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Relationship between Driver's Dynamic Pressure Distribution with their Anthropometric Variables on Car Seat under Paved Road

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Abstract: Driving is a task that requires physical and emotional demands of the driver to control the car while sitting. The driver's condition may be affect due to this repetitive driving task, which can be determined through the performance of alertness, signs of discomfort as well as fatigue level experience by the driver. Past studies showed that anthropometric variable is one of the factor in determining human's performance while performing an activity. However, there is still a lack of systematic explanation on how it relates to driving activity under different road conditions. Thus, this research objectives to determine the relationship between selected driver's anthropometric variables with dynamic pressure distribution experienced on the car seat while driving on paved road under normal driving task. A total of 44 subjects participated in this study. Tactilus pressure sensor was used to record the pattern of pressure distribution while driving. Based on the finding, there is a mild correlation with r=0.61 and ($R^2 = 0.38$) between dynamic pressure on the right thigh with height and weight of the subject. The study revealed that nearly 40 percent of the variance in the dynamic pressure on the left thigh is predictable from the height and weight of the subject.

Keywords: Car seat, pressure distribution, anthropometric, discomfort

1. Introduction

Nowdays, when looking at a car market, customers demand an extra quality factor which does not only depends on the engine and body shape, but the interior materials, trim and fixtures including the comfortability of the product. Improving driver's comfortness has grown a lot of attention with the advancement of technology in the automotive industry. There are several aspects that contribute to discomfort during driving involving both the driver and interior components such as seat, steering wheel, gear, pedal as well as driving tasks [1]. In addition, the condition of the road and the driving duration will also influence the comfort level of the driver.

The near static or minimum static movement, posture, particularly in prolonged sitting in confined space while driving causes discomfort and fatigue because of high muscular pressure from the driver's weight [2]. Ebe mentioned in [3] that driving posture, surface pressure with heat and moisture from the seat influence the driver comfort. Furthermore, [4] mentioned that longer driving and discomfort have an impact on driving performance and health issues such as pain in buttock, neck and back. Furthermore, road surface and other innerside factor such as psychological and spiritual [5] can also influence comfort and safety during driving. An odd seating posture and high vibration experienced during driving can increase the risk to musculoskeletal disruption. In the past, numerous studies have been conducted on driving position. Mixed methods and tools have also been widely used to evaluate drivers' condition. However, there are limited studies that have been conducted to evaluate the effect of the dynamic pressure on the driver's condition. In this case, dynamic pressure refers to the pressure sensation experienced by the driver when driving on the road. A majority of the studies related to pressure measurement on the car seat focused on the static condition.

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Besides, the attention on the driver's state among Malaysian is still in the early stage [6] and although it is important to develop Malaysia's own anthropometric data base for Malaysian preferred and comfortable range, the effort is still minimum [7]. Mohammad in [7] proposed a set of comfortable dimensions for driver's seat: backrest width (480 mm) and height (646 mm); cushion width (503 mm) and length (381 mm) which is based from 1312 respondents.

The anthropometric features incorporate the human body size. This feature has an impact on the seat design by ensuring the occupants' posture while sitting on the seat is comfortable. The sitting posture has a linear measurement with the sitting height, total height, vertebral column or arm span in the limb angle joint [8]. There are a few considerations during designing the seat, such as driver anthropometry, posture and shape of seat which can affect the drivers' comfort and safety. In the early stage of seat design, it should be integrated with the backrest adjustment, seat pan adaptation, route preference, and pathway locomotion to fabricate the seat perfectly [9].

Anthropometrics parameters contribute an important part in determining the impact and health not only to the people in the working environment [10,11] but also on the driver [12,13]. For instance, the Body Mass Index (BMI) as well as the weight and height ratio provide consequence to the body pressure whenever the seat is in contact with the buttock area. The contact zone between the seat with the human body illustrate the body pressure distribution interface and can provide an indication of the comfort sign towards the occupant [14].

For daily driving activities, the interface pressure distribution occurred at the back, buttock, and legs. While driving, discomfort between the seat and feet caused by vibration are transmitted to the upper legs leading to distraction at the thigh area [15]. Both dynamic and static situations should be considered to control the pressure distribution that cause the human body and seat discomfort [16].

Discomfort normally occurs in the legs, back and buttocks during driving and produce tense muscles. The driver might change their sitting posture or taking some break to release the stress of muscles. The driver's sense discomfort will ameliorate the discomfort circumstances with repeated body movement. The effect of different stature drivers and lumbar support prominence on the driver postures developed the dynamic body pressure distribution and had the impact on body inconvenience and back discomfort determined by driving postures [17]. The variables of dynamic body pressure distribution can be used as a rate of occurrence the driver's motion

There are design factors that influenced the ergonomic of designing car seat such as posture, easily adjustable, and control vibration condition [18]. The interface of the human body and seat exposed to the pressure distribution under vibration affected the vehicle driver's health, comfort and services effectiveness of the drivers. The geometry of each parameter highly influenced the comfort, safety and efficiency of the seat design concept in term of ergonomic. The driver's posture could be adjusted vertically and switch their position once in a while to support the spine, relaxes the muscles under tension and alleviate the interface pressure [19].

Thus, the interaction between the driver with the car seat should be monitored in order to assess the driver's condition during driving. This research focuses on evaluating the discomfort of the driver based on the pressure interface on the car seat during the dynamic situation and their relation with the selected anthropometric data. This study can provide an additional information, especially when designing a seat to enhanced the comfort level experience of the user.

2. Methodology

For the anthropometric data, thirteen variables of body dimension were measured from forty-four respondents involved before taking the driving experiments. All of them possessed driving licence and are in good health, which is free from musculoskeletal disease. All the respondents are between 22-24 years old, with a mean BMI of 18-25, and driving experience between 3 to 5 years. The respondents were measured in standing and sitting posture using the Human Body Measuring Kit and Anthropometry device

Fig. 1 shows the setup between the driver and Tactilus Pressure Mat and an example of a road pavement that was chosen to be driven on. The distance between the leg and pedal, back seat angle and steering distance was adjusted according to the drivers' comfort before the start of the experiment but within the specific range allowed. Drivers are also allowed to adjust their seats so as to feel more comfortable, safe and efficient. The backrest was adjusted to recline at 100^{o} in order to decrease pressure and provide support for lumbar. In order to determine the correlation between the seat pan and human body, the respondent must first sit in the perfect driving posture. An automatic-transmission standard Malaysia manufacturer brand car was used in the experiment to represent general car used by Malaysian.

The pressure mat was from Sensor Products Incorporations (*SPI*) which consists of 22 x 22 sensor pad calibrated from 0 to 5 pounds per square inch with 32 x 32 sensor matrix. The interface pressure uses thin and flexible sensor arrays. The scanning electronics are packaged in a handle assembly that clips onto the sensor's interface tab and provides the electrical connection to each sensing cell. The respondent then will drive at the chosen paved road within the range of 20-30km/h with the *SPI* measured at 30 frame per second.

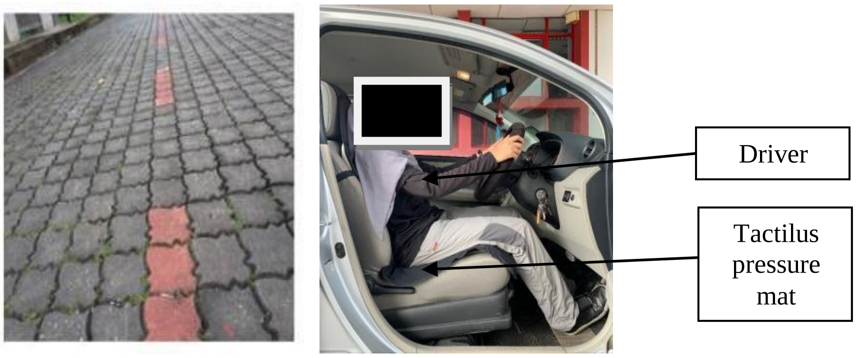

Fig. 1- Example of paved road chosen and the experimental setup

The pressure distribution configuration can be established and calculate the occupant discomfort. Pressure measurement is sensitive to any changes of varied angulation of the body postural. The pressure also has a good relationship with subjective comforts by determining the average ratio, the maximum, and the gradient for the pressure [20]. The measurement of pressure is derived from the force and the area of seating interface. If the force over area is high, the pressure will be high [21].

3. Results and Discussion

Anthropometry Result

The anthropometric data for male respondents and female is recorded and results show that male have a high mean value compared to female in all dimensions except for the length from buttock to popliteal as shown in Table 1. This may be due to biological aspects of the female body. Popliteal part is one of the soft tissue inside the human body. Females person generally has a larger size in this part compared to males. According to Table 2 which is related to seat adjustment variables, male had a higher mean value compared to female. These findings can be related to Table 1, which indicated that subjects with a larger or bigger size of body parts such as height, and height of popliteal are likely to adjust the seat and backrest a bit far away from the steering wheel. It is in line with an earlier study that mentioned driving posture can be categorized according to gender. Woman prefer to drive with closer position to the steering wheel, while man is different [22]. In addition, upper-body sitting strategies has significant effect based from his driver's gender, where female drivers prefer to drive with erect position, while male driver tend to drive in reclined position [23].

Table 1- Selected anthropometric data for male and female respondents

Dimension	Female		Male	
	Mean	Standard Deviation	Mean	Standard Deviation
Height	156.33	4.52	170.43	8.85
Weight	52.85	6.27	63.90	9.02
Buttock length to popliteal	46.20	1.87	46.16	2.38
Buttock length	36.27	2.19	37.82	2.38
Popliteal height	40.55	1.56	42.41	3.57

Table 2- Seat parameter adjustment for male and female

Dimension (kg,cm)	Female		Male	
	Mean	Standard Deviation	Mean	Standard Deviation
Angle between legs	36.48	4.62	51.86	6.81
Angle between stomach to thigh	102.7	5.17	104.38	4.64
Angle between thigh to leg	95.61	8.27	96.71	12.71

Pressure Distribution Result

Fig. 2 illustrates an example of the pressure distribution for the car seat, calculated with the Tactilus software. This data was then converted to Microsoft Excel. The scale colour will represent the pressure scale with red colour represent high pressure. Basically, lighter subject has slight stress concentrated under the ischium tuberosity muscle while heavier subjects will result more pressure data scattered in the buttock area. This statement is supported by a previous study which highlighted the pressure distribution data is produced according to the transmission of the human body weight by sitting over sitting bones (known as tuberosity ischium) and surrounding soft tissue on the seat [24].

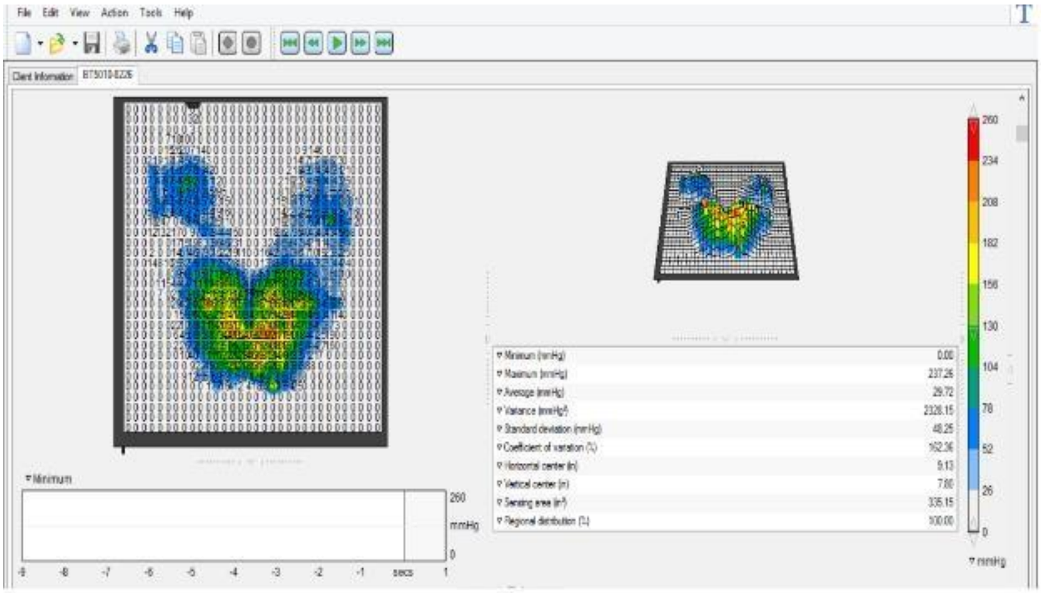

Fig. 2- Example pressure mat reading of Tactilus software

Table 3- The average pressure distribution on body part

Body Parts	Average Pressure Distribution (mmHg)
Thigh (Left)	0.35
Thigh (Right)	0.45
Buttock (Left)	0.75
Buttock (Right)	0.98

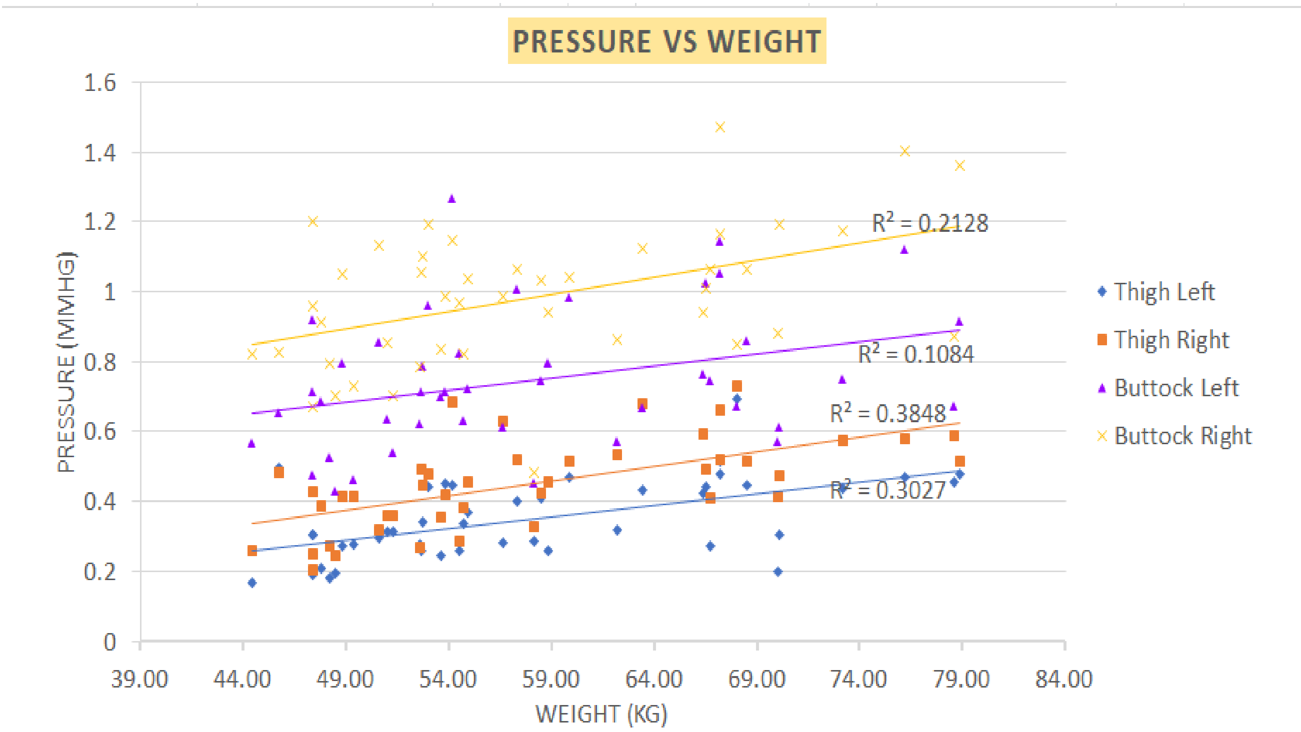

Fig. 3- Correlation between average pressure at the car seat with weight

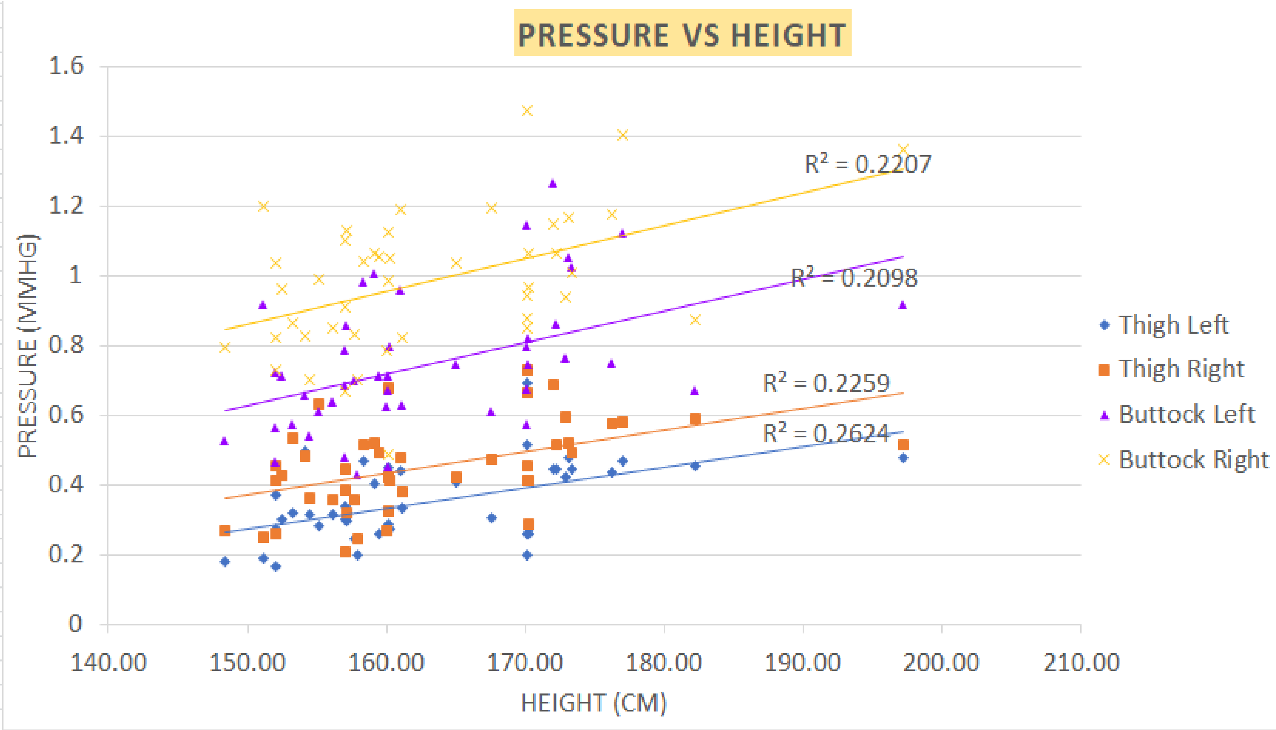

Fig. 4- Correlation between average pressure at the car seat with height

The average pressure distribution shown in Table 3 noted that the right buttock had the highest pressured value at 0.98 mmHg and followed by the left buttock with a value of 0.75 mmHg. In contrast, the left thigh recorded an average value 0.35 of mmHg and right thigh of 0.45 mmHg. This is due to the size of the human buttock area which is bigger than the thigh. In fact, the weight of the buttock is greater than the thigh. Statistical analysis was been done to determine the correlation between each variable. Correlation between the pressure distribution measurements with selected anthropometric variables were conducted by using Microsoft Excel and SPSS.

In general, the R^2 values in figure 3 and 4 are quite low. However, it is as expected since in some field, especially when to predict the behavior of human, such as psychology, R-squared will typically result values lower than 50%. That indicates, humans are simply harder to predict than, say, physical processes. Yet, there is a mild correlation between the dynamic pressure distribution under paved road driving conditions at the right thigh and the weight of the respondent ($r=0.60$, $p<0.05$) with value of R^2 is 0.38. There is also a mild correlation between the left thigh average pressure distribution with the weight of the respondent with $R^2=0.40$. This anthropometric variable is modelled in the linear regression form to predict the pressure on the left thigh under dynamic driving condition based on the weight of the driver as shown in figure 3. This study mentioned that the loading experienced by the seat is solely caused by the weight of the seat occupant [25].

Furthermore, there also a mild correlation between right thigh and left thigh pressure distribution with the height as shown in fig. 4. All in all, the variations in body dimension of each population in different countries such as age, gender and body type could contribute to significant difference in anthropometric data [26, 27,28]. Based from the average pressure distribution value and their relationship with some of anthropometry data, it is known that local anthropometry data may be used to providing comfortness in seat design. For instance, local manufactured car can improve their seat design by considering that there was different pressure experienced between left and right buttock and also left and right thigh. Thus maybe enhancement in seat design can be considered either the material chosen, shape of the car seat and thickness of the seat. Local anthropometry data need to be considered because different countries will have a different set of dimension for their people. There is a lot of factor that contribute to the variety of this anthropometry data such as gender, location, culture, food intake and many more. Generalizing a set of design between countries will result in satisfaction for people in one country but not in the others.

4. Conclusion

Pressure distribution measurement has the ability to deliver a systematic method to find the correlation between the human body and the car seat. Human body variants or known as anthropometric parameters are very unique and varied. These parameters provide significant impact on various activities and tasks. By analyzing the measurement from pressure distribution, car seat design could be improved. A decent pressure dissemination can decrease discomfort sense, and ache. This is by producing a favourable pattern of pressure distribution that can decrease the load concentration, and hence the blood flow of the driver expected will be smoother. In this study, anthropometric parameters show significant impact in determining the average pressure while sitting on the car seat under the paved road condition. In addition, this study was conducted under dynamic circumstance where the driver was required to perform normal driving in a short distance of paved road. Based from the results, there is a mild relation between thigh pressure distribution with height and weight of the respondent and lower in relation to the buttock. In this study, pressure distribution pattern also was being influenced by the driving position. The car used in this experiment was an automatic transmission car. In this case, the right part of the driver (right buttock and right thigh) tended to move more due to acceleration and brake control, which resulted in more average pressure in the right body part compared to the left. To conclude, comfortable while driving are influenced by a lot of factors which including the physical characteristics of the driver, accurate body form, a decent ergonomic car seat design and driver's workspace position. The car seat design that featuring a good pressure distribution scattered at the seat contact to support the driver weight may produce the maximum relaxed seating condition.

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