ISSN:1991-8178

Australian Journal of Basic and Applied Sciences

Journal home page: www.ajbasweb.com

A Comparison Study between Right Hand and Left Hand Grip Pressure Force While Driving

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ARTICLE INFO

Article history:
Received 12 March 2015
Accepted 28 April 2015
Available online 2 May 2015

Keywords:
Hand grip pressure force; tactile grip and pressure measurement; grip sensor; fatigue; car accidents

ABSTRACT

Background: This paper presents the result of hand grip pressure force of male and female drivers driving a vehicle on different road conditions (straight road, hill road, winding road, rough and smooth road) at constant speeds (80 km/h). In this study, there are ten subjects were participated. The force measurement were taken and evaluated by using the tactile grip and pressure measurement (Grip System) which the grip sensor was positioned over important anatomic sections of fingers and palm. The result of this study indicated that the left hand grip pressure force of both gender is higher compared to right hand grip pressure force. Besides, the results showed significantly higher hand grip pressure force values for the male driver in comparison to the female driver. Furthermore, this study showed that palm part of the hand produced more hand grip pressure force compare to others part (fingers and thumb). This study can be used as a referral for the next research, primarily in solving the driving fatigue problem in achieving safety in driving as well as reducing the number of car accidents.

To Cite This Article: Seri Rahayu, Mohammad Firdaus, Kalthom Husain, A Comparison Study between Right Hand and Left Hand Grip Pressure Force While Driving. ***Aust. J. Basic & Appl. Sci.,*** *9(19): 50-58, 2015*

INTRODUCTION

Grip strength can be defines as the force of the hand to pull or hold from the objects. In the other words, it can be defines as the strength of the hand. In driving activity, the drivers need to grasp the steering using their hands. The pressure or force of the hand is to steering in order to control the movement of the car. The static and dynamic pressure from the grasping object can be measures and evaluates using tactile grip and pressure measurement (Grip system). It is the ideal tool in measuring and evaluating pressure and force. This system enables the researcher to analyzed pressure and force felt by each finger, palm and thumb.

The previous study of the grip force for automotive were very limited and the scope of the study were narrowed. Previous researches show that the grip force is commonly used in detection of the driver fatigue. This is done by monitoring the driver's grip force on the steering wheel. Fatigue among drivers can be detected by referring the variation in steering grip force. Chieh *et al*., (2003) reported that the steering grip force reduces when the driver is losing concentration as the driver's muscle are becoming increasingly relaxed. The normal probability distribution function was used to detect significant change in the steering grip force data.

In addition, Eksioglu and Kızılaslan (2008) studied the relationship between the gender of the drivers, type of road conditions and the speed of the cars with the steering grip force. Table 1 shows the experimental variables for this study. While in Table 2 presented the descriptive statistics of the experimental variables categorized for each of the four driving conditions and types. The result from this study concluded that the road condition and speed of the cars would affect the steering grip force. Higher grip force happened when the drivers drive at the rough road condition at the higher speed. This might be due to higher steering vibration cause by that condition. The drivers will experience or feel uncomfortable cause by the higher vibration transmitted to their hand which may bring to fatigue problem while driving. The result also showed that the male drivers exert significantly higher absolute and net steering grip forces than female drivers.

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Table 1: Experimental Variables

Independent variables (factors)	Factor levels	Response variables
Gender	Male Female	Absolute force (F_{abs})
Speed	45 mph (72km/h)- City 65 mph (105km/h)- Highway	Net grip force (F_{net}) Percent of maximum force ($\%F_{max}$)
Road condition	Smooth (asphalt) Rough (asphalt)	Percent exertion (*% Exertion*)

Note. Adapted from Eksioglu, M., & Kızılaslan, K. (2008). Steering-wheel grip force characteristics of drivers as a function of gender, speed, and road condition. *International journal of industrial ergonomics*, *38*(3), 354-361.

Table 2: Descriptive statistics of the experimental variables.

Gender	Road condition	Speed (mph)	Response variable	Mean (std.)
Male	Smooth asphalt	45	F_{abs} (N)	60.1 (23.9)
			F_{net} (N)	31.5 (13.2)
			$\% F_{max}$	27.7 (9.0)
			% Exertion	17.1 (7.5)
		65	F_{abs} (N)	67.3 (23.9)
			F_{net} (N)	38.7 (18.3)
			$\% F_{max}$	31.4 (10.5)
			% Exertion	21.2 (10.8)
	Rough asphalt	45	F_{abs} (N)	71.4 (27.4)
			F_{net} (N)	42.8 (20.7)
			$\% F_{max}$	32.6 (10.6)
			% Exertion	22.6 (10.7)
		65	F_{abs} (N)	66.3 (21.9)
			F_{net} (N)	37.7 (14.6)
			$\% F_{max}$	30.3 (6.9)
			% Exertion	19.9 (6.7)
Female	Smooth asphalt	45	F_{abs} (N)	41.9 (9.9)
			F_{net} (N)	26.3 (12.3)
			$\% F_{max}$	31.2 (5.2)
			% Exertion	22.0 (8.0)
		65	F_{abs} (N)	43.8 (5.3)
			F_{net} (N)	29.7 (6.7)
			$\% F_{max}$	33.4 (5.7)
			% Exertion	25.5 (7.4)
	Rough asphalt	45	F_{abs} (N)	37.8 (6.1)
			F_{net} (N)	22.2 (7.4)
			$\% F_{max}$	28.3 (3.3)
			% Exertion	18.8 (5.3)
		65	F_{abs} (N)	48.7 (7.7)
			F_{net} (N)	34.6 (9.8)
			$\% F_{max}$	37.1 (6.9)
			% Exertion	29.6 (9.1)

Note. Adapted from Eksioglu, M., & Kızılaslan, K. (2008). Steering-wheel grip force characteristics of drivers as a function of gender, speed, and road condition. *International journal of industrial ergonomics*, *38*(3), 354-361.

Research method:

Test Apparatus:

The real road test practice used the national car which is Proton Saga FLX 1.3L engine with automatic transmission as the test vehicle. The design of the steering wheel is identified first. Figure 1 shows the design of the steering wheel for Proton Saga FLX 1.3L.

The Tekscan tactile grip force and pressure measurement was used to measure the hand grip pressure force in this study. This system enables the researcher to analyzed pressure and force felt by each finger, palm and thumb. The analysis can be used for improving the design of the product, study the carpal tunnel syndrome and repetitive motion syndrome. It is very useful especially in the automotive industry. Tactile grip and pressure measurement have wide applications in life such as ergonomics, product design, sport applications and robotics. Figure 2 shows the tactile grip and pressure measurement and the grip sensor of the tactile grip and pressure measurement. This grip system can be used directly on a hand or built into a glove and both hands can be measured simultaneously. For the measurement of hand grip pressure force, the drivers needed to wear gloves which built in with grip system for the both hands.

Participants:

Ten drivers (five males and five females) participated in the study. All participants were experienced drivers with at least two years driving experiences. However, only one population of each gender is been discussed in this paper.

The drivers were asked to grip the steering wheel with 9 and 3 o'clock positions of the wheel. This is the recommended position compared to 10 and 2 o'clock position as this position is no longer acceptable because the driver's hands may throw into his or her face when the airbags deploy. However,

the previous study by Jonsson (2011) reported the common hand position while driving is 10 and 2 o'clock position. Meanwhile, the 9 and 3, and 11 and 1 o'clock position is rare. As recommended, this study only focused on the 9 and 3 o'clock position.

Fig. 1: Proton Saga FLX's steering wheel.

Fig. 2: Tactile Grip and Pressure Measurement (Grip System) by Tekscan.

Test Protocol:

The drivers were asked to wear the built in glove with grip system for both of the hands. The tethered system which is a wire system was connected to a computer or laptop. The hand grip pressure force will display directly on screen. The seat angle and mirror was adjusted according to their comfort. Then, they were asked to take the hand position that has been told before. Before the road test begins, the description of the route was given to the drivers. Besides, the drivers have to drive the test vehicles at constant speed which is 80 km/h. The actual data collection was collected only after the driver drove the car for a few miles to get used to the vehicles and the testing equipment, and ready.

The data was analyzed and evaluated using the Tekscan tactile grip and pressure measurement software. Then, the data from this software was converted and save into ASCI files which the Microsoft Excel is used to open and analyzed as variety of the graphs were created to present the result of the hand grip pressure force.

RESULT AND DISCUSSIONS

Force has been identified as one of the three risk factors associated with the incidence of MSDs. The development of MSDs in the hand, wrist forearm and shoulder as well may be due to excessive grip force. An ergonomics evaluation should include a measure or estimation of applied grip force for the job that require repetitive gripping or long gripping such as driving activity. Hence, this research has conducted the real practice driving study on the actual road condition. This section will discussed the relationship between the hand grip force with the actual road condition and the relationship between the right hand grip forces with the left hand grip forces for male and female drivers.

Hand Grip Pressure Force with Respect to Road Condition:

The grip force of the hand was measured using the Tactile Grip Force and Pressure Sensor. This tools measures and records the dynamic pressures and forces of the hands and fingers apply while grasping, gripping, holding, and using object such as steering wheel. This research focused on measures the forces of three main parts of both hands; palm, thumb and fingers. Figure 4 shows the three main parts of the hand.

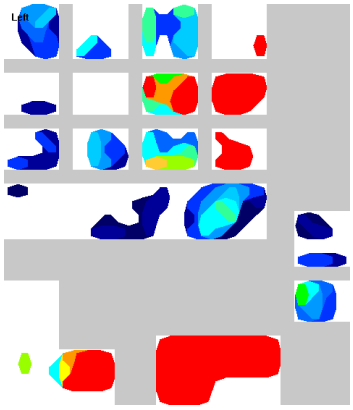

Fig. 4: Three main parts of the hand; palm, thumb and fingers.

The analysis is carried out using the tactile grip measurement system. The analysis data then been converted into Microsoft Excel which consist of the force of the hand and the time. The graph of forces versus times was constructed in order to analyze the relationship between forces for three main part of the hand with the condition of the road. The critical areas or the highest forces of both hands is identified and labeled as shown in Figure 5 and Figure 6 for the male driver and Figure 7 and Figure 8 for female drivers. The right hand's graph will followed the critical areas or highest force of the left hand's graph as to make a comparison between them.

From the graphs, it shows that the left hand have a greater hand grip force compare to the right hand for both male and female drivers. Besides, both graph for male driver show the higher hand grip

force at the palm of the hand, followed by the fingers and the least force is at the thumb area. Meanwhile, for female drivers, the left hand shows the higher force at fingers compare to the palm and thumb. However, the right hand shows the higher force at the palm and followed by the fingers and thumb. Hence, this research can concluded that the respondent or driver used more energy or applied more force at the palm of the hand compare to others part. Indirectly, it shows that the used of the palm is very essential during driving activity.

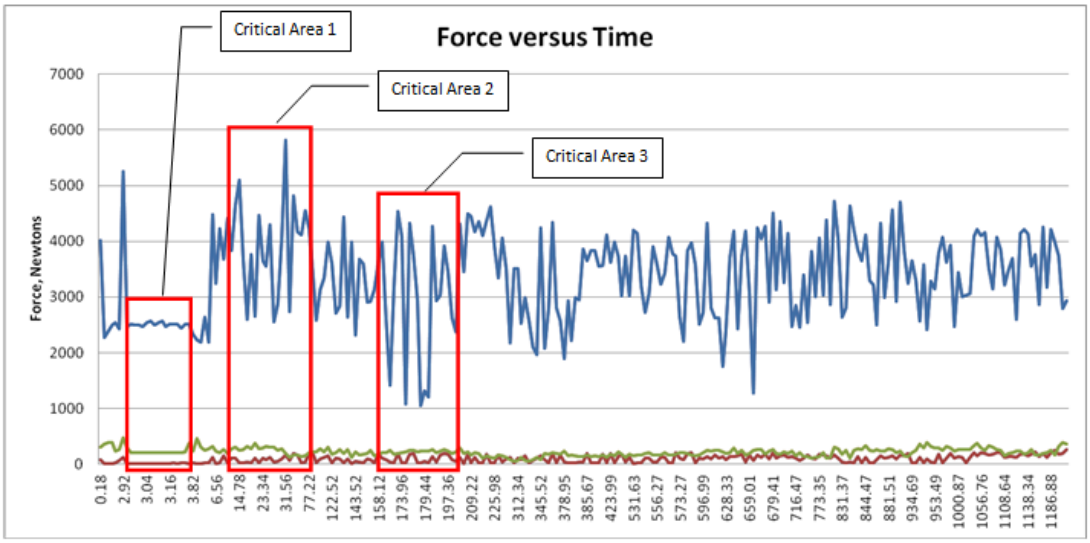

Fig. 5: Force versus Time's graph for left hand (Male).

The graph shows that the three critical areas for the hand grip force of the male's left hand. These three critical areas represent the lower and higher values of hand grip force. At critical area 1, the graph shows the almost constant or uniform values of hand grip force. This uniform values start from 2.96 seconds until 3.26 seconds. At this period of time, the driver drove through the straight and smooth road condition and the speed of the vehicle is slowed as the vehicles just moved from the starting point. The average values of the hand grip force are; 2510.90 N (palm), 219.33 N (fingers) and 18.31 N (thumb).

The critical area 2 represented the highest values of hand grip forces for the left hand. At this critical area, there are two point of that produced the high hand grip force; 14.78 seconds and 31.56 seconds. . Table 3 shows the values of the force for the both points.

Table 3: Hand grip force for both points.

Part Time (sec)	Palm	Thumb	Fingers
14.78	5102.81 N	22.08 N	248.22 N
31.56	5813..63 N	167.51 N	193.53 N

At 14.78 second, the high values of the force produced as the driver turns to the right as to overtake the vehicles. Hence, the left hand will push or grasp the steering wheel to the right and this make the force of the hand become higher.

The high reading of hand grip force was identified at 31.56 second of the journey for the left hand. This high value of the force is caused by the condition of the road which the road surface perforated and uneven. This forces the driver to hold the steering wheel stronger than usual in order to control the car from endangering others road users.

At the critical area 3, there are two point or road conditions that interested to be highlighted. First, during the 172.14 seconds and 177.28 seconds of the journey shows the high values of the forces were produced. Table 4 summarizes the force values of both points

Table 4: The summarization of the hand grip forces for the both points.

Part Time (sec)	Palm	Thumb	Fingers
172.14	4532.89 N	197.59 N	197.52 N
177.28	4319.09 N	175.50 N	250.94 N

These two high values of hand grip forces at these times are caused by the high impact vibration. This vibration produces by the road or bridge expansion joint as the car through this road expansion joint. The driver has to grip the steering wheel stronger to keep the car in the stable or in the lane.

This critical area also produced the low values of the hand grip force for left hand. At 179.10 seconds, the graph shows the lowest force; 1045.63 N (palm), 23.68 N (Thumb) and 235.96 N (Fingers). This happened because during that time the driver drove the vehicle through the straight and smooth road conditions. Hence, the driver grips the steering wheel with low force to handle the vehicle.

For the right hand grip force of the male driver, three critical areas have been identified. Figure 6 shows the hand grip force for the right hand.

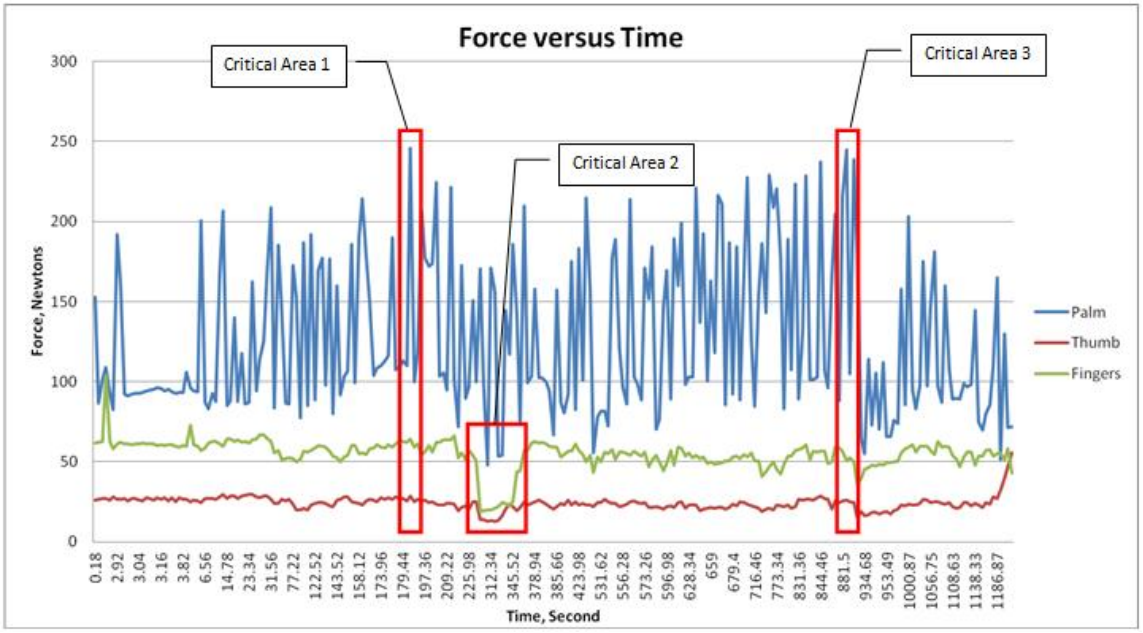

Fig. 6: Force versus Time's graph for right hand (Male).

At critical area 1, the graph shows the high value of hand grip force for the right hand at 181.18 seconds. All the hand's parts produced the high force; 246.06 N for palm, 28.35 N for thumb and 64.22 N for fingers. The high force is caused by some reasons. The first reason is the driver steer or turn to the left. The right hand pushes the steering wheel to the left while the left hand acts as the supporter hand. These actions caused the force to be high at the right hand compared to the left hand. Another reason is the vibration of the car during this time. This vibration is caused by the perforated and uneven road surface. Besides, the road expansion joint also contribute to the vibration of the steering wheel as the car through the flyover on that time. These combinations of the reasons affect the value of hand grip forces especially for the right hand.

For the critical area 2, the graph shows that the forces decline from 303.22 seconds until 362.42 seconds. By referring to the video recording, it shows that the hand grip force drop because the car stop at the traffic light junction. The car stooped for 60.2 seconds which caused the force to be decline. The driver grips the steering wheel with the weak forces. Hence, the low force produced from that action. All three parts of the hand produced the low hand grip forces.

While for the critical area 3, the high hand grip forces were produced by the right hand at 887.30 seconds. All the three parts of the hand produced the high forces; 244.79 N for palm, 26.04 N for thumb and 50.45 N for fingers. The video recording that have been taken during this time shows that this high forces produced by the action of pushing the brake's pedal as the car was ready to stop at the traffic light junction. The driver has to grip the steering wheel stronger in order to control the stability of the car and keep the car in the right track or lane.

The result continues with the analysis of the female driver for both hands. Figure 7 shows the Force versus Time's graph of hand grip force for the left hand. Three critical areas have been detected from this graph. This graph shows that the fingers of the left hand produced more force compared to palm and thumb. However, the differences between the force values of the fingers and palm is very small. Hence, it can be concluded that the fingers and palm of the hand is more important while driving the vehicle compared to thumb of the hand as it produced less forces.

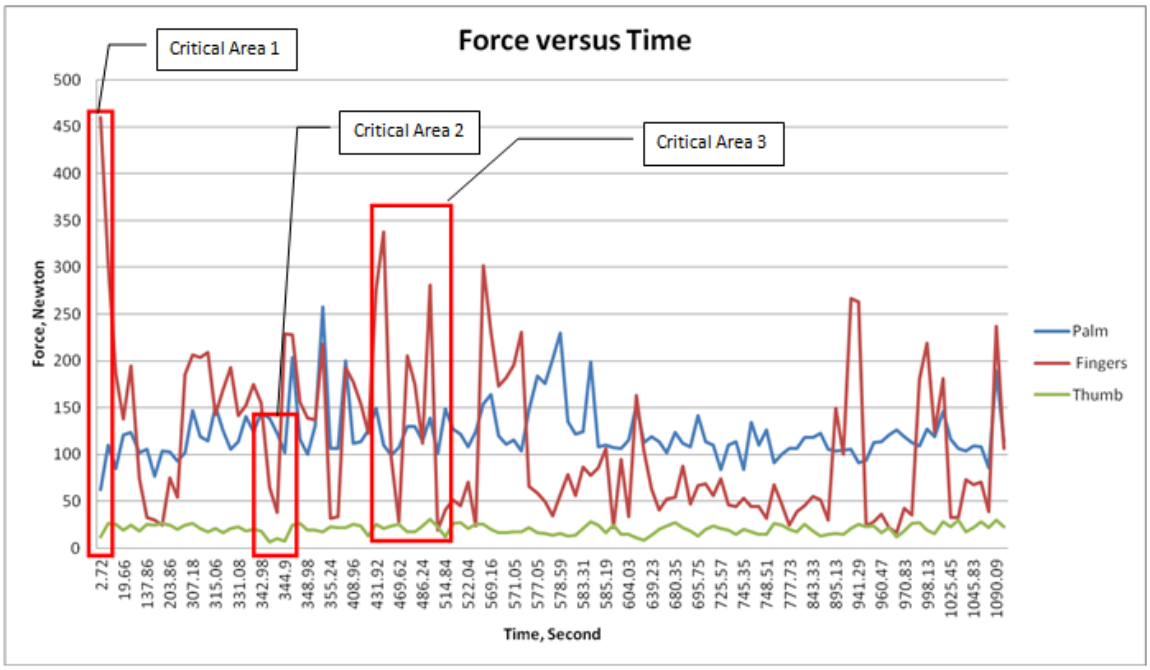

Fig. 7: The critical areas of the hand grip force for the left hand of female driver.

At critical area 1 for the left hand grip force of female, there are two points have been highlighted in this analysis. First, the highest force of the left hand happened at 2.72 seconds. The fingers of the hand recorded the highest force with 459.75 N, followed by the palm (62.18 N) and thumb (12.49). During this time, the vehicle drive by the driver exit from the junction and corner to left. This situation caused the force to be high as the driver has to grip more on steering wheel to control the vehicle. Figure 16 shows the situation of the road and driver at 2.72 seconds.

Another point is at 7.40 seconds as the same situation with the first point. It is continuity from the first situation but at this time the driver have to straighten the steering wheel to sure that the vehicle is on right track or lane. At the same time have to push the brake pedal to control the vehicle. This caused the force to be high at this time; 304.76 N (fingers), 110.15 N (palm) and 26.9 N (thumb).

For the critical area 2, the force of the left hand dropped and recorded the low forces. This situation happened at 334.5 seconds until 343.82 seconds of the journey. Based on video recording, the vehicle went through the straight and smooth road conditions. Due to this situation, the hand grip force of the left hand dropped as low forces is needed to control the vehicle.

The critical area 3 highlighted two higher forces of the left hand. First, the high value of forces recorded at 433.46 seconds; 337.76 N (fingers), 109.95 N (palm) and 20.98 N (thumb). This is due to the driver overtake the other vehicles at the high speed and back to the slow lane (left lane). Second, the high force was identified at 495.66 seconds; 281.37 N (fingers), 138.72 N (palm) and 30.97 N (thumb). At this time, the driver have to gripped the steering wheel strongly as the vehicle downhill and corner to the right.

The result and discussion continues with the analysis of the right hand grip force for female driver. Figure 8 shows the Force versus Time's graph. Three critical areas have been identified in this graph.

The critical area 1 shows that the hand grip forces at 59.26 seconds until 108.64 seconds recorded the low values of forces. This is because, the vehicle is stop or in stationary condition as it stop at the traffic light junction. Besides, the low force of the right hand was identified at 137.86 seconds. The hand grip forces value for palm is 6.39 N, 2.07 N for fingers and 0.67 N for thumb. This happened due to the condition of the road as the vehicle through the smooth and straight conditions. Hence, it easier for the driver to control the vehicle without applies a lot force to grip the steering wheel.

At the critical area 2, the highest force is produced by the right hand of female driver at 698.59 seconds; 49.80 N (palm), 22.25 N (fingers) and 2.20 N (thumb). This highest hand grip force produced due to the several reasons. First reason is the condition of the road which the road turning to left. Hence, the right hand has to push the steering wheel to the left more strongly compared to the left hand which acts as the supported hand. Besides, at the same time the vehicle followed the front vehicles closely. This make the driver have to be more cautious and ready to push brake pedal when the front vehicle stop or slow down. Indirectly, the driver grips the steering wheel strongly than usual. Figure 9

shows the situation at 698.59 seconds.

For the critical area 3, another high value of force was produced by the right hand at 1082.55 seconds; 47.89 N (palm), 26.07 N (fingers) and 2.60 N (thumb). During this time, the vehicle turns to the right to enter the junction. In this case, the right hand produced more force compare to the left hand because the turn is too sharp. Hence, the right hand has to pull the steering wheel to the right with the hard gripped. Indirectly, the force of the right hand becomes high.

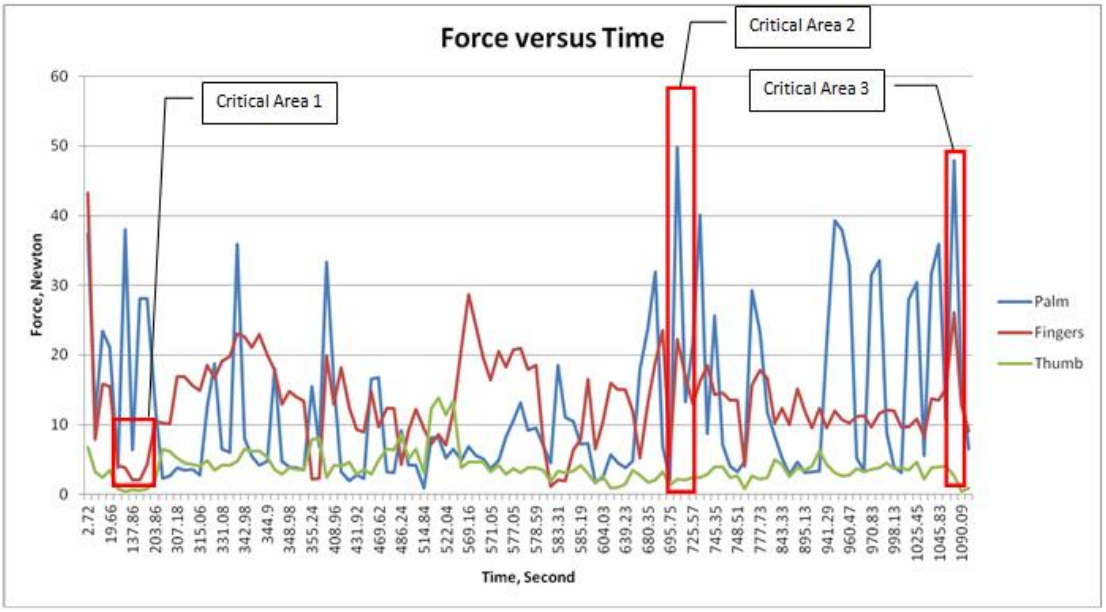

Fig. 8: Force versus time's graph for the right hand of female driver.

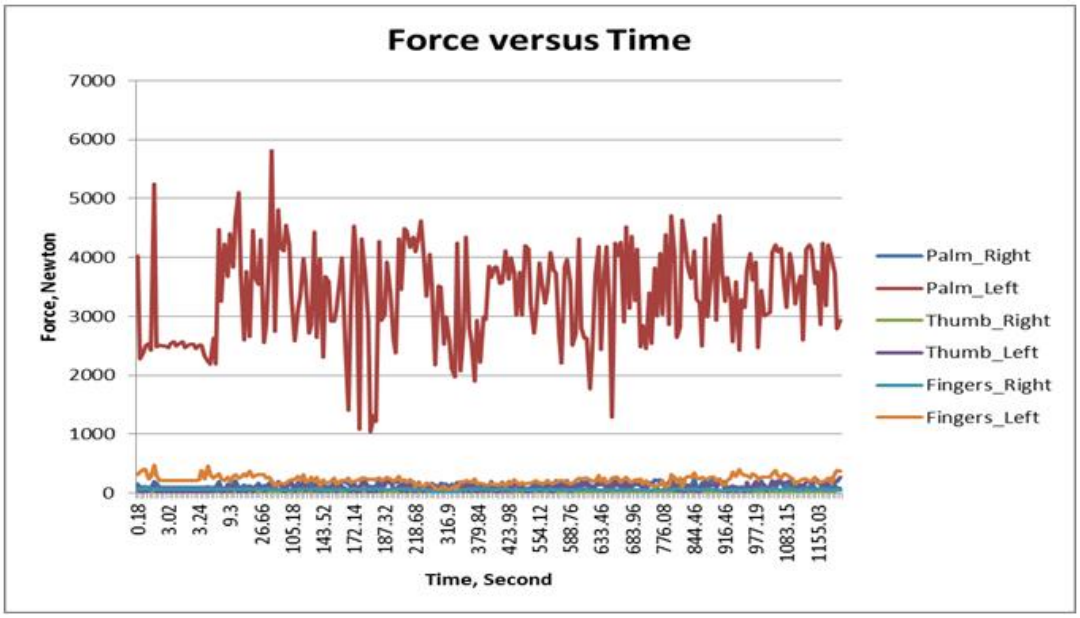

Fig. 10: The comparison between hand grip forces for both hands of male.

Hand Grip Pressure Force with Respect to Side of the Hand:

This research analyzed and discussed continues with the relationship between the left hand grip forces with the right hand grip forces for both genders. The purpose of this section is to make a comparison between the left hand grip forces with the right hand grip forces. Besides, this research makes a conclusion which the sides of the hand produce more forces while driving in certain conditions and environments. The graph of the left hand grip forces was compared with the right hand grip forces. The part of the both hands is compared and the graph is constructed using the Microsoft

Excel as shown in Figure 10 for male driver and Figure 11 for female driver.

Both graphs shows that all parts of the left hand produced more forces compared to the right hand grip forces. The range between the forces of the left and the right hand are too big especially for the part of palm followed by fingers and thumb.

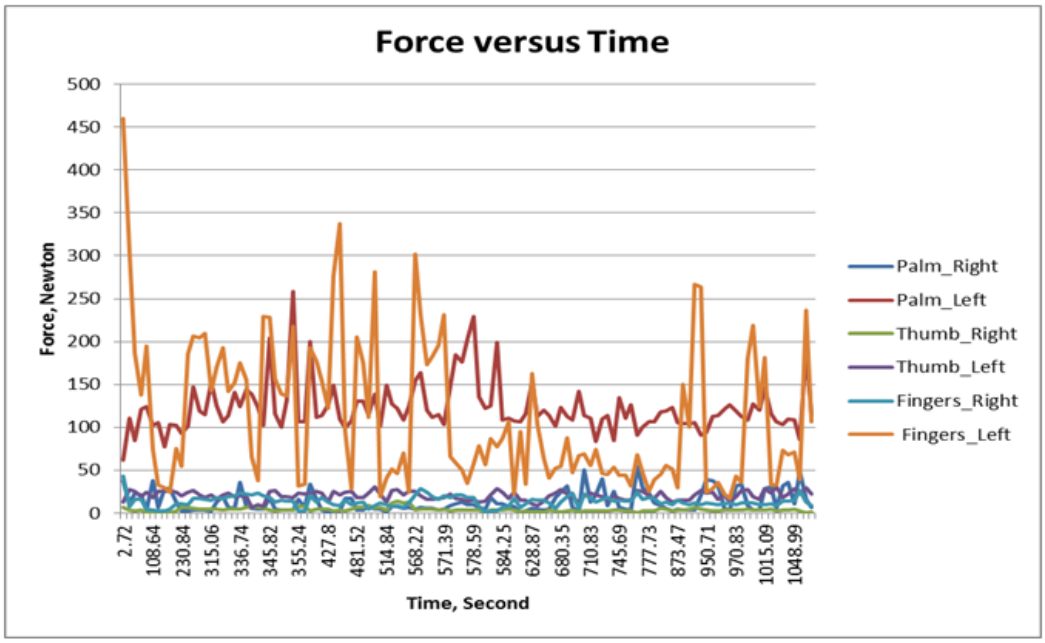

Fig. 11: The comparison between hand grip forces for right and left hand of female.

Conclusion:

This study was conducted to gather steering wheel hand grip force data from everyday drivers while driving in certain and different road conditions and situations. Tekscan tactile grip force and pressure measurement glove was used as the measuring device with a Tekscan software and Microsoft Excel. The result of this study showed that the left hand of both genders produced more hand grip forces compared to right hand of both genders. However, male drivers produced more hand grip forces compared to female drivers. This research concluded that the left hand have a higher risky to be fatigue or injured as it produced more forces and been used more frequently compared to the right hand. It shows that, during driving activity the right hand more acts as the supporter hand in control the steering wheel. The left hand grips the steering wheel stronger than the right hand. In case of driving the manual car, the left hand also been used more often as the left hand have to control the hand brake, gear knob and others system. Besides, this research shows that the palm of the hand produced more forces compared to fingers and thumb. Hence, the palm of the hands is very essential while driving and the assumptions can be made here is handicapped people who lost their fingers or thumb can drive the vehicles like normal peoples. For the future study, the researcher can make the comparison between hand grip forces of the real practice driving study on the actual road with the hand grip force of the simulator driving study.

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