

ORIGINAL ARTICLE

A COMPARISON STUDY FOR THE ROAD CONDITION WITH HAND GRIP FORCE AND MUSCLE FATIGUE

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ABSTRACT

The purpose of this study is to compare the road conditions (straight road, winding road and hill road) with the hand grip pressure force and muscle fatigue for male and female drivers. Ten subjects were participated in this study. The force measurement and electromyography (EMG) responses were taken and evaluated by using the tactile grip and pressure measurement (Grip System) and Electromyography (EMG) device. The result indicated that the winding road produced more muscle fatigue and high hand grip pressure force compared than downhill road, hill up road, and straight road for both male and female subjects. The result compared the muscle fatigue and hand grip pressure force between the first 15 minutes and last 15 minutes of driving activity. The muscle fatigue increasingly high for the last 15 minutes compared to first 15 minutes. However, the hand grip pressure forces become high during the winding road for first 15 minutes of driving session. The muscle fatigue become high as the hand grip pressure force value is high. Furthermore, the male drivers exert higher hand grip pressure force and higher muscle fatigue compared to female drivers. This study can be used as a guideline for the future studies, primarily in solving the driving fatigue problem among the Malaysian's drivers. The method of this study could also be used for early detection of driver fatigue issues. Indirectly, the findings could reduce the number of car accidents in Malaysia.

Keywords: Electromyography (EMG), tactile grip and pressure measurement (Grip System), muscle fatigue, hand grip pressure force, driving fatigue, road condition

INTRODUCTION

In this civilization world, driving activity nowadays become more important as this medium being practically, cheaper and faster on connecting human from one to another places. However, hourly driving can caused fatigue to the drivers, which automatically decreased the alertness, level and increase inattention possibly to create disaster and accident. According to the Malaysian Institute of Road Safety (MIROS), the rate of road accidents in Malaysia is one of the highest compared to other countries in the world. A road traffic statistic from 1997 to 2007 shows that the total number of accidents reached to 215,632 cases. In 2014 it increased to 476,196 cases¹. Hence, this research was conducted to study the relationship between the hand grip pressure force and muscle fatigue while driving through different road conditions and study the effect of hand grip pressure force and muscle fatigue towards road accidents among Malaysian drivers.

Muscle fatigue occurs when the muscle experiences a reduction in its ability to produce force and accomplish the desired movement. The blood flow to the muscle become less because the muscles intensely contracting can reduce blood flow and thus oxygen availability, or the muscle is simply working so intensely that there literally is not enough oxygen to meet demand (a sprint at top speed). In order to measure the muscle fatigue, the Surface Electromyography (SEMG) can be used. The SEMG signal is produced by the ionic flow across the membrane of the muscle fibres that spreads through the

intervening tissues, to reach the detection surface of the electrodes².

The SEMG signal can detect medical irregularities muscle activity level (biomechanics) of man or animal

Grip strength means the force of the hand to pull, push or hold from the objects or can be defined as the strength of the hand. In this study, the subjects need to grasp the steering wheel using their hand to control the steering wheel. The static and dynamic pressure from grasping the steering wheel can be measures and evaluates using tactile grip and pressure measurement (Grip system). The Grip system uses a thin, high-resolution sensor that can be used directly on a hand or built into a glove, which is an ideal device in measuring and evaluating pressure and force of the hand. There are very limited studies about the grip force and the scope of the previous study was narrowed. Based on the previous study, the grip force of the hand is usually used in detection of the driver fatigue. The variation in steering grip force was used as the detection of fatigue among the drivers. According to previous study, the steering grip force decreases when the driver is losing concentration as the driver's muscle are becoming increasingly relaxed³. This previous study used normal probability distribution function to detect significant change in steering grip force data. Furthermore, previous research studied the relationship between the gender, type of road conditions and the speed of the car with the steering grip force⁴. This study concluded that the road conditions and the

speed of the car would influence the steering grip force. Higher steering grip force produced when the drivers drive through the rough road condition at the higher speed. Besides, the drivers feel discomfort caused by the higher vibration of the steering wheel transmitted to their hands, which indirectly bring to fatigue problem while driving.

METHODS

Questionnaire Respond Analysis

The questionnaire is the one of the important parts to investigate the driving experience while undertaken the experiment. This questionnaire consists of three part The first part is more on personal information, which is name, age, weight, height, driving experience, occupation, type of car that the drivers used, and driving information such as duration of driving per day and driving hours per week. The second part is more on driver’s comfort experience throughout the type of road condition. The four types of road condition are straight road, uphill road, downhill road and winding road. The third is more on driver physical comfort. In this part, it had the whole body of the drivers such as head, neck, arm etc. The participant needs to answer the questionnaire before and after the driving session.

Test Apparatus

Proton Saga FLX 1.3L engine with automatic transmission was used as the test vehicle. This car was chosen, as it is a national car, which also a well-known national symbol of Malaysia. Proton Saga is a 4-door subcompact sedan, which, the class size smaller than compact car. Besides, Proton Saga FLX have been choose based on majority of Malaysian population used it as Proton Saga can be categorize as affordable cars or economic cars. This statement further strengthened with awards received by this car. Among awards received is Best People’s Car and Best Value for Money Family Car Award in 2011 and Best Passenger Car Model of the Year in 2010⁵. In measuring hand grip pressure force, the Tekscan tactile grip pressure and force measurement was used in this study. This system uses a thin, high-resolution, tactile pressure sensor that can be used directly on hand or built in into a glove which enables the researcher to analysed pressure and force felt by each fingers, palm and thumb. Instead of very useful in automotive industry, this system also has wide applications in life such as ergonomics product design, sport applications and robotics. This study required the subjects to wear gloves, which is built in with grip system for both hands. Figure 1 shows the tactile grip pressure and force measurement.



Figure 1. Grip System by Tekscan

EMG is a tool that be used in monitoring the overall performance of muscle during the study. EMG is used to ensure the muscle responsiveness with the electrodes for about 30 minutes. There are four types of muscle where the EMG has been placed as shown in Figure 2; left upper trapezius, right upper trapezius⁶, right biceps and left biceps⁷.

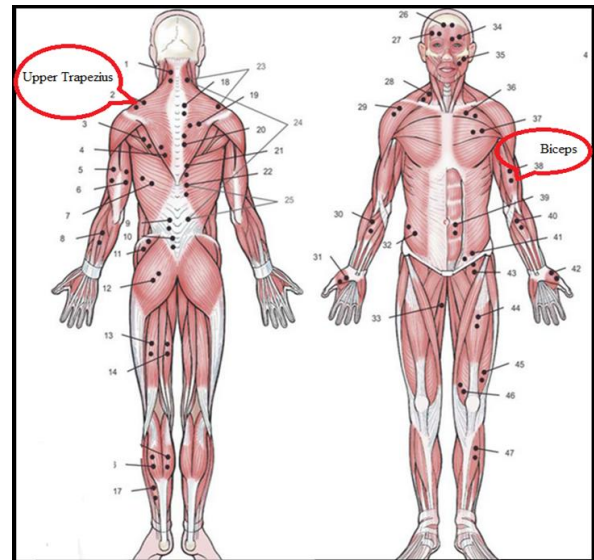


Figure 2. Type of muscles for EMG test⁸

The EMG was set up at the selected muscle of subject’s body as shown in Figure 3.



Figure 3. The EMG was set up at the subject’s body

Road Conditions

The road conditions are independent variables. This real road practices takes places at Lebu AMJ, Melaka that is from Campus Industry of Universiti Teknikal Malaysia Melaka (UTeM) to Penjara Sungai Udang, Melaka. This road conditions can be classified in four main types;

Straight road, winding road, uphill road and downhill road.

Participants

Ten subjects (five males and five females) with at least two years driving experiences participated in this study. However, one population of each gender is been discussed in this study. The subjects are normal and have healthy bodies. Besides that, all the subjects told that they are refrained from drinking coffee, tea or alcohol, smoking, and free taking any medicine. The health evaluation has been done 24 hours before the experiment to ensure they have enough habitual amount of sleep at night before the experiment in order to avoid sleep deprivation⁹. The position of 9 and 3 o'clock of the wheel was recommended to subjects as the suitable position of gripping the steering wheel. Based on the previous study, the common hand position is 10 and 12 o'clock position¹⁰. However, this study focused on the 9 and 3 o'clock position as recommended.

Test Protocol

The EMG tool was set up first at the subject body. The electrodes were placed on the surface of the skin based on the type of muscles. Then, the drivers were asked to wear the glove, which built in with grip system for both of the hands. The tethered system or wire system was connected to computer or laptop to display the hand grip pressure force directly on screen. The seat angle and side mirror was adjusted according to subject's comfort. The subjects have to grip the steering wheel according to recommended position that is 9 and 3 o'clock position. The explanation about the route was given to the subjects before the road test begins. The subjects required driving at constant speed, which is 80 km/h. The data for grip pressure force was analysed and evaluated using the Tekscan tactile grip pressure and force measurement software. This data need then needed to convert and save into ASCII files, which the Microsoft Excel is used to open, and analysed

as variety of the graphs were created to present the result of the hand grip pressure force. While for the EMG data, Microsoft Excel was used to analyze that data. All the data was represented in the form of graph to give a better visualization of the results.

RESULTS AND DISCUSSION

Hand grip pressure force is a risk factors associated with the incidence of Musculoskeletal Disorder (MSD). The excessive grip helps in development of MSDs in the hand, wrist forearm and shoulder. In the driving activity, the drivers require repetitive gripping or long gripping. The function of EMG is for measurement of muscle activation in workspace related tasks during the driving session. The EMG activity was measured with surface electrodes placed bilaterally on the Left Upper Trapezius with Right Upper Trapezius⁶ and Right Biceps with Left Biceps⁷. This study conducted the real practice driving study on the actual road condition. This section will discussed the relationship between grip pressure force and muscle fatigue with respect to road conditions for male and female subjects.

Hand Grip Pressure and Muscle Fatigue with Respect to Road Condition

A. Early 15 minutes of Driving Session

The study started by observing the muscle fatigue and hand grip pressure force for early 15 minutes of driving session for both gender. Table 1 shows the average EMG responses and hand grip pressure force for male subject. There are four types of road condition being observed; straight road, winding road, uphill road and downhill road. The graph was plotted to give better visualization of the result as shown in Figure 4.

Table 1: Average EMG responses and hand grip pressure force for male subject

Road condition	Muscle Fatigue	Grip Force (Right)	Grip Force (Left)
Straight	73.85	297.72 N	4140.37 N
Winding	935.25	330.36 N	4950.49 N
Uphill	75.48	263.63 N	4327.39 N
Downhill	573.93	314.37 N	4588.48 N

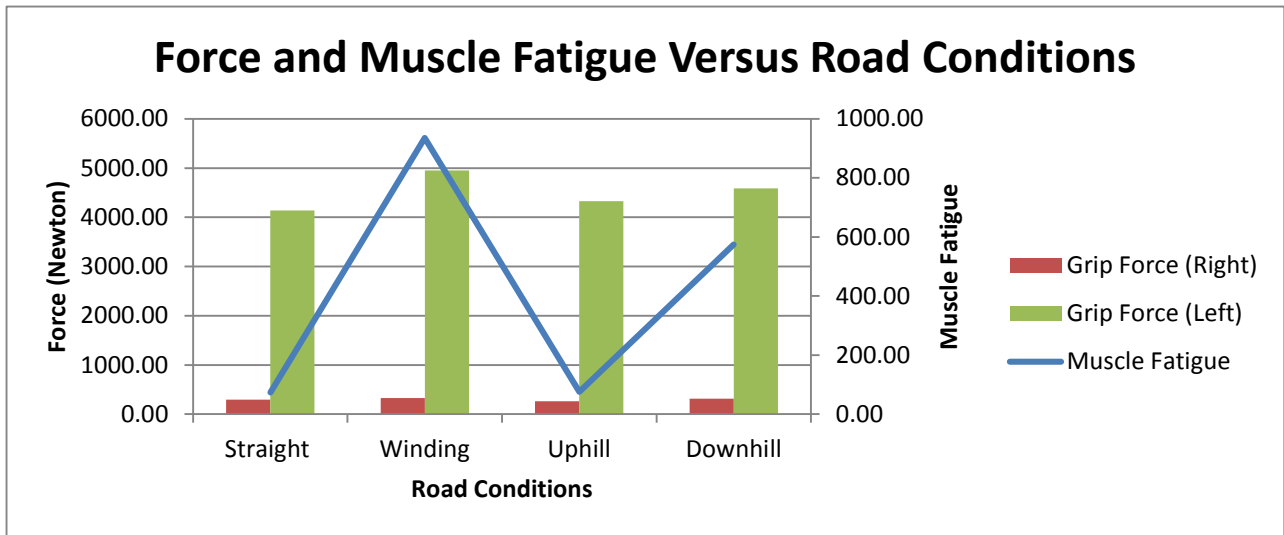


Figure 4. Force and Muscle Fatigue versus Road Condition’s graph for male subject

Besides, the straight road condition produced the lowest hand grip force and muscle fatigue. This is due to the subject feel comfortable and relaxed when driving through this road condition as easy for them to control the vehicles. During this period, there is least muscle activity.

The result of the female subject shows the same pattern of the graph. Table 2 shows the average EMG responses and hand grip pressure force for the female. While Figure 5 shows the graph of force and muscle fatigue with respect to road conditions.

Table 2: Average EMG responses and hand grip pressure force for female subject

Road condition	Muscle Fatigue	Grip Force (Right)	Grip Force (Left)
Straight	89.10	79.20	2330.90
Winding	355.53	105.85	2998.84
Uphill	108.88	82.63	2394.11
Downhill	260.68	75.24	2252.55

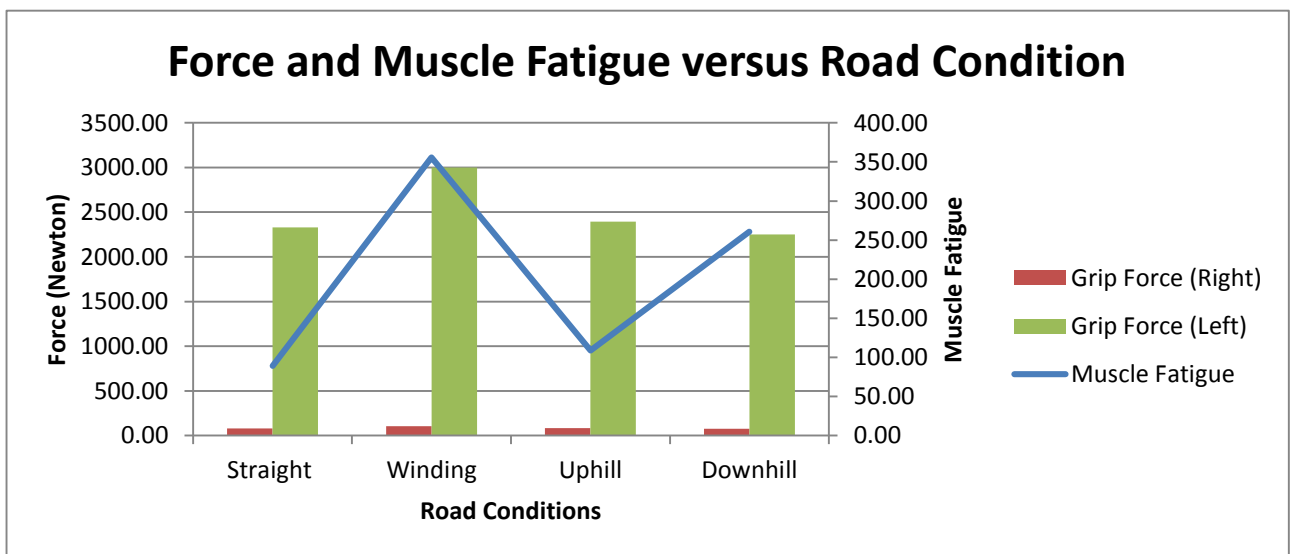


Figure 5. Force and Muscle Fatigue versus Road Condition’s graph for female subject

The result shows that the highest muscle activity happened during driving through the winding road condition. Besides the higher hand grip pressure force produced at this road condition. The drivers have to grip steering wheel strongly than usual. This make the muscle activity increases and muscle becomes fatigue. The highest the risk for the muscle to become fatigues shows the highest the muscle activities⁷.

As same script with male subject, the lowest hand grip force is at straight road condition. As low force produced, the muscle activity during

this condition become less which directly the muscle fatigue decreases.

B. Last 15 minutes of Driving Session

The study continued with the observation of the muscle fatigue and hand grip pressure force for last 15 minutes of the driving session. Table 3 shows the result of muscle fatigue and grip force for the male subject. Meanwhile Figure 5 shows the interpretation of the result in the form of graph.

Table 3: Average EMG responses and hand grip pressure force of last 15 minutes for male subject

Road condition	Muscle Fatigue	Grip Force (Right)	Grip Force (Left)
Straight	208.60	277.91	4125.21
Winding	1035.20	839.78	4799.63
Uphill	645.60	344.99	4729.47
Downhill	650.70	333.00	4751.17

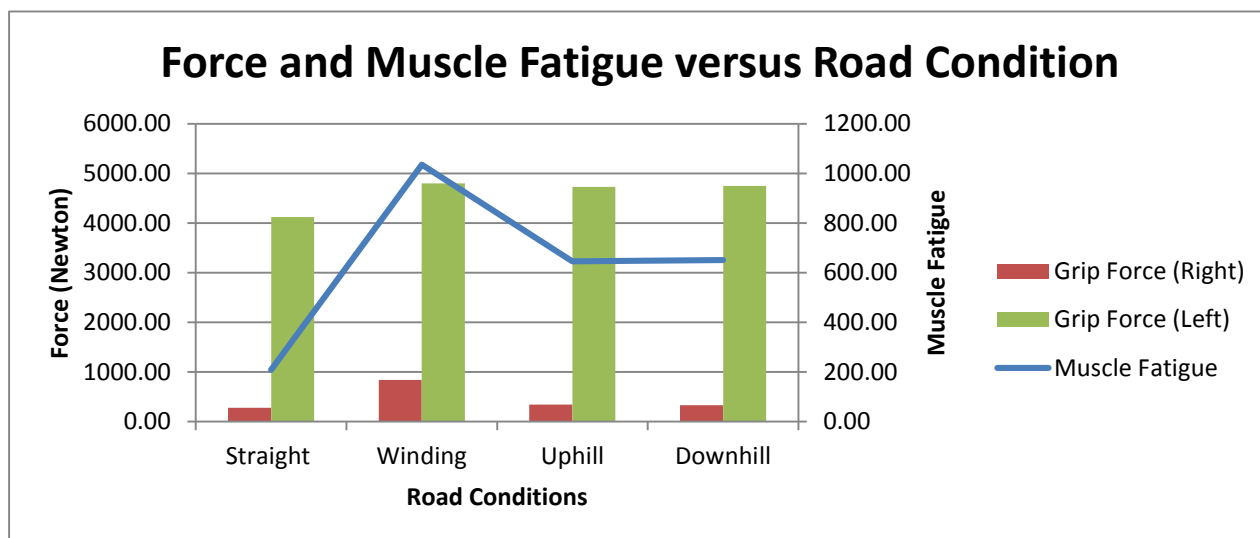


Figure 6. Force and Muscle Fatigue versus Road Condition’s graph for male subject for last 15 minutes of driving

This result shows the last 15 minutes of driving session and the graph shows that the higher grip force and muscle fatigue produced during driving through the winding road. It is followed by the downhill and uphill road condition. This is due to the muscle activity at winding road increases. The driver has to grip the steering wheel with high force as to control the vehicles as to turn left or right. The lowest muscle fatigue and hand grip force happened at straight road condition as the driver feels more relaxed and comfortable.

Furthermore, the female subject also produced the highest muscle fatigue and grip force during driving through the winding road. Table 4 represents the average EMG responses and hand grip pressure force of last 15 minutes driving session for female subject. While Figure 7 shows the graph of force and muscle fatigue versus road conditions. As before, the lowest value of muscle fatigue and grip force is at straight road condition. The driver feels uncomfortable and high muscle activity during driving at winding road and low muscle activity when driving at straight road.

Table 4: Average EMG responses and hand grip pressure force of last 15 minutes for female subject.

Road condition	Muscle Fatigue	Grip Force (Right)	Grip Force (Left)
Straight	164.60	78.14	2171.04
Winding	520.20	108.83	2758.18
Uphill	360.00	71.43	2639.11
Downhill	392.00	89.58	2705.60

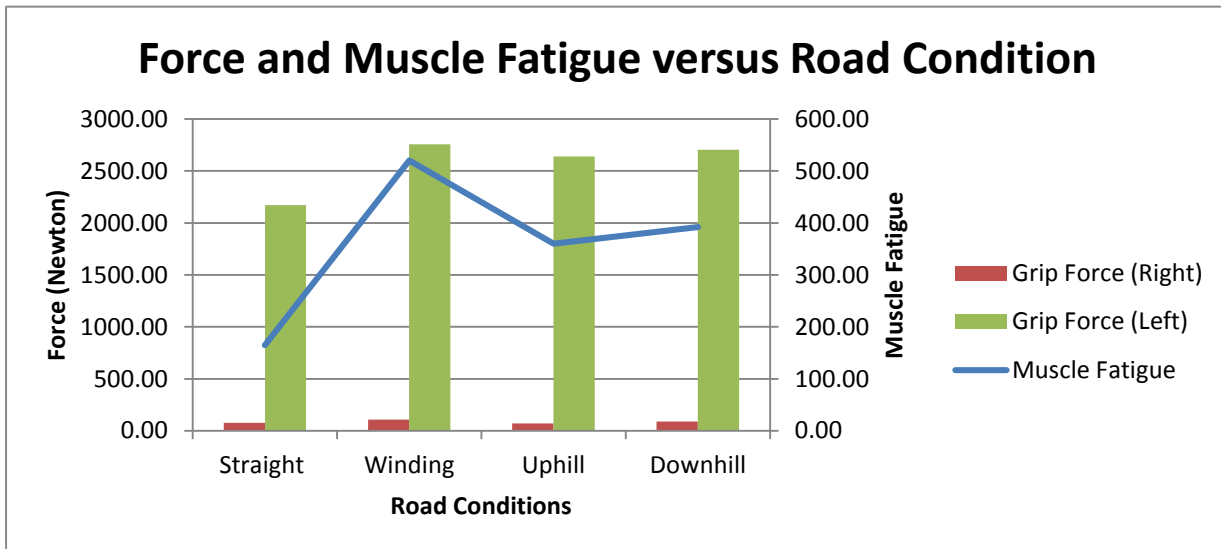


Figure 7. Force and Muscle Fatigue versus Road Condition’s graph for female subject for last 15 minutes of driving

CONCLUSION

As conclusion, the road conditions influenced the drivers to become fatigue while driving as it affect the muscle activity and hand grip pressure force. This study compared the muscle fatigue and hand grip pressure force between the first 15 minutes of driving session and last 15 minutes of driving session. The result shows that the muscle fatigue become higher at last 15 minutes of driving compared than first 15 minutes. However, the drivers produced high hand grip pressure force during first 15 minutes than last 15 minutes of driving activity.

This study concluded that, driving through the winding road could make the drivers become fatigue as highest muscle activity and hand grip pressure force produced. The drivers need to be more focusing and more strongly grip the steering wheel to control the vehicles at winding road condition. Furthermore, high muscle fatigue produced as high hand grip pressure force by the subject during driving through the winding road.

This study also indicated that the male drivers exert higher hand grip pressure force and higher muscle fatigue compared to female drivers. As the drivers become fatigue, the alertness level of the driver decreases and indirectly increases the inattention possibly to create road accidents. This study can be used as methods for early detection of driver fatigue. For the future study,

the researcher can make the comparison between muscle fatigue and hand grip forces of the real practice driving study on the actual road with the muscle fatigue and hand grip force of the simulator driving study.

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