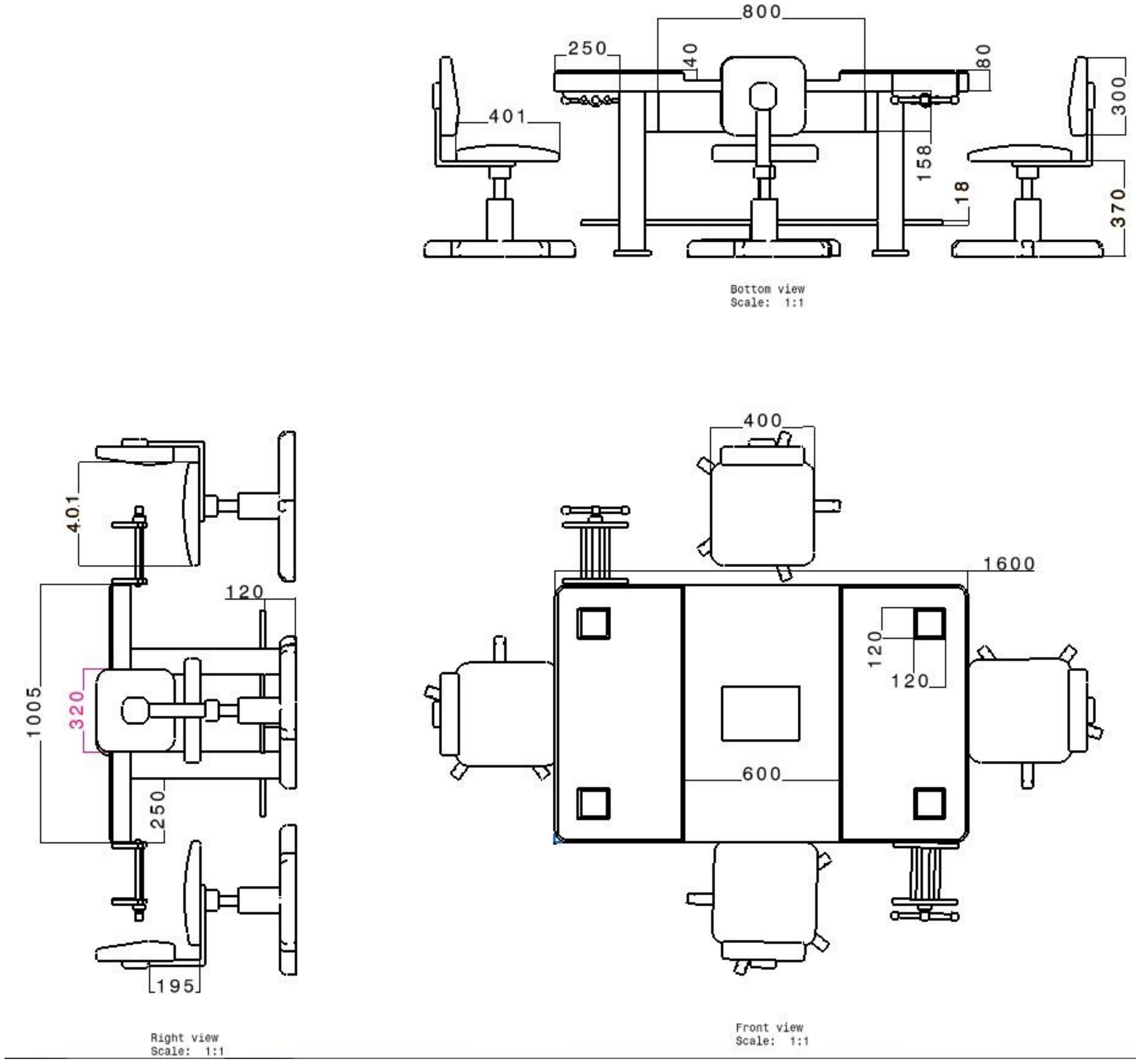
Age	Gender			Stature	Elbow height	Elbow-wrist	Shoulder breath	Buttock-popliteal	Popliteal height	Tight clearence	Hip breath	Foot depth	Forward reach
1	1	N	Valid	22	22	22	22	22	22	22	22	22	22
			Missing	0	0	0	0	0	0	0	0	0	0
		Mean		153.823	93.486	25.750	31.023	41.777	36.618	11.032	28.027	21.586	60.818
		Std. Deviation		7.3954	9.4755	10.7901	4.3173	2.5744	2.9040	2.4614	5.0796	1.6788	9.4485
		Percentiles	5	141.150	61.875	21.130	23.265	37.310	31.335	7.605	23.645	18.590	29.025
			50	152.700	94.950	23.400	29.800	41.600	36.950	10.500	26.500	21.200	61.250
			95	167.095	106.880	66.790	42.810	46.225	43.405	17.810	45.355	24.880	74.615
	2	N	Valid	10	10	10	10	10	10	10	10	10	10
			Missing	0	0	0	0	0	0	0	0	0	0
		Mean		152.740	1026.910	24.290	32.480	42.680	34.130	11.730	30.990	20.750	60.610
		Std. Deviation		3.6372	2943.7619	1.9319	3.2612	1.8510	2.3457	2.4139	3.1068	1.1617	3.4462
		Percentiles	5	146.200	92.800	22.000	28.300	40.400	30.700	8.800	26.900	18.700	55.500
			50	153.450	95.500	24.350	32.750	42.500	33.550	10.850	30.300	20.650	60.200
			95	158.000	9405.000	28.500	39.400	45.500	38.000	17.000	37.200	22.400	66.000

2	1	N	Valid	22	22	22	22	22	22	22	22	22	22
			Missing	0	0	0	0	0	0	0	0	0	0
		Mean		162.650	100.091	26.036	35.127	44.695	38.350	12.368	30.186	22.445	66.868
		Std. Deviation		3.5611	3.3651	1.0974	3.1010	1.8676	1.4388	2.1792	2.6892	1.2405	2.7149
		Percentiles	5	156.555	92.685	23.945	27.560	41.095	35.235	9.230	26.575	20.490	61.380
			50	163.050	100.700	26.050	35.500	45.000	38.400	12.300	29.200	22.100	67.100
			95	170.155	106.175	28.265	41.160	48.465	41.005	17.430	35.380	25.195	71.255
	2	N	Valid	35	35	35	35	35	35	35	35	35	35
			Missing	0	0	0	0	0	0	0	0	0	0
		Mean		152.251	94.211	23.469	30.426	41.623	35.543	10.471	29.140	20.271	61.877
		Std. Deviation		4.2523	3.2857	1.5909	2.9335	2.1531	2.3229	1.5970	2.3137	.9596	2.5457
		Percentiles	5	145.000	89.900	20.640	24.800	37.540	31.640	7.960	25.900	19.020	57.160
			50	152.000	93.800	23.400	30.900	41.600	36.000	10.500	29.100	20.000	61.500
			95	159.100	100.360	26.240	34.960	46.380	39.220	13.520	33.580	22.120	66.580
3	1	N	Valid	22	22	22	22	22	22	22	22	22	22
			Missing	0	0	0	0	0	0	0	0	0	0
		Mean		167.891	106.655	27.891	35.591	46.105	39.364	13.159	31.014	23.068	69.864
		Std. Deviation		6.7853	11.6407	3.0948	3.8322	2.5869	2.4348	2.1300	3.6247	1.4923	4.1284
		Percentiles	5	153.435	93.880	22.770	28.975	40.260	34.945	10.015	24.715	20.250	60.700
			50	169.000	105.750	27.550	35.350	47.100	40.000	13.050	30.350	23.000	69.000
			95	177.940	146.420	36.375	44.040	49.355	43.490	18.040	38.780	26.055	75.355

2	N	Valid	35	35	35	30	35	35	35	35	30	35
		Missing	0	0	0	5	0	0	0	0	5	0
	Mean		153.843	96.349	23.603	31.490	41.900	34.814	11.794	31.109	20.207	61.597
	Std. Deviation		4.5067	3.4702	1.3727	2.6808	2.2769	1.9820	2.4162	2.9218	1.1861	3.1285
	Percentiles	5	145.900	90.520	21.020	26.775	37.680	31.260	8.300	27.060	18.355	57.260
		50	153.500	96.000	23.600	31.450	41.500	35.400	11.200	31.000	20.000	61.200
		95	163.020	102.060	25.820	36.785	47.520	38.280	16.580	37.600	22.850	68.800

Appendix O

Orthographic view of proposed workstation in CAD drawing



Appendix P

RULA analysis summary of each subject

Jack Rapid Upper Limb Assessment Report

Assembly

Job #13, male,

Analysis Summary

Body Group A Posture Rating

Upper arm: 2
Lower arm: 3
Wrist: 1
Wrist Twist: 1
Total: 4

Muscle Use: Normal, no extreme use
Force/Load: 2-10 kg intermittent load
Arms: Supported

Body Group B Posture Rating

Neck: 1
Trunk: 3
Total: 3

Muscle Use: Normal, no extreme use
Force/Load: < 2 kg intermittent load

Legs and Feet Rating

Seated, Legs and feet well supported. Weight even.

Grand Score: 3

Action: Further investigation needed. Changes may be required.

Jack Rapid Upper Limb Assessment Report

Cutting

Job #13, Male,

Analysis Summary

Body Group A Posture Rating

Upper arm: 2
Lower arm: 3
Wrist: 3
Wrist Twist: 2
Total: 5

Muscle Use: Normal, no extreme use
Force/Load: 2-10 kg intermittent load
Arms: Supported

Body Group B Posture Rating

Neck: 1
Trunk: 3
Total: 3

Muscle Use: Normal, no extreme use
Force/Load: < 2 kg intermittent load

Legs and Feet Rating

Standing, weight even. Room for weight changes.

Grand Score: 4

Action: Further investigation needed. Changes may be required.

Jack Rapid Upper Limb Assessment Report

Assembly

Job #13, female,

Analysis Summary

Body Group A Posture Rating

Upper arm: 2
Lower arm: 2
Wrist: 2
Wrist Twist: 1
Total: 3

Muscle Use: Normal, no extreme use
Force/Load: < 2 kg intermittent load
Arms: Supported

Body Group B Posture Rating

Neck: 1
Trunk: 3
Total: 3

Muscle Use: Normal, no extreme use
Force/Load: < 2 kg intermittent load

Legs and Feet Rating

Seated, Legs and feet well supported. Weight even.

Grand Score: 3

Action: Further investigation needed. Changes may be required.

Analysis Summary

Body Group A Posture Rating

Upper arm: 2
Lower arm: 2
Wrist: 2
Wrist Twist: 1
Total: 4

Muscle Use: Normal, no extreme use
Force/Load: 2-10 kg intermittent load
Arms: Supported

Body Group B Posture Rating

Neck: 1
Trunk: 3
Total: 3

Muscle Use: Normal, no extreme use
Force/Load: < 2 kg intermittent load

Legs and Feet Rating

Standing, weight even. Room for weight changes.

Grand Score: 3

Action: Further investigation needed. Changes may be required.

Analysis Summary

Body Group A Posture Rating

Upper arm: 3
Lower arm: 2
Wrist: 2
Wrist Twist: 1
Total: 4

Muscle Use: Normal, no extreme use
Force/Load: < 2 kg intermittent load
Arms: Supported

Body Group B Posture Rating

Neck: 1
Trunk: 3
Total: 3

Muscle Use: Normal, no extreme use
Force/Load: < 2 kg intermittent load

Legs and Feet Rating

Seated, Legs and feet well supported. Weight even.

Grand Score: 3

Action: Further investigation needed. Changes may be required.

Jack Rapid Upper Limb Assessment Report

Cutting

Job #14, Male,

Analysis Summary

Body Group A Posture Rating

Upper arm: 2
Lower arm: 3
Wrist: 2
Wrist Twist: 1
Total: 5

Muscle Use: Normal, no extreme use
Force/Load: 2-10 kg intermittent load
Arms: Supported

Body Group B Posture Rating

Neck: 1
Trunk: 3
Total: 3

Muscle Use: Normal, no extreme use
Force/Load: < 2 kg intermittent load

Legs and Feet Rating

Standing, weight even. Room for weight changes.

Grand Score: 4

Action: Further investigation needed. Changes may be required.

Jack Rapid Upper Limb Assessment Report

Assembly

Job #14, female,

Analysis Summary

Body Group A Posture Rating

Upper arm: 3
Lower arm: 2
Wrist: 2
Wrist Twist: 1
Total: 4

Muscle Use: Normal, no extreme use
Force/Load: < 2 kg intermittent load
Arms: Supported

Body Group B Posture Rating

Neck: 1
Trunk: 3
Total: 3

Muscle Use: Normal, no extreme use
Force/Load: < 2 kg intermittent load

Legs and Feet Rating

Seated, Legs and feet well supported. Weight even.

Grand Score: 3

Action: Further investigation needed. Changes may be required.

Analysis Summary

Body Group A Posture Rating

Upper arm: 1
Lower arm: 3
Wrist: 2
Wrist Twist: 1
Total: 4

Muscle Use: Normal, no extreme use
Force/Load: 2-10 kg intermittent load
Arms: Supported

Body Group B Posture Rating

Neck: 1
Trunk: 3
Total: 3

Muscle Use: Normal, no extreme use
Force/Load: < 2 kg intermittent load

Legs and Feet Rating

Standing, weight even. Room for weight changes.

Grand Score: 3

Action: Further investigation needed. Changes may be required.

Jack Rapid Upper Limb Assessment Report

Assembly

Job #15, Male,

Analysis Summary

Body Group A Posture Rating

Upper arm: 3
Lower arm: 2
Wrist: 2
Wrist Twist: 1
Total: 4

Muscle Use: Normal, no extreme use
Force/Load: < 2 kg intermittent load
Arms: Supported

Body Group B Posture Rating

Neck: 1
Trunk: 3
Total: 3

Muscle Use: Normal, no extreme use
Force/Load: < 2 kg intermittent load

Legs and Feet Rating

Seated, Legs and feet well supported. Weight even.

Grand Score: 3

Action: Further investigation needed. Changes may be required.

Analysis Summary

Body Group A Posture Rating

Upper arm: 2
Lower arm: 3
Wrist: 2
Wrist Twist: 1
Total: 4

Muscle Use: Normal, no extreme use
Force/Load: < 2 kg intermittent load
Arms: Supported

Body Group B Posture Rating

Neck: 1
Trunk: 3
Total: 3

Muscle Use: Normal, no extreme use
Force/Load: < 2 kg intermittent load

Legs and Feet Rating

Seated, Legs and feet well supported. Weight even.

Grand Score: 3

Action: Further investigation needed. Changes may be required.

Jack Rapid Upper Limb Assessment Report

Assembly

Job #15, female,

Analysis Summary

Body Group A Posture Rating

Upper arm: 3
Lower arm: 2
Wrist: 2
Wrist Twist: 1
Total: 4

Muscle Use: Normal, no extreme use
Force/Load: < 2 kg intermittent load
Arms: Supported

Body Group B Posture Rating

Neck: 1
Trunk: 3
Total: 3

Muscle Use: Normal, no extreme use
Force/Load: < 2 kg intermittent load

Legs and Feet Rating

Seated, Legs and feet well supported. Weight even.

Grand Score: 3

Action: Further investigation needed. Changes may be required.

Analysis Summary

Body Group A Posture Rating

Upper arm: 2
Lower arm: 2
Wrist: 2
Wrist Twist: 1
Total: 4

Muscle Use: Normal, no extreme use
Force/Load: 2-10 kg intermittent load
Arms: Supported

Body Group B Posture Rating

Neck: 1
Trunk: 3
Total: 3

Muscle Use: Normal, no extreme use
Force/Load: < 2 kg intermittent load

Legs and Feet Rating

Standing, weight even. Room for weight changes.

Grand Score: 3

Action: Further investigation needed. Changes may be required.

Appendix Q

RULA analysis summary of each percentile

Jack Rapid Upper Limb Assessment Report

Assembly

Job #5th, Male,

Analysis Summary

Body Group A Posture Rating

Upper arm: 2
Lower arm: 2
Wrist: 1
Wrist Twist: 1
Total: 3

Muscle Use: Normal, no extreme use
Force/Load: < 2 kg intermittent load
Arms: Supported

Body Group B Posture Rating

Neck: 1
Trunk: 3
Total: 3

Muscle Use: Normal, no extreme use
Force/Load: < 2 kg intermittent load

Legs and Feet Rating

Seated, Legs and feet well supported. Weight even.

Grand Score: 3

Action: Further investigation needed. Changes may be required.

Jack Rapid Upper Limb Assessment Report

Cutting

Job #5th, Male,

Analysis Summary

Body Group A Posture Rating

Upper arm: 0
Lower arm: 2
Wrist: 2
Wrist Twist: 1
Total: 3

Muscle Use: Normal, no extreme use
Force/Load: 2-10 kg intermittent load
Arms: Supported

Body Group B Posture Rating

Neck: 1
Trunk: 3
Total: 3

Muscle Use: Normal, no extreme use
Force/Load: < 2 kg intermittent load

Legs and Feet Rating

Standing, weight even. Room for weight changes.

Grand Score: 3

Action: Further investigation needed. Changes may be required.

Analysis Summary

Body Group A Posture Rating

Upper arm: 3
Lower arm: 2
Wrist: 2
Wrist Twist: 1
Total: 4

Muscle Use: Normal, no extreme use
Force/Load: < 2 kg intermittent load
Arms: Supported

Body Group B Posture Rating

Neck: 1
Trunk: 3
Total: 3

Muscle Use: Normal, no extreme use
Force/Load: < 2 kg intermittent load

Legs and Feet Rating

Seated, Legs and feet well supported. Weight even.

Grand Score: 3

Action: Further investigation needed. Changes may be required.

Jack Rapid Upper Limb Assessment Report

Cutting

Job #5th, Female,

Analysis Summary

Body Group A Posture Rating

Upper arm: 1
Lower arm: 3
Wrist: 2
Wrist Twist: 1
Total: 4

Muscle Use: Normal, no extreme use
Force/Load: 2-10 kg intermittent load
Arms: Supported

Body Group B Posture Rating

Neck: 1
Trunk: 3
Total: 3

Muscle Use: Normal, no extreme use
Force/Load: < 2 kg intermittent load

Legs and Feet Rating

Standing, weight even. Room for weight changes.

Grand Score: 3

Action: Further investigation needed. Changes may be required.

Jack Rapid Upper Limb Assessment Report

Assembly

Job #50th, Male,

Analysis Summary

Body Group A Posture Rating

Upper arm: 3
Lower arm: 2
Wrist: 2
Wrist Twist: 1
Total: 4

Muscle Use: Normal, no extreme use
Force/Load: < 2 kg intermittent load
Arms: Supported

Body Group B Posture Rating

Neck: 1
Trunk: 3
Total: 3

Muscle Use: Normal, no extreme use
Force/Load: < 2 kg intermittent load

Legs and Feet Rating

Seated, Legs and feet well supported. Weight even.

Grand Score: 3

Action: Further investigation needed. Changes may be required.

Analysis Summary

Body Group A Posture Rating

Upper arm: 3
Lower arm: 3
Wrist: 2
Wrist Twist: 2
Total: 5

Muscle Use: Normal, no extreme use
Force/Load: 2-10 kg intermittent load
Arms: Supported

Body Group B Posture Rating

Neck: 1
Trunk: 3
Total: 3

Muscle Use: Normal, no extreme use
Force/Load: < 2 kg intermittent load

Legs and Feet Rating

Standing, weight even. Room for weight changes.

Grand Score: 4

Action: Further investigation needed. Changes may be required.

Jack Rapid Upper Limb Assessment Report

Assembly

Job #50th, Female,

Analysis Summary

Body Group A Posture Rating

Upper arm: 2
Lower arm: 3
Wrist: 1
Wrist Twist: 1
Total: 3

Muscle Use: Normal, no extreme use
Force/Load: < 2 kg intermittent load
Arms: Supported

Body Group B Posture Rating

Neck: 1
Trunk: 3
Total: 3

Muscle Use: Normal, no extreme use
Force/Load: < 2 kg intermittent load

Legs and Feet Rating

Seated, Legs and feet well supported. Weight even.

Grand Score: 3

Action: Further investigation needed. Changes may be required.

Jack Rapid Upper Limb Assessment Report

Cutting

Job #50, Female,

Analysis Summary

Body Group A Posture Rating

Upper arm: 1
Lower arm: 3
Wrist: 2
Wrist Twist: 1
Total: 4

Muscle Use: Normal, no extreme use
Force/Load: 2-10 kg intermittent load
Arms: Supported

Body Group B Posture Rating

Neck: 1
Trunk: 3
Total: 3

Muscle Use: Normal, no extreme use
Force/Load: < 2 kg intermittent load

Legs and Feet Rating

Standing, weight even. Room for weight changes.

Grand Score: 3

Action: Further investigation needed. Changes may be required.

Jack Rapid Upper Limb Assessment Report

Assembly

Job #95th, Male,

Analysis Summary

Body Group A Posture Rating

Upper arm: 3
Lower arm: 2
Wrist: 1
Wrist Twist: 1
Total: 3

Muscle Use: Normal, no extreme use
Force/Load: < 2 kg intermittent load
Arms: Supported

Body Group B Posture Rating

Neck: 1
Trunk: 3
Total: 3

Muscle Use: Normal, no extreme use
Force/Load: < 2 kg intermittent load

Legs and Feet Rating

Seated, Legs and feet well supported. Weight even.

Grand Score: 3

Action: Further investigation needed. Changes may be required.

Jack Rapid Upper Limb Assessment Report

Cutting

Job #95th, Male,

Analysis Summary

Body Group A Posture Rating

Upper arm: 2
Lower arm: 3
Wrist: 2
Wrist Twist: 2
Total: 5

Muscle Use: Normal, no extreme use
Force/Load: 2-10 kg intermittent load
Arms: Supported

Body Group B Posture Rating

Neck: 1
Trunk: 3
Total: 3

Muscle Use: Normal, no extreme use
Force/Load: < 2 kg intermittent load

Legs and Feet Rating

Standing, weight even. Room for weight changes.

Grand Score: 4

Action: Further investigation needed. Changes may be required.

Jack Rapid Upper Limb Assessment Report

Assembly

Job #95th, Female,

Analysis Summary

Body Group A Posture Rating

Upper arm: 2
Lower arm: 3
Wrist: 1
Wrist Twist: 1
Total: 3

Muscle Use: Normal, no extreme use
Force/Load: < 2 kg intermittent load
Arms: Supported

Body Group B Posture Rating

Neck: 1
Trunk: 3
Total: 3

Muscle Use: Normal, no extreme use
Force/Load: < 2 kg intermittent load

Legs and Feet Rating

Seated, Legs and feet well supported. Weight even.

Grand Score: 3

Action: Further investigation needed. Changes may be required.

Analysis Summary

Body Group A Posture Rating

Upper arm: 2
Lower arm: 3
Wrist: 2
Wrist Twist: 1
Total: 5

Muscle Use: Normal, no extreme use
Force/Load: 2-10 kg intermittent load
Arms: Supported

Body Group B Posture Rating

Neck: 1
Trunk: 3
Total: 3

Muscle Use: Normal, no extreme use
Force/Load: < 2 kg intermittent load

Legs and Feet Rating

Standing, weight even. Room for weight changes.

Grand Score: 4

Action: Further investigation needed. Changes may be required.

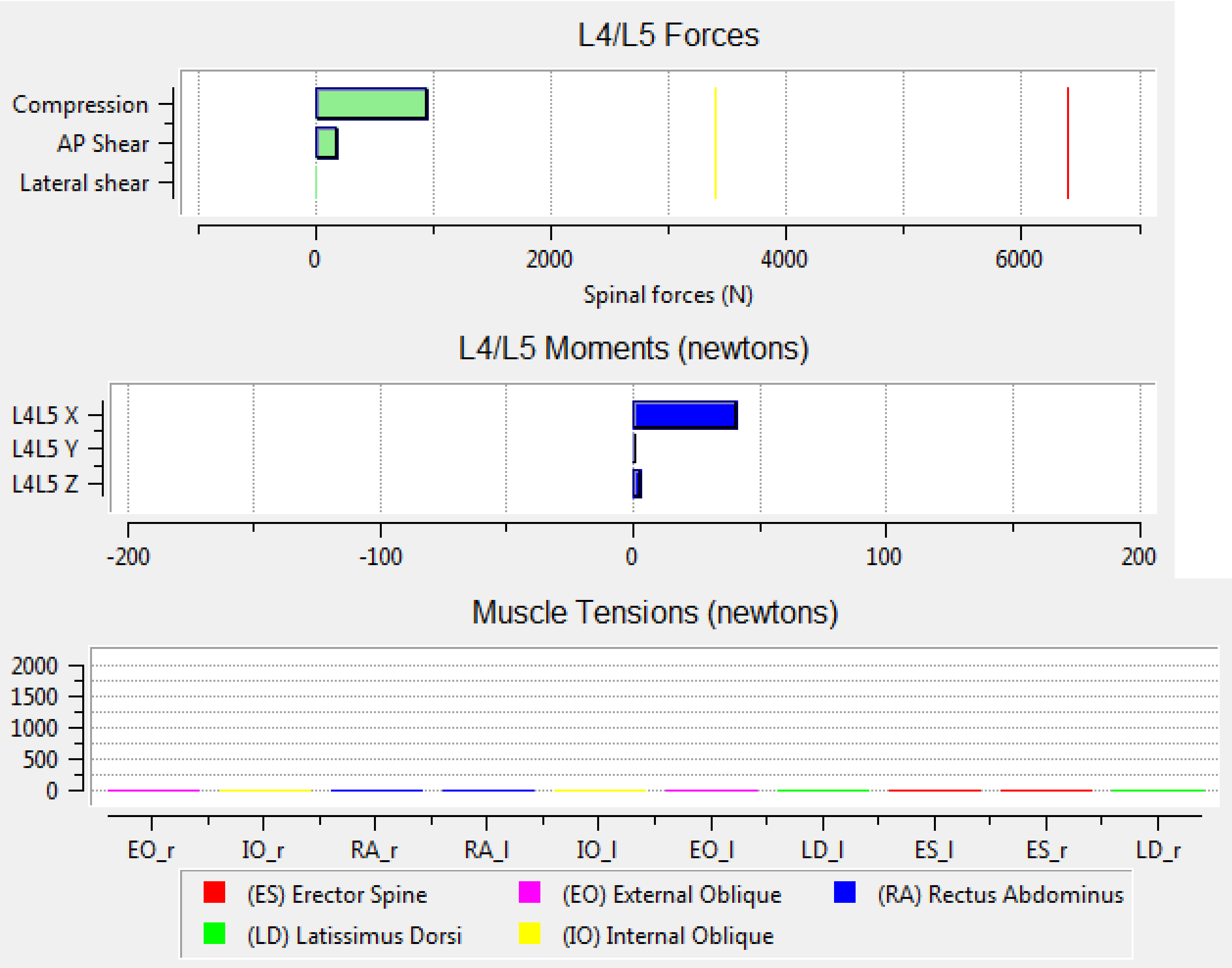
Appendix R

LBA assessment summary of each subject

Jack Low Back Analysis Report

Assembly

Job #13, male, 26 Apr 2012

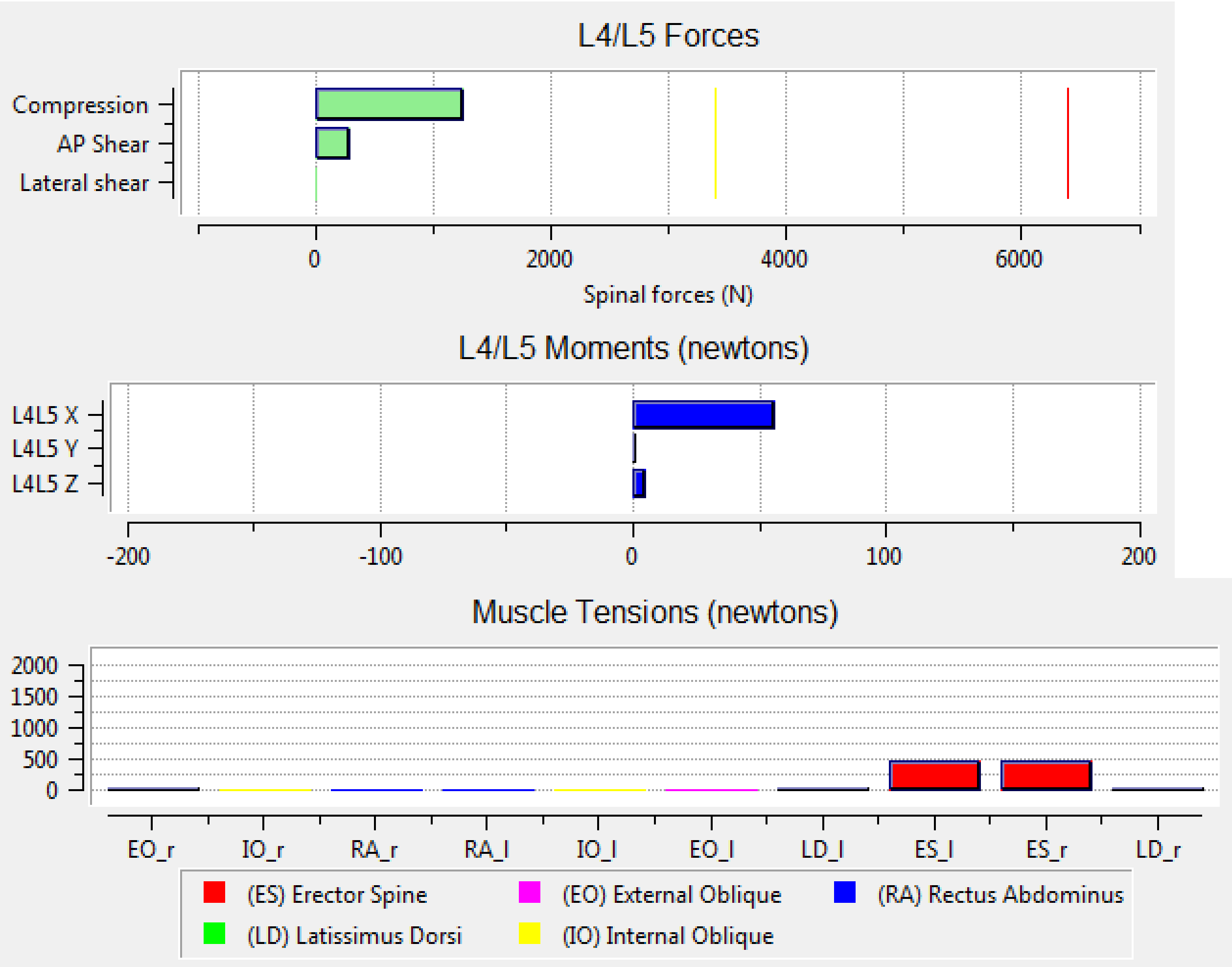


Analysis Recommendations

The low back compression force of 940.00 is below the NIOSH Back Compression Action Limit of 3400 N, representing a nominal risk of low back injury for most healthy workers.

Cutting

Job #13, Male, 16 May 2012



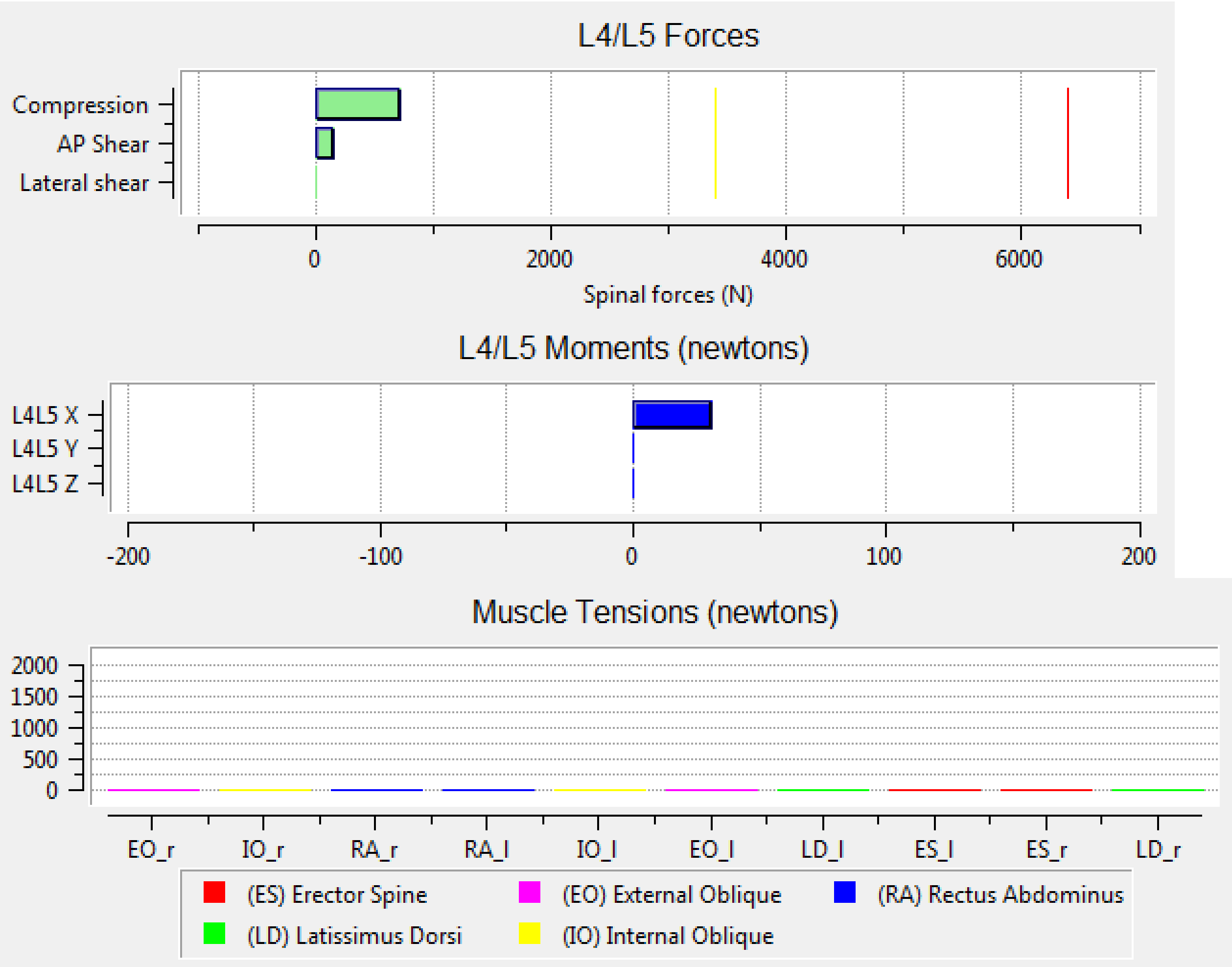
Analysis Recommendations

The low back compression force of 1240.00 is below the NIOSH Back Compression Action Limit of 3400 N, representing a nominal risk of low back injury for most healthy workers.

Jack Low Back Analysis Report

Assembly

Job #13, female, 26 Apr 2012



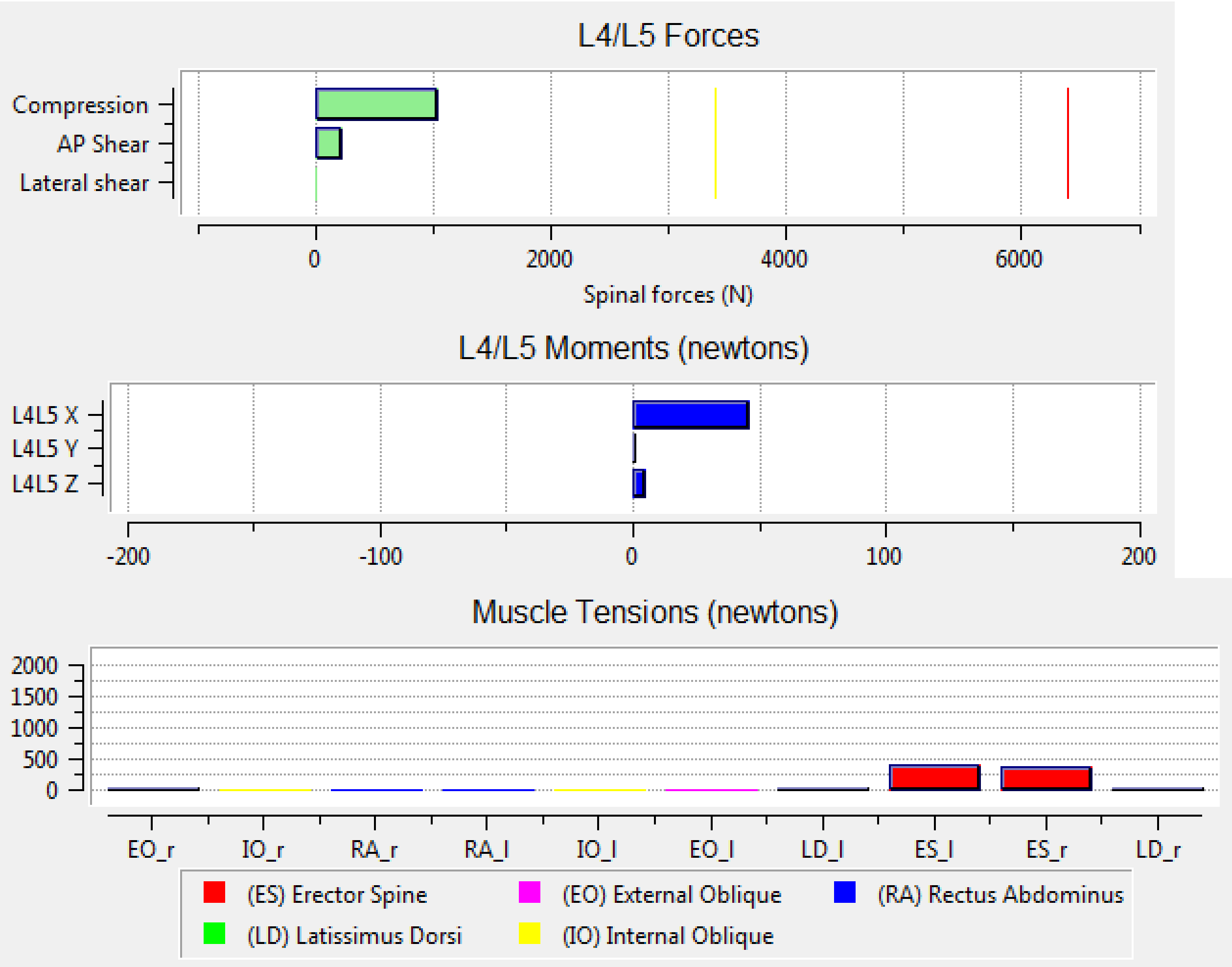
Analysis Recommendations

The low back compression force of 710.00 is below the NIOSH Back Compression Action Limit of 3400 N, representing a nominal risk of low back injury for most healthy workers.

Jack Low Back Analysis Report

Cutting

Job #13, female, 26 Apr 2012

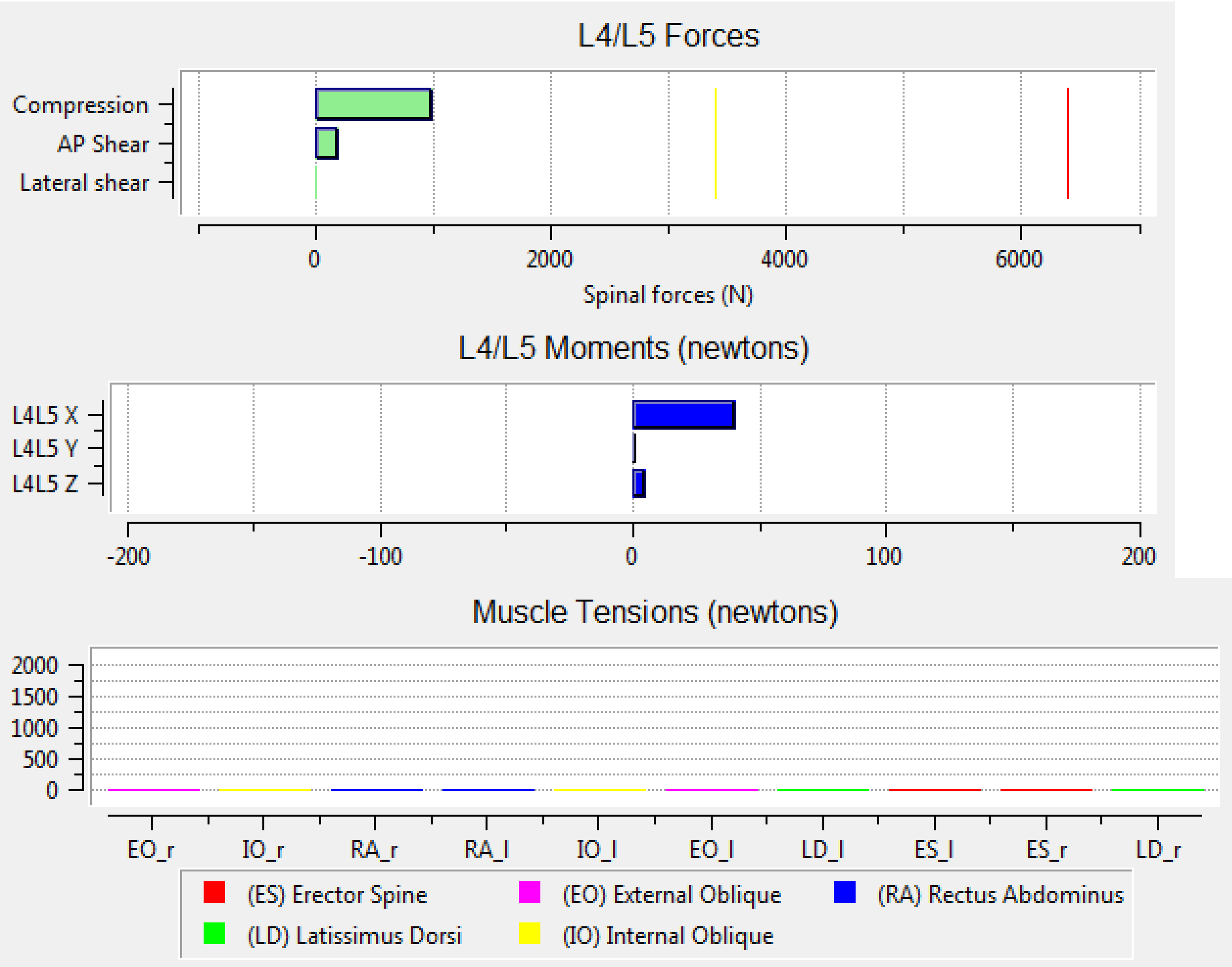


Analysis Recommendations

The low back compression force of 1036.00 is below the NIOSH Back Compression Action Limit of 3400 N, representing a nominal risk of low back injury for most healthy workers.

Assembly

Job #14, male, 26 Apr 2012

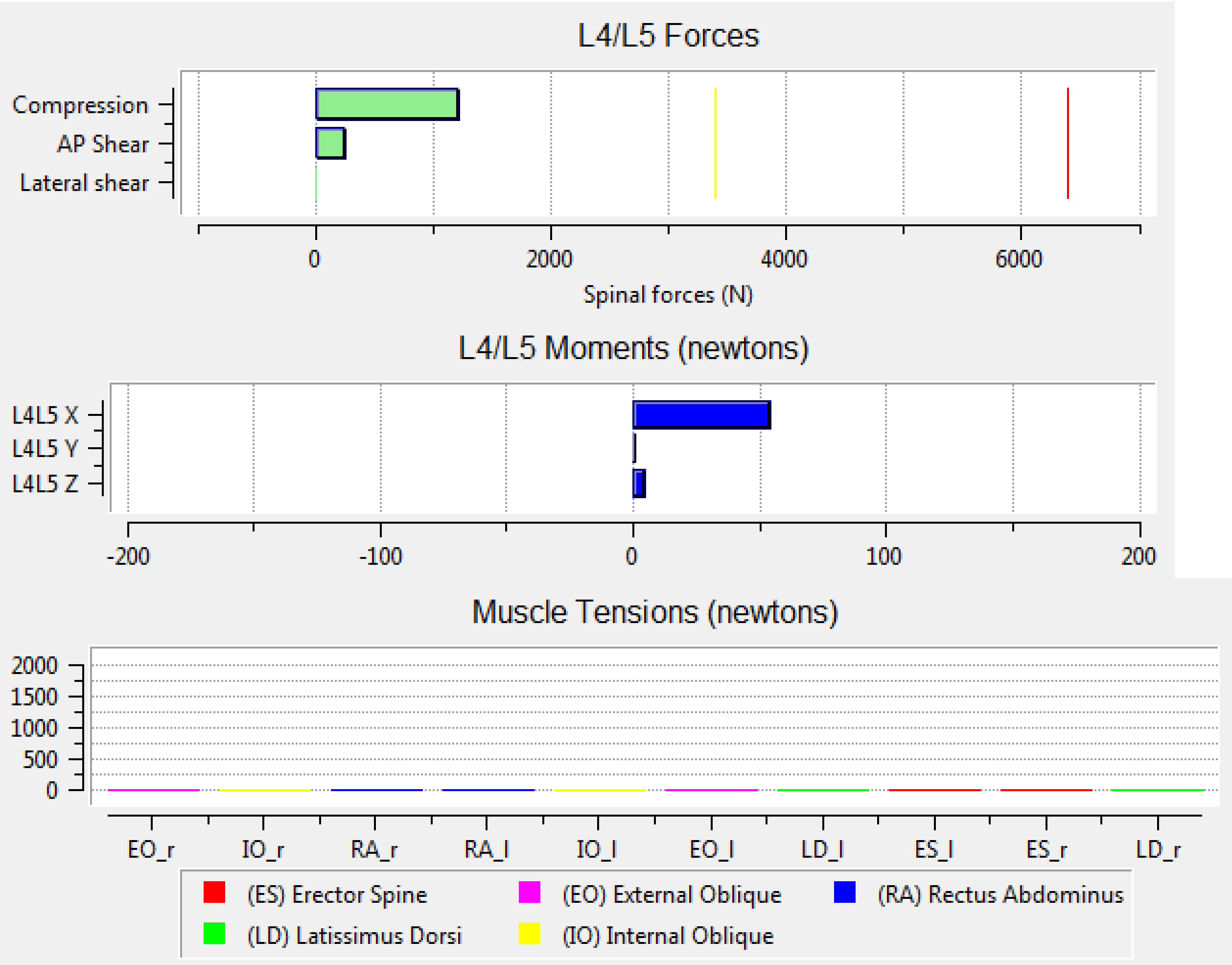


Analysis Recommendations

The low back compression force of 978.00 is below the NIOSH Back Compression Action Limit of 3400 N, representing a nominal risk of low back injury for most healthy workers.

Cutting

Job #14, male, 26 Apr 2012

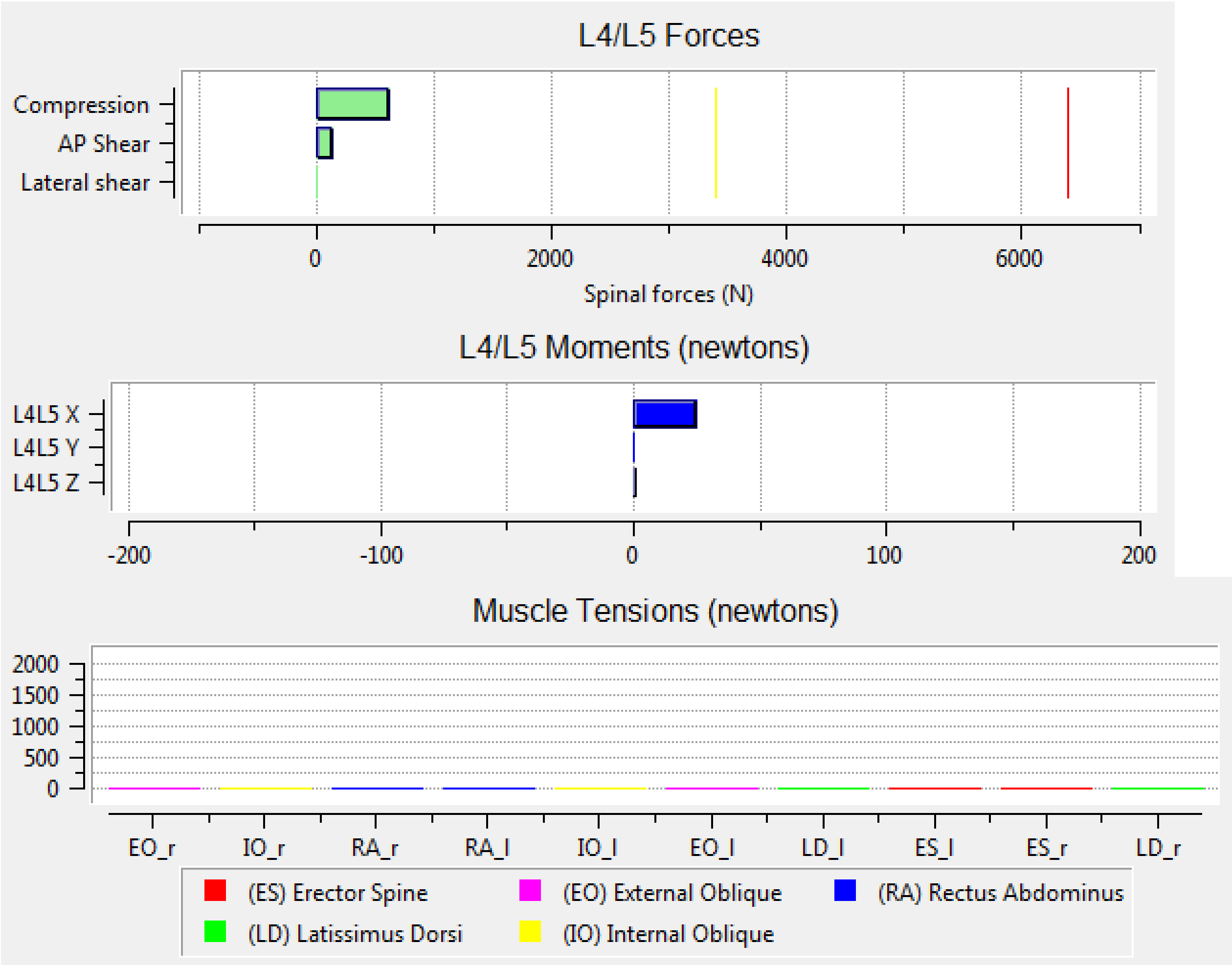


Analysis Recommendations

The low back compression force of 1214.00 is below the NIOSH Back Compression Action Limit of 3400 N, representing a nominal risk of low back injury for most healthy workers.

Assembly

Job #14, female, 26 Apr 2012

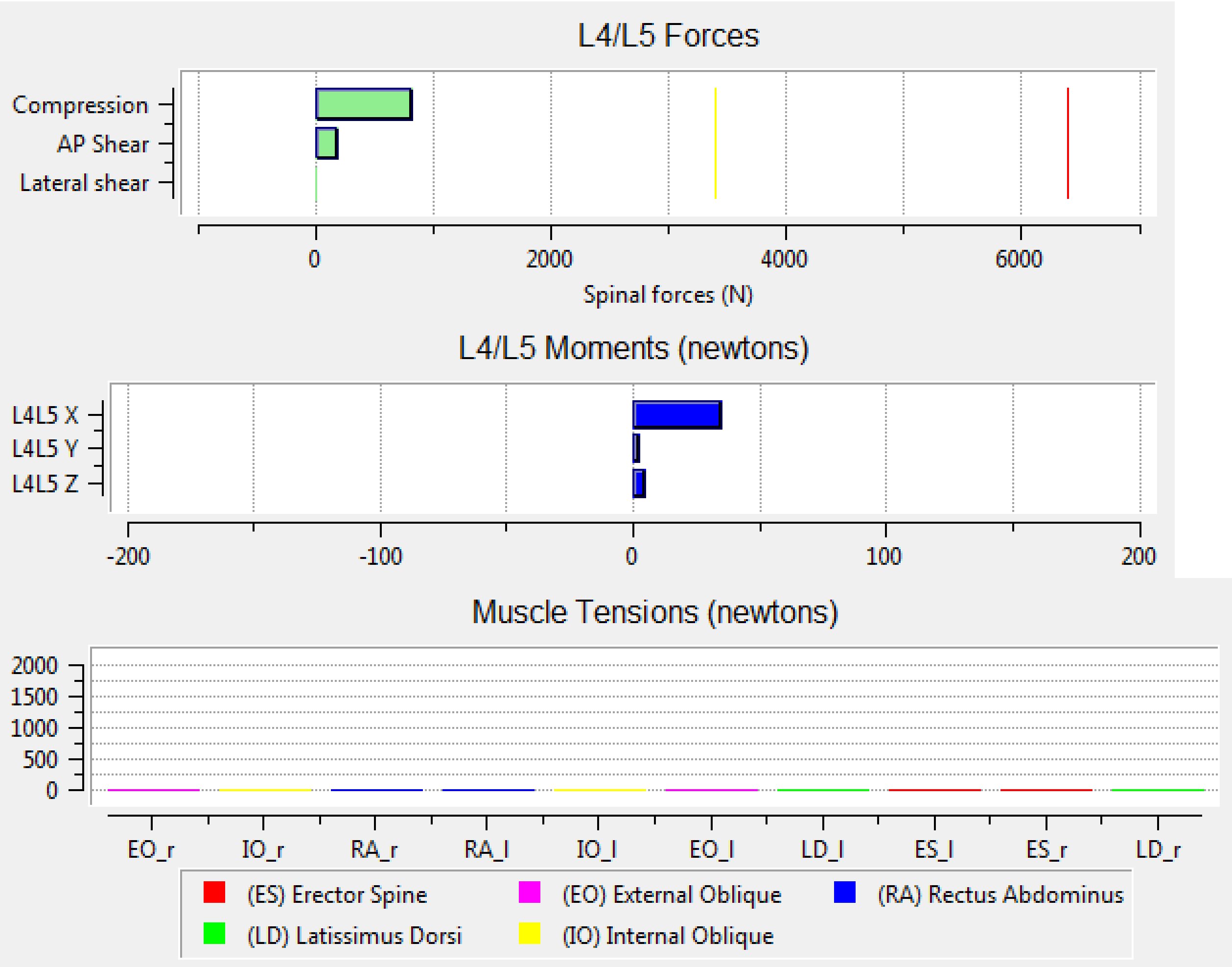


Analysis Recommendations

The low back compression force of 608.00 is below the NIOSH Back Compression Action Limit of 3400 N, representing a nominal risk of low back injury for most healthy workers.

Cutting

Job #14, female, 26 Apr 2012



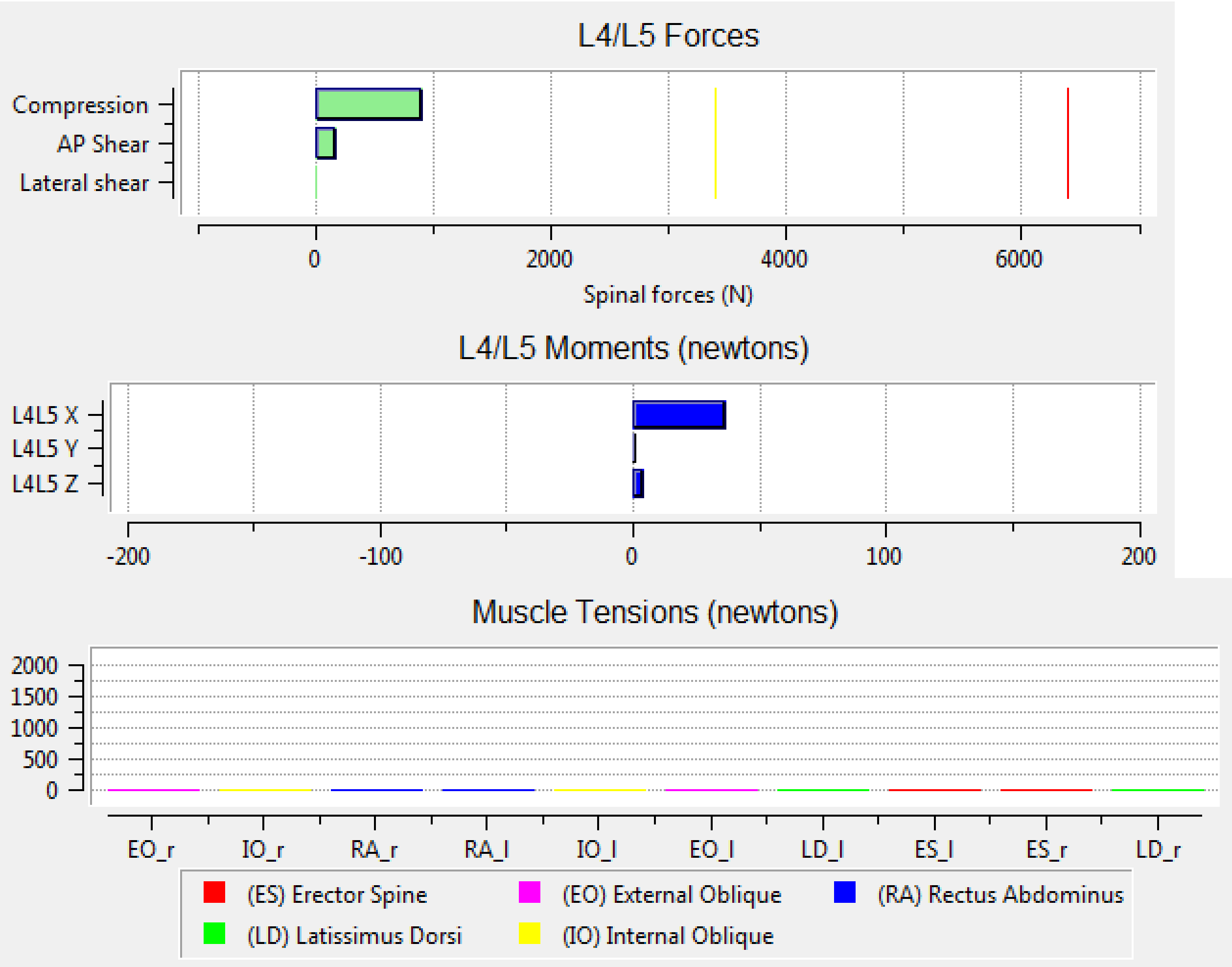
Analysis Recommendations

The low back compression force of 810.00 is below the NIOSH Back Compression Action Limit of 3400 N, representing a nominal risk of low back injury for most healthy workers.

Jack Low Back Analysis Report

Assembly

Job #15, male, 26 Apr 2012



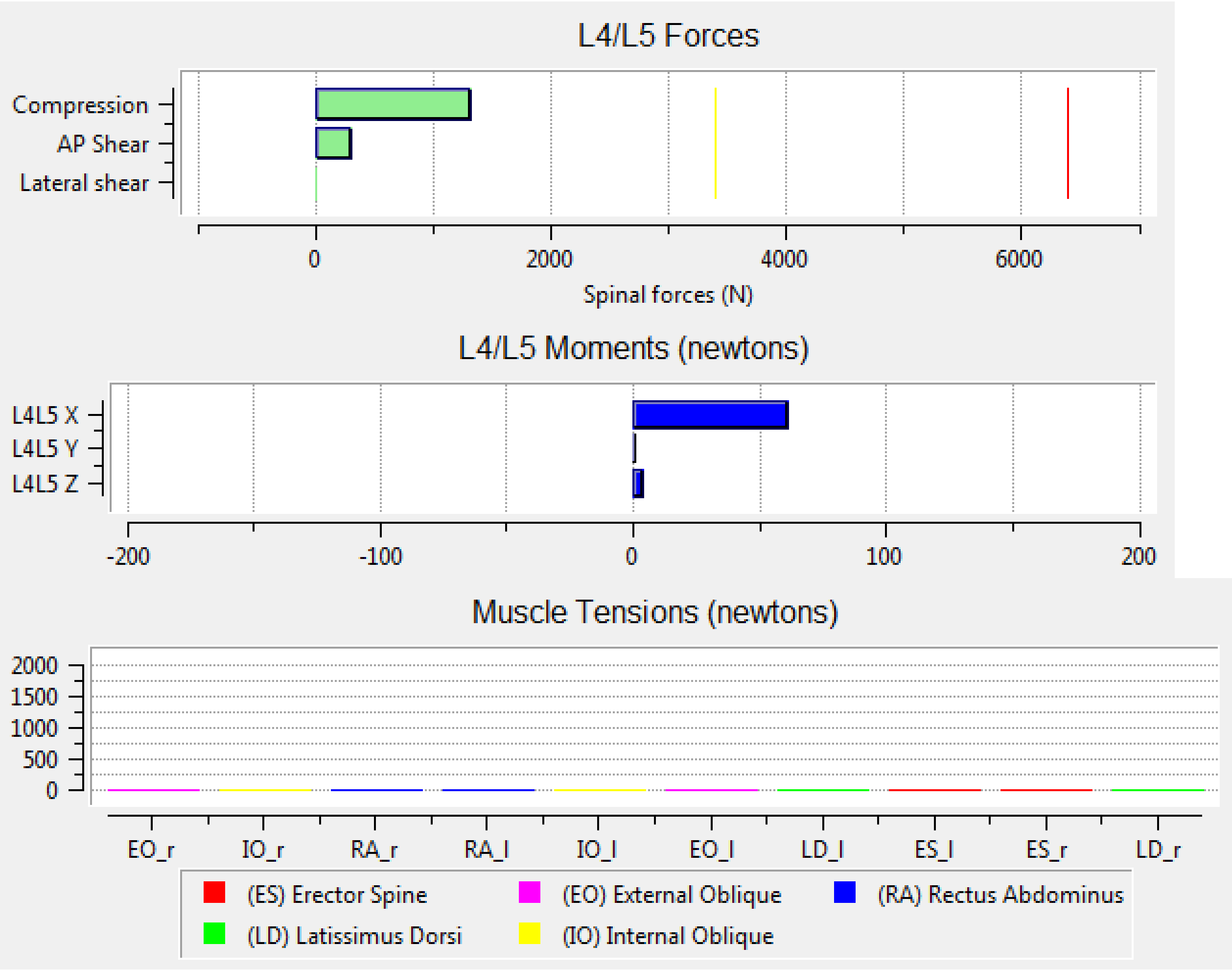
Analysis Recommendations

The low back compression force of 891.00 is below the NIOSH Back Compression Action Limit of 3400 N, representing a nominal risk of low back injury for most healthy workers.

Jack Low Back Analysis Report

Cutting

Job #15, male, 26 Apr 2012



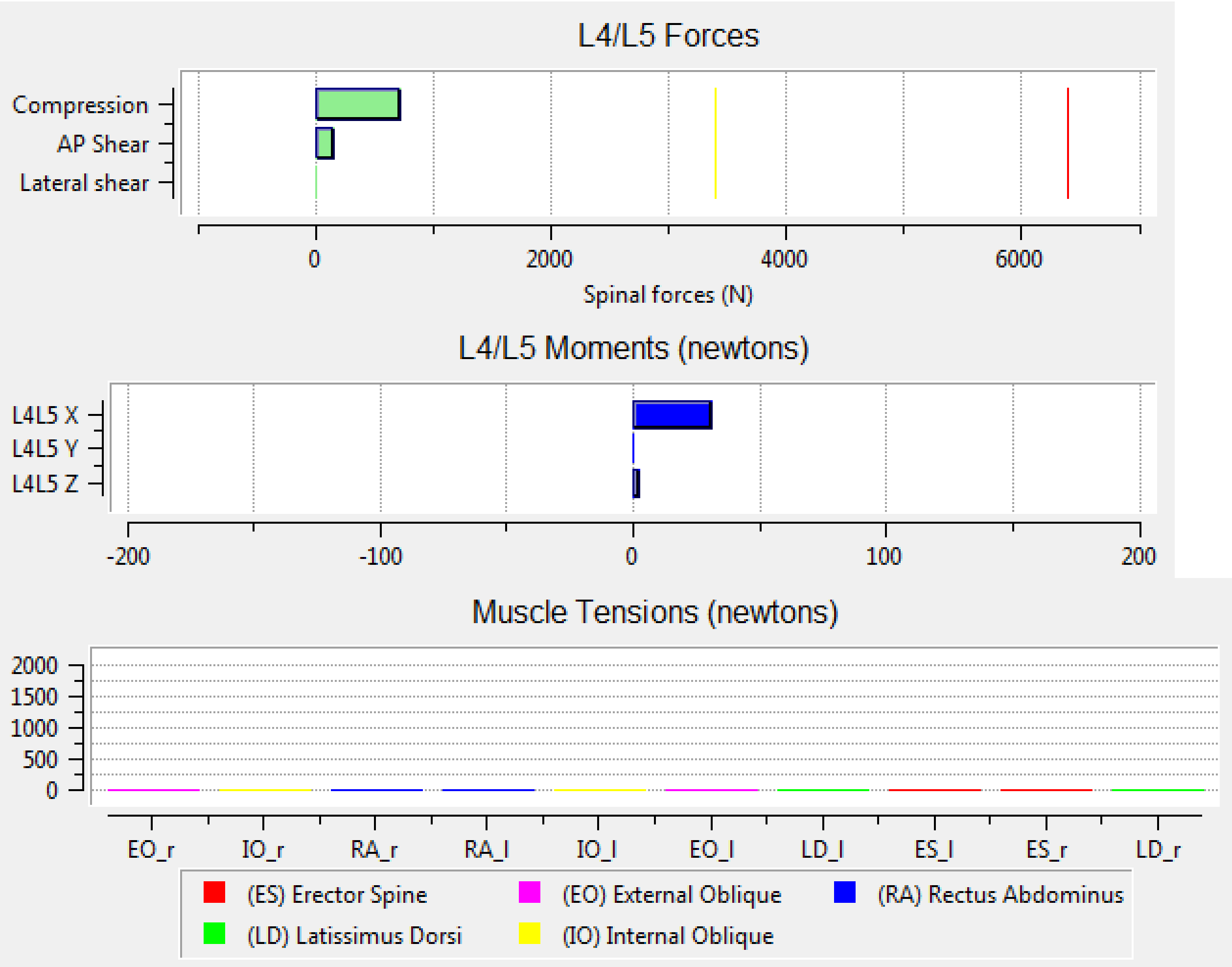
Analysis Recommendations

The low back compression force of 1306.00 is below the NIOSH Back Compression Action Limit of 3400 N, representing a nominal risk of low back injury for most healthy workers.

Jack Low Back Analysis Report

Assembly

Job #15, female, 26 Apr 2012



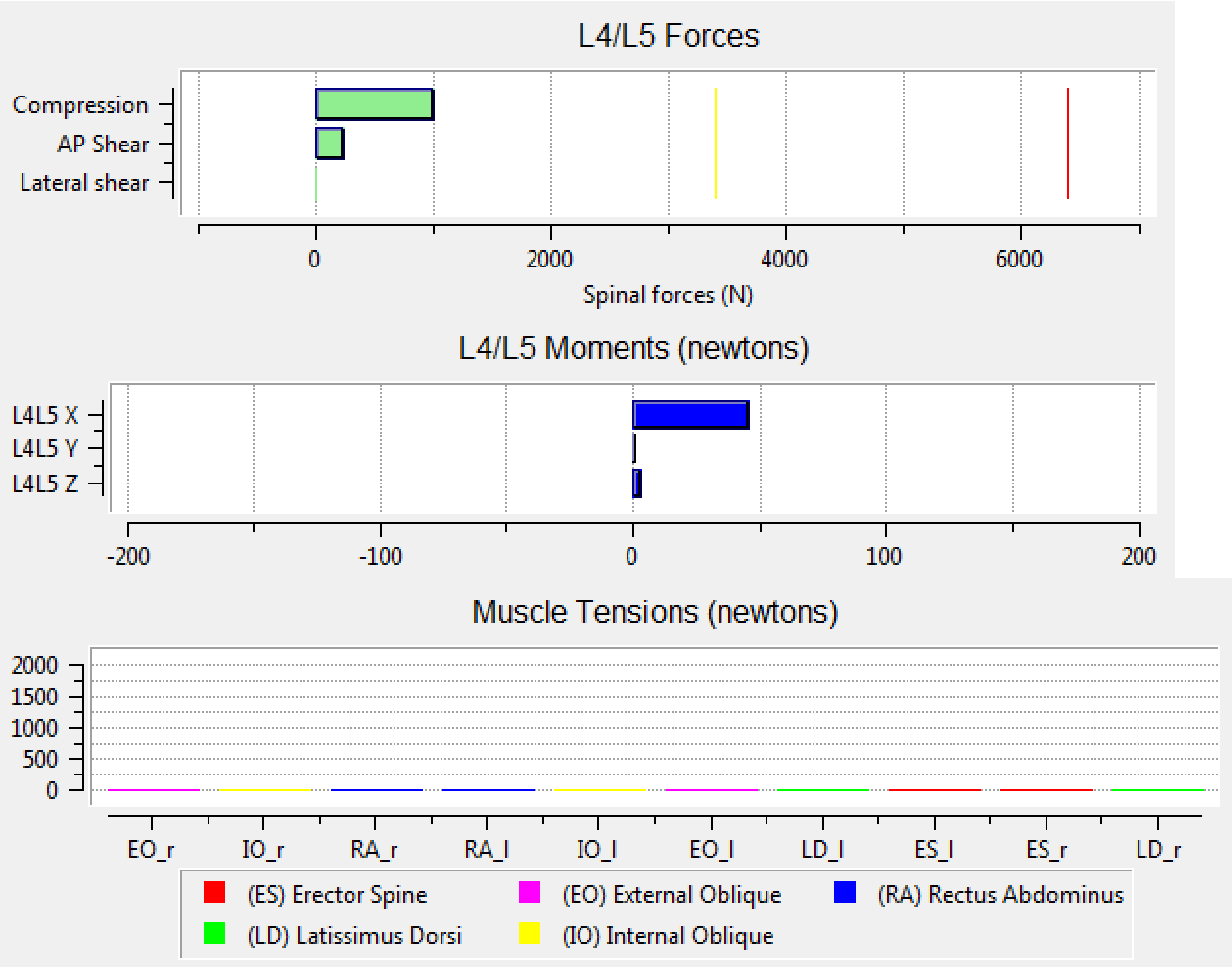
Analysis Recommendations

The low back compression force of 707.00 is below the NIOSH Back Compression Action Limit of 3400 N, representing a nominal risk of low back injury for most healthy workers.

Jack Low Back Analysis Report

Cutting

Job #15, female, 26 Apr 2012



Analysis Recommendations

The low back compression force of 993.00 is below the NIOSH Back Compression Action Limit of 3400 N, representing a nominal risk of low back injury for most healthy workers.

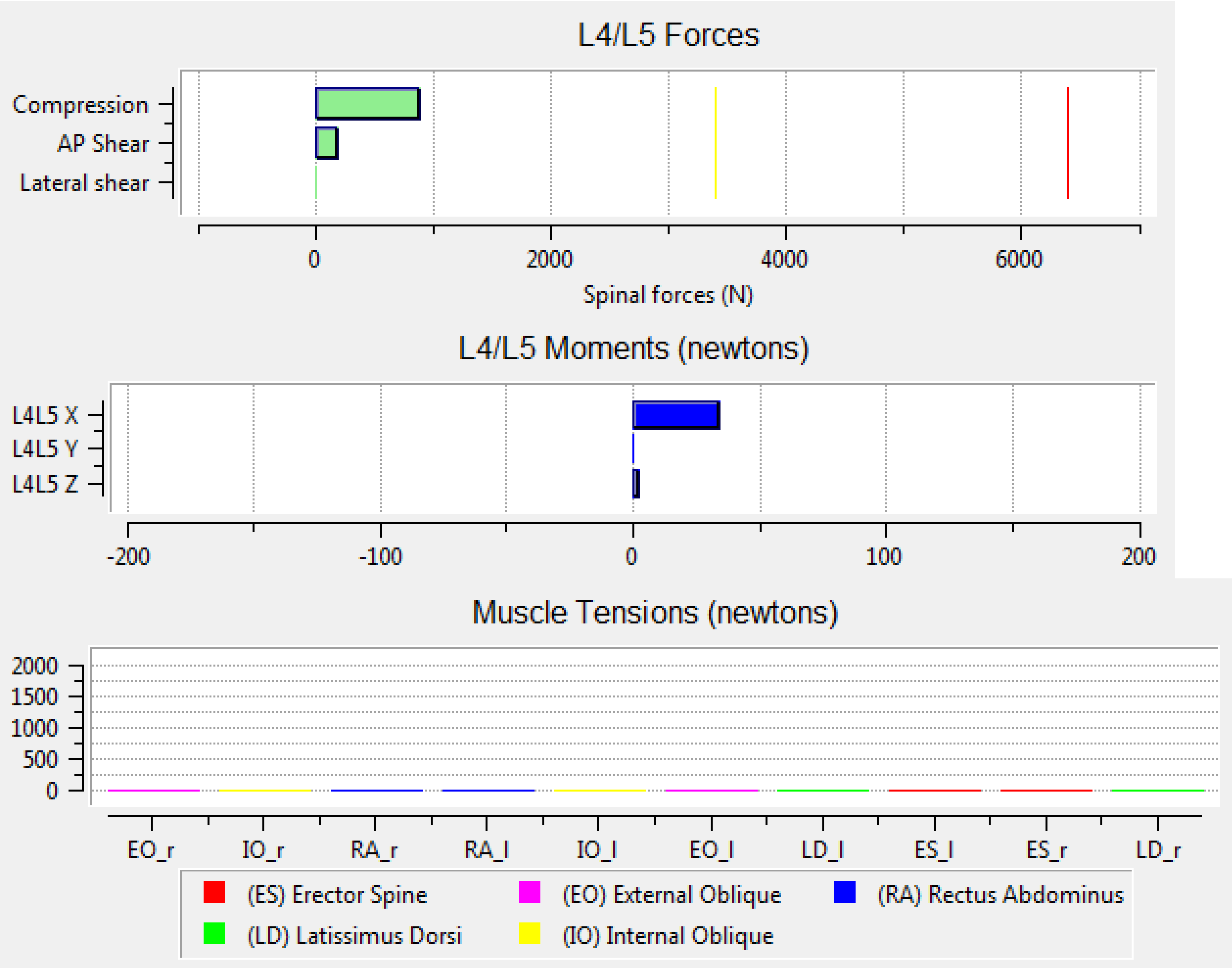
Appendix S

LBA assessment summary of each percentile

Jack Low Back Analysis Report

Assembly

Job #5, male, 26 Apr 2012



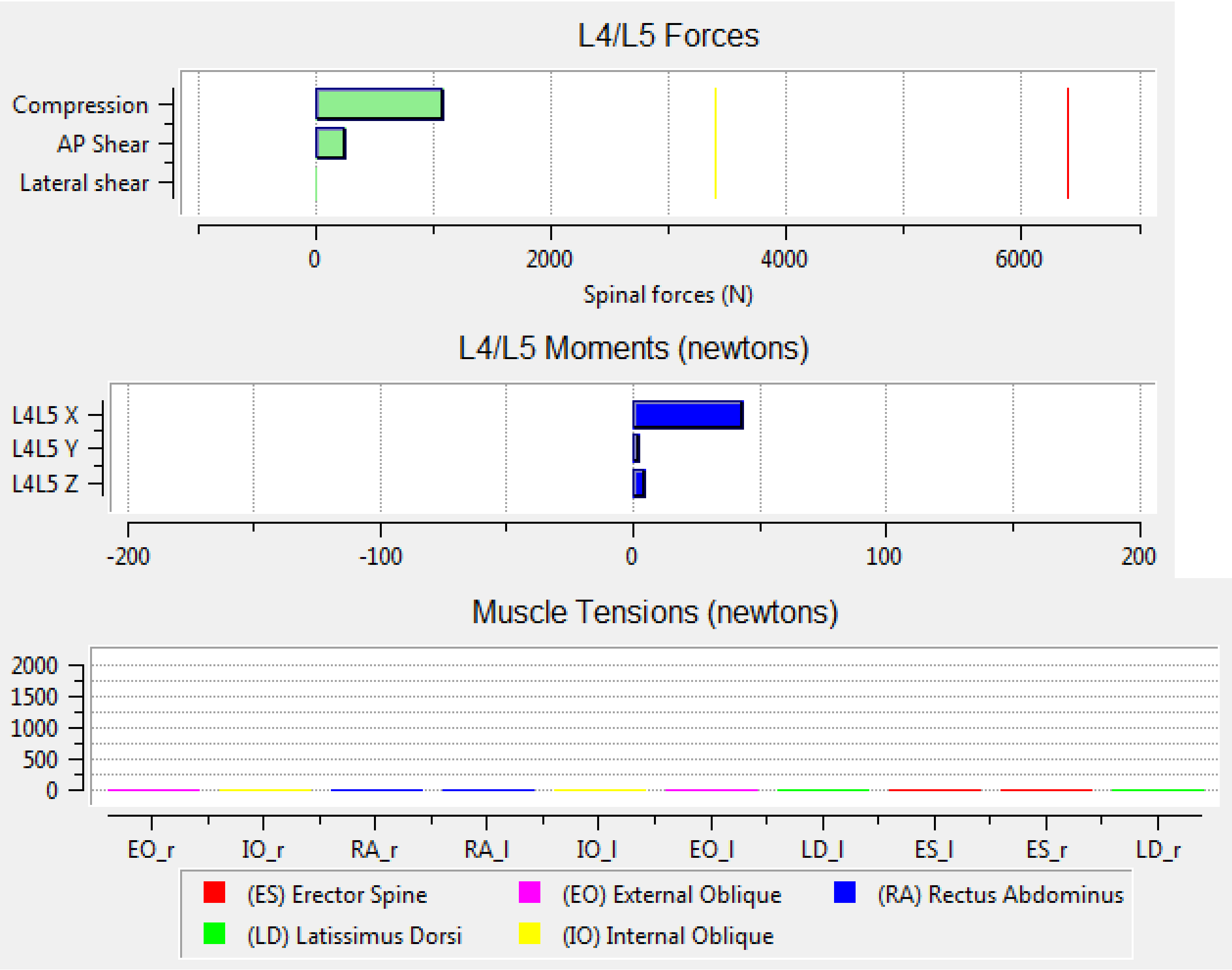
Analysis Recommendations

The low back compression force of 883.00 is below the NIOSH Back Compression Action Limit of 3400 N, representing a nominal risk of low back injury for most healthy workers.

Jack Low Back Analysis Report

Cutting

Job #5, male, 26 Apr 2012



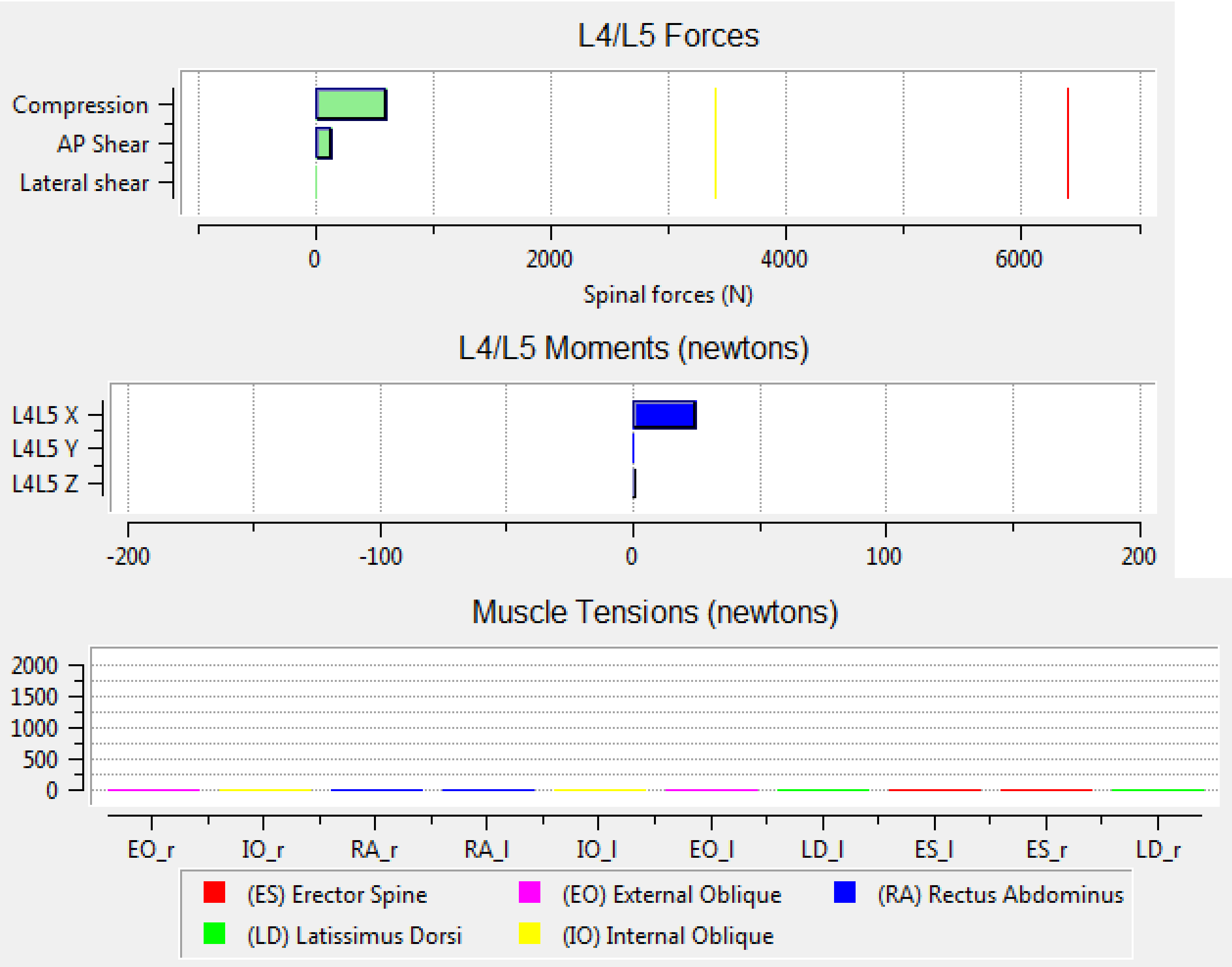
Analysis Recommendations

The low back compression force of 1081.00 is below the NIOSH Back Compression Action Limit of 3400 N, representing a nominal risk of low back injury for most healthy workers.

Jack Low Back Analysis Report

Assembly

Job #5, female, 26 Apr 2012



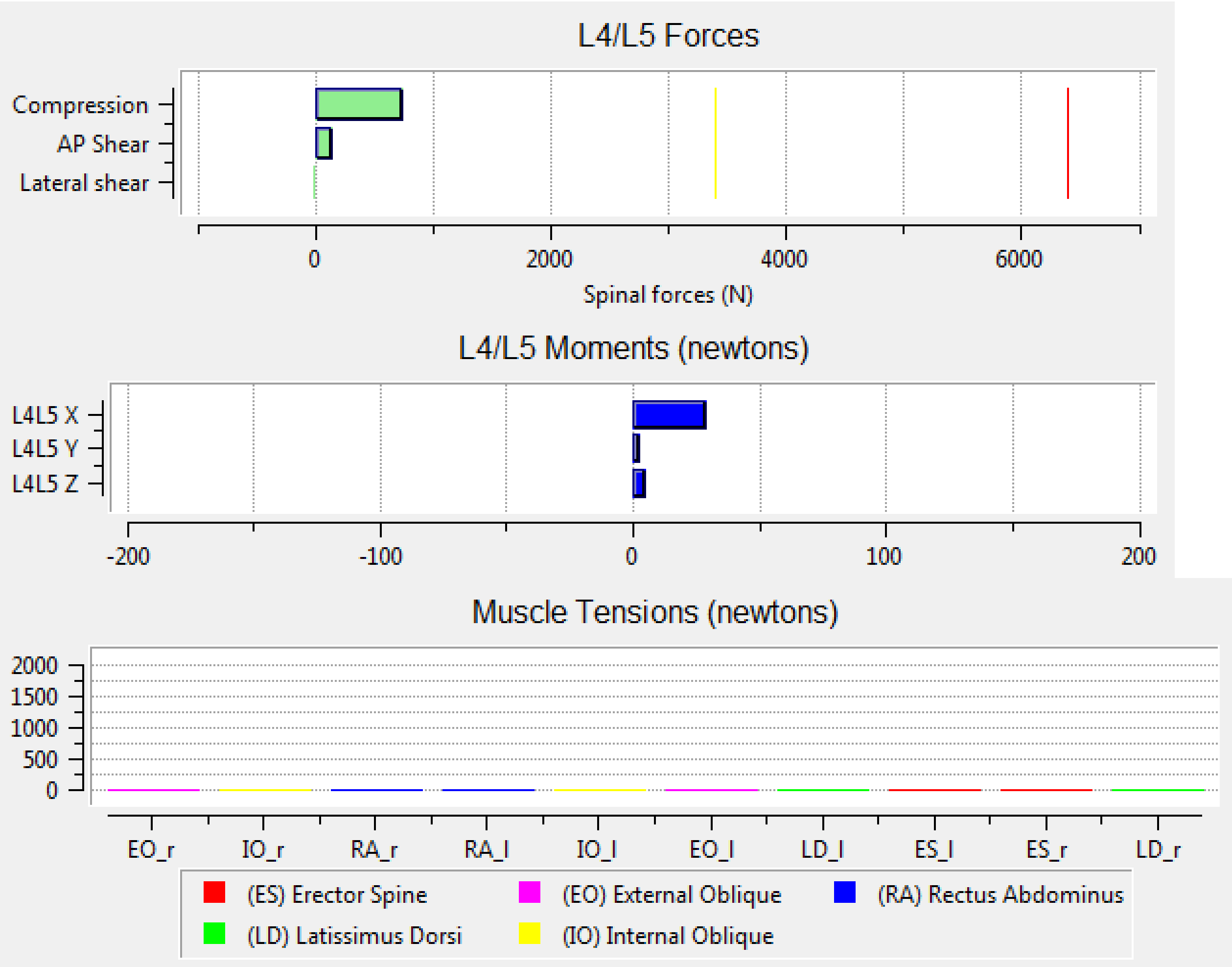
Analysis Recommendations

The low back compression force of 604.00 is below the NIOSH Back Compression Action Limit of 3400 N, representing a nominal risk of low back injury for most healthy workers.

Jack Low Back Analysis Report

Cutting

Job #5, female, 26 Apr 2012



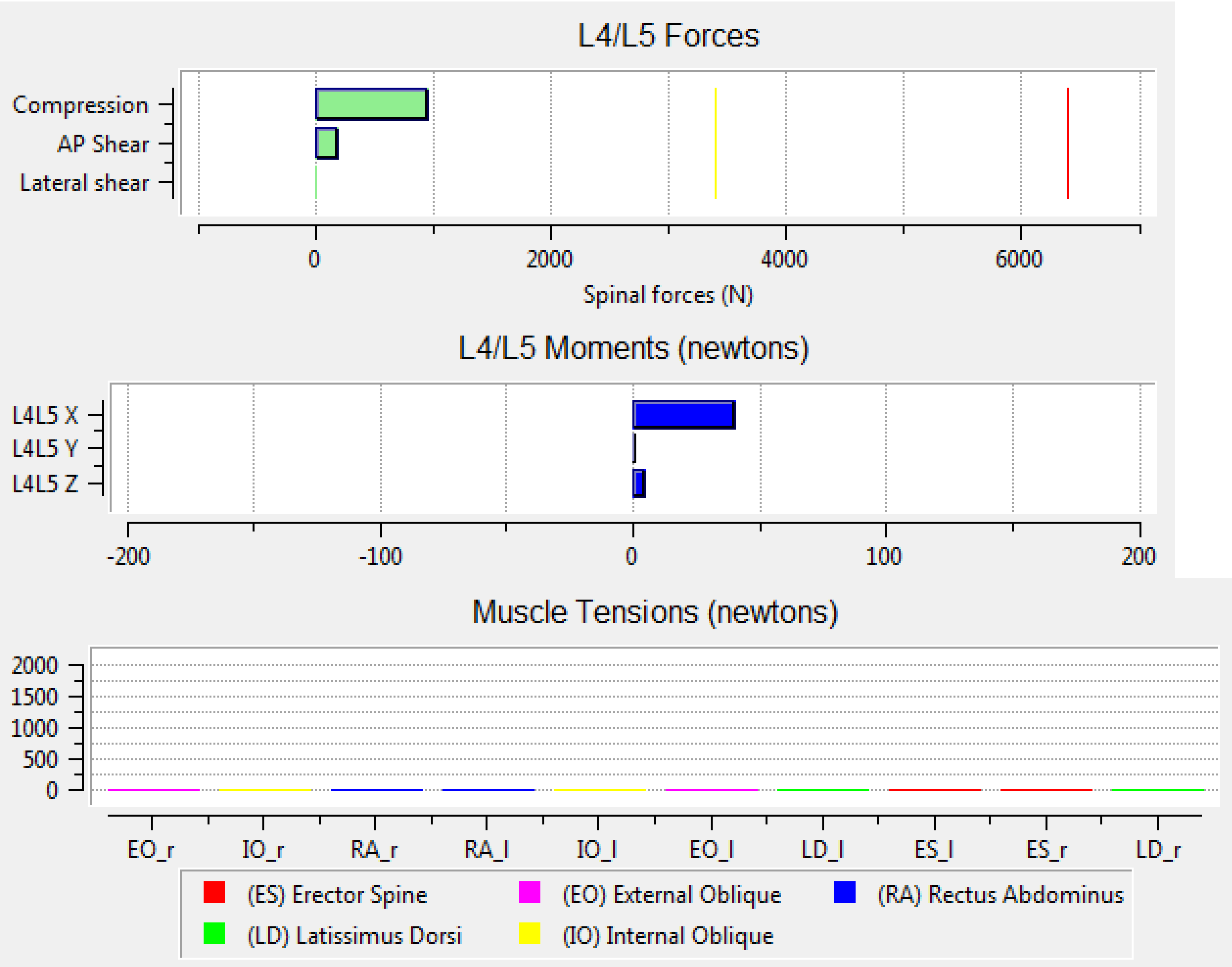
Analysis Recommendations

The low back compression force of 733.00 is below the NIOSH Back Compression Action Limit of 3400 N, representing a nominal risk of low back injury for most healthy workers.

Jack Low Back Analysis Report

Assembly

Job #50, male, 26 Apr 2012



Analysis Recommendations

The low back compression force of 956.00 is below the NIOSH Back Compression Action Limit of 3400 N, representing a nominal risk of low back injury for most healthy workers.

Cutting

Job #50, male, 26 Apr 2012

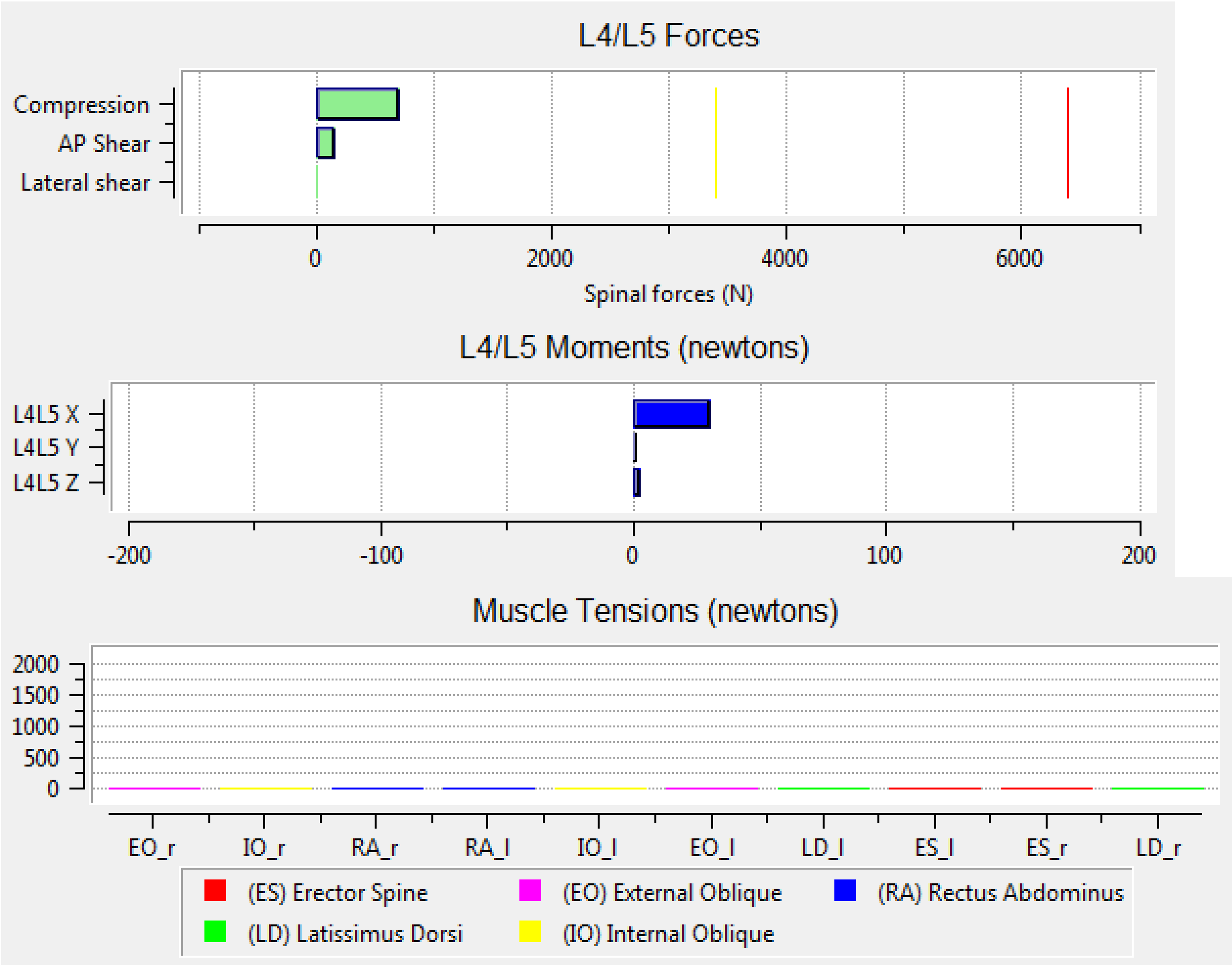
Analysis Recommendations

The low back compression force of 1170.00 is below the NIOSH Back Compression Action Limit of 3400 N, representing a nominal risk of low back injury for most healthy workers.

Jack Low Back Analysis Report

Assembly

Job #50, female, 26 Apr 2012

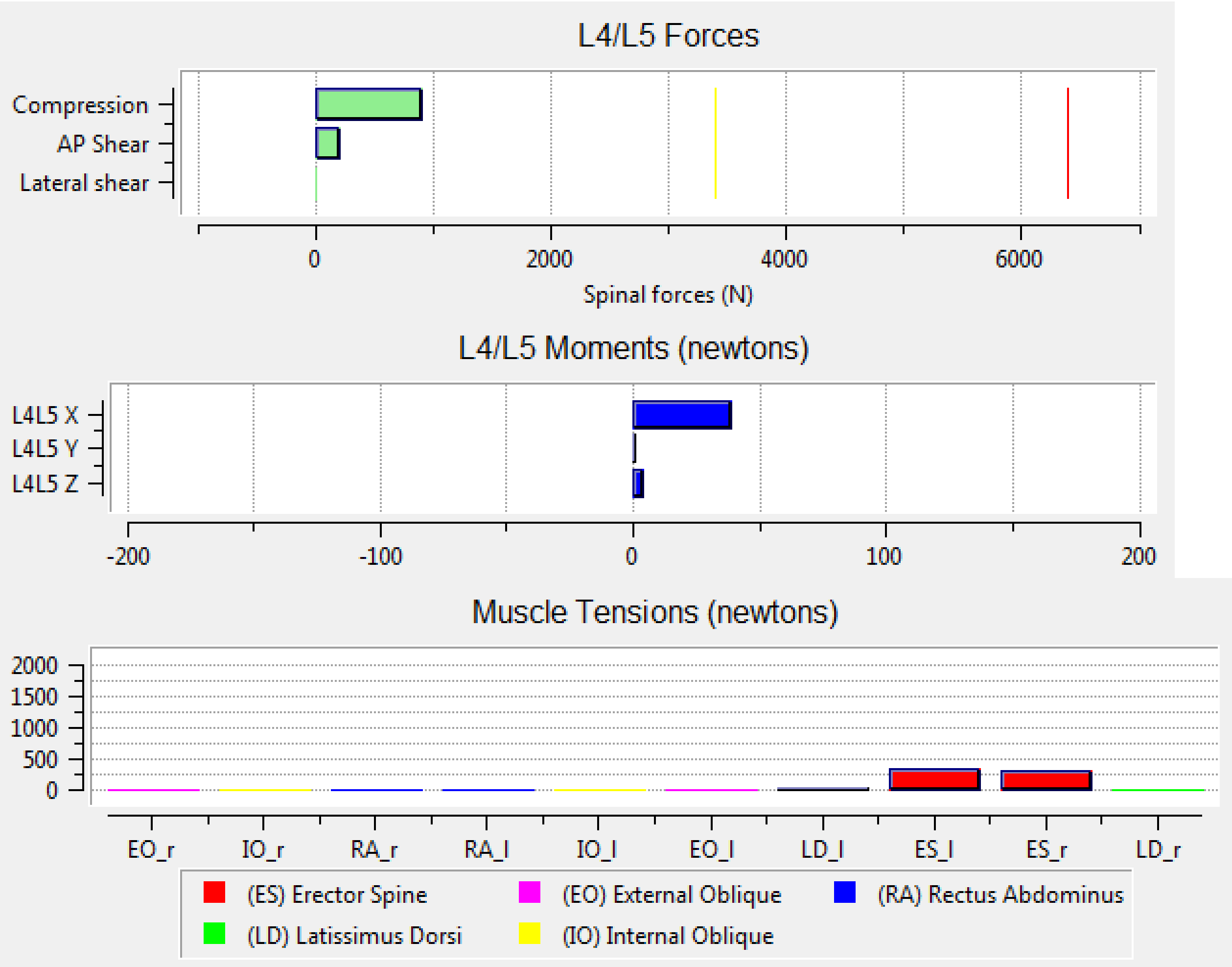


Analysis Recommendations

The low back compression force of 698.00 is below the NIOSH Back Compression Action Limit of 3400 N, representing a nominal risk of low back injury for most healthy workers.

Cutting

Job #50, Female, 16 May 2012

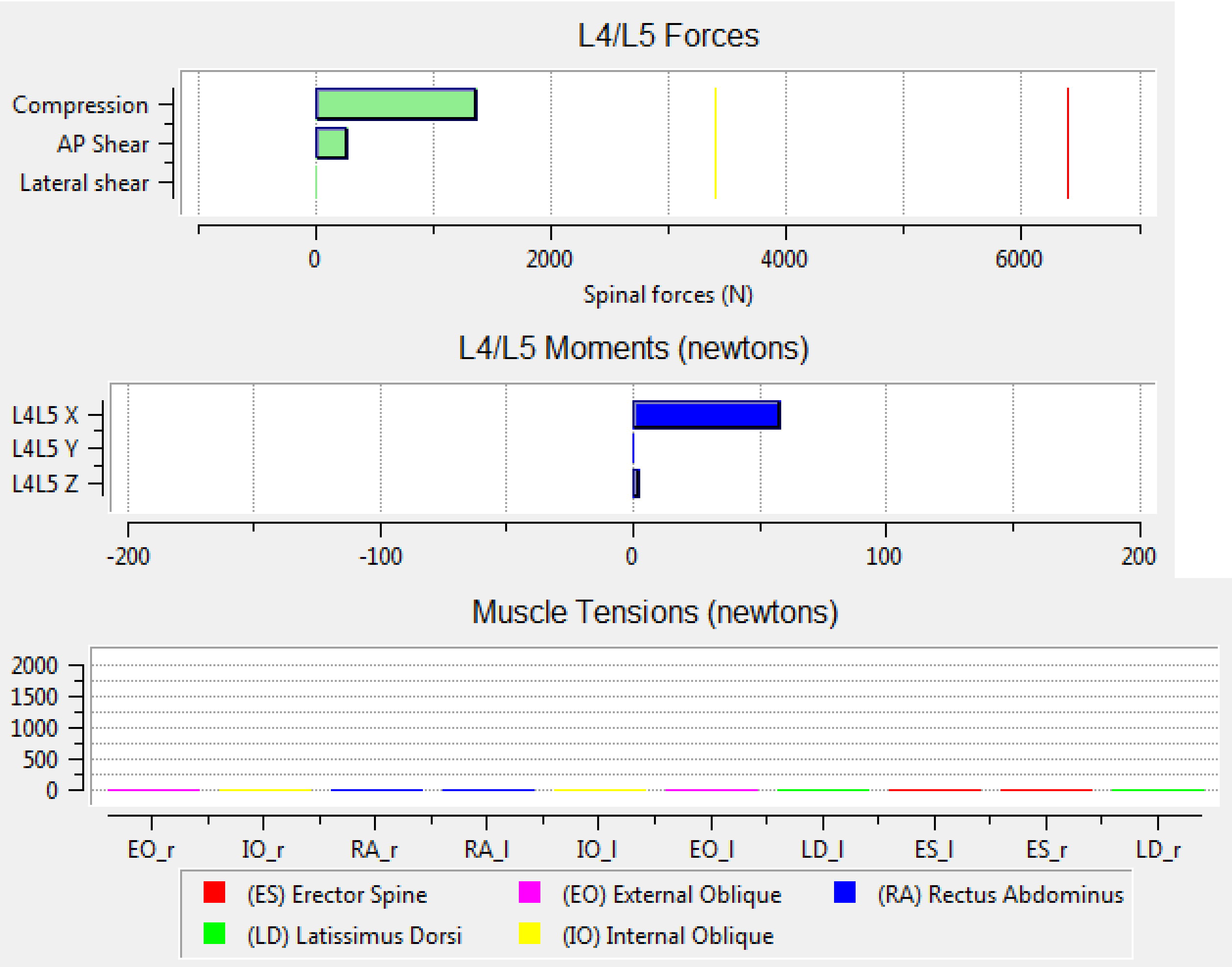


Analysis Recommendations

The low back compression force of 898.00 is below the NIOSH Back Compression Action Limit of 3400 N, representing a nominal risk of low back injury for most healthy workers.

Assembly

Job #95, male, 26 Apr 2012



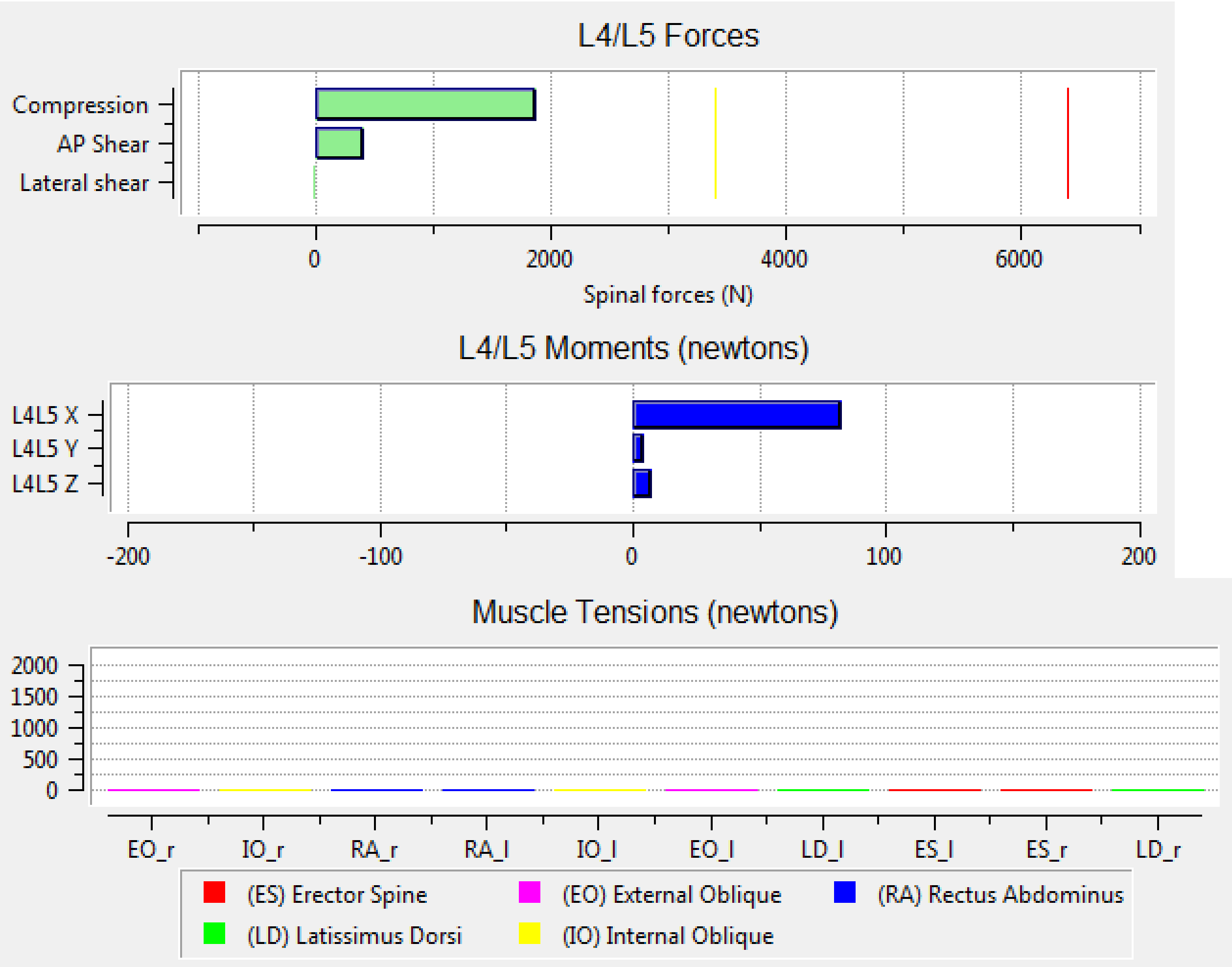
Analysis Recommendations

The low back compression force of 1356.00 is below the NIOSH Back Compression Action Limit of 3400 N, representing a nominal risk of low back injury for most healthy workers.

Jack Low Back Analysis Report

Cutting

Job #95, male, 26 Apr 2012



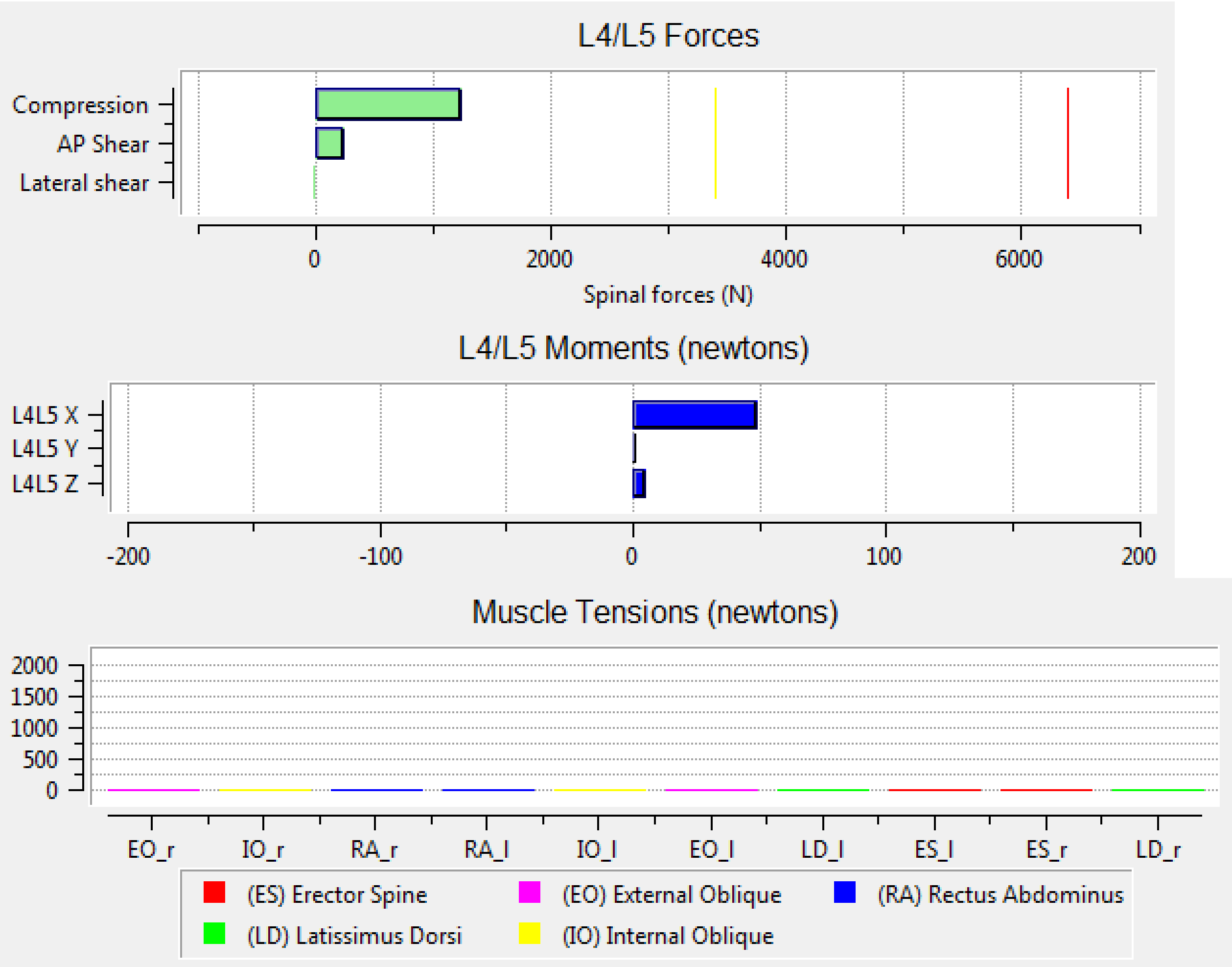
Analysis Recommendations

The low back compression force of 1869.00 is below the NIOSH Back Compression Action Limit of 3400 N, representing a nominal risk of low back injury for most healthy workers.

Jack Low Back Analysis Report

Assembly

Job #95, female, 26 Apr 2012



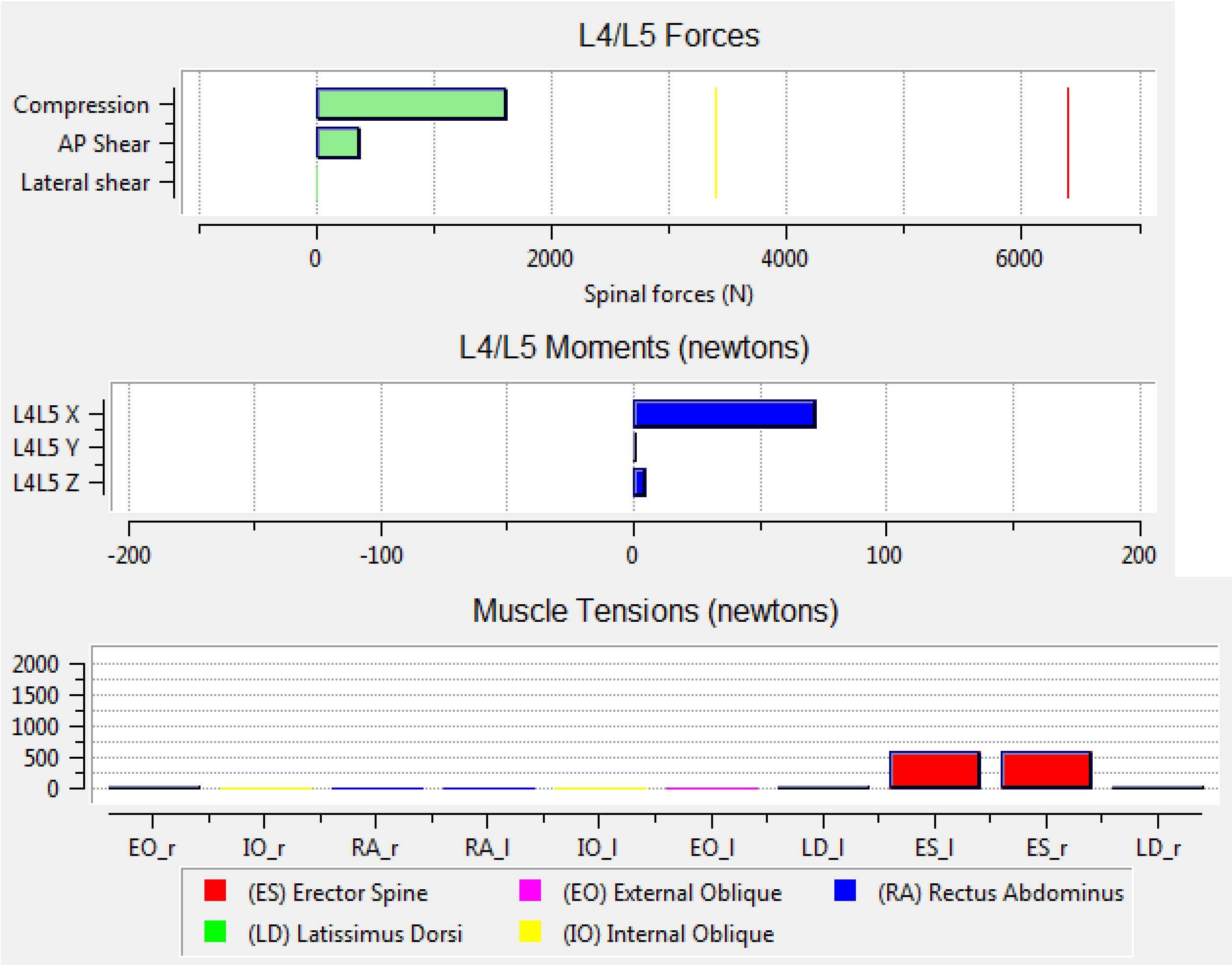
Analysis Recommendations

The low back compression force of 1225.00 is below the NIOSH Back Compression Action Limit of 3400 N, representing a nominal risk of low back injury for most healthy workers.

Jack Low Back Analysis Report

Cutting

Job #95, female, 26 Apr 2012



Analysis Recommendations

The low back compression force of 1617.00 is below the NIOSH Back Compression Action Limit of 3400 N, representing a nominal risk of low back injury for most healthy workers.

Appendix T

Lists of Publication

1. Adila Md Hashim, Siti Zawiah Md Dawal, & Nukman Yusoff. (2012). Ergonomic evaluation of postural stress in school workshop. *Work: A Journal of Prevention, Assessment and Rehabilitation, 41*, 827-831.

2. Adila Md Hashim, & Siti Zawiah Md Dawal. (2012). Kano Model and QFD integration approach for Ergonomic Design Improvement. *Procedia - Social and Behavioral Sciences, 57*, 22-32.

3. Adila Md Hashim, & Siti Zawiah Md Dawal. (2013). Evaluation of Students' Working Postures in School Workshop. *International Journal of Ergonomics, 3*(1), 25-32.