ERGONOMICS ASSESSMENT FOR SEAT BELT ANCHORAGE LOCATION AT REAR CENTER SEAT

MOHD BUKHARI MAT SALLEH

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UNIVERSITY MALAYA
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MOHD BUKHARI MAT SALLEH

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ABSTRACT

Since implementation of the new revision of ECE R14.07, there is a need to change seatbelt anchorage (SBA) design specification at center position of passenger seat from two points SBA to three points SBA. This study is conducted to investigate which shoulder seatbelt anchorage position is preferred in term of ergonomics assessment. The study focus on perceived comfort/discomfort in specific task of reaching for the seatbelt tongue between two types of SBA position. Two different types of passenger car which are fitted with two different types of SBA position at the second row of the passenger seat were chosen. The two types of SBA position involved in the study are SBA at roof panel and SBA at seatback. Outcomes of the study are determined by the level of exertion and postural analysis using the Borg RPE Scale and the Comfort Index method, respectively. Results of the Borg RPE Scale and Comfort Index agreed that SBA at roof panel is more comfortable compared to SBA at seatback. The ergonomic assessment carried out in the study had managed to identify the level of exertion and body segment that heavily affected the overall scores. Significant findings of the study help to provide value added to ergonomics design and help designers during early stage of a new vehicle development. Most importantly, ease of use and effectiveness characteristics shown by both methodologies suitable to be applied in any situation and industry. In conclusion, the findings of the study have proven that in reaching for the seatbelt tongue task, SBA at roof panel is more comfortable compared to SBA at seatback.

ABSTRAK

Sejak penguatkuasaan peraturan baru ECE R14.07, wujud keperluan untuk menukar spesifikasi reka bentuk temper sauh tali pinggang keledar di tempat duduk posisi tengah bagi kerusi penumpang daripada dua ke tiga tempat bersauh. Kajian ini menyiasat posisi SBA yang mana yang menjadi pilihan mengikut penilaian ergonomik. Fokus kajian adalah selesa/tidak selesa sewaktu melakukan satu tugas tertentu iaitu mencapai lidah tali pingang keledar di antara dua posisi SBA. Dua jenis kenderaan penumpang berbeza yang mana tempat duduk penumpang posisi tengah masing-masing dipasang dengan dua posisi SBA berlainan telah dipilih. Dua jenis posisi SBA yang terlibat dalam kajian ini adalah SBA yang terletak di panel bumbung dan SBA yang terletak dibelakang tempat duduk. Hasil kajian ditentukan oleh tahap kepenatan dan analisa postur dengan masing-masing menggunakan kaedah Borg RPE Skala dan Indeks Keselesaan. Keputusan daripada Borg RPE Skala dan Indeks Keselesaan bersetuju SBA di posisi panel bumbung lebih selesa berbanding SBA di posisi belakang tempat duduk. Penilaian ergonomik yang dibuat dalam kajian ini berjaya mengenalpasti tahap kepenatan dan segmen badan yang banyak mempengaruhi markah keseluruhan. Hasil carian yang ketara daripada kajian ini membantu dalam menyediakan nilai tambah dari segi ergonomik kepada pereka di peringkat awal pembangunan kenderaan baru. Yang paling penting ciri-ciri yang ditunjukkan oleh kedua-dua kaedah iaitu senang dan berkesan sesuai digunakan dalam apa jua situasi dan industri. Kesimpulannya, hasil kajian telah membuktikan dalam tugas mencapai lidah tali pinggang keledar, SBA di posisi panel bumbung lebih selesa berbanding SBA di posisi belakang tempat duduk.

ACKNOWLEDGEMENT

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LIST OF SYMBOLS AND ABBREVIATIONS

DHM	Digital human
DOF	Degree of freedom
ECE	Economic Commission for Europe
EMG	Electromyography
HMI	Human-Machine Interface
ISO	International Organization for Standardization
^{o}	Degree
cm	Centimetre
kg	Kilogram
MPV	Multi-Purpose Vehicle
MSD	Musculoskeletal Disorder
OEM	Original Equipment Manufacture
OSH	Occupational Safety and Health
ROM	Range of Motion
RP	Rest Posture
RPE	Rating of Perceived Exertion
SBA	Seat Belt Anchorage
SD	Standard deviation
WHO	World Health Organization

CHAPTER 1

INTRODUCTION

1.1 Overview of the Study

According to World Health Organization (WHO, 2004) road traffic accident was the ninth place of the leading causes of death. Not many people realize that safest seat inside a moving passenger car is the center occupant of the rear seat (J. Mayrose, 2008). Most of current passenger cars are not promoting the use of this particular seat. Research shows that people prefer to seat on the outboard seat compare to the center of the seat (Matthew, 2009). Although the use of seat belt for front seat is increasing, study shows that compliance level for the rear seat is still low in Malaysia (Choy, 2013).

Factors that lead to seat belt non-compliance for rear seat are varied but this paper will be focusing on the ease of use of the seatbelt. This paper hypothesis is that occupant is likely to fasten their seat belt if it is easy to use. Comfort/discomfort perception is essential to evaluate ease of use thus postural comfort is chosen as one of the tools for measurement. In order to evaluate the discomfort level, it's compulsory to understand body movement during fastening a seat belt. Normally at that moment most of seat occupants will need to reach for seat belt tongue and pull it to the seat belt buckle where it will be locked. Body segment and movements involved during this interaction are;

1) Shoulder abduction/adduction,

2) Shoulder flexion/extension,

3) Forearm and elbow flexion/extension,

4) Forearm and elbow pronation/supination, and

5) Hand flexion/extension.

These interactions result in the perceived comfort\discomfort of the user which can be investigated via various methodologies. Current study plan to apply a self-assessment

questionnaire and a new quantitative method which will explain further in this paper. Due to the location of SBA will be the main attribute for this situation, two types of SBA are discussed further in this paper but only focus on the shoulder SBA. Data collected from this investigation will be synthesize and comparison between the methods used will be discussed further in this paper. Result from this investigation will provide add in value in term of ergonomics to decision making on which SBA are preferred by participants of this investigation.

1.2 Problem Statement

Seatbelt is an instrument to restraint passenger in case of vehicle is suddenly stoped or involved in collision with other vehicle. It consists of a pieces cloth which is anchored at a couple or more anchorage point. Anchorage points are mainly influenced by regulation requirement, previously lap seatbelt with two anchorage points has been outdated with new ECE R14-07 which stated that the mandatory of three points seatbelt anchorage. Normally, at rear center seating position the three seatbelt anchorage's points consist of two points at the vehicle structure to accommodate lap belt and the third point accommodate shoulder belt which can either at vehicle structure or seat structure. Most of the OEMs avoid locating this anchorage at the seat structure due to additional pulling load will be imposed during regulation test ECE R14.07 but some are still using anchorage at seat structure. For an example, two cars model from a local OEM, one is a sedan and another is a hatchback. The difference between these two models at rear portion in regards to SBA is the absentee of rear shelf panel for hatchback model had influenced the rear seat design. Shoulder belt anchorage had been located at seat structures (seatback) which result in increasing the seat weight due to additional parts and reinforcement's brackets. Additional weight reduces fuel efficiency

performance and new parts are not cost effective due to reducing common parts to build the car.

In term of ergonomic issues according to (Naddeo, Cappetti et al. 2015)(A.Naddeo, 2015), in every Human-Machine Interface (HMI) design, several parameters have to be evaluated in order to ensure safety of the user and to avoid health problem such as Musculoskeletal Disorders (MSD). There is no reported case of MSD problem from using seatbelt but frequency seatbelt application for vehicle users are two times per one way trip.

User preferences to fasten seat belt can be related with seat belt anchorages design position. Ease of use which indicates perceived comfort/discomfort of the seat occupant is one the main factors that will determine seatbelt utilization. It's important for everyone to fasten their seatbelt because there many studies and reported case that mentioned rear passengers whom are not fasten their seatbelt will not only among the rear passengers but also the front seat occupants (Choy, 2013). It is in the hope that by increasing the comfortable level for the seat occupant, seatbelt compliance among road user will be increased.

Therefore, current study is also intended to add values in deciding the SBA's location in term of ergonomics assessment. Opportunity for the study to contribute in designing seat belt anchorages position for the second row passenger seat of the new Multi-Purpose Vehicle (MPV) from local OEM. Currently center seating position for second row of new MPV only option for shoulder SBA is at seat structure due to carryover part (seat) from export variant. Although current study can only investigate on the rear center seating position where shoulder SBA location can be either at seatback or at vehicle structure. Methodology and the aim of this study can be used to assess perceived discomfort level when reaching for the seat tongue for any seating position.

1.3 Objectives of the Study

The objectives of the study are listed as followed:

1. To identify anthropometric parameters involved related to determine perceived discomfort among participants.
2. To analyse perceived discomfort among participants using Borg RPE scale and Comfort Index.
3. To propose which SBA position is preferred in term of ergonomics assessment.

1.4 Scope of the Study

The design of the study involved two types of anchorage locations, which are at seatback and vehicle structure. Two types of passenger cars that applied these anchorage locations at rear center seating position are chosen, test car 1 (vehicle structure) and test car 2 (seatback). Two DSLR camera were used to record participants performing the task of reaching for the seatbelt. Participants were randomly selected in the workplace with age range from 24 to 46 years old and all of them had no MSD problems.

1.5 Limitation of the Study

Although the study has reached its objectives and was carefully prepared, there were some inevitable limitations. The study was carried out on two different test cars due to high cost in preparing prototype car and small sample of the subject whom were performing the reaching for seat belt tongue task. Hence, to define the results for larger groups, the study should be conducted with more participants.

1.6 Flow Chart of the Study

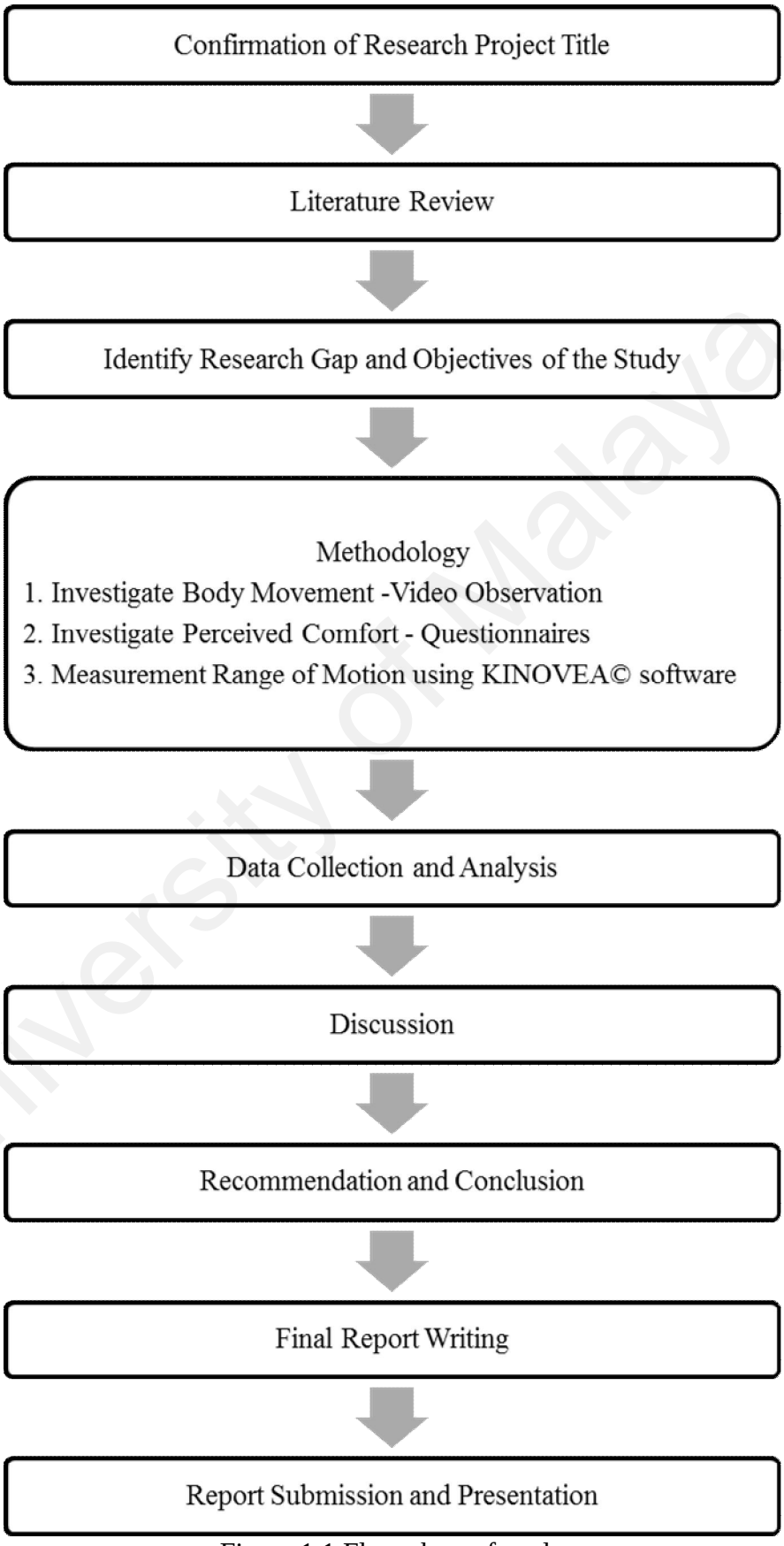


Figure 1.1 Flow chart of study.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, the perceived discomfort and the prevalence of MSD problem is discussed. According to (Naddeo, 2015), during Human-Machine Interface, HMI design stage, several parameters have to be evaluated in order to ensure safety and well-being of users (humans) and to avoid health problems like muscular-skeletal disease, MSD. Previous research studies found that analysis tools such as Borg Rating of Perceived Exertion (RPE) Scale are successfully applied to assess the MSD problems. Comfort Index is new introduced quantitative method for evaluating comfort based on anthropometric parameters and upper limbs posture. In the current study, these assessment tools (Borg RPE Scale and Comfort Index) will be used to evaluate the perceived discomfort, based on the performance of participants when they perform the given task.

2.2 Ergonomic Assessment

According to (Mike Kolich, 2002), there are two categories of ergonomics criteria which are physiological and anthropometric. Basically from anthropometry perspective, during Human-Machine Interface (HMI) design, it must be fit to range of people, from large to small person. This is achieved by noting the values of appropriate anthropometric dimensions of a target population which usually 5^{th} percentile female and 95^{th} percentile male. The physiological aspect which deal with muscles and joints, have traditionally been quantified using electromyography, EMG (Nurhayati, 2010; Tessy et. al, 2015). Some of the studies are to trying to relate physiological factor and the perceived comfort (Galinsky et al., 2000; Hamberg-van Reenen et al., 2008; Naddeo and Memoli, 2009).

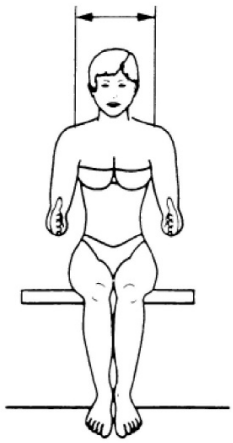
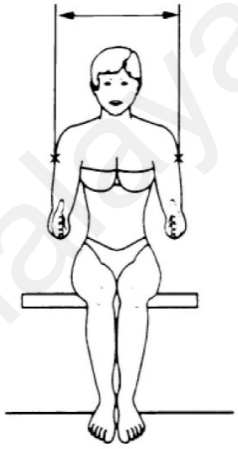
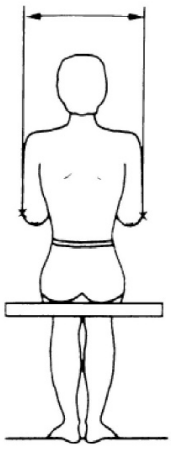
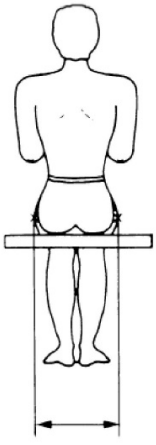
2.2.1 Anthropometric

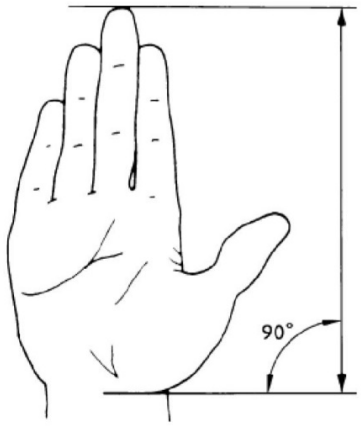
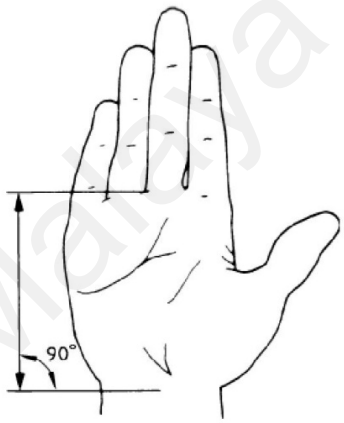
Anthropometry is the branch of the human sciences that deals with body measurements such as measurements of body size, shape, strength and working capacity (Pheasant, 1996). Anthropometric data on the general population is essential in ergonomics to specify the physical dimensions of workspace, equipment, furniture and clothing to fit the user and to avoid a physical mismatch between the dimensions of products or equipment and corresponding user dimension (Bridger, 1995). There are several works that have been done to establish Malaysian anthropometric database such as (Nursalbiah Nasir et al., 2011; Darliana Mohamad et al., 2010; Hooi-Jiun Ngoh et al., 2011; Zawiah et al., 2012; Shahida et al., 2015). For the purpose of current study, only a numbers of upper limb dimension have been identified which are depicted according to ISO 7250-1 in table 2.1 of figures with corresponding descriptions.

Table 2.1 Dimension and landmarks. (ISO 7250-1)

Sitting height Description: Vertical distance from a horizontal sitting surface to the highest point of the head (vertex).	
Eye height Description: Vertical distance from a horizontal sitting surface to the outer corner of the eye.	

Shoulder height Description: Vertical distance from a horizontal sitting surface to the acromion.	
Elbow height Description: Vertical distance from a horizontal sitting surface to the lowest bony point of the elbow bent at a right angle with the forearm horizontal.	
Shoulder-elbow length Description: Vertical distance from acromion to the bottom of the elbow bent at a right angle with the forearm horizontal.	
Elbow-wrist length Description: Horizontal distance from wall to wrist (ulnar styloid process).	

Shoulder (biacromial) breadth Description: Distance along a straight line from acromion to acromion.	
Shoulder (bideltoid) breadth Description: Distance across the maximum lateral protrusions of the right and left deltoid muscles.	
Elbow-to-elbow breadth Description: Maximum horizontal distance between the lateral surfaces of the elbow region.	
Hip breadth Description: Breadth of the body measured across the widest portion of the hips.	

Hand length Description: Perpendicular distance from a line drawn between the styloid processes to the tip of the middle finger.	
Palm length Description: Distance from a line drawn between the styloid processes to the proximal fingercrease of the middle finger on the palm of the hand.	

The standard deviation, 5^{th} and 95^{th} percentiles are calculated for each set of data comprising the anthropometric measurements. The definitions of standard deviation, 50^{th}, 5^{th} and 95^{th} percentiles are given as follows:

1. Standard deviation (SD): SD is a measure of the dispersion of a set of data from its mean. A small SD indicates that the data is concentrated towards the mean whereas a large SD indicates that the data is highly dispersed from the mean.

2. Mean: Mean is a simple mathematical average of a set of two or more numbers.

3. Percentile: Percentile is the value of a variable below which a certain percent of observations fall. For example, the 95^{th} percentile is the value below which 95% of the observations fall. Likewise, the 5^{th} and 50^{th} percentile is the value below which

5 and 50% of the observations will fall, respectively. The 50th percentile is also known as the median since it represents the middle value in an array of values.

Calculation for 50th, 5th and 95th percentile is presented below.

Percentile, P = m + (k ×S)

Where:

m = mean

k = factor (k is negative if p-value is below the 50th percentile and k is positive if p-value above the 50th percentile)

S = Standard Deviation

Calculation for mean is as presented below.

Mean, m $= \frac{\sum x}{n}$

Where:

n = total number of subjects

x = measurement value

Σx = summation of measurement values

Calculation for standard deviation is as presented below.

Standard Deviation, S = $\sqrt{\frac{1}{n-1}\left[\sum x^2 - \frac{(\sum x)^2}{n}\right]}$

Where:

n = total number of subjects

x = measurement value

Σx = summation of measurement values

Σx^2 = summation of the squared measurement values

Factor k is given as per table 2.2.

Table 2.2 Factor k

p	*k*	*p*	*k*	*p*	*k*	*p*	*k*	*p*	*k*
1	-2.33	21	-0.81	41	-0.23	61	0.28	81	0.88
2	-2.05	22	-0.77	42	-0.20	62	0.31	82	0.92
3	-1.88	23	-0.74	43	-0.18	63	0.33	83	0.95
4	-1.75	24	-0.71	44	-0.15	64	0.36	84	0.99
5	-1.64	25	-0.67	45	-0.13	65	0.39	85	1.04
6	-1.55	26	-0.64	46	-0.10	66	0.41	86	1.08
7	-1.48	27	-0.61	47	-0.08	67	0.44	87	1.13
8	-1.41	28	-0.58	48	-0.05	68	0.47	88	1.18
9	-1.34	29	-0.55	49	-0.03	69	0.50	89	1.23
10	-1.28	30	-0.52	50	0	70	0.52	90	1.28
11	-1.23	31	-0.50	51	0.03	71	0.55	91	1.34
12	-1.18	32	-0.47	52	0.05	72	0.58	92	1.41
13	-1.13	33	-0.44	53	0.08	73	0.61	93	1.48
14	-1.08	34	-0.41	54	0.10	74	0.64	94	1.55
15	-1.04	35	-0.39	55	0.13	75	0.67	95	1.64
16	-0.99	36	-0.36	56	0.15	76	0.71	96	1.75
17	-0.95	37	-0.33	57	0.18	77	0.74	97	1.88
18	-0.92	38	-0.31	58	0.20	78	0.77	98	2.05
19	-0.88	39	-0.28	59	0.23	79	0.81	99	2.33
20	-0.84	40	-0.25	60	0.25	80	0.84	99.5	2.58

Anthropometric measurement is important in order to identify human dimension and physical characteristics which crucial during designing an HMI. Its common understanding that in every design, it's best to fit the 95th percentile and able to reach by the 5th percentile.

2.2.2 Postural study

Definition of postural comfort is the "level of well-being" perceived by human during interaction with working environment. Qualitative/quantitative analysis can be applied to investigate postural comfort through individual judgement/scoring. Several models to simplify the mechanism of comfort/discomfort perception have been developed starting

from (Moes, 2005) as shown in Figure 2.1 and (Vink and Hallback, 2012) as shown in Figure 2.2 Both started by compiling various literature overview into five main topics which are 1) sensory input (De Korte et al., 2012; Vink et al., 2012), 2) activities conducted during the measurement with an influence on comfort (Groenesteijin et al., 2012; Ellegast et al., 2012); 3) different bodily regions (Franz et al., 2012; Kong et al., 2012); 4) effect of the product's contour on comfort (Kamp, 2012; D'Oria et al., 2010; Noro et al., 2012); 5) physical loading (Borg, 1982; Knee and Lee, 2012; Di Pardo et al., 2008; Zenk et al., 2012)

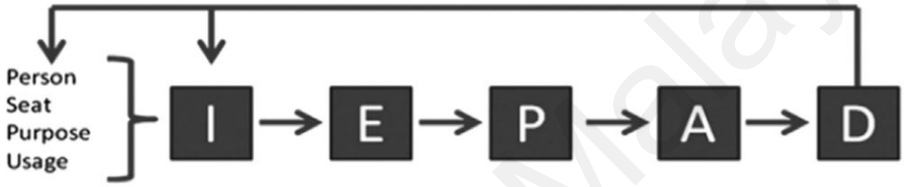


Figure 2.1 Moes's model of discomfort perception.

According to (Moes, 2005) in a study on seat design, during a person uses a seat, an interaction (I) begin between human and the seat which can be pressure distribution of the contact area. This result in internal body effects (E) due to tissue deformation or nerves compression. Then, effects will be interpreted or perceived (P) for example as pain. The perception then will be appreciated (A), if not it can lead to feeling discomfort (D).

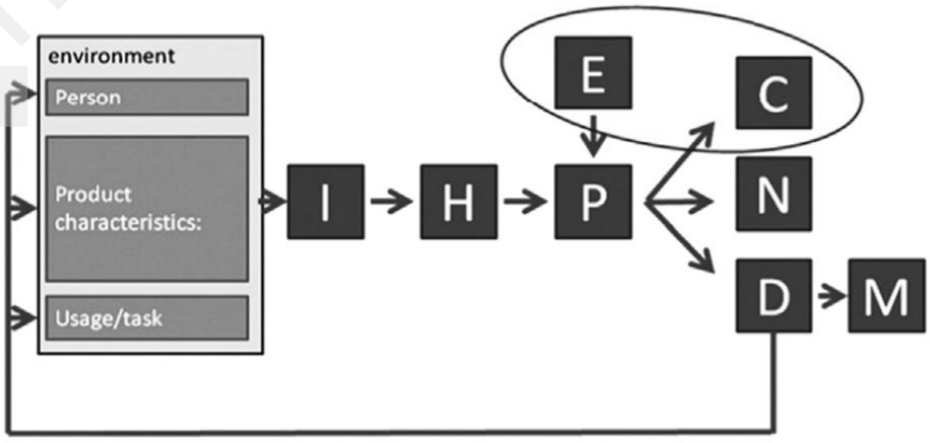


Figure 2.2 Vink-Hallbeck model of comfort/discomfort perception.

(Vink and Hallback, 2012) have modified Moes model and taken into account that interaction with an environment result in internal body human effects (H). The perceived effects (P) also influenced by expectations (E) which then interpreted into comfortable (C), feel nothing (N) or feeling discomfort (D). Feeling discomfort can lead to musculoskeletal complaints (M). This model has been modified by (Nadeeo et al, 2014) as shown in Figure 2.3. This model has taken into account expectations and perception modification in testing devices.

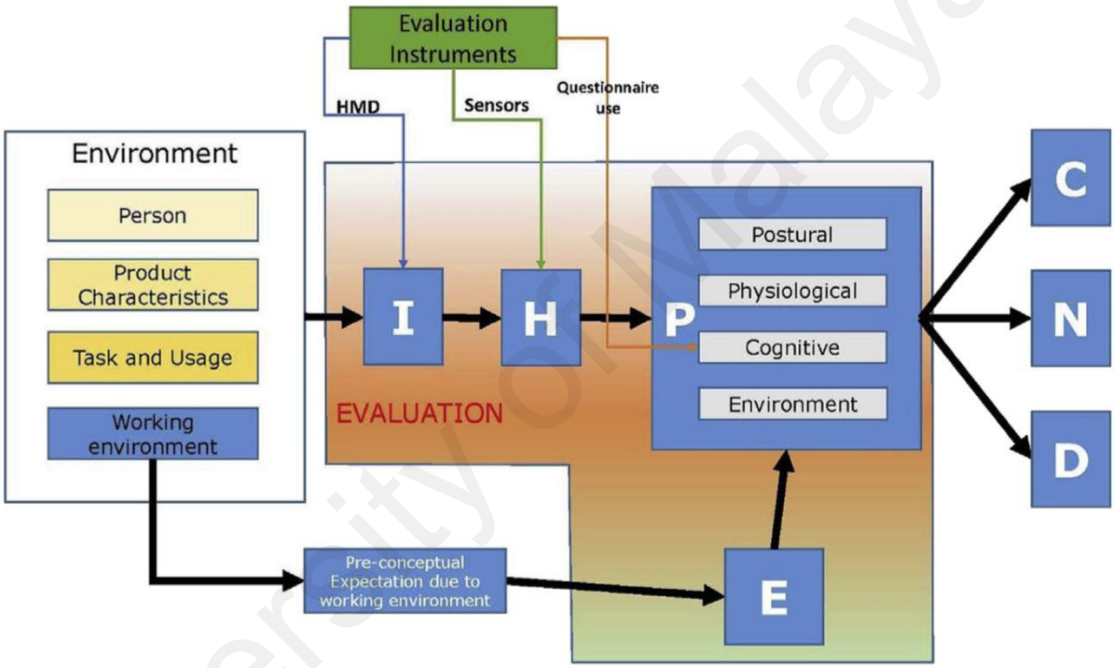


Figure 2.3 Cappetti and Naddeo comfort/discomfort perception model.

All of these models have considered the body effects and perceived effects which contributes in defining the Maximum Level of Comfort (MLC) and comfort evaluation base on measurement of angular Range of Motion (ROM) of each human joint (A. Apostolic, 2013).

2.3 Musculoskeletal Disorders (MSD)

MSD are diseases associated and/or irritated by the task itself or by the environment that can affect many regions of the body such as the upper limb extremities (arms and

hands), the lower limbs (feet and leg) and the lower back area (Ilkka Kuorinka et al., 1987). MSD can be defined as the degenerative diseases and inflammatory conditions that cause illnesses by the impairments of bodily structures such as injuries in the ligaments, nerves tendons, muscles, body's joints, and structures that support limbs, neck and back (Nunes, 2009). The MSD can be widespread body pain or localized in one area, that can worsen with movement. In fact, one of the most common types of musculoskeletal pain is low back pain while other common forms of MSD such as stress fractures, nerve compressions, tendonitis and myalgia (muscle pain) (Brunner et al., 2010).

MSD arise from the continuous pressure of arm and hand movements include holding, twisting, gripping, bending, straightening, reaching and clenching (Velaga & Telaprolu, 2013). These ordinary movements are naturally safe activities, however figure 2.4 shows these can lead to the high risks by the awkward posture, repeated overuse, excessive force, and most significantly, the insufficient recovery period between them and the movements task speed. (Nunes & Bush, 2012) stated that other factors that play a role rising to the onset of MSD are the stress, task intensification and other psychosocial factors. Commonly, MSD cannot be occurred by these risk factors separately because all of these factors interact among each other to develop MSD. Typically, the symptom that can be associated with MSD is pain. Sometimes the symptoms may include muscle sprains, joint inflammation, tenderness, redness and swelling of the affected region. There are several stages of MSD which ranges progressively from mild to very severe phase.

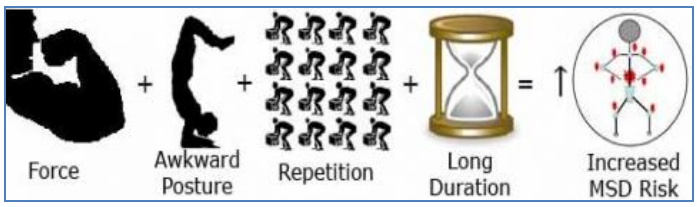


Figure 2.4 Combining the risk factors increases the risk of injury. Source: Occupational Health and Safety Council of Ontario (2007).

However, it is complicated to determine exactly at which point one phase ends and continue to the next phase because different people may experience different type of stages of MSD. Most importantly, when experiencing the initial pain, it is an indicator to notify that the tendons and muscles require to have a rest and recover. Otherwise, if it is left untreated, an injury can turn permanent and sometimes irreversible, until it results in a real MSD injury such as inflammation of the tendon which is tenosynovitis, slip disc, tendonitis, trigger finger, de Quervain's disease or even median nerve compressed injury like carpal tunnel syndrome (Parker, 1992). Therefore, a quick response to the symptom is a good prevention towards MSD.

2.4 Method and Tools Used for Ergonomic Investigation and Analysis

2.4.1 Borg Rating of Perceived Exertion (RPE) Scale

2.4.1.1 Background of Borg RPE Scale

The Borg (RPE) scale is a common method to determine the physical activity intensity level. The term "perceived exertion" can be described as how hard the task that a person experience when his body is doing physical activity. The Borg RPE scale is measured based on physical feelings of a person during performing tasks, which consider the increased of breathing rate, heart rate, sweating, and muscle soreness. Even though this method is totally an individual's exertion score, it may represent the actual heart rate during physical activity (Borg, 1985, 1998).

The Borg RPE scale is rates the body perceived exertion on a rating ranging from 6 to 20, where 6 describes "no exertion at all" while 20 describes "maximal exertion". The person is required to select the rating that most describes the level of body perceived exertion during physical activity. In general, the perceived exertion ratings between 12 and 14 on the Borg RPE Scale are described that physical task is being performed at a moderate level of intensity (Callaghan et al., 2011). As example, a walker would rate

the Borg RPE Scale level of "somewhat hard" (12-14 on the Borg RPE Scale), if he wants to keep in moderate-intensity activity. But if the presence of muscle fatigue and breathing he describes as "very light" (9) he would need to increase his intensity to the level of "somewhat hard" (12-14). Conversely, if he felt his exertion during physical activity was "extremely hard" (19) he should reduce his movements' speed to attain the moderate level of intensity. The person who has experienced on monitoring of the Borg RPE scale, may be capable to alter the level of intensity of the physical task by either increasing or decreasing the speed of movement.

There is a relationship between the body's perceived exertion and actual heart rate where the exercise levels is scaled to the equivalent of one tenth of the heart rate. This would convey that, during physical activity the number of scale needs to be multiplied by 10 to be equivalent to the actual heart rate; thus the Borg RPE scale can justify a fairly good estimation of the actual heart rate to assess physical activity intensity (Borg, 1998). For instance, consider experiencing body's perceived exertion of 9, thus 9 x 10 = 90; then the heart rate is supposed to be around 90 beats per minute. However, this computation is just an estimation of the heart rate because the actual heart rate can be slightly different due to the factors of age and physical conditions of the person. The Borg RPE scale is also used by people whom consume the medications to measure the intensity of physical activity which affecting their heart rate.

2.4.1.2 Application areas of Borg RPE Scale

According to cross-sectional study done by (Chim, 2006) that was conducted in Australia with focus on the food services of health sector. Four operators (participants) of kitchen hands performed six manual handling tasks and assessed their perceived discomfort to determine the ergonomic risk factors based on the given tasks. The assessment involved the tray line serving which include tasks of delivering and

collecting food trolleys to the patients. These tasks have significant risk factors which contribute to a higher level of MSD. The rating of body's perceived exertion was obtained by using the Borg's RPE Scale based on the perception of exertion level for each task. Based on the result (Chim, 2006) which collected from four test subjects, the mean scale of delivery lunch trolleys showed the Borg RPE scale of 11, which is indicated as a light task, while serving tray line task showed that the Borg RPE scale of 15.8, which is referred as a heavy task. Furthermore, from the six manual handling tasks, the perception of exertion for the tray line serving task was defined as "somewhat hard but it's OK to continue". Therefore, recommendations should be focused on work design of equipment and trolleys to reduce risk of injury and improve productivity.

2.4.2 Comfort range of motion (CROM)

2.4.2.1 Background of CROM

Each human joint has variability limits of Range of Motion (ROM) as described in Orthopedics' treatises (Thompson, 2010) and in every ROM of body joints, there is a subset of position where human feel to stay in comfort as described by (Apostolico, Cappetti et al. 2013) as Comfort Range of Motion (CROM). Based on study by (S. Koley, 2008) CROM is defined as intersection of all suggested comfort range as depicted in (Figure 2.5). (Fagarasanu et al., 2004) described that in each joint has its own natural Rest Posture (RP) where the muscles are completely relaxed or at minimum strain level. In this RP, musculoskeletal disease could be reduced while comfort perception is optimized (Galinsky et al., 2007). (A. Apostolic, 2013) used the concept of RP to identify the Range of Rest Posture (RRP) due to the fact that RP is different for each human. Relation RRP to CROM is as show in (Figure 2.5).

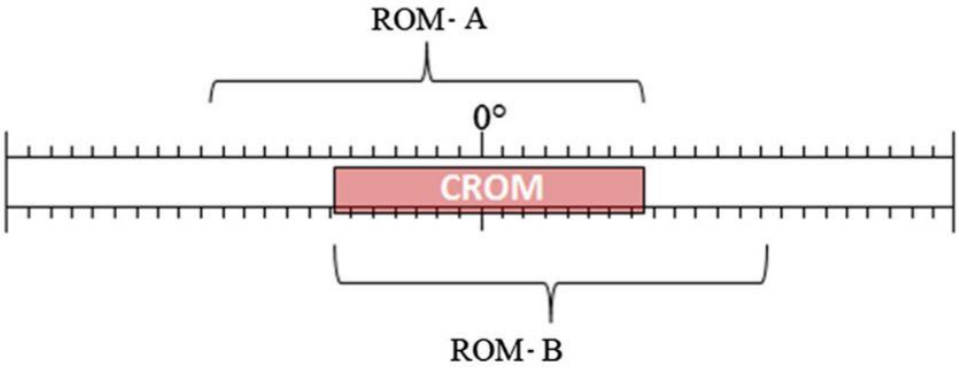


Figure 2.5 Intersection between two ROMs (A. Apostolic, 2013).

Figure 2.6 Definition of RRP (A. Apostolic, 2013).

RRP can be considered to be “statistically” in rest and it is obtained the analysis of human whose joints are in a natural position with relaxed musculature. Maximum comfort is obtained when joints angular value are within RRP (Apostolic, 2013). As of result from collecting data on judgement of several types of postures and statistical method, (Naddeo, 2015) introduced the comfort versus posture curve. The study intended to provide designers an instrument to evaluate comfort level of an HMI and can be integrated into digital human modelling (DHM).

Study conducted by (Naddeo, 2015) only focused on upper limb but due to the research methodology accuracy and ease of use, it is also can be applied in all cases on which load factors can be neglected. Boundary conditions that was set during the study are 1) Subject in standing or seated position (no intermediate position were tested), 2) Arms and legs are free from constraints or footholds, 3) No load were applied. The study concluded that comfort curves that had been introduced were not symmetric because 1) The presence of gravity force, 2) Interaction with other human body parts leading to interference with other joint movements, 3) Natural limit of joint movements.

2.4.2.2 Application areas of Comfort Curve

Comfort curve that had been introduced by (Naddeo, 2015) can be applied to several design context and can be used to support decision-making steps in industrial projects. Such example has been described in (Naddeo, 2015) where postural study had been conducted for person in driving position. Joints angles were calculated using software Kinovea© after processing the image captured by digital cameras. Three driving posture were investigated, 1) outstretched position, 2) curled up position and 3) with respect to ergonomic suggestions given in literature (Kolich, 2003).

Result from (A. Naddeo, 2015) investigation shows that in posture 1, wide joints angles were implied although perceived to be comfortable. Perception among those with poor eyesight on posture 2 also seems comfortable but elbow flexion\extension value scored poorly reducing overall comfort. Based on the result Posture 3 scored optimal comfort values and it is assumed that the position is comfortable. Similar investigation also been done by (Rosaria Califon et al., 2016) for Lunch Payment Station and Lunch-Boxes' Distribution Station at University of Salerno.

2.5 Summary

To summarize, based on the results that were obtained from the past research studies, it is definitely showed that the Borg RPE Scale and Comfort Curve\Index method is suitable assessment tools to evaluate the perceived discomfort during the task of reaching for seatbelt tongue. Although the ease of use is the main characteristics of these methodology but evaluation of several previous assessment show that these ergonomic methods have been created based on statistical method, and its relevant results may cover application in many industrial projects.

CHAPTER 3

METHODOLOGY

3.1 Introduction

In this chapter, method and material are explained and elaborated further mainly on the instruments used in this study. Also step by step taken to identify critical items such as body segments that involved and measurement data required to evaluate perceived discomfort. Two quantitative methods used in the study which are comfort index (Naddeo, 2015) and Borg Rating of Perceived Exertion (RPE) Scale.

Comfort index is applied to provide a scoring system for this aspect of comfort based on anthropometric parameters and upper limbs posture. The use of the comfort index in this study is to observe and analyse the body postural of the particular seat occupant. The score indicate comfortable level which higher the score means more comfort the user feel. Digital cameras were utilized to capture videos and images of the seat occupants performing the task and body segment ROM or joints-angle measurement using Kinovea© software.

The Borg RPE Scale is used to assess the effort, strain, discomfort, and/or fatigue experienced during performing the tasks. The scale provides fruitful information as it is able to control limited amount of energy for completing the tasks through maintaining a normal level of exertion and provide warning indicators when the level of exertion may put the user at risk for injury.

Finally, after investigating the significance of prevalence in reaching for the seatbelt tongue task, the recommendations are given to which type of seatbelt anchorage's position is preferred among the participants. This is mainly to give designers an assessment of product's perceived comfort in the early stage of the product development process.

3.2 Design Study

This study is conducted in the duration of 3 months using two test car from local OEM hatchback which participants were asked to fasten their seatbelt at rear center seating position. Test car 1 is fitted with seatbelt anchorage at the roof panel (vehicle structure) while test car 2 is fitted with seatbelt anchorage at the seatback (seat structure). Participants were briefed before proceeding with the test and task of fastening the seatbelt that need to be completed. Participant's actions were video recorded and they were asked to fasten the seatbelt at own preferences. After that they were asked to fill in Borg RPE Scale form and comfort index is given after video analysis. The similar process is repeated for both test cars. The detail process flow is illustrated in Figure 3.1**.**

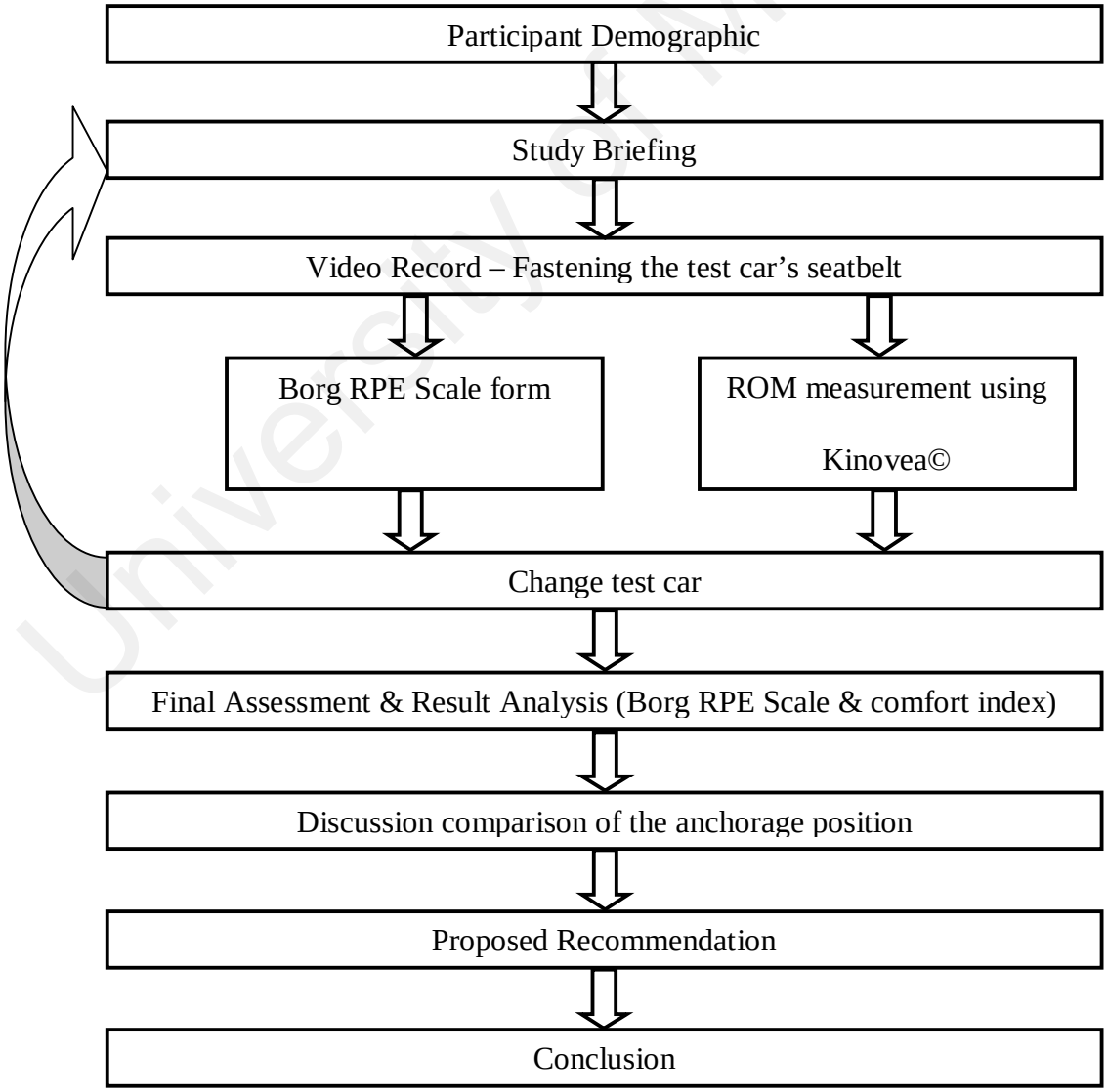


Figure 3.1 Process flow of the design study.

3.3 Participants

There are 15 healthy persons consist of 10 males and 5 females with no history of MSD, both males and females with aged between 24 to 46 years, and selected according to their heights and weights to be the participants or subject matter for involving in this study. All participants were selected could represent 5^{th} percentile and 95^{th} percentile. All participants are using seatbelt daily and familiar with the test car. Short briefing was given to carry out the tasks and all have given consent to video that had been recorded. In this study, participants need to fasten each test car seatbelt and fill in the Borg RPE Scale form given.

3.4 Description of the Task for Test Car 1

The test car is fitted with particular seatbelt anchorage at the roof panel (vehicle structure). The seatbelt tongue is not positioned through an effective anchorage which means that the whole seatbelt retractor is located at the same location. The components are located at elevated position on the right side of seat occupant‘s shoulder. Before starting the task of reaching for the seatbelt tongue, participants were asked to seat their normal rest position with their back leaning against the seatback and hip as close to intersection of seatback plane and seat bottom plane (Figure 3.2). Median line of the test car needs to be in between participant’s legs (Figure 3.3). After that participants begin reaching for the seatbelt tongue with their right hand. Noted that participants were required to repeat the task twice and measurements were taken from the second attempt. Body segments that involve in this task are 1) neck 2) shoulder 3) elbow and 4) wrist. It begins with neck rotation to right when looking for the seatbelt tongue. Then participants will raise their right hand to reach for the seatbelt tongue.

Figure 3.2 Participant at rest posture in test car 1.

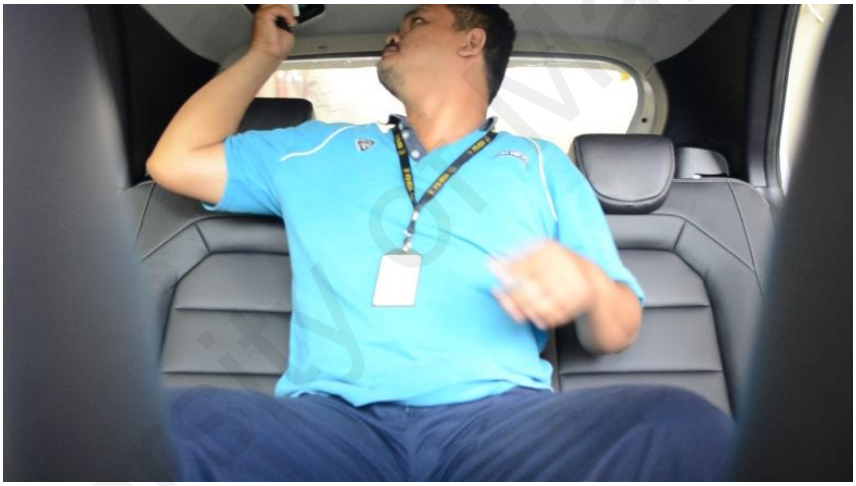


Figure 3.3 Participant reaching for the seatbelt tongue in test car 1.

3.5 Description of the Task for Test Car 2

Test car 2 is fitted with seatbelt anchorage at seat structure which is positioned at the seatback. The whole components including seatbelt retractor is located at the seatback and the belt comes out from the seatback through an effective point. The effective point is located at a brief distance from the seat occupant's right shoulder. OEM's design position for seatbelt tongue of this particular seating position is at occupant hip's area but for the sake of current study, seatbelt tongue has been positioned at the effective point. Participants as illustrated in Figure 3.4 and need to seat at rear center seating

position as described for test car 1 and perform similar task twice and measurements were taken on the second attempt.

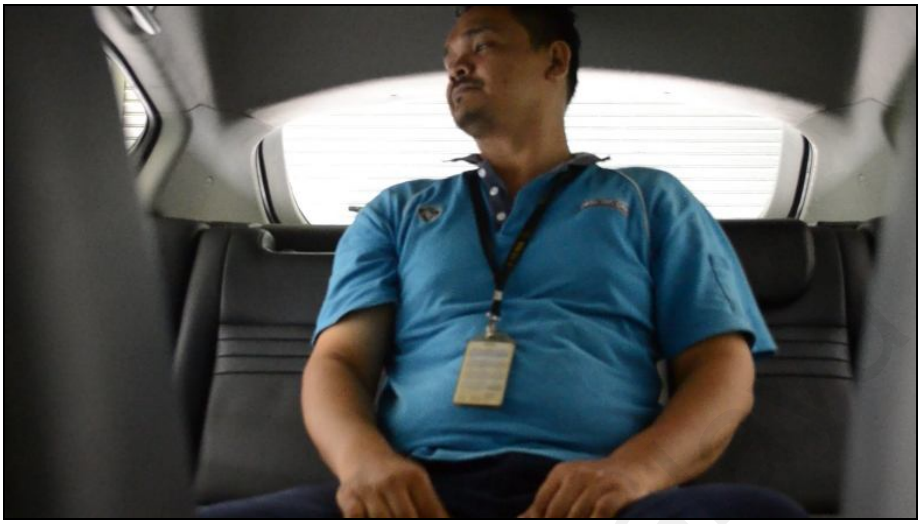


Figure 3.4 Participant at rest posture in SUPRIMA S.

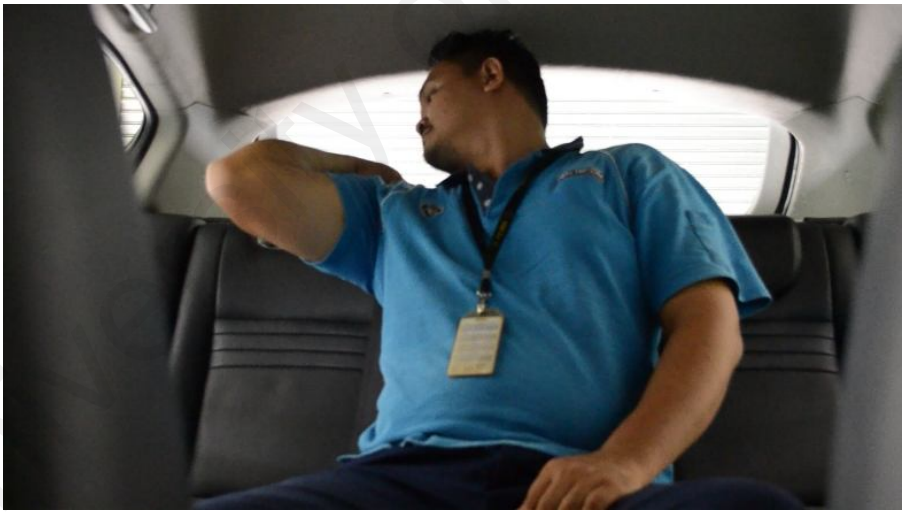


Figure 3.5 Participant reaching for the seatbelt tongue in test car SUPRIMA S.

3.6 Outcome Measures

The outcome of this study is focused on the perceived discomfort using the Borg RPE Scale and the assessment of the postural comfort, determined by using the comfort index method. The measurements were taken for both test cars which test car 1

represents seatbelt anchorage at vehicle structure and test car 2 represents anchorage at seat structure.

3.6.1 Physical Exertion Assessment Tool: Borg RPE Scale

Borg RPE scale is used as a survey with ratings to define the level of difficulty of an activity. When participants carry out the task, they could translate their body's perceived discomfort into Borg RPE scale or scoring points. During the measurement process of the intensity level of activity, the participants should estimate their exertion as honestly and neutrally as possible by concentrating on the inner feeling of exertion and without considering about what type or model of the test car they were in.

The level of body's perceived exertion is often measured with a 15 category scale ranging from rating 6 to 20, where rating 6 indicates "no exertion at all" while rating 20 indicates "maximal exertion." Hence, as indicated above, the operators should choose the rating in Table 3.1 that best describes their level of exertion.

Table 3.1 Borg RPE Scale of body perceived exertion.

Borg RPE	Intensity
6	No exertion at all
7	Extremely light
8-9	Very light
10-11	Light
12-13	Somewhat hard
14-15	Hard (heavy)
16-17	Very hard
18-19	Extremely hard
20	Maximal Exertion

The numbers can be described as follow:

- Rating 9 match to "very light" physical activity. The activity is like short and slow walk at a persons' own pace for average 5-10 minutes.

- Rating 13 match to “somewhat hard” physical activity, yet it is still regarded as OK to carry on.

- Rating 17 match to “very hard” is very tiring and tough activity. The activity is very heavy until the person become very tired. The person can still continue, but need to push himself/herself.

- Rating 19 match to an extremely strenuous activity level. The activity is the most strenuous and exhausting activity that the person has ever done.

3.6.2 Postural Analysis Assessment Tool: Comfort Index

The comfort index method was introduced as a correlation between comfort/discomfort perception and biomechanics parameters form a several well-defined postures. Photographic data acquisition, the RRP concept were used to define and build the comfort curve or indexes for each degree of freedom (DOF) of human upper limb joints. Two digital cameras were utilized to capture video and images during the participants performing reaching for the seatbelt tongue. Both cameras were positioned perpendicular to each other in order to capture video from front view and side view. The captured videos were synthesized into images to measure the body postural related to comfort index angles analysing requirement using Kinovea© software.

3.6.2.1 Application of Comfort Index Method

Comfort index is a new quantitative method for evaluating comfort/discomfort, based on anthropometric parameters and upper limb postures. The objective of comfort index is to provide an assessment of product’s perceived comfort in early stage of products development process by making postural-based quantitative evaluation. It’s also allows designers to redesign existing product’s configuration to improve comfort level. The next section reveals the step-by-step calculation and the interpretation process to complete the comfort evaluation**.**

1. Observe the activity and choose the posture for assessment

Two digital cameras were utilized to make the observation of participants performing the task. Cameras were positioned perpendicular taking view from in front and right side of the test car. Then the acquired posture is identified at the moment when participants finger grab the seatbelt tongue. Posture in Figure 3.3 and Figure 3.5 represent the posture to be for each participant.

2. Process the score

Using Kinovea© software to process the images, joint-angles are measured shown in green line connecting three references points that were selected for each body segment measurement. Shoulder joints-angle using torso-acromion-elbow bony point as references points. Joints-angles for elbow using styloid processes-elbow bony point-acromion. For wrist joint-angles, fingercrease of middle finger-styloid processes-elbow bony point are used as references points but requires deduction from 180° straight line. Figure 3.3 and figure 3.5 shows how the joints-angle are obtained.

3. Establish Comfort Index score

Next is to interpret the joints-angle into comfort values is by referring to comfort curve as shown in Figure 3.6 To Figure 3.8. The posture scores for body segment in Figure 3.6 covers the segments of shoulder, while comfort curve in Figure 3.7 covers the elbow postures. Figure 3.8 covers for wrist segment. Example, if joints-angle for shoulder adduction/abduction is 60° in x-axis (refer figure 3.6 Shoulder's Abduction/Adduction Comfort curve), then comfort index's value is read from the y-axis which is 5.1 point. Data of all participants for each body segment are recorded and compiled into tables. The final score of Comfort Index is obtained by using sum-like combinations (Vergara and Page, 2002) due to the influence of all the joints-angle on the overall comfort perception.

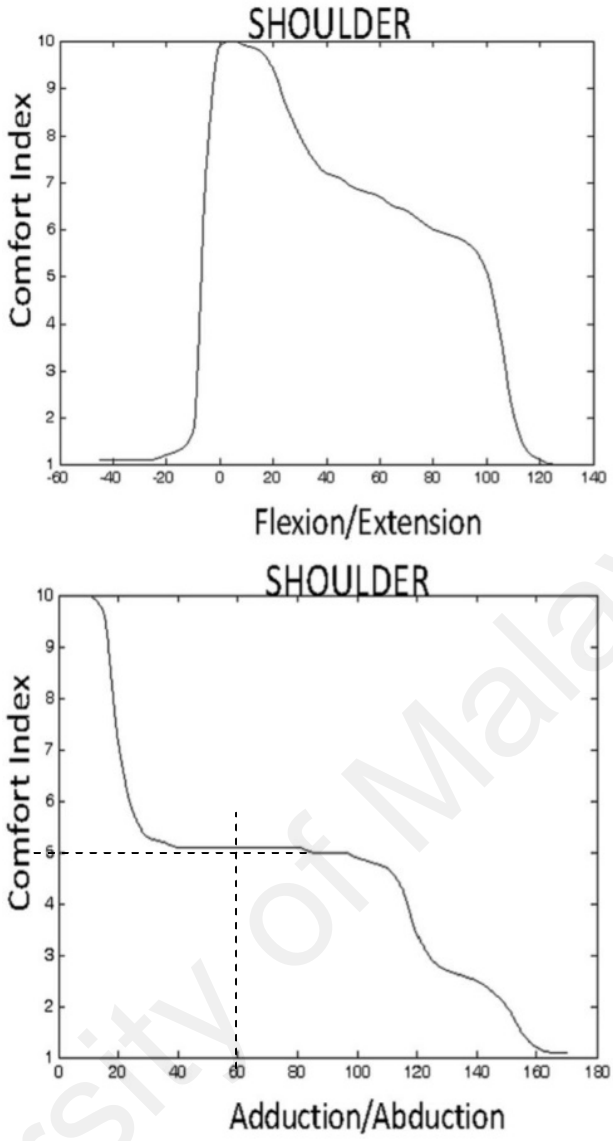


Figure 3.6 Shoulder's flexion/extension and Abduction/Adduction Comfort curve. (A. Naddeo, 2015)

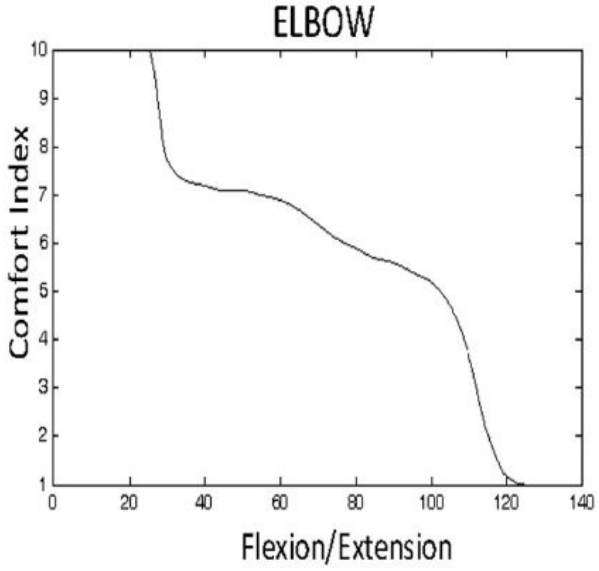


Figure 3.7 Elbow's flexion/extension Comfort curves. (Naddeo, 2015)

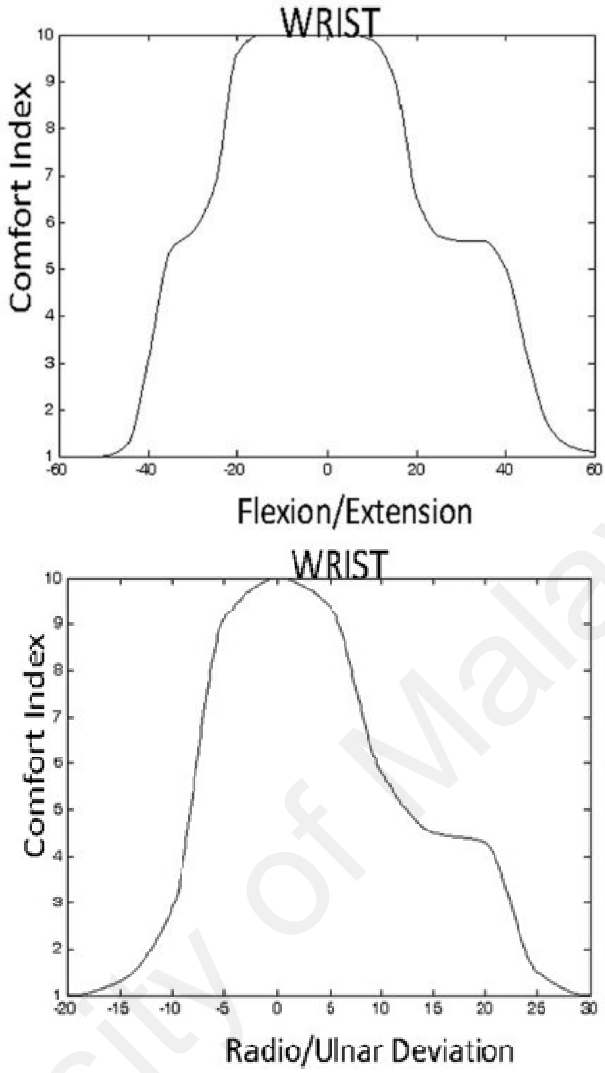


Figure 3.8 Wrist's flexion/extension and Radio/Ulnar Deviation Comfort curves. (Naddeo, 2015)

3.7 Summary

Study starts by collecting the participant's demographic data and ended by recommendations of shoulder SBA position. Study only focusing on the task of reaching for the seatbelt's tongue between two types of anchorage positions. The Borg RPE scale assessed the body's perceived exertion by participants, whereas the Comfort Index focused on the body postural with a new quantitative evaluation. The analyzed data are expressed sum-like combinations and based on the analyzed data, the best shoulder SBA location for rear center passenger seat was suggested for high perceived comfort from the user.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Introduction

In this chapter, the results including the demographic data, body's perceived discomfort and comfort index score obtained from the self-reported assessment on the Borg RPE Scale and comfort curve base on a new quantitative method for postural comfort evaluation introduced by (Naddeo, 2015), are discussed respectively. Three body segment's scores were obtained from the postural analysis, whereas the Borg RPE Scale is based on the physical feelings of an individuals' performance during conducting the task.

4.2 Participant Background Information

There are five female and ten male subjects involved in the study. The demographic data of participants are the mean and standard deviation of the participant's age, weight and height are tabulated in Table 4.1 for female and Table 4.2 for male.

Table 4.1 Mean and standard deviation on female participants background information.

No	Participant	Age (years)	Weight (kg)	Height (cm)
1	Female 1	25	44	154
2	Female 2	27	90	165
3	Female 3	27	85	166
4	Female 4	26	76	154
5	Female 5	30	58	161
	Total	135	353	800
	Mean	27.0	70.6	160.0
	Std Deviation	1.9	19.2	5.8

Table 4.2 Mean and standard deviation on male participants background information.

No	Participant	Age (years)	Weight (kg)	Height (cm)
1	Male 1	35	94	174
2	Male 2	35	60	180
3	Male 3	44	95	169
4	Male 4	40	82	176
5	Male 5	30	69	173
6	Male 6	30	120	187
7	Male 7	30	58	166
8	Male 8	46	50	160
9	Male 9	45	73	163
10	Male 10	26	57	165
	Total	361	758	1713
	Mean	36.1	75.8	171.3
	Std Deviation	7.2	21.9	8.3

The mean age of the female's participants is 27.0±1.9, mean weight is 70.6±19.2, and mean height is 160.0±5.8. The mean age of the male's participants is 36.1±7.2, mean weight is 75.8±21.9, and mean height is 171.3±8.3. All participant's age range from 25 to 46 with experience of driving the test cars. Additionally, all of the participants are right hand dominant and none had a reported history of musculoskeletal injuries that might affect their performance on the given task.

4.3 Result of Borg RPE Scale

Based on the evaluation, the score of Borg RPE Scale for both test cars is shown in Table 4.3 and Figure 4.1, respectively. Findings from conducting the survey shows that body's perceived exertion of participants in test car 1 have a lower scoring point when comparing to the test car 2. Test car 1 which represents SBA at the roof panel has the

mean Borg RPE Scale score of 9.2±2.28 and the mean score in test car 2 is 11.0±2.62. With reference to the result presented in Table 4.3 and Figure 4.1, the mean of Borg RPE Scale score is in the range of 9 to 11. This indicates that the participants agreed that reaching for the seatbelt tongue is somewhere between "very light" and "light". The SBA position that obtains "very light" for the seat occupant is located at roof panel. This shows that the participants feel less discomfort using SBA at the roof panel compare to SBA at seatback.

Table 4.3 Outcome Borg RPE scale scores for both test cars.

Outcome Measure	**Test Car 1**	**Test Car 2**
Female 1	10	12
Female 2	9	18
Female 3	10	12
Female 4	7	13
Female 5	11	12
Male 1	8	10
Male 2	10	11
Male 3	6	8
Male 4	12	11
Male 5	10	8
Male 6	10	11
Male 7	7	9
Male 8	11	12
Male 9	6	7
Male 10	11	11
(Mean ± SD)	9.2±1.93	11.0±2.62

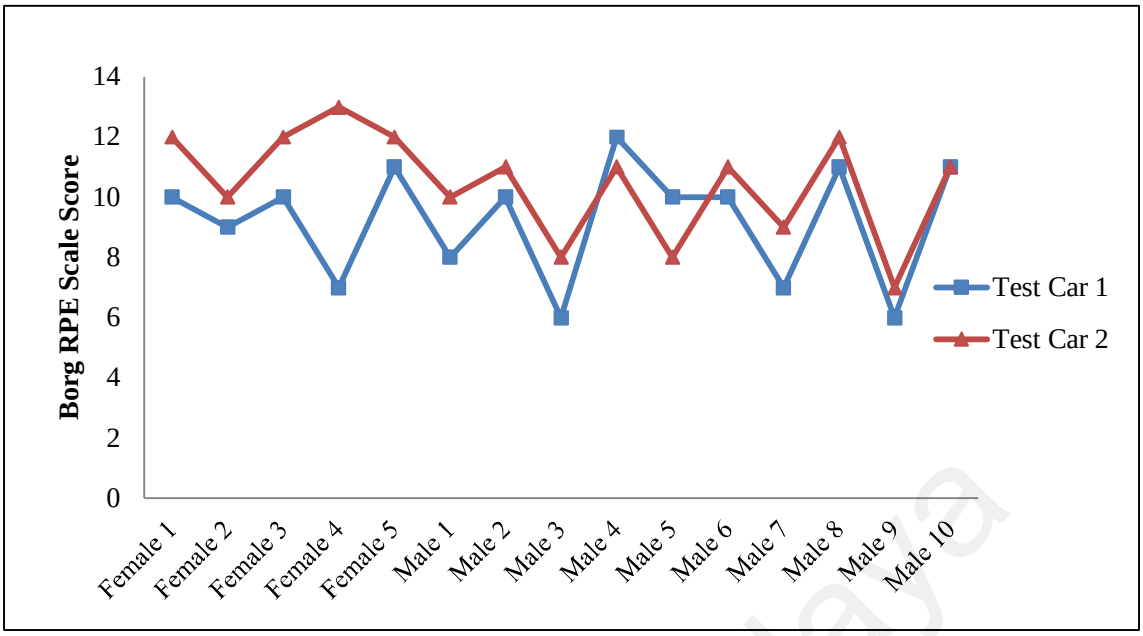


Figure 4.1 Borg RPE Scale scores for both test cars.

Most of the participants agreed that the task of reaching for the seatbelt tongue in test car 2 is harder due to it involves awkward posture and movement that could increase the body perceived exertion. Awkward as well as stressful postures are amongst the risk factors that have been identified to be connected with the increased risk of the MSD (David et al., 2008). For 95th percentile person, awkward postures occurs due to shoulder height is higher than SBA location making it on the edge of visible area and when reaching for the seatbelt tongue, most of them feel difficult to grab the seatbelt tongue.

4.4 Result of Comfort Index

Based on video analysis, joints-angle for three body segments are measured when seat occupant touched the seatbelt tongue. The synthesized data of all participants joints-angle for test car 1 and test car 2 are shown in Table 4.4 and Table 4.5, respectively. The score of Comfort Index for all participants is presented in Table 4.6 and Figure 4.2, respectively. Some of the parameters are either close to “geometric zero” position (Naddeo, 2014) or the third landmarks are not visible which cannot be measured.

Table 4.4 Outcome Comfort Index joints-angle and Comfort Index score for test car 1.

Joints-angle Outcome Measure	**Body Segment**				
	Shoulder		Elbow	Wrist	
	Flexion/ Extension	Abduction/ Adduction	Flexion/ Extension	Flexion/ Extension	Radio /Ulnar
Female 1	146° (1)	102° (4.8)	110° (3.4)	89° (1.0)	19° (4.3)
Female 2	0° (9.9)	65° (5.1)	130° (1.0)	13° (10.0)	19° (4.3)
Female 3	0° (9.9)	73° (5.1)	106° (4.4)	30° (5.7)	22° (3.2)
Female 4	0° (9.9)	56° (5.1)	124° (1.1)	23° (5.8)	23° (2.9)
Female 5	0° (9.9)	81° (5.1)	108° (4.0)	44° (3.3)	0° (10.0)
Male 1	0° (9.9)	72° (5.1)	150° (1.0)	51° (1.8)	6° (8.9)
Male 2	101° (4.8)	92° (5.0)	137° (1.0)	95° (1.0)	19° (4.2)
Male 3	0° (9.9)	82° (5.0)	129° (1.0)	38° (5.5)	0° (10.0)
Male 4	0° (9.9)	70° (5.1)	133° (1.0)	41° (4.9)	0° (10.0)
Male 5	0° (9.9)	77° (5.0)	136° (1.0)	30° (5.5)	40° (1.0)
Male 6	0° (9.9)	88° (5.0)	136° (1.0)	38° (5.5)	0° (10.0)
Male 7	0° (9.9)	57° (5.1)	118° (1.9)	0° (10)	12° (5.0)
Male 8	0° (9.9)	91° (5.0)	124° (1.1)	19° (6.9)	0° (10.0)
Male 9	0° (9.9)	79° (5.1)	126° (1.0)	0° (10.0)	13° (4.8)
Male 10	0° (9.9)	79° (5.1)	129° (1.0)	54° (1.2)	15° (4.5)

Based on Table 4.4, most of the participants scored the same for shoulder abduction with Comfort Index scoring range between 5.0 and 5.1 exclude Female 1 which scored 4.8. This is due to Female 1 is small thus required wide angle of shoulder abduction for her to reach the seatbelt tongue. For the same reason Elbow Flexion scoring also low for most of the participants which had scored poorly except Female 1,3,5 and Male 7. Score for wrist segment are vary from 1 to 10 in each Flexion/Extension and Radio/Ulnar with justification that if the participant had reached the SBA position by only flexion of the elbow angle, no need to adjust the wrist hence the scoring will be high.

Table 4.5 Outcome Comfort Index joints-angle and Comfort Index score for test car 2.

Joints-angle Outcome Measure	**Body Segment**				
	Shoulder		Elbow	Wrist	
	Flexion/ Extension	Abduction/ Adduction	Flexion/ Extension	Flexion/ Extension	Radio /Ulnar
Female 1	0° (9.9)	63° (5.1)	158° (1.0)	0° (10.0)	0° (10.0)
Female 2	35° (7.6)	48° (5.1)	161° (1.0)	-	-18° (1.1)
Female 3	0° (9.9)	32° (5.3)	151° (1.0)	45° (3.2)	46° (1.0)
Female 4	0° (9.9)	28° (5.3)	159° (1.0)	-23° (7.0)	0° (10.0)
Female 5	0° (9.9)	26° (5.7)	149° (1.0)	20° (6.7)	19° (4.3)
Male 1	108° (2.3)	92° (5.0)	130° (1.0)	58° (1.1)	0° (10.0)
Male 2	67° (6.4)	102° (4.9)	167° (1.0)	-	0° (10.0)
Male 3	0° (9.9)	58° (5.1)	154° (1.0)	47° (2.1)	0° (10.0)
Male 4	69° (6.4)	92° (5.0)	173° (1.0)	-12° (10.0)	0° (10.0)
Male 5	0° (9.9)	85° (5.0)	161° (1.0)	43° (4.0)	-35° (1.0)
Male 6	0° (9.9)	99° (4.9)	167° (1.0)	-80° (1.0)	-30° (1.0)
Male 7	0° (9.9)	73° (5.1)	165° (1.0)	16° (9.1)	0° (10.0)
Male 8	0° (9.9)	47° (5.1)	157° (1.0)	0° (10.0)	0° (10.0)
Male 9	0° (9.9)	87° (5.0)	164° (1.0)	-16° (10.0)	-35° (1.0)
Male 10	0° (9.9)	29° (5.2)	150° (1.0)	20° (6.7)	1° (10.0)

Results shown in Table 4.5 is the compiled data after images analysis for test car 2. Based on the results, Comfort Index scores for shoulder abduction are between 4.9 and 5.7 and most of shoulder flexion/extension scores are 9.9 due to close to “geometric zero”. Due to position of the SBA is slightly behind participant’s shoulder, all of them have to use wide angle of elbow flexion to reach for the seatbelt tongue result in all the participants scored not higher than 1.0. Two participants which are Female 2 and Male 2 had not been measured their wrist flexion/extension angle due to one of the landmarks is not visible.

Table 4.6 Outcome Comfort Index scores

Outcome Measure	Test Car 1	Test Car 2
Female 1	14.5	36.0
Female 2	30.3	14.8
Female 3	28.3	20.4
Female 4	24.8	33.2
Female 5	32.3	27.6
Male 1	26.7	19.4
Male 2	16.0	22.3
Male 3	31.4	28.1
Male 4	30.9	32.4
Male 5	22.4	20.9
Male 6	31.4	17.8
Male 7	31.9	35.1
Male 8	32.9	36.0
Male 9	30.8	29.6
Male 10	21.7	32.8
(Mean ± SD)	**27.1±6.0**	**26.9±7.2**

Findings from conducting the postural comfort analysis based on the results in Table 4.6 shows that Comfort Index score of participants in test car 1, have a slightly difference when comparing to test car 2. Test car 1 has slightly higher mean Comfort Index score which is 27.1±6.0 compare to test car 2 which score is 26.9±7.2. This mean that according to method introduced by (Naddeo, 2015), reaching for seatbelt tongue at the center seating position in test car 1 is more comfortable compare to test car 2. Based from the result in Table 4.4, total Comfort Index scores for test car 2 are poor due to seat occupants have to use wide joints-angle during the task of reaching for the seatbelt tongue especially the elbow flexion.

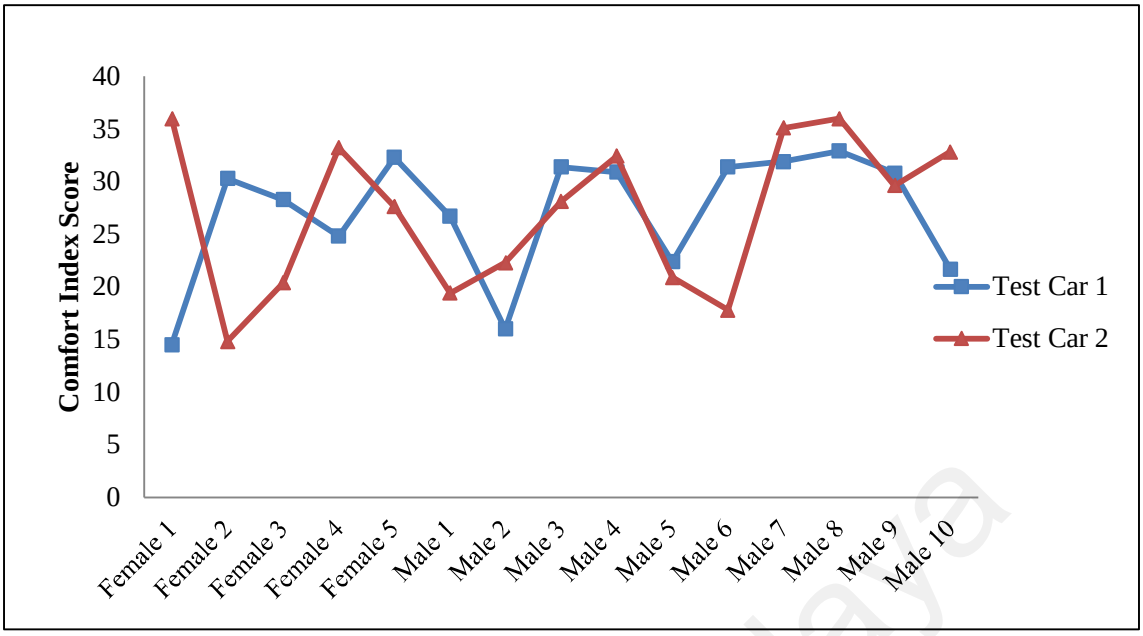


Figure 4.2 Comfort Index scores for both test cars.

4.4.1 Comparison Postural Score

According to the result of comfort index, comparison between types of SBA position in each test car shows significant differences when examining the result in term of 1) Comfort level between 5th percentile and 95th percentile for SBA at roof panel, 2) Comfort level between 5th percentile and 95th percentile for SBA at seatback, 3) Comfort level between SBA at roof panel and SBA at seatback among 95th percentile person, 4) Comfort level between SBA at roof panel and SBA at seatback among 5th percentile person.

Based on images analysis and total comfort index score, 5th percentile is found to be discomfort in test car 1 compared to 95th percentile participants. This is due to SBA at roof panel probably too far to reach for a small person. Distance of SBA at roof panel has resulted in large shoulder and wrist joint-angles which lower the total score of Comfort Index for 5th percentile participant. 95th percentile participants are moderately comfortable due to SBA at roof panel is not far to reach. Although some of measured joints-angle values are exceeded sub-ranges of motion in (Naddeo, Cappetti et al. 2015) but for the purpose of this study, the score for Comfort Index considers as 1.0 point.

On another discussion that can be made, result shows that 5th percentile person of the participants are more comfortable with SBA at seatback due to the SBA is near to the seat occupant compare to SBA at roof panel plus 5th percentile person shoulder height is lower than the SBA position compare to 95th percentile person. Therefore, during performing the task, 95th percentile's participants had made several body movements to help improve their view when reaching for the seatbelt tongue. Example situation in test car 2, Male 3 has submarining his body and depressed shoulder during performing the given task which also results in deviation of initial H point body.

There are several body movements such as neck and elbow pronation/supination which are not taken into account in current study because measurements only done in 2D view. Some of the wrist flexions /extensions couldn't be measured in test car 2 due to the third references point at fingercrease of middle finger is not visible as happened to Female 2 and Male 2.

4.6 Summary

The results from the Borg RPE scale survey and Comfort Index scores showed the same results. Results from both methods indicate that test car 1 is more comfortable compare to test car 2. Even though some of data from several body segments are not available, results from Comfort Index scores still indicate that comfort level in test car 1 is higher than test car 2. Factors that lead to data unable to collect in the result had been identified which are absenteeism of several ROM's measurement from images analysis in Comfort Index method due to landmark is not visible and measurement was done in 2D.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

An investigation on the comfort/discomfort for a specific task of reaching for the seatbelt tongue between two types of SBA position is conducted in this study. The application of evaluation of body posture is carried out for this study by using two assessment tools, namely Borg RPE Scale and Comfort Index scores. Based on the study, the results indicate that there is a relationship between these two applied methods where the participants during performing the task in test car 1 are less discomfort and the awkward postures in test car 2 as found basis of the analysis.

The result obtained from the Borg RPE Scale of body's perceived exertion score was between 9 and 11, showing the participants agreed that the performing the task in test car 1 is "very light" compare to test car 2 which is "light". Assessment from the overall Comfort Index scores also shows that test car 1 scored 27.1±6.0 which is slightly higher than test car 2 which scored 26.9±7.2. Comfort Index method proves that discomforts in the body posture among the participants occurred at the shoulder, elbow and wrist. Also by using this method, elbow movement had been identified as key contributor which heavily affected the overall scores. The Borg RPE Scale and Comfort Index methods are interrelated especially in identifying the perceived discomfort in the HMI design and identifying the possible risk for occurrence of MSD. Thus, it is highly recommended to conduct assessment of perceived discomfort in any other situation using these methods. As conclusion, several significant of the findings had been identified and presented below.

6.2 Significant of the Findings

The significance of the findings of this study, are:

1. Provide information to the designer in developing a HMI with DHM to reduce the level of discomfort and MSD risk factors on the user.
2. Provide recommendation to the project management on which SBA position is preferred in term of ergonomics based on result of assessment tools.
3. Provide ergonomics knowledge to the testing department on the new quantitative method to evaluate body postural comfort/discomfort.
4. Provide awareness regarding awkward postures that may lead to MSD occurrence to the seat occupants.

6.3 Recommendation for Future Work

Based from result of the study, several data couldn't be measured via images analysis due to poor landmarks visibility. Therefore, for the future study, it is highly recommended that a proposed designed HMI using digital human modelling (DHM) and its simulation should be taken into consideration. In order to improve current methodology, measurement could be done using video with 3D analysis tools such as TEMA automotive. Comparison on both methods could increase accuracy of future study. The study also should increase amount of the participants with focus to children and elderly demography due to high prevalence of occupying that particular seat. Current study only focuses on using right hand, therefore, for future investigation should also consider left hand utilization when performing the task. There are two rest points for the seatbelt tongue and current study only focus on the upper rest point, future investigation should include the other rest point.

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APPENDIX A : QUESTIONNAIRE

BORG RPE SCALE SURVEY FORM

BORANG PENILAIAN SKALA BORG RPE

Gender / Jantina :
Age / Umur :
Weight / Berat :
Height / Tinggi :
Health Status / Status Kesihatan :

***Question* / Soalan:**

Based on the activity you are doing, please select the number that best describes the level of difficulty of the activity. Try to evaluate your feelings when doing activities such as honest as possible and it cannot be compared with scores of others.
Berdasarkan aktiviti yang anda lakukan, sila pilih nombor yang paling menggambarkan tahap kesukaran activiti tersebut. Cuba untuk menilai perasaan anda ketika melakukan activiti itu sejujur yang mungkin dan ianya tidak boleh dibandingkan dengan markah orang lain.

***Rating Number* / Nombor Rating**	**Description / Penerangan**	**Assessment / Penilaian**	
		Test Car 1	**Test Car 2**
6	*Lightest* / Paling ringan		
7	*Extremely light* / Amat ringan		
8	*Very light* / Sangat ringan		
9	*Very light* / Sangat ringan		
10	*Light* / Ringan		
11	*Light* / Ringan		
12	*Somewhat heavy* / Agak berat		
13	*Somewhat heavy* / Agak berat		
14	*Heavy* / Berat		
15	*Heavy* / Berat		
16	*Very heavy* / Sangat berat		
17	*Very heavy* / Sangat berat		
18	*Extremely heavy* / Amat berat		
19	*Extremely heavy* / Amat berat		
20	*Heaviest* / Paling berat		

----------THE END / TAMAT----------
----------THANK YOU / TERIMA KASIH----------

BORG RPE SCALE SURVEY FORM

BORANG PENILAIAN SKALA BORG RPE

Gender / Jantina : Female
Age / Umur : 25
Weight / Berat : 44 kg
Height / Tinggi : 154 cm
Health Status / Status Kesihatan : Good

***Question* / Soalan:**
Based on the activity you are doing, please select the number that best describes the level of difficulty of the activity. Try to evaluate your feelings when doing activities such as honest as possible and it cannot be compared with scores of others.
Berdasarkan aktiviti yang anda lakukan, sila pilih nombor yang paling menggambarkan tahap kesukaran activiti tersebut. Cuba untuk menilai perasaan anda ketika melakukan activiti itu sejujur yang mungkin dan ianya tidak boleh dibandingkan dengan markah orang lain.

***Rating Number* / Nombor Rating**	**Description / Penerangan**	**Assessment / Penilaian**	
		Test Car 1	**Test Car 2**
6	*Lightest* / Paling ringan		
7	*Extremely light* / Amat ringan		
8	*Very light* / Sangat ringan		
9	*Very light* / Sangat ringan		
10	*Light* / Ringan	✓	
11	*Light* / Ringan		
12	*Somewhat heavy* / Agak berat		✓
13	*Somewhat heavy* / Agak berat		
14	*Heavy* / Berat		
15	*Heavy* / Berat		
16	*Very heavy* / Sangat berat		
17	*Very heavy* / Sangat berat		
18	*Extremely heavy* / Amat berat		
19	*Extremely heavy* / Amat berat		
20	*Heaviest* / Paling berat		

----------THE END / TAMAT----------
----------THANK YOU / TERIMA KASIH----------

BORG RPE SCALE SURVEY FORM

BORANG PENILAIAN SKALA BORG RPE

Gender / Jantina : PEREMPUAN.
Age / Umur : 27.
Weight / Berat : 90 kg.
Height / Tinggi : 165 cm.
Health Status / Status Kesihatan : GOOD.

***Question* / Soalan:**
Based on the activity you are doing, please select the number that best describes the level of difficulty of the activity. Try to evaluate your feelings when doing activities such as honest as possible and it cannot be compared with scores of others.
Berdasarkan aktiviti yang anda lakukan, sila pilih nombor yang paling menggambarkan tahap kesukaran activiti tersebut. Cuba untuk menilai perasaan anda ketika melakukan activiti itu sejujur yang mungkin dan ianya tidak boleh dibandingkan dengan markah orang lain.

I S

***Rating Number* / Nombor Rating**	**Description / Penerangan**	**Assessment / Penilaian**	
		Test Car 1	**Test Car 2**
6	*Lightest* / Paling ringan		
7	*Extremely light* / Amat ringan		
8	*Very light* / Sangat ringan		
9	*Very light* / Sangat ringan	✓	
10	*Light* / Ringan		
11	*Light* / Ringan		
12	*Somewhat heavy* / Agak berat		
13	*Somewhat heavy* / Agak berat		
14	*Heavy* / Berat		
15	*Heavy* / Berat		
16	*Very heavy* / Sangat berat		
17	*Very heavy* / Sangat berat		
18	*Extremely heavy* / Amat berat		✓
19	*Extremely heavy* / Amat berat		
20	*Heaviest* / Paling berat		

----------THE END / TAMAT----------
----------THANK YOU / TERIMA KASIH----------

BORG RPE SCALE SURVEY FORM

BORANG PENILAIAN SKALA BORG RPE

Gender / Jantina : FEMALE
Age / Umur : 27
Weight / Berat : 85
Height / Tinggi : 166
Health Status / Status Kesihatan : HEALTHY

***Question* / Soalan:**
Based on the activity you are doing, please select the number that best describes the level of difficulty of the activity. Try to evaluate your feelings when doing activities such as honest as possible and it cannot be compared with scores of others.
Berdasarkan aktiviti yang anda lakukan, sila pilih nombor yang paling menggambarkan tahap kesukaran activiti tersebut. Cuba untuk menilai perasaan anda ketika melakukan activiti itu sejujur yang mungkin dan ianya tidak boleh dibandingkan dengan markah orang lain.

***Rating Number* / Nombor Rating**	**Description / Penerangan**	**Assessment / Penilaian**	
		Test Car 1	**Test Car 2**
6	*Lightest* / Paling ringan		
7	*Extremely light* / Amat ringan		
8	*Very light* / Sangat ringan		
9	*Very light* / Sangat ringan		
10	*Light* / Ringan	✓	
11	*Light* / Ringan		
12	*Somewhat heavy* / Agak berat		✓
13	*Somewhat heavy* / Agak berat		
14	*Heavy* / Berat		
15	*Heavy* / Berat		
16	*Very heavy* / Sangat berat		
17	*Very heavy* / Sangat berat		
18	*Extremely heavy* / Amat berat		
19	*Extremely heavy* / Amat berat		
20	*Heaviest* / Paling berat		

----------THE END / TAMAT----------
----------THANK YOU / TERIMA KASIH----------

BORG RPE SCALE SURVEY FORM

BORANG PENILAIAN SKALA BORG RPE

Gender / Jantina : FEMALE
Age / Umur : 26
Weight / Berat : 76kg
Height / Tinggi : 154cm
Health Status / Status Kesihatan : SIHAT, OK!!

***Question* / Soalan:**
Based on the activity you are doing, please select the number that best describes the level of difficulty of the activity. Try to evaluate your feelings when doing activities such as honest as possible and it cannot be compared with scores of others.
Berdasarkan aktiviti yang anda lakukan, sila pilih nombor yang paling menggambarkan tahap kesukaran activiti tersebut. Cuba untuk menilai perasaan anda ketika melakukan activiti itu sejujur yang mungkin dan ianya tidak boleh dibandingkan dengan markah orang lain.

***Rating Number* / Nombor Rating**	**Description / Penerangan**	**Assessment / Penilaian**	
		Test Car 1	**Test Car 2**
6	*Lightest* / Paling ringan		
7	*Extremely light* / Amat ringan	✓	
8	*Very light* / Sangat ringan		
9	*Very light* / Sangat ringan		
10	*Light* / Ringan		
11	*Light* / Ringan		
12	*Somewhat heavy* / Agak berat		
13	*Somewhat heavy* / Agak berat		✓
14	*Heavy* / Berat		
15	*Heavy* / Berat		
16	*Very heavy* / Sangat berat		
17	*Very heavy* / Sangat berat		
18	*Extremely heavy* / Amat berat		
19	*Extremely heavy* / Amat berat		
20	*Heaviest* / Paling berat		

----------THE END / TAMAT----------
----------THANK YOU / TERIMA KASIH----------

BORG RPE SCALE SURVEY FORM

BORANG PENILAIAN SKALA BORG RPE

Gender / Jantina : Perempuan
Age / Umur : 30
Weight / Berat : 58 kg
Height / Tinggi : 161 cm
Health Status / Status Kesihatan : Sihat

***Question* / Soalan:**
Based on the activity you are doing, please select the number that best describes the level of difficulty of the activity. Try to evaluate your feelings when doing activities such as honest as possible and it cannot be compared with scores of others.
Berdasarkan aktiviti yang anda lakukan, sila pilih nombor yang paling menggambarkan tahap kesukaran activiti tersebut. Cuba untuk menilai perasaan anda ketika melakukan activiti itu sejujur yang mungkin dan ianya tidak boleh dibandingkan dengan markah orang lain.

***Rating Number* / Nombor Rating**	**Description / Penerangan**	**Assessment / Penilaian**	
		Test Car 1	**Test Car 2**
6	*Lightest* / Paling ringan		
7	*Extremely light* / Amat ringan		
8	*Very light* / Sangat ringan		
9	*Very light* / Sangat ringan		
10	*Light* / Ringan		
11	*Light* / Ringan	✓	
12	*Somewhat heavy* / Agak berat		✓
13	*Somewhat heavy* / Agak berat		
14	*Heavy* / Berat		
15	*Heavy* / Berat		
16	*Very heavy* / Sangat berat		
17	*Very heavy* / Sangat berat		
18	*Extremely heavy* / Amat berat		
19	*Extremely heavy* / Amat berat		
20	*Heaviest* / Paling berat		

----------THE END / TAMAT----------
----------THANK YOU / TERIMA KASIH----------

BORG RPE SCALE SURVEY FORM

BORANG PENILAIAN SKALA BORG RPE

Gender / Jantina : LELAKI
Age / Umur : 35 TAHUN
Weight / Berat : 94 kg
Height / Tinggi : 174 cm
Health Status / Status Kesihatan : SIHAT

***Question* / Soalan:**
Based on the activity you are doing, please select the number that best describes the level of difficulty of the activity. Try to evaluate your feelings when doing activities such as honest as possible and it cannot be compared with scores of others.
Berdasarkan aktiviti yang anda lakukan, sila pilih nombor yang paling menggambarkan tahap kesukaran activiti tersebut. Cuba untuk menilai perasaan anda ketika melakukan activiti itu sejujur yang mungkin dan ianya tidak boleh dibandingkan dengan markah orang lain.

***Rating Number* / Nombor Rating**	**Description / Penerangan**	**Assessment / Penilaian**	
		Test Car 1	**Test Car 2**
6	*Lightest* / Paling ringan		
7	*Extremely light* / Amat ringan		
8	*Very light* / Sangat ringan	✓	
9	*Very light* / Sangat ringan		
10	*Light* / Ringan		✓
11	*Light* / Ringan		
12	*Somewhat heavy* / Agak berat		
13	*Somewhat heavy* / Agak berat		
14	*Heavy* / Berat		
15	*Heavy* / Berat		
16	*Very heavy* / Sangat berat		
17	*Very heavy* / Sangat berat		
18	*Extremely heavy* / Amat berat		
19	*Extremely heavy* / Amat berat		
20	*Heaviest* / Paling berat		

----------THE END / TAMAT----------
----------THANK YOU / TERIMA KASIH----------

BORG RPE SCALE SURVEY FORM

BORANG PENILAIAN SKALA BORG RPE

Gender / Jantina : Lelaki
Age / Umur : 35 Tahun
Weight / Berat : 60
Height / Tinggi : 180
Health Status / Status Kesihatan : Sihat

***Question* / Soalan:**
Based on the activity you are doing, please select the number that best describes the level of difficulty of the activity. Try to evaluate your feelings when doing activities such as honest as possible and it cannot be compared with scores of others.
Berdasarkan aktiviti yang anda lakukan, sila pilih nombor yang paling menggambarkan tahap kesukaran activiti tersebut. Cuba untuk menilai perasaan anda ketika melakukan activiti itu sejujur yang mungkin dan ianya tidak boleh dibandingkan dengan markah orang lain.

***Rating Number* / Nombor Rating**	**Description / Penerangan**	**Assessment / Penilaian**	
		Test Car 1	**Test Car 2**
6	*Lightest* / Paling ringan		
7	*Extremely light* / Amat ringan		
8	*Very light* / Sangat ringan		
9	*Very light* / Sangat ringan		
10	*Light* / Ringan	✓	
11	*Light* / Ringan		✓
12	*Somewhat heavy* / Agak berat		
13	*Somewhat heavy* / Agak berat		
14	*Heavy* / Berat		
15	*Heavy* / Berat		
16	*Very heavy* / Sangat berat		
17	*Very heavy* / Sangat berat		
18	*Extremely heavy* / Amat berat		
19	*Extremely heavy* / Amat berat		
20	*Heaviest* / Paling berat		

----------THE END / TAMAT----------
----------THANK YOU / TERIMA KASIH----------

BORG RPE SCALE SURVEY FORM

BORANG PENILAIAN SKALA BORG RPE

Gender / Jantina : LELAKI
Age / Umur : 44
Weight / Berat : 75
Height / Tinggi : 169
Health Status / Status Kesihatan : SIHAT

***Question* / Soalan:**
Based on the activity you are doing, please select the number that best describes the level of difficulty of the activity. Try to evaluate your feelings when doing activities such as honest as possible and it cannot be compared with scores of others.
Berdasarkan aktiviti yang anda lakukan, sila pilih nombor yang paling menggambarkan tahap kesukaran activiti tersebut. Cuba untuk menilai perasaan anda ketika melakukan activiti itu sejujur yang mungkin dan ianya tidak boleh dibandingkan dengan markah orang lain.

***Rating Number* / Nombor Rating**	**Description / Penerangan**	**Assessment / Penilaian**	
		Test Car 1	**Test Car 2**
6	*Lightest* / Paling ringan	✓	
7	*Extremely light* / Amat ringan		
8	*Very light* / Sangat ringan		✓
9	*Very light* / Sangat ringan		
10	*Light* / Ringan		
11	*Light* / Ringan		
12	*Somewhat heavy* / Agak berat		
13	*Somewhat heavy* / Agak berat		
14	*Heavy* / Berat		
15	*Heavy* / Berat		
16	*Very heavy* / Sangat berat		
17	*Very heavy* / Sangat berat		
18	*Extremely heavy* / Amat berat		
19	*Extremely heavy* / Amat berat		
20	*Heaviest* / Paling berat		

----------THE END / TAMAT----------
----------THANK YOU / TERIMA KASIH----------

BORG RPE SCALE SURVEY FORM

BORANG PENILAIAN SKALA BORG RPE

Gender / Jantina : Rohaimi b. Hassan
Age / Umur : 40
Weight / Berat : 82
Height / Tinggi : 176
Health Status / Status Kesihatan : Sihat

***Question* / Soalan:**
Based on the activity you are doing, please select the number that best describes the level of difficulty of the activity. Try to evaluate your feelings when doing activities such as honest as possible and it cannot be compared with scores of others.
Berdasarkan aktiviti yang anda lakukan, sila pilih nombor yang paling menggambarkan tahap kesukaran activiti tersebut. Cuba untuk menilai perasaan anda ketika melakukan activiti itu sejujur yang mungkin dan ianya tidak boleh dibandingkan dengan markah orang lain.

***Rating Number* / Nombor Rating**	**Description / Penerangan**	**Assessment / Penilaian**	
		Test Car 1	**Test Car 2**
6	*Lightest* / Paling ringan		
7	*Extremely light* / Amat ringan		
8	*Very light* / Sangat ringan		
9	*Very light* / Sangat ringan		
10	*Light* / Ringan		
11	*Light* / Ringan		✓
12	*Somewhat heavy* / Agak berat	✓	
13	*Somewhat heavy* / Agak berat		
14	*Heavy* / Berat		
15	*Heavy* / Berat		
16	*Very heavy* / Sangat berat		
17	*Very heavy* / Sangat berat		
18	*Extremely heavy* / Amat berat		
19	*Extremely heavy* / Amat berat		
20	*Heaviest* / Paling berat		

----------THE END / TAMAT----------
----------THANK YOU / TERIMA KASIH----------

BORG RPE SCALE SURVEY FORM

BORANG PENILAIAN SKALA BORG RPE

Gender / Jantina : LELAKI
Age / Umur : 30
Weight / Berat : 69kg.
Height / Tinggi : 173cm
Health Status / Status Kesihatan : sihat.

***Question* / Soalan:**
Based on the activity you are doing, please select the number that best describes the level of difficulty of the activity. Try to evaluate your feelings when doing activities such as honest as possible and it cannot be compared with scores of others.
Berdasarkan aktiviti yang anda lakukan, sila pilih nombor yang paling menggambarkan tahap kesukaran activiti tersebut. Cuba untuk menilai perasaan anda ketika melakukan activiti itu sejujur yang mungkin dan ianya tidak boleh dibandingkan dengan markah orang lain.

***Rating Number* / Nombor Rating**	**Description / Penerangan**	**Assessment / Penilaian**	
		Test Car 1	**Test Car 2**
6	*Lightest* / Paling ringan		
7	*Extremely light* / Amat ringan		
8	*Very light* / Sangat ringan		✓
9	*Very light* / Sangat ringan		
10	*Light* / Ringan	✓	
11	*Light* / Ringan		
12	*Somewhat heavy* / Agak berat		
13	*Somewhat heavy* / Agak berat		
14	*Heavy* / Berat		
15	*Heavy* / Berat		
16	*Very heavy* / Sangat berat		
17	*Very heavy* / Sangat berat		
18	*Extremely heavy* / Amat berat		
19	*Extremely heavy* / Amat berat		
20	*Heaviest* / Paling berat		

----------THE END / TAMAT----------
----------THANK YOU / TERIMA KASIH----------

BORG RPE SCALE SURVEY FORM

BORANG PENILAIAN SKALA BORG RPE

Gender / Jantina : MALE
Age / Umur : 30
Weight / Berat : 120kg
Height / Tinggi : 187cm
Health Status / Status Kesihatan : Healthy

***Question* / Soalan:**
Based on the activity you are doing, please select the number that best describes the level of difficulty of the activity. Try to evaluate your feelings when doing activities such as honest as possible and it cannot be compared with scores of others.
Berdasarkan aktiviti yang anda lakukan, sila pilih nombor yang paling menggambarkan tahap kesukaran activiti tersebut. Cuba untuk menilai perasaan anda ketika melakukan activiti itu sejujur yang mungkin dan ianya tidak boleh dibandingkan dengan markah orang lain.

***Rating Number* / Nombor Rating**	**Description / Penerangan**	**Assessment / Penilaian**	
		Test Car 1	**Test Car 2**
6	*Lightest* / Paling ringan		
7	*Extremely light* / Amat ringan		
8	*Very light* / Sangat ringan		
9	*Very light* / Sangat ringan		
10	*Light* / Ringan	✓	
11	*Light* / Ringan		✓
12	*Somewhat heavy* / Agak berat		
13	*Somewhat heavy* / Agak berat		
14	*Heavy* / Berat		
15	*Heavy* / Berat		
16	*Very heavy* / Sangat berat		
17	*Very heavy* / Sangat berat		
18	*Extremely heavy* / Amat berat		
19	*Extremely heavy* / Amat berat		
20	*Heaviest* / Paling berat		

----------THE END / TAMAT----------
----------THANK YOU / TERIMA KASIH----------

BORG RPE SCALE SURVEY FORM

BORANG PENILAIAN SKALA BORG RPE

Gender / Jantina : LELAKI
Age / Umur : 30 TAHUN
Weight / Berat : 59 KG
Height / Tinggi : 166 CM
Health Status / Status Kesihatan : SIHAT .

***Question* / Soalan:**
Based on the activity you are doing, please select the number that best describes the level of difficulty of the activity. Try to evaluate your feelings when doing activities such as honest as possible and it cannot be compared with scores of others.
Berdasarkan aktiviti yang anda lakukan, sila pilih nombor yang paling menggambarkan tahap kesukaran activiti tersebut. Cuba untuk menilai perasaan anda ketika melakukan activiti itu sejujur yang mungkin dan ianya tidak boleh dibandingkan dengan markah orang lain.

***Rating Number* / Nombor Rating**	**Description / Penerangan**	**Assessment / Penilaian**	
		Test Car 1	**Test Car 2**
6	*Lightest* / Paling ringan		
7	*Extremely light* / Amat ringan	✓	
8	*Very light* / Sangat ringan		
9	*Very light* / Sangat ringan		✓
10	*Light* / Ringan		
11	*Light* / Ringan		
12	*Somewhat heavy* / Agak berat		
13	*Somewhat heavy* / Agak berat		
14	*Heavy* / Berat		
15	*Heavy* / Berat		
16	*Very heavy* / Sangat berat		
17	*Very heavy* / Sangat berat		
18	*Extremely heavy* / Amat berat		
19	*Extremely heavy* / Amat berat		
20	*Heaviest* / Paling berat		

----------THE END / TAMAT----------
----------THANK YOU / TERIMA KASIH----------

BORG RPE SCALE SURVEY FORM

BORANG PENILAIAN SKALA BORG RPE

Gender / Jantina : LELAKI
Age / Umur : 46
Weight / Berat : 50 kg.
Height / Tinggi : 160 cm
Health Status / Status Kesihatan : OK.

***Question* / Soalan:**
Based on the activity you are doing, please select the number that best describes the level of difficulty of the activity. Try to evaluate your feelings when doing activities such as honest as possible and it cannot be compared with scores of others.
Berdasarkan aktiviti yang anda lakukan, sila pilih nombor yang paling menggambarkan tahap kesukaran activiti tersebut. Cuba untuk menilai perasaan anda ketika melakukan activiti itu sejujur yang mungkin dan ianya tidak boleh dibandingkan dengan markah orang lain.

***Rating Number* / Nombor Rating**	**Description / Penerangan**	**Assessment / Penilaian**	
		Test Car 1	**Test Car 2**
6	*Lightest* / Paling ringan		
7	*Extremely light* / Amat ringan		
8	*Very light* / Sangat ringan		
9	*Very light* / Sangat ringan		
10	*Light* / Ringan		
11	*Light* / Ringan	✓	
12	*Somewhat heavy* / Agak berat		✓
13	*Somewhat heavy* / Agak berat		
14	*Heavy* / Berat		
15	*Heavy* / Berat		
16	*Very heavy* / Sangat berat		
17	*Very heavy* / Sangat berat		
18	*Extremely heavy* / Amat berat		
19	*Extremely heavy* / Amat berat		
20	*Heaviest* / Paling berat		

----------THE END / TAMAT----------
----------THANK YOU / TERIMA KASIH----------

BORG RPE SCALE SURVEY FORM

BORANG PENILAIAN SKALA BORG RPE

Gender / Jantina : LELAKI
Age / Umur : 45
Weight / Berat : 73
Height / Tinggi : 165
Health Status / Status Kesihatan : BAIK

***Question* / Soalan:**
Based on the activity you are doing, please select the number that best describes the level of difficulty of the activity. Try to evaluate your feelings when doing activities such as honest as possible and it cannot be compared with scores of others.
Berdasarkan aktiviti yang anda lakukan, sila pilih nombor yang paling menggambarkan tahap kesukaran activiti tersebut. Cuba untuk menilai perasaan anda ketika melakukan activiti itu sejujur yang mungkin dan ianya tidak boleh dibandingkan dengan markah orang lain.

***Rating Number* / Nombor Rating**	**Description / Penerangan**	**Assessment / Penilaian**	
		Test Car 1	**Test Car 2**
6	*Lightest* / Paling ringan	✓	
7	*Extremely light* / Amat ringan	/	✓
8	*Very light* / Sangat ringan		
9	*Very light* / Sangat ringan		
10	*Light* / Ringan		
11	*Light* / Ringan		
12	*Somewhat heavy* / Agak berat		
13	*Somewhat heavy* / Agak berat		
14	*Heavy* / Berat		
15	*Heavy* / Berat		
16	*Very heavy* / Sangat berat		
17	*Very heavy* / Sangat berat		
18	*Extremely heavy* / Amat berat		
19	*Extremely heavy* / Amat berat		
20	*Heaviest* / Paling berat		

----------THE END / TAMAT----------
----------THANK YOU / TERIMA KASIH----------

BORG RPE SCALE SURVEY FORM

BORANG PENILAIAN SKALA BORG RPE

Gender / Jantina : LELAKI
Age / Umur : 26
Weight / Berat : 57 kg
Height / Tinggi : 165 cm
Health Status / Status Kesihatan : SIHAT

***Question* / Soalan:**
Based on the activity you are doing, please select the number that best describes the level of difficulty of the activity. Try to evaluate your feelings when doing activities such as honest as possible and it cannot be compared with scores of others.
Berdasarkan aktiviti yang anda lakukan, sila pilih nombor yang paling menggambarkan tahap kesukaran activiti tersebut. Cuba untuk menilai perasaan anda ketika melakukan activiti itu sejujur yang mungkin dan ianya tidak boleh dibandingkan dengan markah orang lain.

***Rating Number* / Nombor Rating**	**Description / Penerangan**	**Assessment / Penilaian**	
		Test Car 1	**Test Car 2**
6	*Lightest* / Paling ringan		
7	*Extremely light* / Amat ringan		
8	*Very light* / Sangat ringan		
9	*Very light* / Sangat ringan		
10	*Light* / Ringan		
11	*Light* / Ringan	✓	✓
12	*Somewhat heavy* / Agak berat		
13	*Somewhat heavy* / Agak berat		
14	*Heavy* / Berat		
15	*Heavy* / Berat		
16	*Very heavy* / Sangat berat		
17	*Very heavy* / Sangat berat		
18	*Extremely heavy* / Amat berat		
19	*Extremely heavy* / Amat berat		
20	*Heaviest* / Paling berat		

----------THE END / TAMAT----------
----------THANK YOU / TERIMA KASIH----------

APPENDIX B : VIDEO IMAGES ANALYSIS

Front view female 1 in test car 1

Side view female 1 in test car 1

Front view female 1 in test car 2

Side view female 1 in test car 2

Front view female 2 in test car 1

Side view female 2 in test car 1

Front view female 2 in test car 2

Side view female 2 in test car 2

Front view female 3 in test car 1

Side view female 3 in test car 1

Front view female 3 in test car 2

Side view female 3 in test car 2

Front view female 4 in test car 1

Side view female 4 in test car 1

Front view female 4 in test car 2

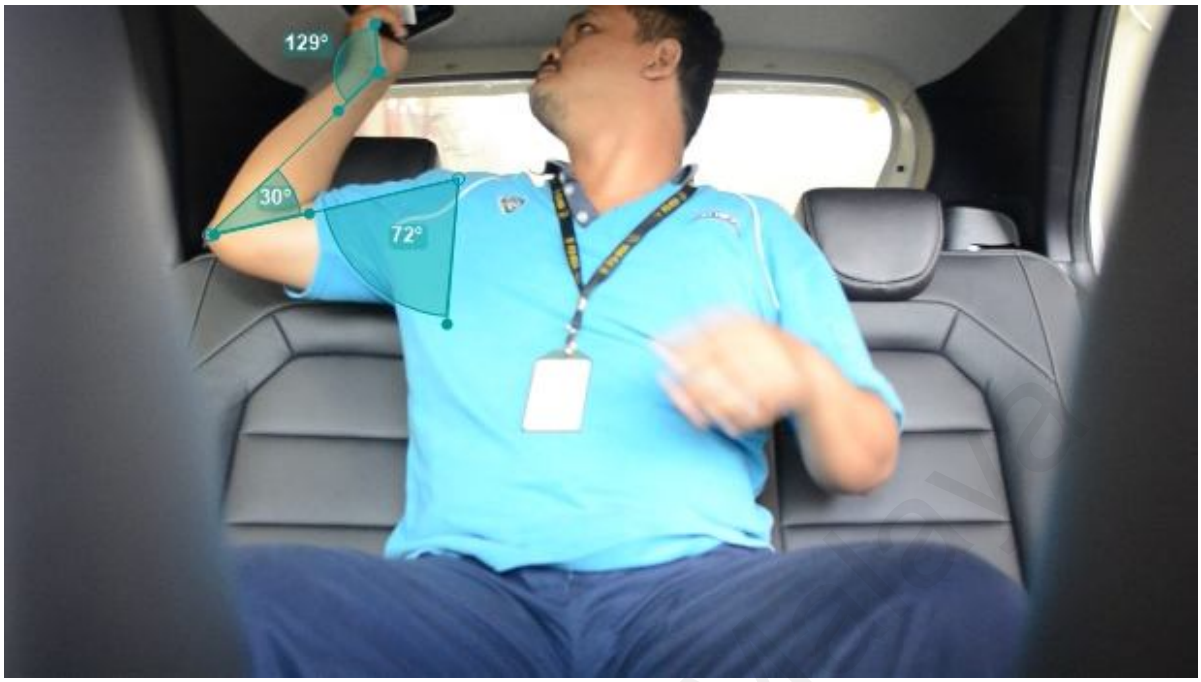
Side view female 4 in test car 2

Front view female 5 in test car 1

Front view female 5 in test car 1

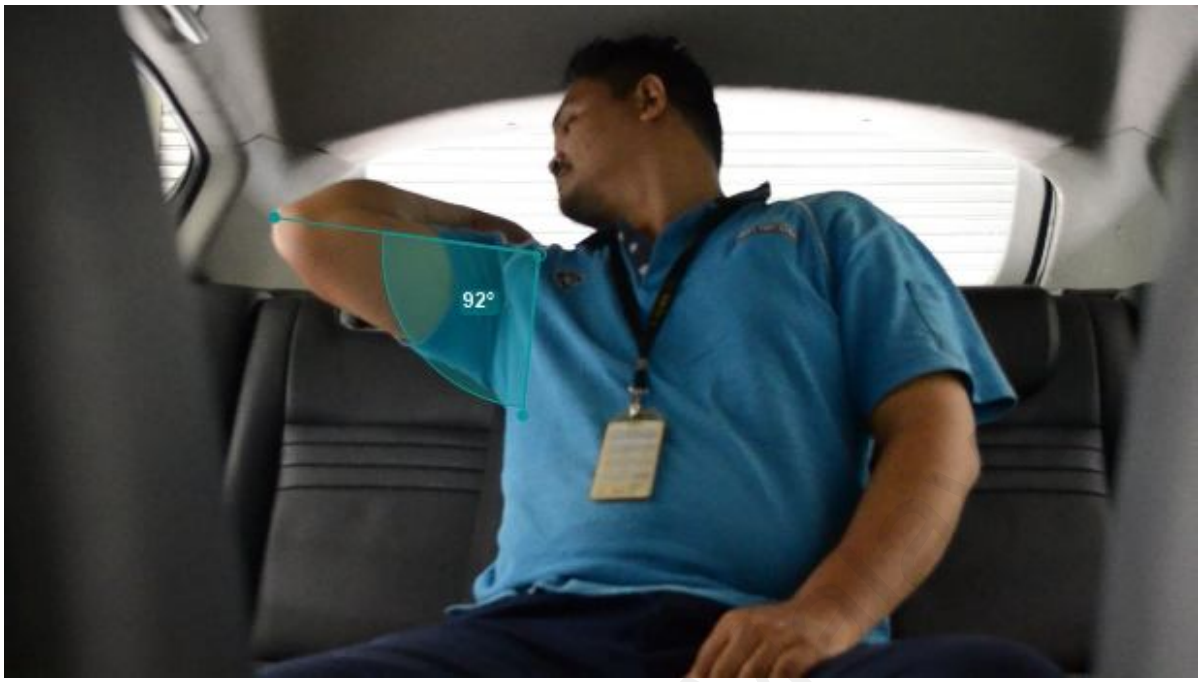
Front view female 5 in test car 2

Front view female 5 in test car 2



Front view male 1 in test car 1

Front view male 1 in test car 1



Front view male 1 in test car 2

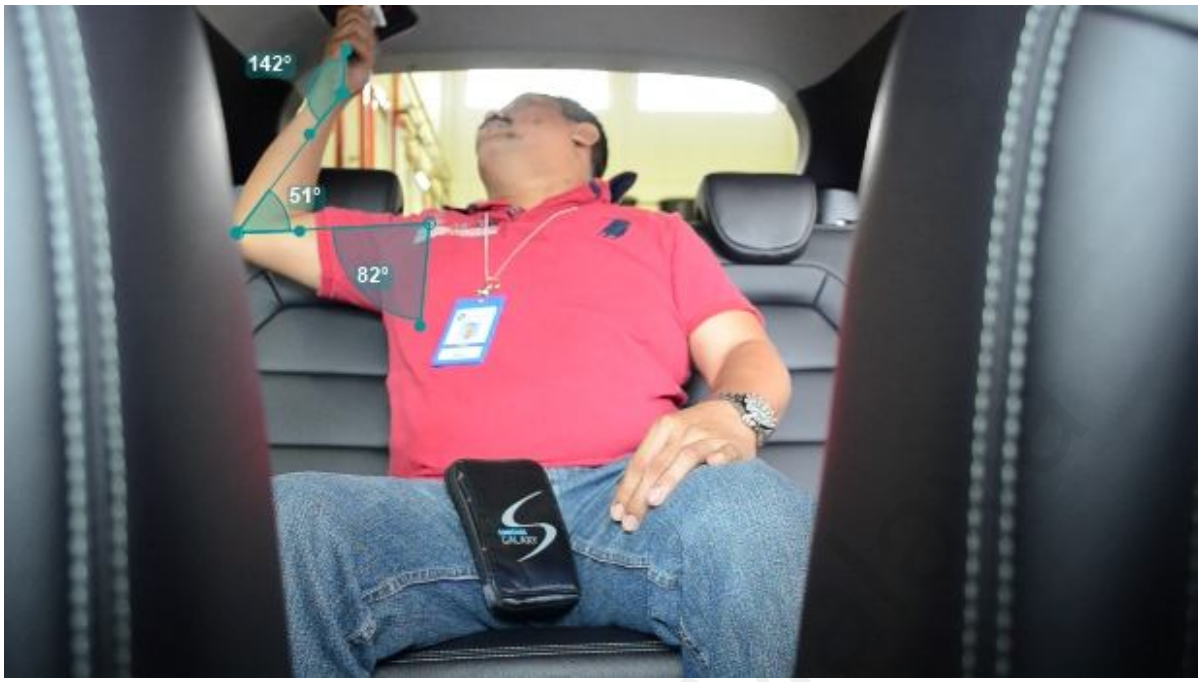
Side view male 1 in test car 2

Front view male 2 in test car 1

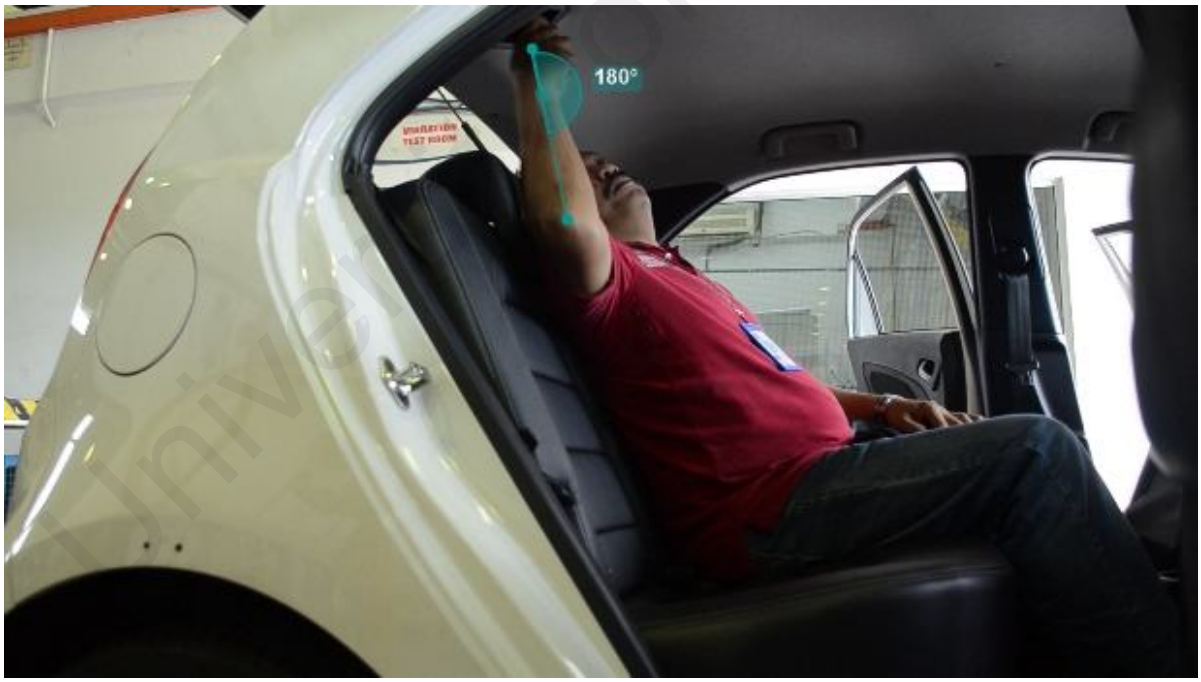
Side view male 2 in test car 1

Front view male 2 in test car 2

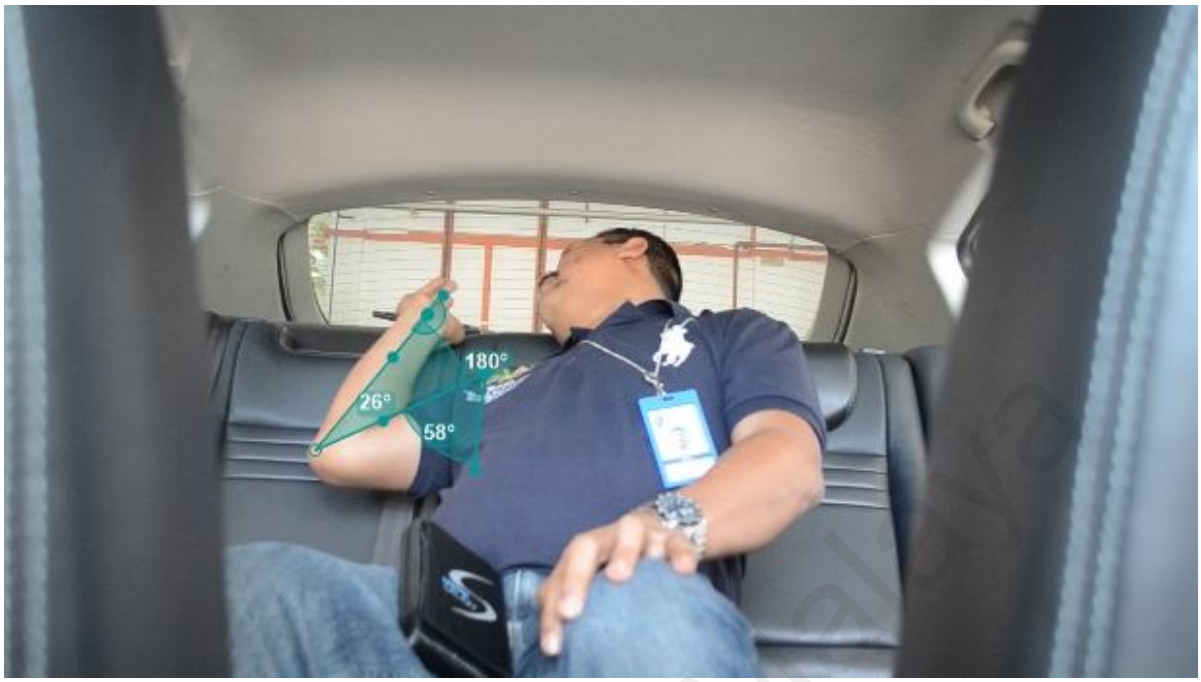
Side view male 2 in test car 2



Front view male 3 in test car 1

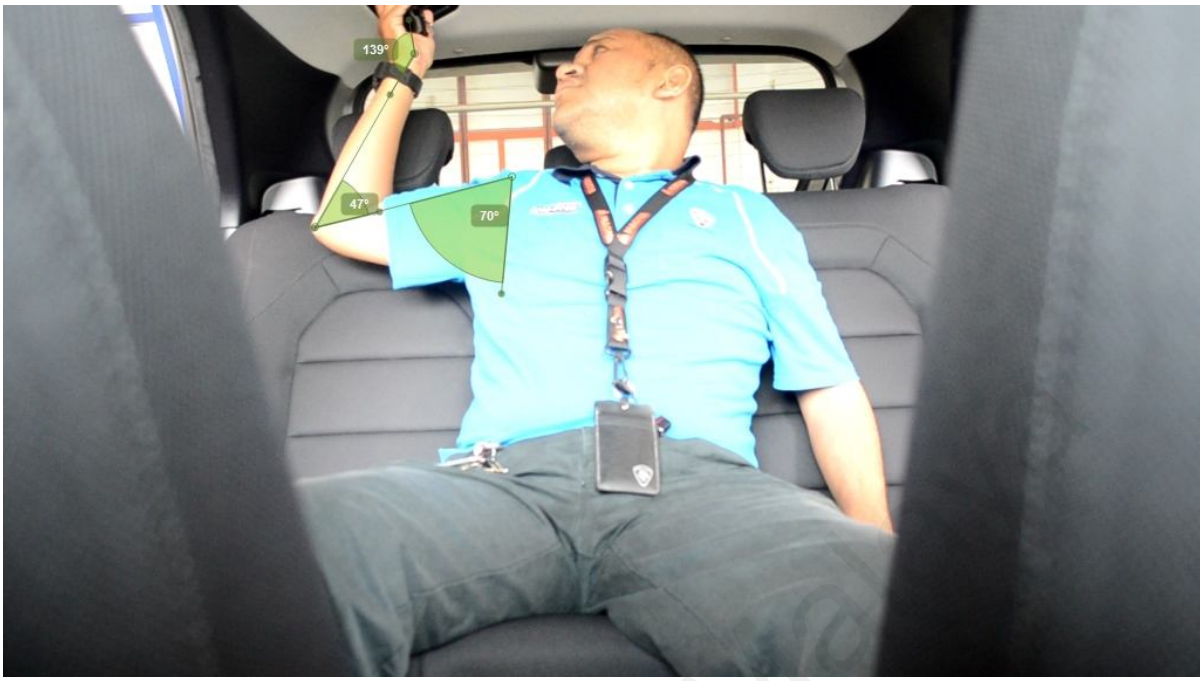


Front view male 3 in test car 1



Front view male 3 in test car 2

Side view male 3 in test car 2

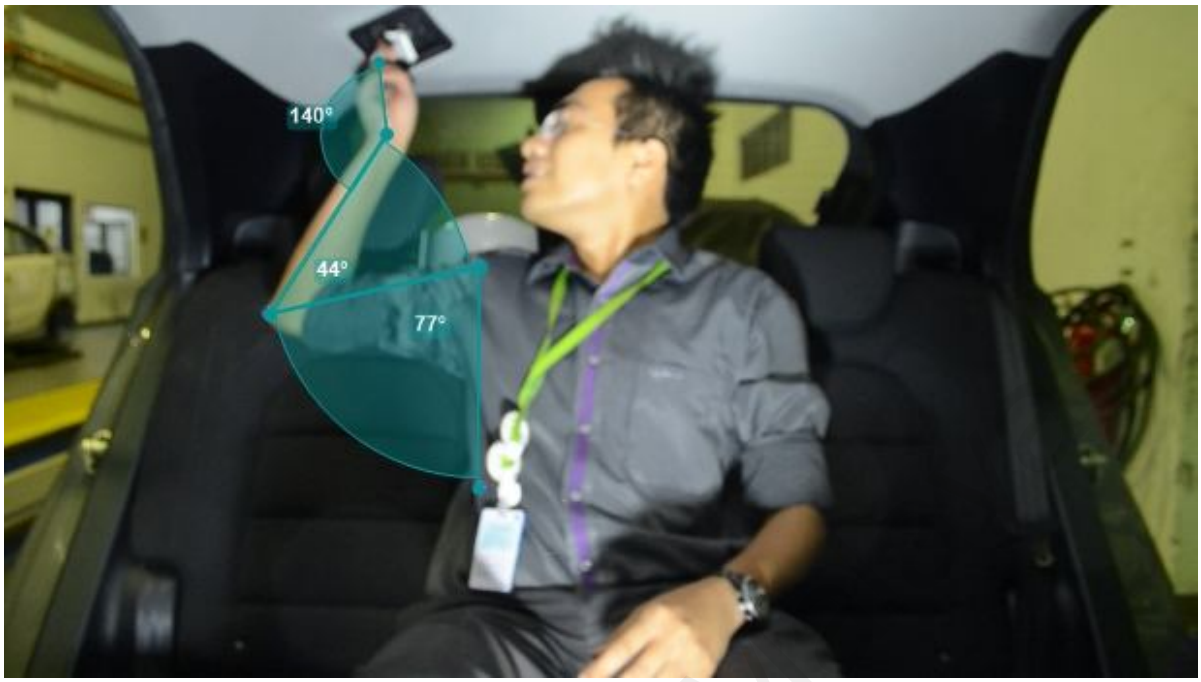


Front view male 4 in test car 1

Side view male 4 in test car 1

Front view male 4 in test car 2

Side view male 4 in test car 2



Front view male 5 in test car 1

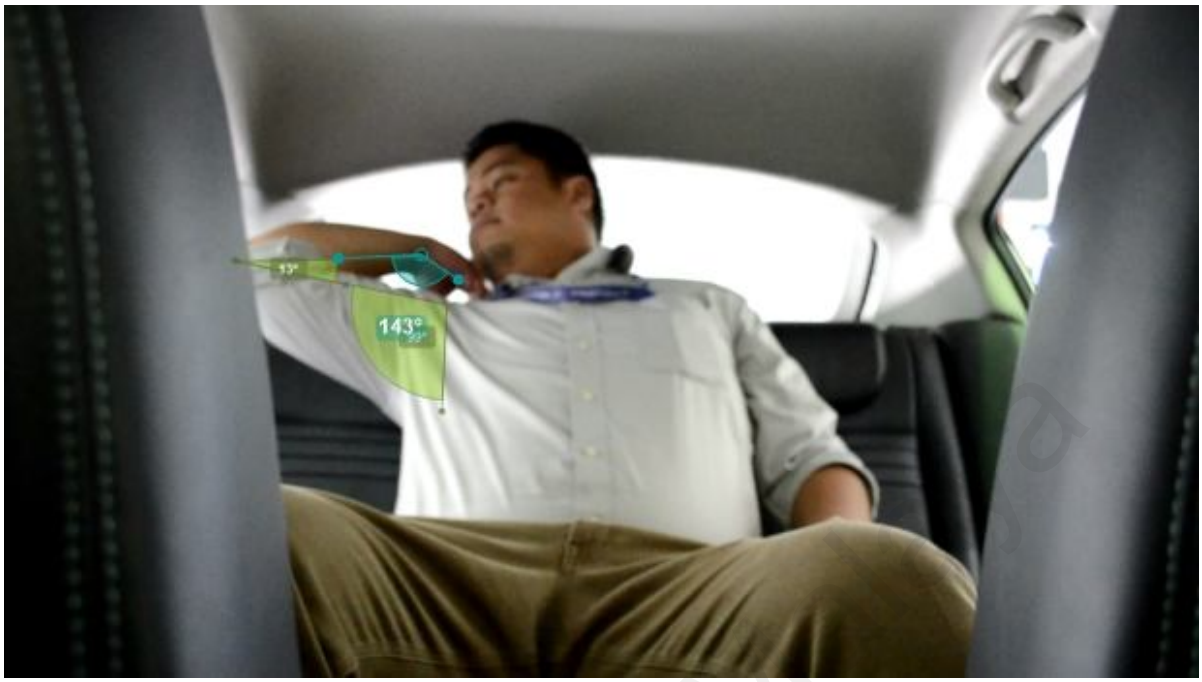
Side view male 5 in test car 1

Front view male 5 in test car 2

Front view male 5 in test car 2

Front view male 6 in test car 1

Front view male 6 in test car 1



Front view male 6 in test car 2

Front view male 6 in test car 2

Front view male 7 in test car 1

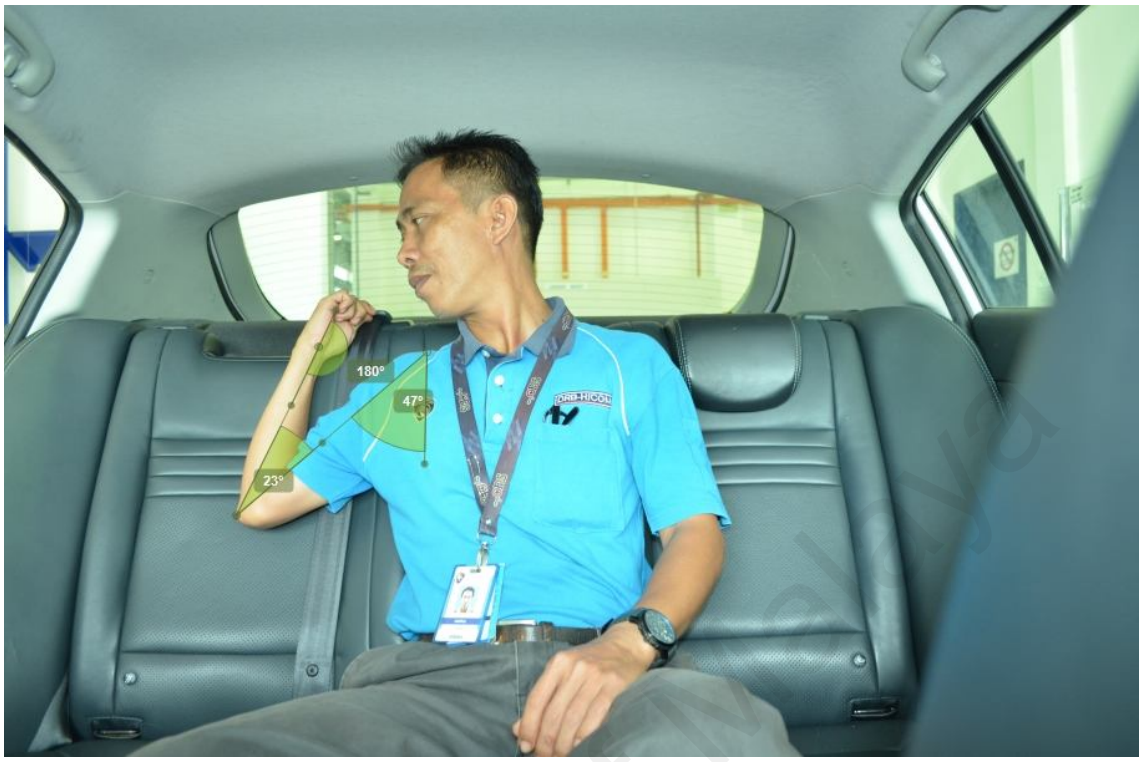
Side view male 7 in test car 1

Front view male 7 in test car 2

Side view male 7 in test car 2

Front view male 8 in test car 1

Side view male 8 in test car 1



Front view male 8 in test car 2

Side view male 8 in test car 2

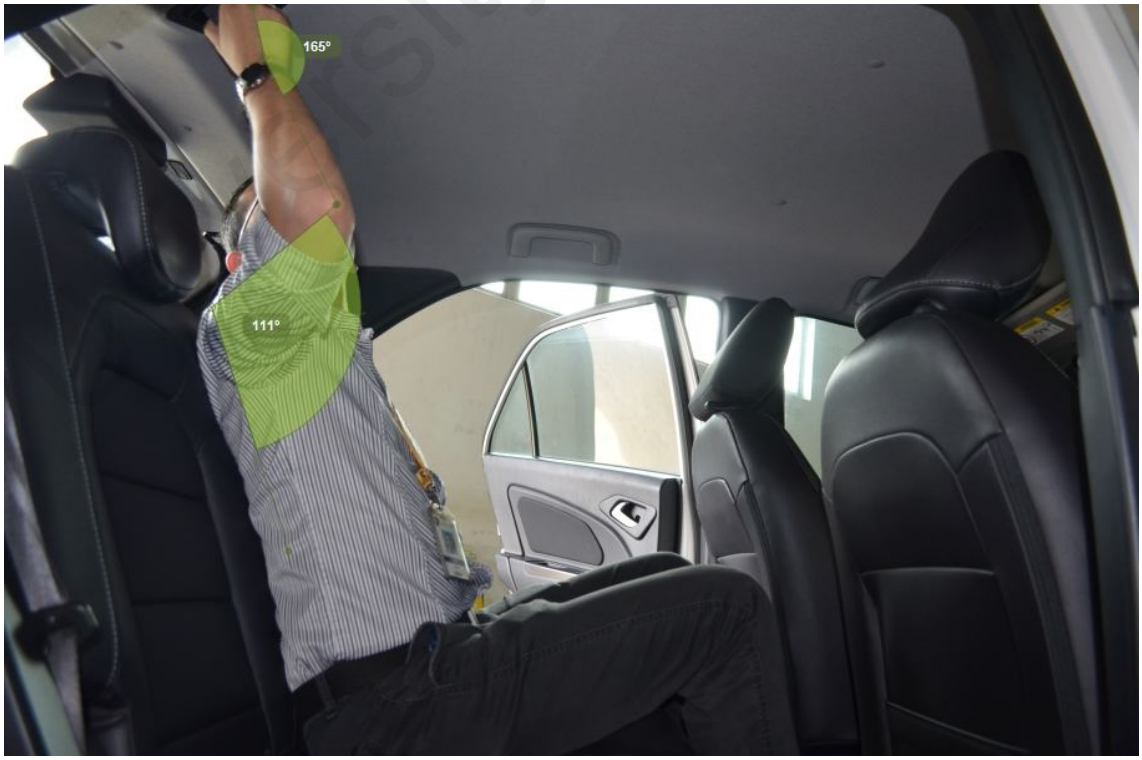
Front view male 9 in test car 1

Side view male 9 in test car 1

Front view male 9 in test car 2

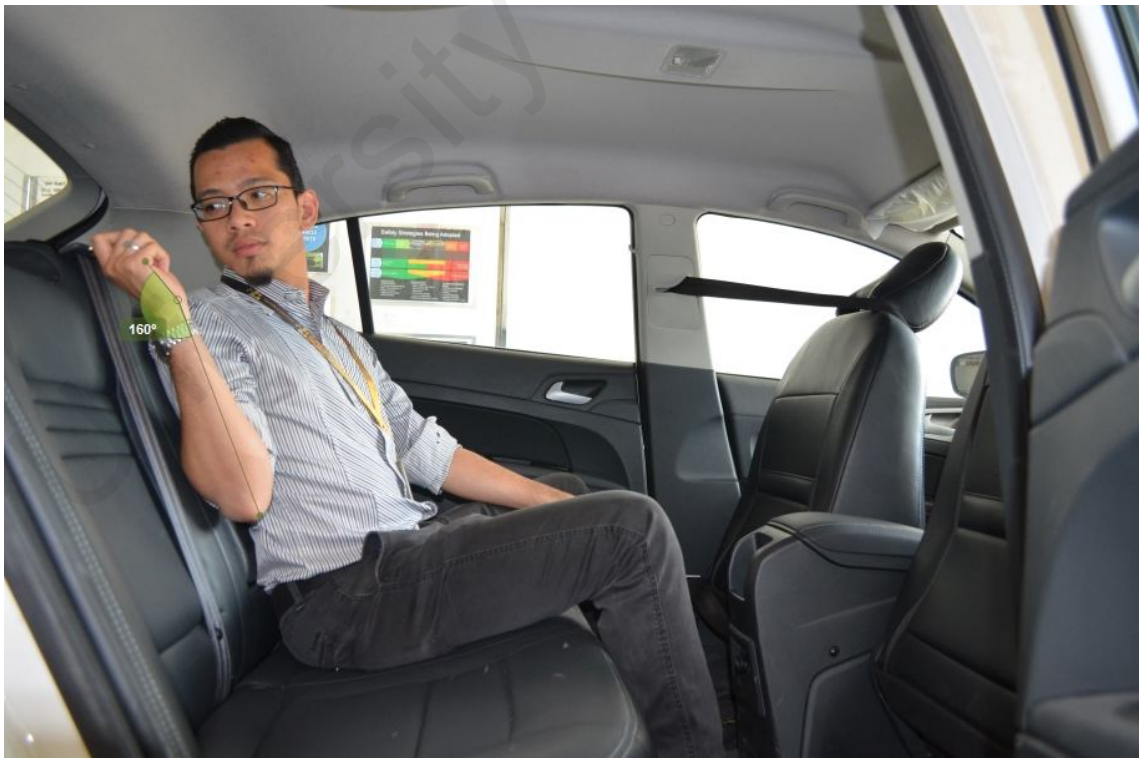
Front view male 9 in test car 2

Front view male 10 in test car 1



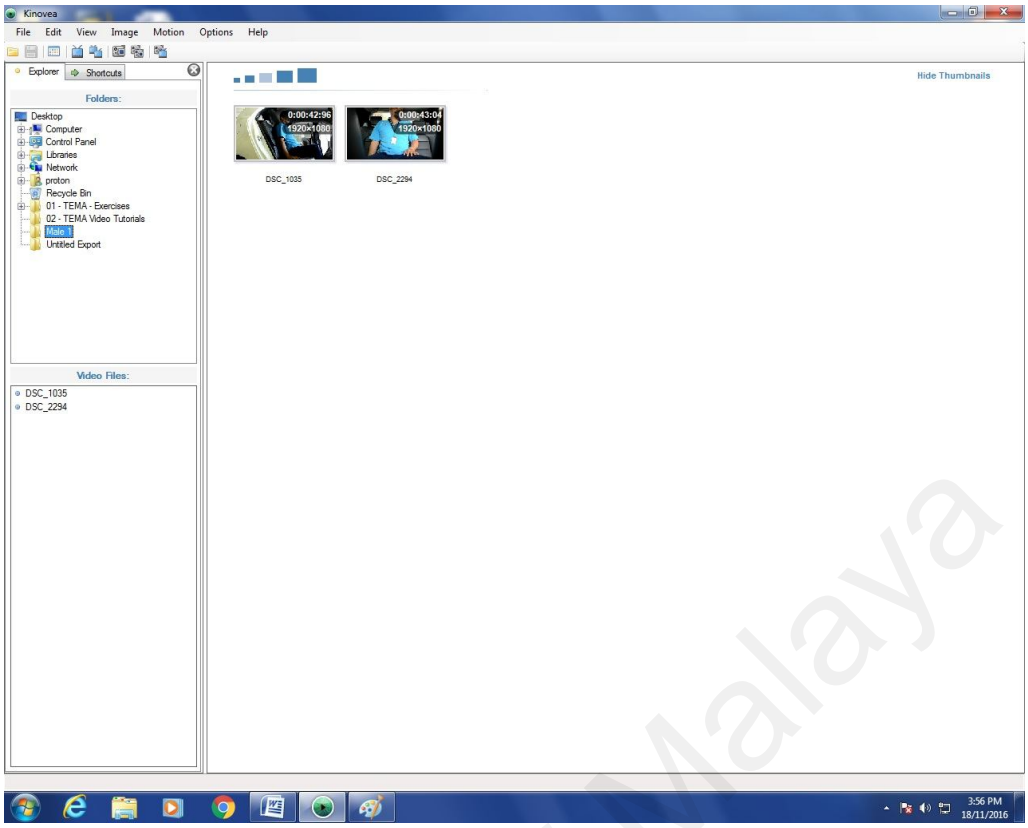
Side view male 10 in test car 1

Front view male 10 in test car 2

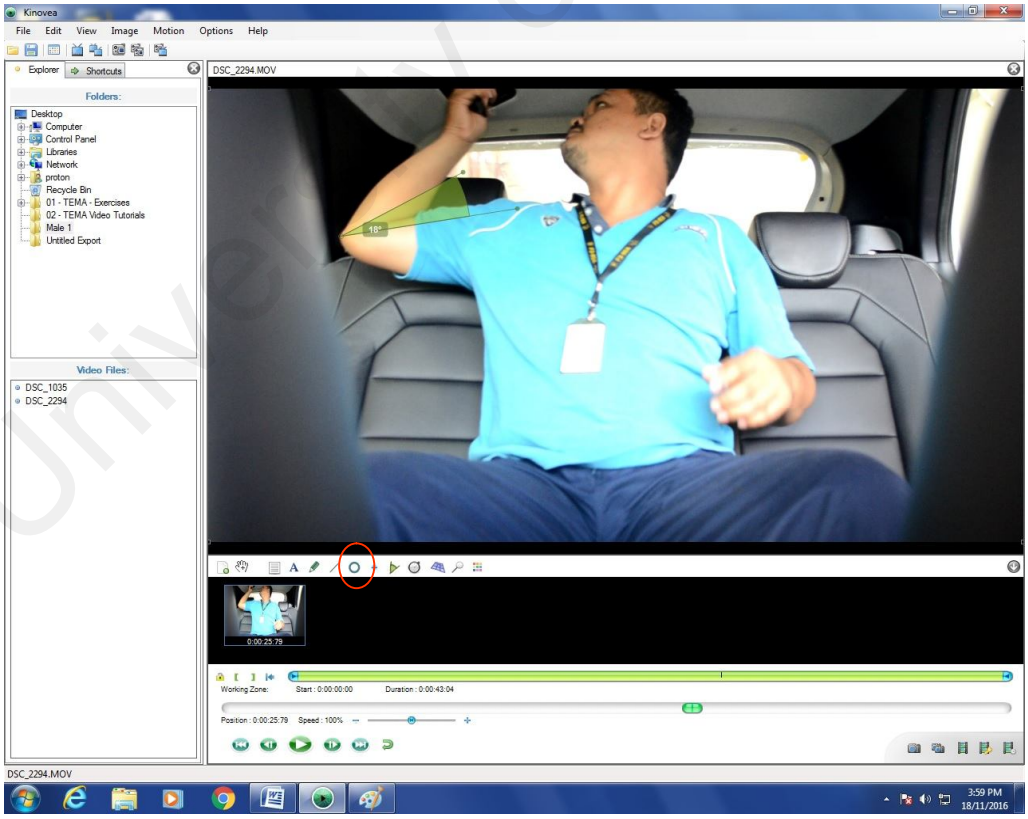


Side view male 10 in test car 2

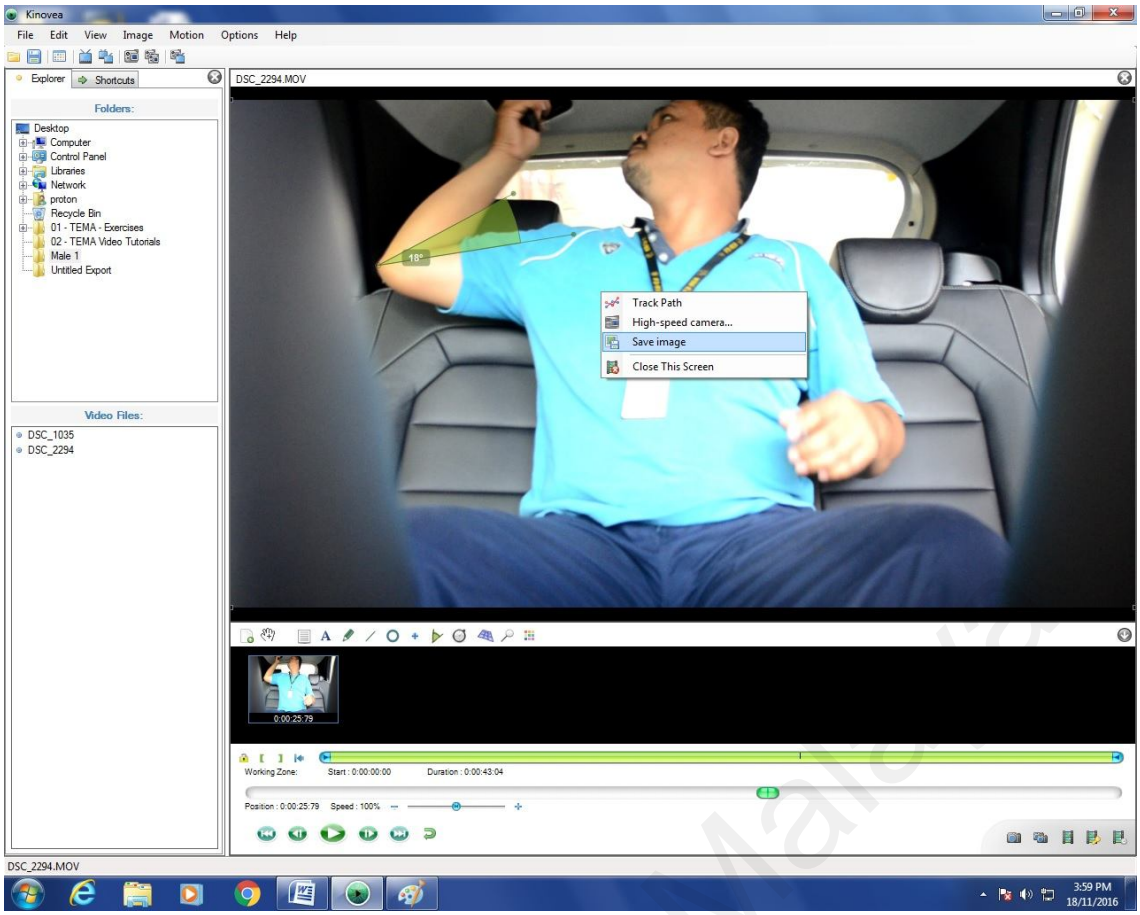
APPENDIX C : KINOVEA©



Step 1. Open software and load video



Step 2. Select angle measurement



Step 3. Right click to save images.