



**UNIVERSITI PUTRA MALAYSIA**

***EFFECTS OF LUMBAR SUPPORT TO REDUCE DISCOMFORT DURING  
PROLONGED RIDING AMONG MOTORCYCLISTS***

**UMI KALSOM BINTI MOHD SHAFIEI**

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By

**UMI KALSOM BINTI MOHD SHAFIEI**

**Thesis Submitted to the School of Graduate Studies, Universiti Putra  
Malaysia, in Fulfilment of the Requirements for the Degree of Master of  
Science**

**November 2015**

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Master of Science

## **EFFECTS OF LUMBAR SUPPORT TO REDUCE DISCOMFORT DURING PROLONGED RIDING AMONG MOTORCYCLISTS**

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**November 2015**

**Chairman : Karmegam Karuppiah, PhD**  
**Faculty : Medicine and Health Sciences**

Vehicle population in Malaysia has increased tremendously causing extremely congested roads with all types of vehicles and passengers. Due to serious traffic congestion problem in Malaysia, motorcycle becomes the best mode of transportation compared to other types of vehicles. There are many attractions offered by a motorcycle but it is undeniable that motorcycle is the most hazardous type of vehicle mode and therefore requires more effort to improve their safety and comfort level. Instead of exposed to the risk of death, motorcyclists may possibly expose to the musculoskeletal problem due to prolonged sitting and poor riding posture. This prolonged sitting posture can cause motorcyclists to experience muscle discomfort, fatigue and pain. The purpose of this study was to evaluate the effects of lumbar support in order to reduce riding discomfort and to provide a good riding posture for motorcyclists during prolonged riding. This study was conducted among male motorcyclists at University Putra Malaysia (UPM). 94 respondents were participated, with 47 respondents for each control and experimental group. Each respondents in experimental group were received lumbar support intervention whereas respondents in control group were not received lumbar support intervention. Borg's scale CR-10 questionnaires were used to assess motorcyclists discomfort at every 15 minutes interval. Electromyography (EMG) signals were recorded from right and left erector spinae musculature during 2 hours riding session. The results showed lower back part experienced greatest discomfort compared to other body parts. The highest percentage of improvement can be seen at upper back (44.36%), followed by arms (39.75%, shoulder (38.33%), lower back (37.75%) and neck (32.22%). Percentage muscle exertion on RES was higher compared to the percentage muscle exertion on LES. Experimental group recorded the highest percentage of improvement on RES (-24.98%) and LES (-15.00) than control group. Borg's scale discomfort ratings showed significant reduction between pre and post-test study within control ( $p < 0.001$ ) and experimental group ( $p < 0.001$ ). On the other hand, percentage muscle exertion on RES ( $p < 0.001$ ) and LES ( $p < 0.001$ ) showed significant reduction in

experimental group only. There were statistically significant differences found in Borg's scale measurement ( $p < 0.001$ ) and percentage muscle exertion on RES ( $p < 0.001$ ) and LES ( $p = 0.001$ ) between control and experimental groups. Results of Friedman test were found statistically significant differences in the Borg's scale discomfort ratings ( $\chi^2 = 275.621$ ,  $p < 0.001$ ), percentage muscle exertion on RES ( $\chi^2 = 335.115$ ,  $p < 0.001$ ) and LES ( $\chi^2 = 131.501$ ,  $p < 0.001$ ) over 120 minute of riding session. In conclusion, the results of this study suggested that with the application of lumbar support (prototype) during 2 hours riding session can improve the comfort level among motorcyclists. Lumbar support may therefore has potential in reducing the occurrence of low back pain particularly among motorcycle users.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia  
sebagai memenuhi keperluan untuk ijazah Master Sains

**KESAN-KESAN SOKONGAN LUMBAR DALAM MENGURANGKAN  
KETIDAKSELESAAN SEMASA PENUNGGANGAN YANG  
BERPANJANGAN DI KALANGAN PENUNGGANG MOTOSIKAL**

Oleh

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Populasi kenderaan di Malaysia telah meningkat dengan pesat menyebabkan jalan raya menjadi sangat sesak dengan semua jenis kenderaan dan penumpang, yang bergerak pada kelajuan yang berbeza. Oleh kerana masalah kesesakan lalu lintas yang serius di Malaysia, motosikal menjadi mod pengangkutan yang terbaik berbanding dengan jenis kenderaan yang lain. Terdapat banyak tarikan yang ditawarkan oleh motosikal tetapi tidak dapat dinafikan bahawa motosikal adalah sejenis mod kenderaan yang paling berbahaya dan oleh itu ia memerlukan lebih banyak usaha untuk meningkatkan tahap keselamatan dan keselesaan penunggang. Selain daripada terdedah kepada risiko kematian, penunggang motosikal juga mungkin boleh terdedah kepada masalah otot akibat duduk terlalu lama dan postur penunggang yang kurang baik. Postur duduk yang terlalu lama ini boleh menyebabkan penunggang motosikal mengalami ketidakselesaan otot, keletihan dan kesakitan. Tujuan kajian ini adalah untuk menilai kesan sokongan lumbar dalam mengurangkan ketidakselesaan semasa menunggang dan memberi postur penunggang yang baik untuk penunggang motosikal semasa penunggang yang lama. Kajian ini dijalankan di kalangan penunggang motosikal lelaki di Universiti Putra Malaysia (UPM). 94 responden telah mengambil bahagian, dengan 47 responden bagi setiap kumpulan kawalan dan eksperimen. Setiap responden dalam kumpulan eksperimen telah menerima sokongan lumbar manakala responden dalam kumpulan kawalan tidak menerima sokongan lumbar. Skala CR-10 soal selidik Borg telah digunakan untuk menilai tahap ketidakselesaan penunggang motosikal pada setiap 15 minit. Isyarat elektromiografi telah dicatatkan dari kanan dan kiri otot erektor spinae semasa sesi menunggang selama 2 jam. Hasil kajian menunjukkan bahagian bawah belakang mengalami ketidakselesaan yang besar berbanding bahagian-bahagian badan yang lain. Peratusan tertinggi peningkatan dapat dilihat pada bahagian atas belakang (44.36%), diikuti dengan tangan (39.75%, bahu (38.33%), belakang (37,75%) dan leher (32.22%). Peratusan kepenatan otot pada RES adalah lebih tinggi berbanding dengan peratusan kepenatan otot

pada LES. Kumpulan eksperimen mencatatkan peratus tertinggi peningkatan pada RES (-24,98%) dan LES (-15,00) daripada kumpulan kawalan. Penilaian ketidakselesaian skala Borg menunjukkan pengurangan signifikan antara kajian sebelum dan selepas dalam kumpulan kawalan ( $p < 0.001$ ) dan kumpulan eksperimen ( $p < 0.001$ ). Sebaliknya, peratusan kepenatan otot pada RES ( $p < 0.001$ ) dan LES ( $p < 0.001$ ) menunjukkan pengurangan yang ketara dalam kumpulan eksperimen sahaja. Terdapat perbezaan yang signifikan secara statistik dijumpai di dalam pengukuran skala Borg ( $p < 0.001$ ) dan peratusan kepenatan otot pada RES ( $p < 0.001$ ) dan LES ( $p = 0.001$ ) antara kumpulan kawalan dan kumpulan eksperimen. Keputusan ujian Friedman telah mendapati perbezaan statistik yang signifikan dalam penilaian ketidakselesaian skala Borg ( $\chi^2 = 275,621$ ,  $p < 0.001$ ), peratusan kepenatan otot pada RES ( $\chi^2 = 335,115$ ,  $p < 0.001$ ) dan LES ( $\chi^2 = 131,501$ ,  $p < 0.001$ ) sepanjang 120 minit sesi menunggang. Kesimpulannya, hasil kajian ini menunjukkan bahawa dengan penggunaan sokongan lumbar (prototaip) selama 2 jam ketika sesi menunggang boleh meningkatkan tahap keselesaan di kalangan penunggang motosikal. Oleh itu, sokongan lumbar ini juga berpotensi dalam mengurangkan kejadian sakit pinggang terutamanya di kalangan pengguna motosikal.

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I certify that a Thesis Examination Committee has met on 27 November 2015 to conduct the final examination of Umi Kalsom binti Mohd Shafiei on her thesis entitled "Effects of Lumbar Support to Reduce Discomfort During Prolonged Riding Among Motorcyclists" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

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## LIST OF ABBREVIATIONS

UPM	University Putra Malaysia
SOCISO	Social Security Organisation of Malaysia
MIROS	Malaysian Institute of Road Safety Research
RTD	Road Transport Department
WBV	Whole Body Vibration
BMI	Body Mass Index
SPSS	Statistical Package for Social Science
MSD	Musculoskeletal Disorder
EMG	Electromyography
sEMG	Surface Electromyography
SOP	Standard Operating Procedure
MVC	Maximal Voluntary Contraction
MVIC	Maximal Voluntary Isometric Contraction
RMS	Root Mean Square
MF	Median Frequency
MNF	Mean Frequency
ARV	Average Rectified Value
MAV	Mean Absolute Value
IEMG	Integrated Electromyography
RPE	Ratings of Perceived Exertion
RES	Right Erector Spinae
LES	Left Erector Spinae
n	Sample Size
r	Effect Size
IQR	Interquartile Range
$\chi^2$	Chi Square
Z	Z Score
Md	Median

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## CHAPTER 1

### INTRODUCTION

#### 1.1 Background

Most Asian countries are experiencing an economic boom. However, only a few countries such as Japan and Singapore can be considered as developed high-income countries. Other countries including Malaysia were considered as middle or low-income country categories (Yusuf et al., 2011). As a middle-income country, Malaysia also has faced major economic development with growth in population, industrialization and motorization over the last 10 to 15 years back. However, most of the middle and low-income countries choose motorcycle as an important mode of transportation especially for commuting and daily activities (Oxley et al., 2013).

Majority of Asian countries considered motorcycle as a common mode of transportation. For example in Malaysia, motorcycle contribute almost half of registered vehicles (Ambak et al., 2009). Statistic from Malaysian Road Transport Department (MRTD) reported that in 2013, motorcycles and cars become as the main contributors to the number of registered vehicles in Malaysia.

Other country such as China also has made a remarkable progress in its economic development in the past two decades. Motorcycles have turn out to be one of the most popular mode of transportation in China instead of walking and cycling. According to Yang et al. (2008), the production and sales volume of motorcycle in China were reported over 20 million in year 2006 only. This shows that motorcycles are very important for people in certain period in China. Besides that, motorcycles also become a regular mode of commuting in India. They use motorcycle for numerous activities such as for postal delivery, food delivery and police patrols (Balasubramaniam & Jagannath, 2014).

Most of people in Malaysia is afford to have private vehicles due to rapid growth of Malaysian economic status. Because of that situation, the vehicle population in Malaysia has increased tremendously causing extremely congested roads with all types of vehicle and passengers (Almselati et al., 2011). However, due to serious traffic congestion problem in Malaysia, motorcycle becomes the best mode of transportation compared to other types of vehicles.

In Malaysia, Taiwan and Japan, people use motorcycles and scooters as their main transport due to high efficiency and suitability for commuting especially in city areas (Wong, 2013). Besides that, there are many attractions offered by a motorcycle such as its economical features especially in terms of ownership costs. Motorcycle also offer priced five-folds lower than the cheapest car in the market as well as it is certainly not a fuel consumer (Lai & Lu, 2007). Other advantages that make motorcycles a very convenient and attractive mode of transportation are it's entitled for nominal road tax and excluded from being tolled in most highways. Other than that, the most important characteristic that will

attract people to use motorcycle is due to its small size that can make easy to move and enables it user to change lane and also save time during traffic congestion (Isa et al., 2013).

Malaysia has experienced a fluctuation in fuel price recently. With this current situation, the motorcycle sales is expected to increase drastically as the lower income group will prefer to use motorcycle compared to cars. Perhaps, it might reduce the numbers of cars on the road when more people choose motorcycle to commute. However, a previous study done by Manan et al. (2013) stated that Malaysian primary roads are dangerous for motorcyclists and they contribute in more than 50% of the road accident fatalities in Malaysia. According to Datuk Seri Chua Soi Lek, "research has shown that motorcycle fatalities shot up as a result of the March 2006 and June 2008 fuel price hike and the lower income group switched from cars to motorcycles" (Dorothy & Edmund, 2013). It is expected that the same thing will happen if the retail price of petrol is continued to increase.

MIROS (2013) reported that in 2012, motorcyclists were accounted for 61% of road deaths in Malaysia followed by car occupants with 21%. Besides, a major proportion of motorcycle accidents occurred is during commuting trips. According to Social Security Organisation of Malaysia (SOCSO), two thirds of the 50,000 workplace injury incidents each year are contributed by commuting accidents which is workers who are involved in accidents during travelling to and from workplaces and for work purposes (Oxley et al., 2013).

As mentioned earlier, motorcycle is the most hazardous type of vehicle and for that reason it requires more effort to improve their safety and comfort level. Instead of exposed to the risk of death, motorcyclists also may possibly expose to the musculoskeletal problem (Behm et al., 2002). Previous study done by Akinbo et al. (2008) among commercial drivers and motorcyclists in Lagos, Nigeria found that the prevalence of back pain was 64.5% and 60% among commercial drivers and commercial motorcyclists respectively. Instead of back pain, the prevalence of upper back or neck pain also was high in commercial motorcyclists which was 13.7% higher than commercial drivers. However, a study done in Malaysia conducted by Mohd Hafzi et al. (2009) among non-occupational motorcyclists and occupational motorcyclists found that the most commonly affected body parts (>50%) among motorcyclists were lower back, neck, shoulder, upper back and hips/thighs/buttocks. Other than that, low back pain was the most reported symptoms among occupational motorcyclists (82.3%) as compared with non-occupational motorcyclists (62.8%).

These problems experienced by motorcyclists are possibly due to riding posture. Motorcyclists usually sits in the same position with restricted movement during riding. As a consequence, this poor sitting posture especially in prolonged riding can cause motorcyclists to experience muscle discomfort, fatigue and pain (Balasubramaniam & Jagannath, 2014). Based on the previous study, there is no specific time in order to define the meaning of prolonged riding. However, a study done by Talib et al. (2015) have mentioned in their study that prolonged riding can be defined as a continuous motorcycle riding which is beyond 2 hours riding session. Riding motorcycle within this extended period of time would

create many problems toward motorcyclists. For example, according to Motorcycle Council of New South Wales (2005), sitting in the similar posture with limited movement for prolonged periods may contribute to muscle stiffness and decreased blood flows, subsequently causing discomfort and probably fatigue. The increment of discomfort level from prolonged sitting can contribute to muscle fatigue which occurred from continuous contraction of back muscles in seated postures (Waongenngarm et al., 2015).

MIROS (2011) in the Annual Report also mentioned that the main causes of traffic accidents in Malaysia are caused by risky driving, followed by speeding and fatigue. Although there are many factors contributing to traffic accidents in Malaysia, this study was specifically focus on fatigue because there is a relation between motorcycle road accidents with the cases of human error due to motorcycling fatigue (Talib et al., 2015). Recently, in many developed countries, fatigue now is considered as a work place hazard (Dawson et al., 2012). This is due to reason that fatigue can contribute to human error and subsequently might lead to accidents and injuries. Same goes to the motorcyclists because they are tend to make some error while riding in a fatigue state.

In order to improve motorcyclists discomfort resulted by poor sitting posture during prolonged riding, an ideal sitting posture can be achieved by providing a back rest. As suggested by Vergara and Page (2002), back rest would decrease the stresses exerted on the vertebral column by relaxing erector spinae musculature while protecting lumbar lordosis and increase comfort. In addition, several studies also have revealed that the use of a back rest or lumbar support system has been shown to help in the maintenance of a person's natural lordotic lumbar curvature during sitting which has been associated with reducing lower back discomfort (Donnelly et al., 2009). Therefore, since motorcycle provide with lack of protection and comfort towards motorcyclists, some basic ergonomic adjustment is required such as lumbar support in order to enhance comfort level among motorcyclists.

## **1.2 Problem Statement**

Riding a motorcycle exposing motorcyclists to extreme physical demand especially on long-distance rides. Motorcyclists tend to feel discomfort and possibly fatigue while riding due to poor riding posture and also static sitting position with constrained movements. Static sitting position and poor posture are both were found to be significantly associated with the development of musculoskeletal disorders and discomfort in human body (Karmegam et al., 2011). Due to poor sitting posture, motorcyclists discomfort or fatigue usually occurred when high intramuscular pressure created during static seated posture obstructing the blood supply. Then, it cause lack of oxygen supply to the tissue cells which would contribute to seating discomfort and fatigue (Jagannath & Balasubramaniam, 2014). Apart from that, during the process of riding, motorcyclists also tend to adopt for a variety of postures in order to balance the equilibrium of stresses in the body (Karmegam et al., 2012). This problem happened due to lack of comfort and safety aspects offered by a motorcycle towards their user. Thus, in context of ergonomic, poor sitting posture

experienced by motorcyclists during riding process was getting a significant attention in this study.

Feeling of discomfort are normally related with pain, tiredness, soreness and numbness. These feelings are assumed to be imposed by physical restrictions and arbitrated by physical factors like joint angles, tissue pressure and circulation blockage (De Looze et al., 2003). Seated postures have been seen as potentially hazardous and considered as one of the main contributing factors for several musculoskeletal disorders such as lower back pain, neck pain and shoulder pain (Kyung, Nussbaum & Reeves, 2008). According to Vergara and Page (2002), the most common discomfort occurred during sitting is in the neck and lumbar regions, followed by buttock, dorsal regions and thighs. However, only the increase of discomfort in lumbar, dorsal and neck regions produce a great reduction in general comfort whereas buttock and thigh discomforts are considered as not as important for general feelings. Also, the only existence of some discomfort in the lumbar region provokes in itself a decrease of general comfort. Thus, lumbar discomfort is seen as the most important measurement for comfort.

Recently, the end user comfort of products has developed into an important issue in Western societies. One of the products frequently considered is the seat (De Looze et al., 2003). Dunk and Callaghan (2005) suggested that ergonomic intervention has to play an important role in order to provide sitting comfort due to increased exposures to seated postures. However, ergonomics teaching usually recommends to sit in a reclined chair with the spine supported by the backrest. According to Fitzsimmons (2014), this option seems to provide a high margin of safety because the muscles are relaxed, lumbar disc pressures are lower and it is more comfortable. Presently, it is unlucky for the motorcyclists because the majority of motorcycle seat design over the world does not provided with a lumbar support.

A study done by Donnelly et al. (2009) pointed out in their study that the greatest sources contribute to low back discomfort during in-vehicle activities are seat feature, computer use and duty belt worn by officers. Also, they found that by using prototype automobile seats with an active lumbar support system and foam structural modifications, low back discomfort has been shown to reduce by 35 percent. This showed that ergonomic intervention has become an important issue in order to improve sitting comfort towards vehicle users especially for motorcycle users. Nevertheless, one of the studies done in Malaysia by Karmegam et al. (2011) had proposed a new prototype of lumbar support to improve level of discomfort among motorcyclists. The main function of this prototype is to support motorcyclists' back region during riding. In this study, a new prototype of build in lumbar support developed by Karmegam (IP number: 2013701235) was used as an intervention in the motorcycle seat. However, this prototype still has not been tested for its performance and need some further field testing to enhance its capability in providing support to lumbar region during the riding process. Therefore, there is a need for this study to evaluate the effect of lumbar support (prototype) in order to reduce the discomfort level among motorcyclists since most of the motorcycle seat design in Malaysia does not equipped with a lumbar support.

Current methods of assessing muscle discomfort and muscle activity are limited to subjective and objective measurement (Velagapudi et al., 2010). In this study, motorcyclist discomfort level and their muscle activity were measured using Borg's scale discomfort ratings and surface electromyography (sEMG). Borg's scale was considered as a subjective measure in order to measure motorcyclists discomfort in various body parts. Muscle discomfort is considered occurred when the respondents rated their discomfort level at rating 5 and above in the Borg's scale. Nevertheless, sEMG was used as an objective measure to quantify muscle activity at right and left erector spinae muscle. Many clinical experiments for biomechanical and musculoskeletal analyses used sEMG for measuring muscle function because sEMG application is very dynamic and involve with non-invasive procedure (Hu et al., 2014).

### **1.3 Significance of Study**

Motorcycle has become the most preferable, useful and inexpensive mode of transport for many years in Malaysia. Based on the trend for two decades, the number of motorcyclists has shown to grow rapidly more than other road users and the number of registered motorcycles has reached almost nine million in year 2009 (MIROS, 2011). Even though motorcycles have become the most popular mode of transportation in Malaysia, but in terms of ergonomic, motorcycle does not provide comfortability towards motorcyclists during process of riding. A study done in Malaysia found that more than 50% of male and female motorcyclists were reporting of having discomfort when riding the motorcycle (Karmegam et al., 2012). Hence, it is necessary to conduct a study concerning motorcyclist posture using a new developed motorcycle seat (prototype) to predict in improving riding comfort.

People nowadays are using motorcycle for various daily activities especially for commuting purposes. Motorcycle offered many advantages that can attract people to use it. One of the main attraction that provided by a motorcycle is about the cost. Motorcycle costs are relatively cheaper compared to other types of vehicles and it is also not consume more fuel compared to cars. However, in terms of safety and health, riding a motorcycle will expose people to several hazards because motorcycle providing with lack of safety equipment. Thus, findings of this study might help motorcyclists in improving the sitting comfort and also preventing them from getting any musculoskeletal problems related to riding process.

There were a lot of studies regarding discomfort among motor vehicle users. However, previous studies have primarily concentrated more on driving discomfort compared to riding discomfort among motorcyclists. There are very little information regarding motorcyclists' discomfort especially in Malaysia and the sources of information also is very inadequate. Obviously, riding a motorcycle is far more physically and mentally challenging rather than driving a car but only a few studies are aware to explore about motorcyclists' discomfort.



## **1.4 Research Objectives**

### **1.4.1 General Objective**

To evaluate the effect of lumbar support in reducing riding discomfort among motorcyclists.

### **1.4.2 Specific Objectives**

The specific objectives of this study were as follows:

1. To determine the discomfort level and percentage muscle exertion using Borg's scale and EMG for control and experimental group.
2. To compare the Borg's scale and EMG results between pre-test and post-test study.
3. To compare the Borg's scale and EMG results between control and experimental group.
4. To determine the differences in the effect of time measurement on discomfort level and percentage muscle exertion for control and experimental group.

## **1.5 Hypotheses**

The hypotheses tested were shown below in null form:

H1: There is no significant difference in the discomfort level and percentage muscle exertion for control and experimental group.

H2: There is no significant difference in the Borg's scale and EMG results between pre-test and post-test study.

H3: There is no significant difference in the Borg's scale and EMG results between control and experimental group.

H4: There is no significant difference in the effect of time measurement on discomfort level and percentage muscle exertion for control and experimental group.

## **1.6 Definitions of Terms**

### **1.6.1 Conceptual Definitions**

#### **1.6.1.1 Motorcyclist**

According to Cambridge Dictionaries Online (2015), motorcyclist is defined as a person who rides a motorcycle. However, there are variations in types of motorcycles design and performance capability. Motorcyclist may choose certain motorcycle types based on the riding preferences (Teoh & Campbell, 2010).

#### **1.6.1.2 Muscle discomfort**

Muscle discomfort is often related to tension, overuse or muscle injury from exercise or physically-demanding work. The pain or discomfort usually tends to involve specific muscles and starts during or just after the activity (National Library of Medicine, 2014). It can affect any part of the body which include hands, back, neck, arms and legs.

### **1.6.1.3 Prolonged riding**

Prolonged means “to make something last a longer time” and riding means “to sit on something such as a bicycle, motorbike or horse and travel along on it controlling its movements” (Cambridge Dictionaries Online, 2015).

### **1.6.1.4 Lumbar support**

Lumbar support is a type of lumbosacral orthotic made of soft, flexible fabric which may have horizontal or vertical rigid reinforcements (O’sullivan, Schmitz & Fulk, 2013).

## **1.6.2 Operational Definitions**

### **1.6.2.1 Motorcyclist**

A person who rides a motorcycle of 150cc and below.

### **1.6.2.2 Muscle discomfort**

Muscle discomfort is considered occurred during the experimental session when the respondents rated their discomfort level at rating 5 and above in the Borg’s scale.

### **1.6.2.3 Prolonged riding**

In this study, prolonged riding is considered as endurance riding for 2 hours. During experimental session, respondents were asked to sit on a static motorcycle and the duration of the testing is 2 hours.

### **1.6.2.4 Lumbar support**

A motorcycle seat with built-in lumbar support prototype was used in this study. The main function of this prototype is to support a back of the motorcyclist during prolonged motorcycle riding.

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