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Effects of Anthropometric Towards Interface Pressure Variables and Design Optimization on the Car Seat

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ABSTRACT

The design optimisation of car seats is vital in ensuring comfort and safety whilst driving. The main aim of this study is to determine the relationship between anthropometric parameters, interface pressure on car seats and driver's safety in a preferred driving position. A pressure-map sensor was used to identify the pressure patterns on the car seat. Results indicate significant relationships were found between interface pressure of car seat and certain anthropometrics dimension. A strong correlation was established amongst body mass, body mass index and interface pressure at certain body parts, with r of nearly 0.50. Majority of the anthropometric dimensions and interface pressure show medium correlations between 0.31 and 0.49. The established relationship helps to estimate the perceived comfort and safety related to the car seat design. Hence, this guideline can help to prevent driver's fatigue by considering the elements of anthropometrics and interface pressure in the car seat design.

Keywords: Anthropometric; pressure; design; car seat; comfort

INTRODUCTION

The number of vehicle ownership is increasing worldwide, with vehicles becoming a major necessity amongst families. Nowadays, vehicle ownership is not simply a sign of luxury. Hence, user demand needs to be considered in the development of vehicles. Given the increasing demand for comfort and safety in vehicle design, automotive manufacturers have continuously aimed to improve the quality of their vehicles. Manufacturers are also presently adopting ergonomic elements in their design. The interactions of driver, driving task and design of vehicle components are extremely vital in ensuring balance in comfort, pleasure and safety whilst driving (Guo et al. 2016; Mohd Mohid and Khamis, 2018). At present, the demand from users to consider seating comfort in car seat design is high. In attracting users, seat designs should consider elements that influence the experience of comfort and safety level of users. A good seat should allow people to feel pleasant after sitting for few minutes and without experiencing discomfort.

Sitting comfort can be influenced by numerous factors. The comfort theories issued by several human factor experts describe the comfort feeling as an enjoyable condition of the human body with respect to the physical environment (De Looze et al. 2003; Kyung and Nussbaum, 2008; Zhang et al. 1996). Seat design, user posture and their relationship with sitting assessment should be therefore studied. The past studies have generally concluded that three main features (task, seat and human) affect sitting comfort (De Looze et al. 2003; Kyung and Nussbaum 2008; Zhang et al. 1996; Mohamad et al. 2017; Fojtlin et al. 2018; Paul et al. 2012; Vink and Hallbeck 2012; Khamis et al. 2018; Hiemstra-van Mastrigt et al. 2017). In this study, the human role in the sitting comfort factors is related to the user. User characteristics are mainly affected by body dimensions, biomechanical factors and perception (Khamis et al. 2018; Hiemstra-van Mastrigt et al. 2017). Amongst the measurable and physical parameters, the anthropometric factor, also called body dimension, contributes to the comfort phase.

Anthropometry and ergonomics are the elementary knowledge of design in the process of formulating efficient humanistic products. The standards and related tools and methods of anthropometry are primarily based on the guidelines of the International Organization for Standardization (ISO) (ISO 2017; Norton 2020). Many anthropometric design guidelines are currently used in the interior design of vehicles. Nonetheless, the design and development of vehicle seats that consider anthropometric dimensions to benefit the users' perceived comfort and well-being have limited capabilities. Vehicle seat designs should consider the appropriate anthropometric dimensions in view of producing great innovation and invention that can offer comfort and safety in relation to the driving elements (Paul et al. 2012; Deros et al. 2015; Yusuff et al. 2009). The selection of different anthropometric parameters, such as gender, age and population, should be carefully planned in the design of vehicle components by considering the driving environment. Proper selection can potentially increase usability, productivity and comfort. In addition, the well-being of users outside of the driving activities should also be considered (Hanson et al. 2009; Peng et al. 2017; Sulaiman et al. 2016; Won et al. 2017; Linder et al. 2013; Kim et al. 2017; Tahir et al. 2020)

Due to this variation, additional assessments on sitting posture related to driving tasks must be conducted in order to provide supplementary support regarding the relationships of comfort, anthropometric and other related parameters. Sitting assessments can be implemented by considering many parameters. Nevertheless, pressure analysis is the frequently used objective method of determining rapid results (Khamis et al. 2018; Tahir et al. 2020; Park et al. 2014; Mitsuya et al. 2019; Jones et al. 2017; Zemp et al. 2015). Pressure map analysis can provide an assessment between body and seat interface. This analytical technique can also describe how forces are exchanged between human and seat parameters. Pressure assessment is sensitive to postural changes and can describe the good correlation with subjective comfort (Park et al. 2014; Zemp et al. 2015). Inadequately supported body posture in sitting position for a prolonged time results in a discomfort sensation, which in turn may lead to injury (Rohlmann et al. 2011). Given these potentially adverse impacts, the development and design of car seats should be carefully and comprehensively investigated by linking all parameters related to users and driving conditions.

Hence, the aim of this study is to investigate the relationship between pressure distribution variables and anthropometric variables with respect to car seats under static condition whilst drivers perform a normal driving task. The findings can be used to materialise an ideal solution for automotive manufacturers when designing seats with ergonomic elements. Using this context, three research questions (RQ) have been formulated in detail by evaluating its relationship, as follows:

RQ1:What are differences of anthropometric and interface pressure variables between female and male participants.
RQ2: How anthropometric influence interface pressure variables under static driving condition?
RQ3: How anthropometrics and interface pressure help to optimize the car seat's design and improve driver's safety.

METHODOLOGY

PARTICIPANTS

This study involved 44 volunteers (21 males and 23 females) with mean age = 24 years old, mean BMI = 21.85 kg/m2, mean height = 162.62 cm and mean weight = 58.12 kg. This study was performed in Universiti Kebangsaan Malaysia (UKM), involving university students. The targeted eligible participants possessed valid driving licenses for at least three years and had not reported musculoskeletal disorders. All participants were requested to sign an informed consent form prior involvement, and the successful respondents were provided with a token of appreciation. The procedure and protocol of this study was approved and granted by the Ethical Committee from UKM, with reference number UKM PPI/111/8/JEP-2019-529.

EXPERIMENT DESIGN AND PROCEDURE

A field-based session was conducted in a real environment by using a driver's car seat of one of the locally manufactured compact cars. The car seat was made of a fabric material. Prior to the measurement session, each participant underwent a consent procedure and was given an overview on the purpose of the experiment and the expected result to be obtained from their participation. The participants were advised to wear light clothes for reliable and accurate data gathering. The anthropometry measurements were taken in the Faculty of Engineering and Built Environment, UKM. Then, after the participants were instructed to take enough rest and a break, each of them was required to sit on the driver's car seat outside the laboratory by adapting to a preferred driving position. Proper gap and break time between each participant's interface pressure analysis was implemented to ensure that the surface of the seat had returned back to normal condition.

ANTHROPOMETRY MEASUREMENT

The linear body landmarks of the dimensions in standing and sitting postures are shown in Table 1 and Figure 1. Twelve dimensions, as recommended by Kroemer et al. (2010) were chosen in this study according to the body parts that come in contact with the car seat surface. Each participant was instructed to stand and sit properly on the chair whilst the measurements were recorded using a measuring tape and an anthropometer. The measurements were based on the guidelines recommended by ISO 7250-1:2008 (MS 2008). Stature and weight measurements were performed in the standing posture. Ten measurements including six heights, two lengths, one breadth and one thickness, were taken in the sitting posture.

Table 1. Landmarks and human body measurements

No.	Parameter measurements (see Fig.1)
1	Stature (1)
2	Body mass (2)
3	Sitting height (3)
4	Sitting eye height (4)
5	Sitting shoulder height (5)
6	Sitting waist height (6)
7	Sitting thigh thickness (7)
8	Sitting knee height (8)
9	Sitting popliteal height (9)
10	Buttock to knee length, sitting (10)
11	Buttock to popliteal length, sitting (11)
12	Hip breadth, sitting (12)

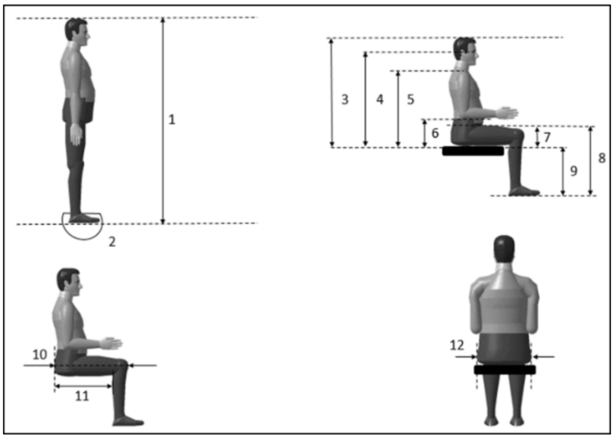


FIGURE 1. Body landmarks for anthropometric measurement while sitting and standing.

Pressure distribution is one of the objective evaluation metrics of comfort and discomfort circumferences. The participants were instructed to wear appropriate clothing and remove items from their back pockets before sitting on the car seat. Each participant sat on the car seat in a real environment. Tactilus® pressure mapping with a 32 × 32 sensor matrix from Sensor Products Inc. was used to measure the interface pressure between the participant's body parts and the car seat surface. The method in this study was designed to produce data on the axial force, which is perpendicular to the interface. Then, the participants were instructed to sit down and familiarise themselves with the car seat and pressure map. In this manner, the participant's most comfortable driving position could be determined. Pressure measurements were performed for five minutes under static condition, with each participant's body leaning on the backrest, both legs on the accelerator and pedal and both hands grasping the steering wheel at the 10 and 2 o'clock positions. The participant's right leg was placed on the accelerator pedal, whereas the left foot was rested on the floor near the clutch pedal. Each participant was not allowed to move or change position whilst on the car seat. This action was required to ensure that the pressure measurement could be recorded on the basis of the driving task under static condition. The pressure map data was subsequently transferred to Microsoft Excel for analyses.

DATA ANALYSIS

Pressure distribution was also measured, and the result from the Tactilus® software was also transferred to Microsoft Excel for analysis. Interface pressure was evaluated using the four body parts that mostly contacted the pressure map. Then, the result was analysed in Statistical Packages for Social Sciences (SPSS) version 23. Independent t-test was used to determine whether there was a difference in statistical differences exist between gender with anthropometric parameters and interface pressure. The anthropometric and interface pressure variables were used known as the dependent variable, whereas gender was used indicates as the independent variable. Then, two-tailed Pearson's correlation coefficients with two-tailed was used as the method to evaluate the result between anthropometric parameters and pressure distribution. The p-level of 0.05 was considered statistically significant of statistical procedures in all of the cases differences were considered p-levels at 0.05.

RESULTS AND DISCUSSION

This section presents the results for the anthropometric measurement, pressure distribution measurement and relationship between anthropometric and pressure distribution data.

ANTHROPOMETRIC RESULTS

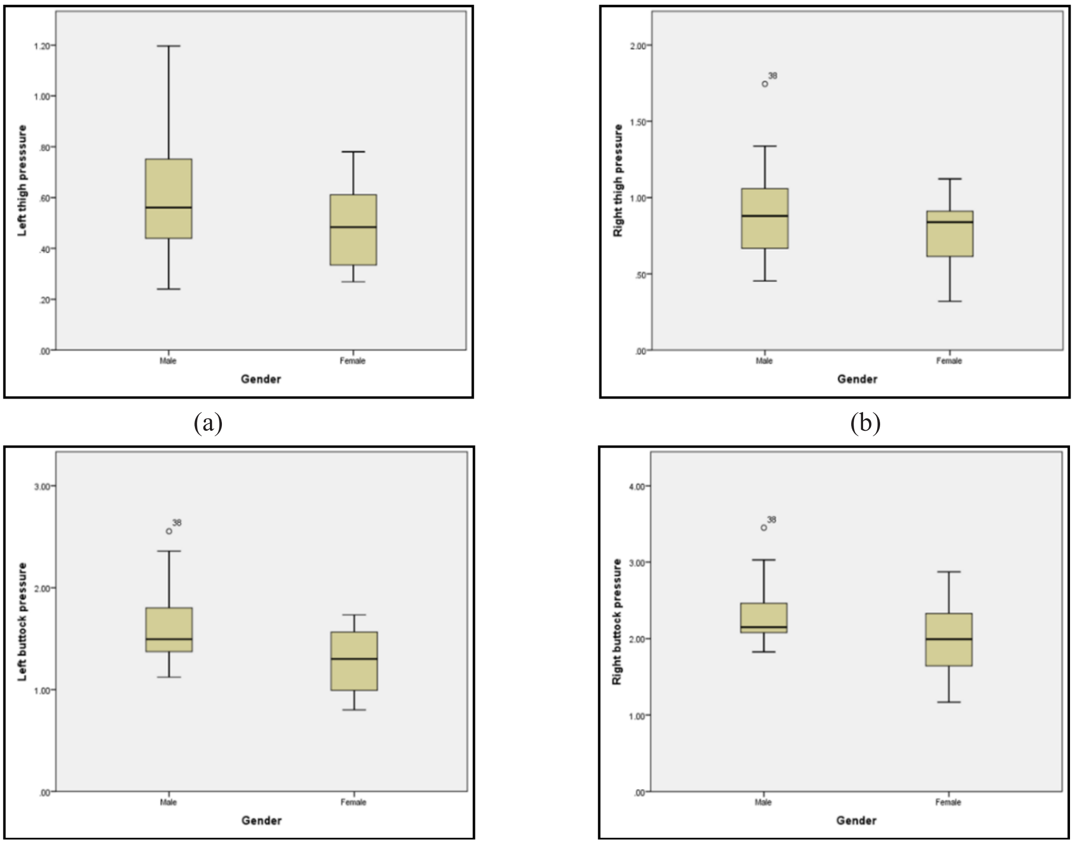
This study collected 12 anthropometric measurements on the basis of the parameter that was mostly attached on the seat interface. Table 2 shows the mean values, standard deviations and 5th and 95th percentiles of N = 44 participants for 12 body dimensions.

INTERFACE PRESSURE ON CAR SEAT

The pressure map analysed the pressure distribution related to most body contact to the seat pan and divided into four parts; left thigh, right thigh, left buttock and right buttock. Figure 2 shows the interface pressure value for both gender at four body parts; a) left thigh, b) right thigh, c) left buttock and d) right buttock. Figure 3 shows the pattern of pressure distribution from the software based on gender and BMI.

TABLE 2. Anthropometric dimension data

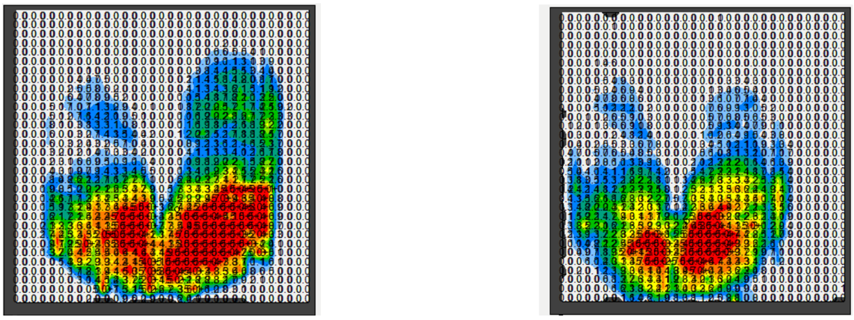
No.	Dimension	Mean (cm)		Standard deviation		5th percentile		95th percentile	
		Male	Female	Male	Female	Male	Female	Male	Female
1	Stature	170.43	156.33	6.64	4.52	158.45	148.92	181.75	168.31
2	Body mass	63.90	52.85	9.02	6.27	49.19	44.70	78.87	68.71
3	Sitting height	85.02	78.76	4.06	3.24	79.27	72.78	91.12	85.83
4	Sitting eye height	73.40	68.67	3.86	2.70	67.25	65.09	80.05	74.01
5	Sitting shoulder height	55.06	52.32	2.90	2.17	50.27	48.04	60.03	55.49
6	Sitting waist height	17.01	16.74	1.41	1.78	14.29	13.81	19.39	19.71
7	Sitting thigh thickness	12.84	11.30	1.54	1.38	10.58	9.53	16.06	15.53
8	Sitting knee height	50.92	47.57	2.85	2.88	45.33	41.55	55.97	55.23
9	Sitting popliteal height	42.41	40.55	3.57	1.56	30.61	37.67	45.53	43.93
10	Buttock to knee length	56.24	55.37	2.99	2.17	51.93	51.56	63.73	61.67
11	Buttock to popliteal length	46.16	46.20	2.38	1.87	40.87	42.03	49.22	49.75
12	Hip breadth	37.82	36.71	2.38	3.53	33.97	33.05	43.04	47.95



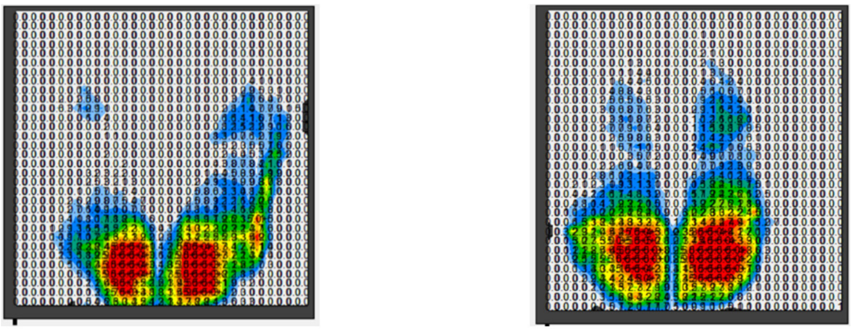
(a) (b)

(c) (d)

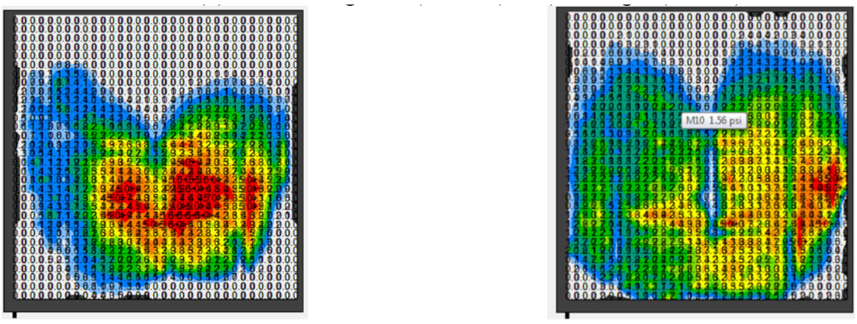
FIGURE 2. Interface pressure value based on gender



(a) Normal BMI – left (male) and right (female)



(b) Underweight BMI – left (male) and right (female)



(c) Overweight BMI – left (male) and right (female)

FIGURE 3. Pressure distribution pattern based on gender

TABLE 3. Independent t-test results for anthropometric variables with gender

		Levene's Test for Equality of Variances		t-test for Equality of Means		
		F	Sig.	t	df	Sig. (2-tailed)
Stature	Equal variances assumed	3.081	.086	6.743	42	.000
	Equal variances not assumed			6.562	29.153	.000
Body mass	Equal variances assumed	5.363	.026	4.753	42	.000
	Equal variances not assumed			4.677	35.316	.000
Sitting height	Equal variances assumed	3.463	.070	5.678	42	.000
	Equal variances not assumed			5.620	38.221	.000
Knee height	Equal variances assumed	.762	.388	3.870	42	.000
	Equal variances not assumed			3.872	41.714	.000
Shoulder height	Equal variances assumed	4.268	.045	3.566	42	.001
	Equal variances not assumed			3.519	36.888	.001
Eye height	Equal variances assumed	2.680	.109	4.743	42	.000
	Equal variances not assumed			4.668	35.418	.000

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Buttock-knee length	Equal variances assumed	3.708	.061	1.110	42	.273
	Equal variances not assumed			1.094	36.257	.281
Waist height	Equal variances assumed	2.311	.136	.558	42	.580
	Equal variances not assumed			.564	41.181	.576
Buttock-popliteal length	Equal variances assumed	1.850	.181	-.051	42	.960
	Equal variances not assumed			-.050	37.953	.960
Hip breadth	Equal variances assumed	2.777	.103	-.670	42	.507
	Equal variances not assumed			-.701	22.349	.491
Popliteal height	Equal variances assumed	4.483	.040	2.269	42	.028
	Equal variances not assumed			2.198	26.870	.037

TABLE 4. Independent t-test results for interface pressure variables with gender

		Levene's Test for Equality of Variances		t-test for Equality of Means		
		F	Sig.	t	df	Sig. (2-tailed)
Left thigh pressure	Equal variances assumed	2.191	.146	2.046	42	.047
	Equal variances not assumed			2.011	34.736	.052
Right thigh pressure	Equal variances assumed	1.205	.279	1.818	42	.076
	Equal variances not assumed			1.790	35.590	.082
Left buttock pressure	Equal variances assumed	.377	.542	3.154	42	.003
	Equal variances not assumed			3.123	38.447	.003
Right buttock pressure	Equal variances assumed	.929	.341	2.687	42	.010
	Equal variances not assumed			2.704	41.926	.010

DIFFERENCES IN GENDER WITH ANTHROPOMETRIC AND INTERFACE PRESSURE VARIABLES

Table 3 and Table 4 show independent-samples t-test results in gender for anthropometric and interface pressure variables, in which the difference between females and males was significant for certain mean variables. Table 3 shows the statistically significant differences between the two genders and some anthropometric variables. The results suggest that the variances in anthropometrics except for four parameters, namely, buttock–knee length, waist height, buttock–popliteal length and hip breadth, differ between females and males. Meanwhile, Table 4 shows the statistically significant differences between the two genders and interface pressure variables, namely, left thigh (t(42) = 2.046, p = 0.047), left buttock (left thigh (t(42) = 3.154, p = 0.003) and right buttock (t(42) = 2.687, p = 0.010). However, the variances between gender and right thigh are equal between females and males according to the Lavene's test.

RELATIONSHIP BETWEEN ANTHROPOMETRIC MEASUREMENT AND PRESSURE DISTRIBUTION

This study also measured the interface pressure of four body parts with anthropometric dimensions at the specific body parts under static condition. Table 5 shows the correlation analytic results of the relationship between anthropometric measurements and pressure distribution on the car seat used by the participant. A high degree of correlation was found between the left and right thighs with BMI and body mass ($r > 0.50$, $n = 44$, $p < 0.05$). Majority of the anthropometric dimensions and interface pressure at certain body parts showed a moderate degree of correlation, with r between 0.311 and 0.493 ($p < 0.05$). No correlations were found between specific mean pressure in relation to area and certain anthropometric dimensions, such as buttock–knee length, waist height, buttock–popliteal length, hip breadth and popliteal height, at $p > 0.05$.

TABLE 5. Correlation between anthropometric measurement and pressure distribution

Anthropometric r - Pressure Area	Left thigh	Right thigh	Left buttock	Right buttock
Stature	0.394**	0.341*	0.444**	0.358*
Body mass	0.528**	0.500**	0.281	0.311*
Sitting height	0.430**	0.438**	0.337*	0.330*
Knee height	0.108	0.134	0.157	0.109
Shoulder height	0.493**	0.482**	0.359*	0.351*
Eye height	0.397**	0.418**	0.323*	0.293
Buttock-knee length	0.097	0.136	-0.095	-0.049
Waist height	0.237	0.218	-0.130	-0.129
Buttock-popliteal length	-0.091	0.104	-0.204	-0.113
Hip breadth	-0.004	-0.022	-0.232	-0.286
Popliteal height	0.177	0.107	0.208	0.194
BMI	0.557**	0.520**	0.022	0.157

DISCUSSION

COMPARISON BETWEEN GENDERS

Anthropometric dimensions have been identified as an influencing factor of human–seat interface apart from seating comfort and safety. For majority of the body dimensions, the results of the female participants were smaller than those of the male participants based on mean value (Table 2). The variations in body configuration occur differently between the two genders and across various phases of aging, which subsequently influence anthropometry (Yusuff et al. 2009). In fact, as shown in Table 2, the statures or heights and body masses of the female participants are much smaller than those of the male participants. However, the mean value and the 5th and 95th percentiles of the buttock to popliteal length have different value patterns (Table 2). The popliteal part is located in the knee and back of the leg. This part is one of the soft tissues with fat inside the human body, and females generally have a larger size in this part than males (Tahir et al. 2020). In this case, the female participants are show to be 0.04 to 1.2 cm larger than the male participants. The mean values are 46.16 and 46.20 cm for the male and female participants, with 40.87 and 42.03 cm at the 5th percentile and 49.22 and 49.75 cm at the 95th percentile, respectively. The findings indicate that when the combined user population is taken into account in design practice, the 5th percentile for the females and the 95th percentile for the males for the lower and upper values as a design limitation should also be considered. These specifications can help to accommodate the highest number of users with respect to seat and seat adjustment range. Studies conducted by Taifa and Desai (2017) highlighted that, there were high correlation between female and male at two parameters; buttock-popliteal length and buttock-knee length likewise to female students. However, this study has not mentioned another variable to correlate with, such as with pressure variables as conducted in the current study.

The differences between the two genders and human body compositions can also help to identify the potentiality of tissue perfusion and deformation and conclusively affect the design of the interface pressure distribution on the car seats. For instance, male and female subject measurements slightly vary in terms of anthropometry and body mass index (BMI) because of their difference in body composition (Yusuff et al. 2009). Consequently, the variation between the two genders can also affect the interfaces between upper body and seat pan and between seatback and head constraint, which may result in pain and risk of injury. This finding has been previously reported by Linder et al. (2013) citing that the mean pressure of a car seat with respect to gender could be attributed the body mass of the sitter. The findings in the present case refer to BMI information, which represents the measurement of body fat based on height and body mass. Localised pressure normally appears on the ischial tuberosity area and near the bony prominence where internal pressure is high (Zemp et al. 2015; Rohlmann et al. 2011; Kroemer et al.2010; Makhsous et al. 2012). The shape of the human back is also uneven, a condition that results in different pressures between the seat interface and the user's buttock at related areas. The variations in localised pressure, also known as pressure distribution, is influenced by numerous factors, such as seat shape, seat materials and the anatomical characteristics of the human buttock. Pressure distribution can provide considerable information on the average values of contact area and peak pressure at specific locations (Zemp et al. 2015).

The three main significant outputs of gender variation can be deduced from the interface pressure analysis (Figure 2). Firstly, the mean pressure values of the female participants for the four body parts mentioned above are smaller than those of the male participants, and the difference is nearly 0.2 mmHg pressure units. The males have exhibited higher pressure, as they have less fat in the buttocks. This condition may explain the cause of higher sensitivity amongst males compared with females in terms of seat interface. In addition, the lower average pressure result of the female participants is also associated with their lower mass besides their larger contact areas compared with their male counterparts. Pressure is derived from the force and area of the seating interface area. In this case, a linear correlation with mass can be observed. The higher is the force on the area, the higher is the pressure (Paul et al. 2012; Hiemstra-van Mastrigt et al. 2017; Tahir et al. 2020). Secondly, due to driving action task, great pressure is exerted on the right side of the participants. Given that the driving task is suited for right-hand cars, the participants expectedly exerted more pressure at the right side than in the left side to control the car. This finding can also be explained by the extra force exerted on the right side to press on the accelerator pedal whilst in the driving position. In this case, the finding refers to the participant's movement when pressing the accelerator pedal. The high pressure distribution amongst all subjects is more focused on the right buttock (male = 2.2 mmHg, female = 2 mmHg), then left buttock (male = 1.6 mmHg, female = 1.3 mmHg), followed by the right thigh (male = 0.9 mmHg, female = 0.8 mmHg) and left thigh area (male = 0.6 mmHg, female = 0.5 mmHg). Thirdly, the findings about interface pressure on the car seat indicates that different types of BMI have varying interface pressure patterns. BMI and body mass have significant effects on the contact area between the buttock and the seat even whilst sitting for a short duration. Thus, the onset of pressure distribution provides a clear relationship with the sitter's characteristics.

RELATIONSHIP BETWEEN ANTHROPOMETRIC AND INTERFACE PRESSURE VARIABLES

A Pearson product-moment correlation coefficient was computed to assess the relationship between anthropometric and interface pressure parameters. Regarding relationship between anthropometric dimension and interface pressure according to body parts (Table 5), the body mass and BMI parameters have a significant positive influence on the increase in maximum interface pressure. The contact area of the human body increases with r-value at above 0.50, which indicates strong correlation between the two variables. Body mass is generally considered the best anthropometric indicator of the seat pan contact area. However, in this study, a strong correlation exists only between body mass and mean pressure on the thighs but not on all of the limbs. This finding may be related to the driving conditions performed in static circumstances, in which a driver-participants have to lean against the back rest whilst holding the steering wheel and the right foot is on the pedals. Restricted movement and changes whilst collecting the pressure data may have also influenced this finding.

Stature, sitting height and shoulder height are shown to have a medium correlation with mean interface pressure. Nevertheless, these anthropometric dimensions are the most influencing parameters, with the pressure distribution amongst all body parts on the seat pan as most prominent for the left thigh, right thigh, left buttock and right buttock. The finding accords with the report of Peng et al. (2017) who cited that the stature group tended to be the same regardless of the trunk–thigh angle. The finding implies a significant impact on the driver, as the preferred posture is dependent on the seat characteristics.

Few past studies have also mentioned that buttock–popliteal length and hip breadth are amongst the other best parameters in predicting mean pressure other than using body mass and stature (Kyung and Nussbaum, 2013; Vincent et al. 2012). However, as shown in Table 5, no correlations exist between anthropometric dimensions and mean pressure for all of the lower body parts. This finding may be explained by the different characteristics, driving positions and seat characteristics adopted by the participant in the experiment. The current finding is different to the observation of Kyung and Nussbaum who worked with older subjects in their experiment. Yusuff et al. (2009) also reported that age plays an important role in determining the anthropometric dimensions. Vincent et al. used an office armchair to determine interface pressures in sitting position; however, their seat was designed using foam materials and with a different shape as that of the car seat used in this study (Vincent et al. 2012)

PRACTICAL IMPLICATIONS OF ANTHROPOMETRICS AND INTERFACE PRESSURE VARIABLES ASSESSMENT TOWARDS DESIGN OPTIMIZATION ON THE CAR SEAT

Pressure distribution measurement provides a systematic approach in determining the pressure relationship between human body and car seat. The outcome of this assessment offers a strong predictive ability of comfort to guide the management or control of preferable designs. The weaknesses in seat design can be predicted by analysing the pressure distribution measurement. Good pressure distribution can reduce the feeling of discomfort, pain and injury because its pattern can minimise load concentration, allowing for the smooth blood flow of drivers. As a result, good pressure distribution can also help to prevent the occurrence of driving fatigue and improve driver's safety and performance.

The seat geometry, hardness and support properties of static seats can also affect static comfort and safety. The sensation of high discomfort yields a higher-pressure distribution around the ischial tuberosities, which is a small part at the buttock. Meanwhile, high contact pressure near the soft thigh tissues may unpleasantly affect the blood flow to the legs. Highly localised pressure distributions may support the view about improper body posture and the subsequent feeling of physiological pain. Similarly, inadequately supported body posture for a prolonged time results in back pain and injury, spinal disorder and abdominal pain and, consequently, a discomfort sensation. Given these potentially adverse impacts, the development and design of car seats should be carefully and comprehensively investigated by linking all parameters related to users and driving conditions.

The results of this study have helped to determine the correlations of the drivers' body parts and their driving characteristics besides the pattern of pressure distribution. Given the pros and cons that can be deduced from the anthropometric variables, suitable dimensions should be applied to create and design a seat for respective vehicles. Variations across populations of different countries, such as ethnicity, age, gender and body composition, can also contribute significantly to the design process that considers the anthropometric result [Mohamad et al. 2010; Deros et al. 2015; Yusuff et al. 2009; Hanson et al. 2009; Zuska et al. 2016). Comfortable, adjustable and safe seats are the main reasons for creating, designing and fabricating satisfactory models for users with the aid of global standards. Furthermore, the past studies have shown that anthropometry, subjective assessment and objective evaluation of postural, biomechanics and physiological parameters are the best ways to evaluate comfort (Vink and Hallbeck, 2012; Khamis et al. 2018; Hiemstra-van Mastrigt et al. 2017). The interaction between seat surface and human body caused by pressure and driving conditions can further help to develop seat design guidelines aiming for comfort, safety and efficient driving. Concerning difference in a drivers' anthropometric measurements, it is sometimes a problem to adjust the car seats according to the best driving position. A good driving position should provide good interface pressure between the driver and the car seat, and consequently it will improve the driver's performance and safety whilst driving.

CONCLUSION

This study has evaluated the relationship between anthropometrics and interface pressure variables under static condition for a specific driving or sitting task at a specific duration. Anthropometric parameters and mean pressure variables are correlated, but the relationship depends on numerous factors. This study has shown that gender, anthropometric variables, sitting or driving task and body posture affect the pressure variables. In general, the anthropometric parameters are influenced by the driver's posture and seat adjustability, whilst the pressure variables depend on the car's classification, time duration, seat geometry, seat design, driving posture and seat material. The driver-participants felt comfortable and safe at the short driving distance, but the feeling of discomfort, tiredness, numbness and stiffness have become prominent after a prolonged duration, along with numerous and differential postures during seating. Human body parameters, such as BMI, body mass and stature, are the common measurements used to evaluate the impact of anthropometric parameters on car seat. A driver with a large dimension can affect the body posture and require huge space for adjustability prior the perception of comfort, safety and effectiveness when driving. Hence, ergonomically good seats can significantly reduce fatigue and musculoskeletal pain and enhance the comfort, safety and competency amongst the drivers. Future research may concentrate on the differences in seat materials, car classifications and durations of seating in static condition.

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DECLARATION OF COMPETING INTEREST

None

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