

MEASURING PRESSURE INTERFACE OF LOCAL CAR SEATS UNDER STATIC AND DYNAMIC CIRCUMSTANCES: A COMPARATIVE STUDY

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ABSTRACT

Measuring discomfort toward the car seat is important as the act of driving requires a driver to remain at the car seat while controlling the car. The seat condition, including sitting position as well as the driver's posture can lead to discomfort and fatigue. The objective of this study is to investigate a driver's pressure distribution in static and dynamic circumstances for two types of cars; the sedan and compact car. This study involved both subjective and objective evaluations of 12 respondents. For the subjective evaluation, the Visual Analog Scales (VAS) were used to obtain respondents' perception of discomfort. For the objective evaluation, pressure distribution readings of the seat interface were obtained using piezo capacitive sensors. The findings showed that the highest pressure was recorded for the compact car. Furthermore, the static circumstance showed greater pressure compared to the dynamic state. Subjective evaluation indicated that the right buttocks and the lower back (lumbar) experience the highest discomfort for both types of seats. The type of seat found to contribute to the value of different pressure. Thus, it can be concluded that appropriate seat selection can reduce pressure as well as discomfort.

Keywords: Pressure; car seat; back rest; static; dynamic; sedan; compact

INTRODUCTION

Appropriate car seat selection is important as the type of seat determines the level of car driver comfort. This is due to the direct contact between the driver and the car seat during driving. Gross¹ stated that an appropriate seat would be able to accommodate users of various size and body shapes and should provide adequate support. In addition, Grieco² and White et al.³ argued that a good seat is necessary to avoid complications including lower back pain, usually due to bad sitting posture.

Previous studies also indicated that both comfort and discomfort have different definitions. Zhang et al.⁴ concluded that comfort and discomfort are based on different factors. The feeling of discomfort is caused by pain, fatigue, and numbness while comfort involves a relaxed feeling of well-being. There are various factors that contribute to the discomfort of sitting, for example the seat cushion material, seat dimension, contoured seat, sitting posture, and anthropometric dimension of the driver.

Two important characteristics must be considered in determining the comfort of vehicle seat, namely the static or dynamic conditions of the seat itself. Static comfort can be assessed by using posture assessment, ergonomics technique, and pressure interface. Dynamic comfort, on the

other hand, is tested by conducting a study using vibration on the seat surface; through test-driving either on actual road or through simulation in the laboratory.

Various experiments have been undertaken to investigate the relationship between body postures and seat discomfort. Among them are experiments performed by Andreoni et al.⁵, Shen & Galer⁶, Tewari & Mehta⁷ and Gyi et al.⁸. Andreoni et al.⁵ developed a biomechanical model comprising 11 delineated anatomical areas and the subjects were allowed to choose the most comfortable sitting position (anterior-posterior position, backrest angle). Four driving postures were repeated in the cockpit and two pressure maps (one for the cushions, one for the headrest) were analyzed for each subject. Two strategies were then identified for the seat cushion, namely ischiatic and trochanteric; as well as two adjustable regulations (seating position 'anteroposterior' and backrest inclination).

Experiments involving driver anthropometric were conducted by Kolich⁹, Bindu and More¹⁰, and Paul et al.¹¹. Kolich⁹ studied whether the design specifications using anthropometric data did not contribute to the production of comfortable vehicle seats. The finding showed that consideration of the target user was needed for development of comfortable seat.

Hewson et al.¹² performed a study regarding evolution of the index of fatigue, discomfort, and performance, for test subjects who sat in two types of car seats, namely with vibration and without vibration. Based on the study, performance of the subjects was reduced when they sat on the vibrated seat. Wuet al.¹³ and Gyi et al.⁸ also conducted experiments of dynamic conditions through vibration.

Kolich⁹, Nussbaum et al.¹⁴, Lee and Ferraiuolo¹⁵, and Ng et al.¹⁶ are examples of researchers who applied subjective evaluation in their studies. Ng et al.¹⁶ produced two questionnaire forms to subjectively evaluate comfort of the backrest and car seat. The first questionnaire required the subjects to rate comfort on a scale from 1 to 10; with 1 representing very uncomfortable and 10 representing very comfortable. The second questionnaire had a scale of -10 to +10 to represent the extreme state of the parameters used. The mid-point 0 on the scale represented a neutral state.

Although various research has been done regarding car seat pressure, there is a limited number of studies involving local car seat in Malaysia using Malaysian subjects under different circumstances. For such a reason, this study aims to investigate pressure distribution of driver in static and dynamic circumstances for two types of cars; namely the sedan and compact car.

METHODS

Subjects

The study involved eleven healthy subjects with no previous record of health problems (mean age of 33 years, mean height = 162 cm, mean weight = 68.5 kg). The subjects were selected randomly upon considering the size of their body. This meant that the subjects would be representing different categories of body size based on Body Mass Index (BMI). As a prerequisite, each subject must have at least three years driving experience to participate in this study. All the subjects signed the respective informed consent form before participating in the study, which complied with the ethics guidelines of the declaration in Malaysia. The protocol was approved and granted by the local ethics committee from Universiti Kebangsaan Malaysia.

Types of car seat

Two types of car seat were used in this study, as depicted in Figure 1. Figure 1(a) shows the seat from a Malaysian made compact car, while Figure 1(b) shows the seat from the local sedan car. Both are new car models released in Malaysia by two different automobile manufacturers. Leather cover seat was used in the compact car, while

the fabric cover seat was installed in the sedan car. Table 1 shows the dimension for both types of car seat.



(a) Seat from the compact car



(a) Seat from the sedan car

Figure 1- Types of car seat

Table 1-Dimension of car seat

| Dimension | Sedan (cm) | Compact (cm) |
|-------------------------|------------|--------------|
| Length of the seat pan | 54 | 54 |
| Width of the seat pan | 52 | 48 |
| Height of the back rest | 57 | 56 |
| Width of the back rest | 55 | 50 |
| Height of the head rest | 20 | 24 |

Data collection protocol

The subjects were allowed to familiarise themselves with the car seat adjustment prior to the experiment. The study involved two conditions, namely static and dynamic. For each condition, subjects were asked to sit on the car seat and adjust the seat distance from the steering wheel and the backrest angle according to their preference. Once the subjects had adapted to the most suitable position, a pressure mat was placed on the seating surface and the subjects were asked to put their right foot on the acceleration pedal and their left foot near the clutch pedal. In addition, both their hands were placed on the steering wheel according to the position most comfortable to them.

Tactilus® pressure mat as shown in Figure 2 was used for recording the pressure distribution data.

The technology used was a piezo capacitive with grid size 32 x 32 and pressure ranges between 0 to 5 psi. Subjects were asked to wear appropriate clothing and remove items from their back pockets before pressure measurements were recorded.

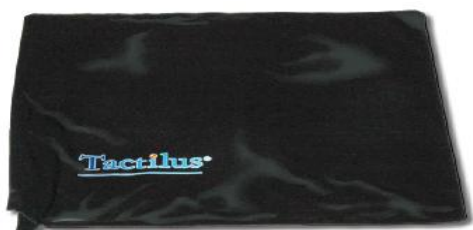


Figure 2- Tactilus pressure mat

Pressure distribution data were recorded for five minutes and during the recording, the subjects were not allowed to move. After five minutes, the subjects were asked to get up and pressure mat was transferred to the backrest. The pressure distribution data was then recorded for another five minutes. This procedure was repeated for the dynamic situation, but the subjects were allowed to move if they felt uncomfortable during the dynamic test.

Before the pressure distribution test was performed, the subjects were asked to complete a questionnaire related to their demographic and assessment of discomfort level based on the vehicle seat characteristics. Static and dynamic tests for seat and backrest were done for five minutes each, followed by two repetitions to obtain accurate data. This process was done for both the sedan and compact car. After the pressure distribution test concluded, the subjects were asked to rate the discomfort level of the body parts that came into contact with the seat and backrest as well as the overall level of discomfort.

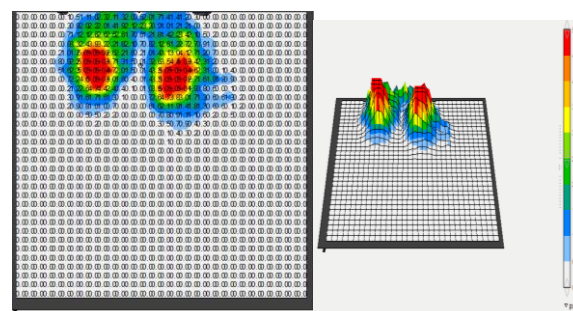
RESULTS AND ANALYSIS

This section shall reveal the findings for the test on static and dynamic circumstances based on two types of car seat. There are two subsections, namely pressure distribution on subject's seat according to the Body Mass Index (BMI) and pressure distribution in static and dynamic circumstances.

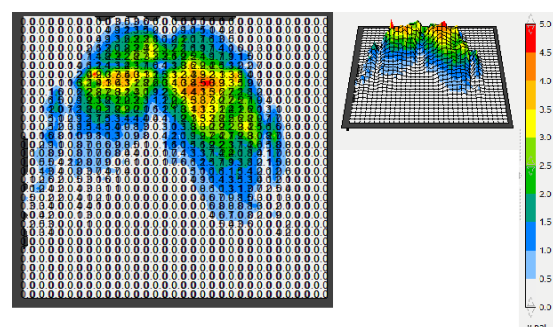
General pressure distribution on the seat pan according to BMI

Figure 3 (a), (b), (c) and (d) shows four samples of pressure distribution on the seat for four subjects with different BMI, namely underweight (BMI = 18.4), normal weight (BMI = 22.9), overweight (BMI = 28.3), and obese (BMI = 43.6). These figures only show the general pressure distribution pattern without considering the types of car seat. With regard to Figure 3 (a) to (d), it can be seen that the pressure of heavier

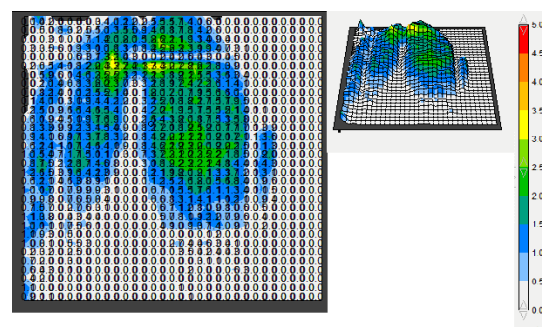
subject is more scattered at the buttock area, while the lighter subject has mild stress concentrated under the ischium tuberosity.



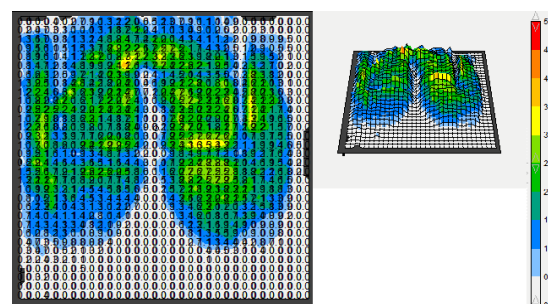
(a) Underweight subject



(b) Normal weight subject



(c) Overweight subject



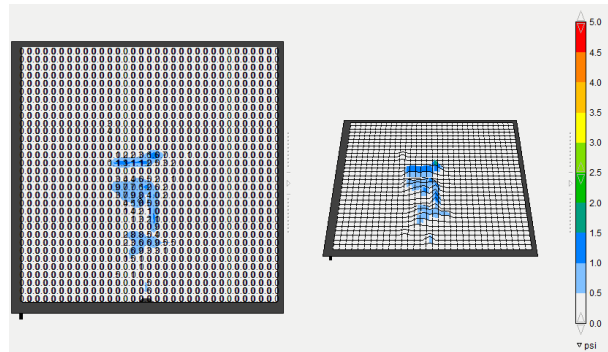
(d) Obese subject

Figure 3- Pressure distribution pattern according to different BMI

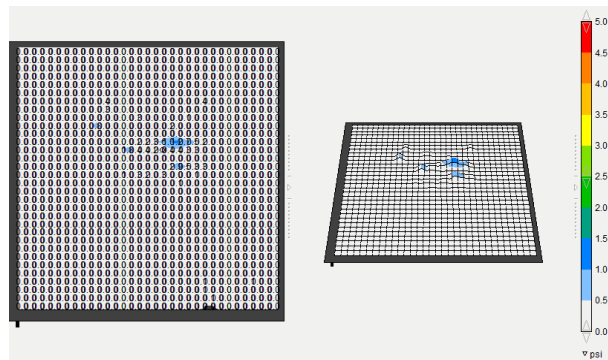
General pressure distribution on the back rest according to BMI

Figure 4 (a), (b), (c) and (d) shows three samples of pressure distribution on the seat occupied by

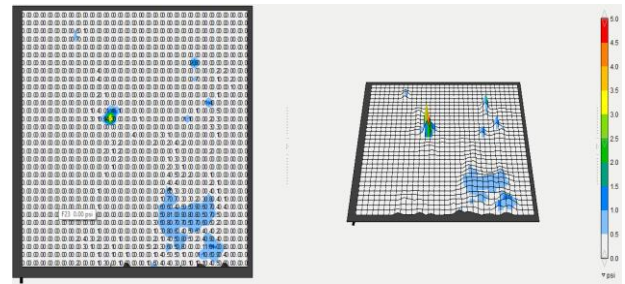
subjects with different BMI. Generally, overweight and obese subjects presented quite similar pressure distribution patterns. The pressure of the heavier subject is more scattered, and concentrated particularly at the lower back, while the lighter subject has mild stress concentrated at the middle back.



(a) Underweight subject



(b) Normal weight subject



(c) Overweight and obese subject

Figure 4- Pressure distribution pattern according to different BMI

Pressure distribution of the seat pan in static and dynamic circumstances

Figure 5 shows the pressure distribution on the sedan's seat pan while Figure 6 shows the pressure distribution on the compact's seat pan. Both figures show results from pre and post studies under two different circumstances, namely static and dynamic. Based on BMI of each subject, subjects 6, 8, and 10 are categorized as underweight. Subjects 2, 4, 7, 9, and 11 are categorized under normal weight. Meanwhile, subjects 1 and 3 belong to the overweight category and subject 5 belongs to the obese category.

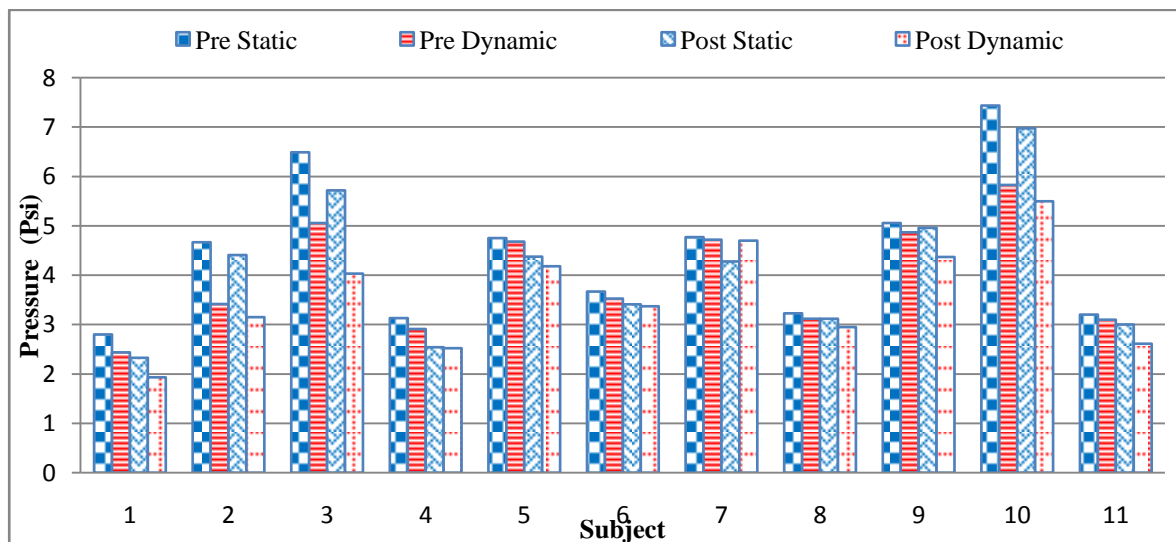


Figure 5- Pressure distribution of the sedan seat pan

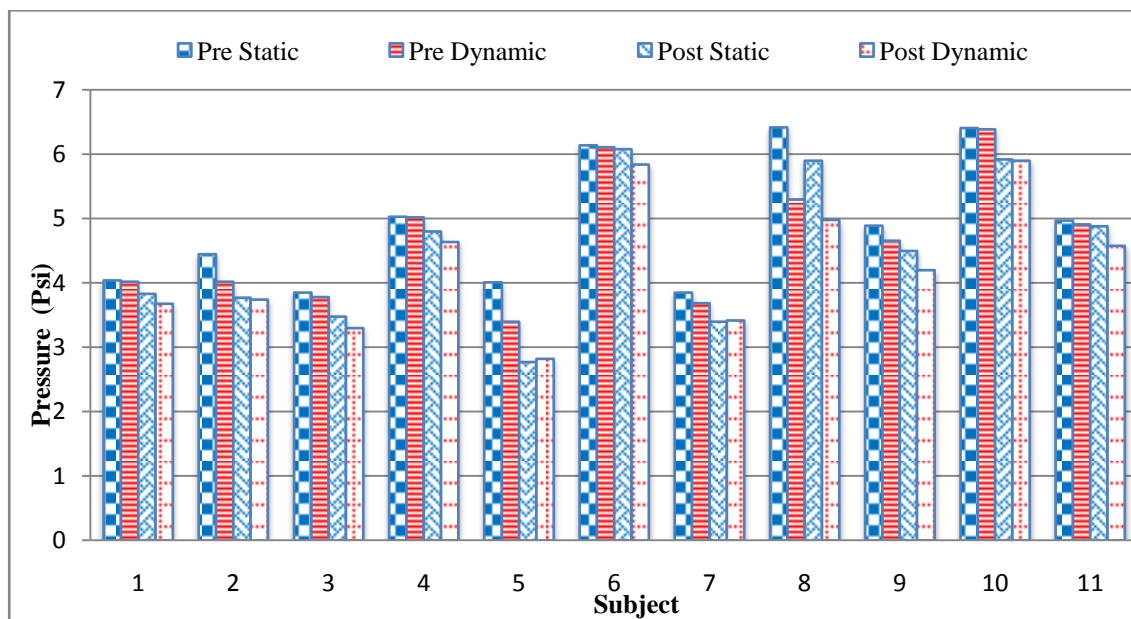


Figure 6- Pressure distribution on the compact seat pan

With regard to Figures 5 and 6, the average pressure between pre and post study for both circumstances indicated a decrease. It can be concluded that the average pressure under static and dynamic circumstances will be reduced throughout the sitting period. The sitting duration is also one of the factors to determine the amount of pressure exerted by the subjects. Such a condition possibly occurs due to the high force applied to the seat occupant at the beginning of the sitting activity. When the time passes and the end of the experiment approaches, the contact area between the lower leg and thigh is evenly distributed.

Pressure distribution data indicate that the pressure felt under static conditions is higher compared to the pressure in dynamic conditions. Pressure in a static state is higher than in the dynamic state because in the latter, no movement occurs or exists whether from the car

or the subject. This causes the force from the subject's body weight to concentrate in one area compared to in the dynamic state when the car engine is turned on, where the force flows toward the seated subject and his surroundings. Based on the pressure formula, which is 'force divided by area', the force flowing around the area during the dynamic state causes the pressure to be low.

Based on the pressure distribution data, it can be concluded that there is no significant difference between the car seat for both sedan and compact cars. Table 2 shows the average pressure distribution in the seating area of the sedan and compact car according to body part area. The highest pressure recorded for both cars is at the buttock, which is in between 2.8 to 3.5 psi.

Table 2- Pressure distribution of car seats on sedan and compact car

| Sedan | | Compact | |
|---------------|------------------------|---------------|------------------------|
| Body part | Average pressure (Psi) | Body part | Average pressure (Psi) |
| Buttock right | 1.36 | Buttock right | 1.82 |
| Buttock left | 1.49 | Buttock left | 1.64 |
| Thigh right | 0.72 | Thigh right | 0.69 |
| Thigh left | 0.97 | Thigh left | 0.83 |

Pressure distribution of the backrest in static and dynamic circumstances

The pressure distribution on the sedan and compact car's back rest is shown in Figures 7 and 8. Similar to the seat pan's result, the average pressure between pre and post study for both

circumstances show a decrease. It can be concluded that, as the time passes and the end of the experiment approaches, the contact area between the upper and lower body is distributed evenly.

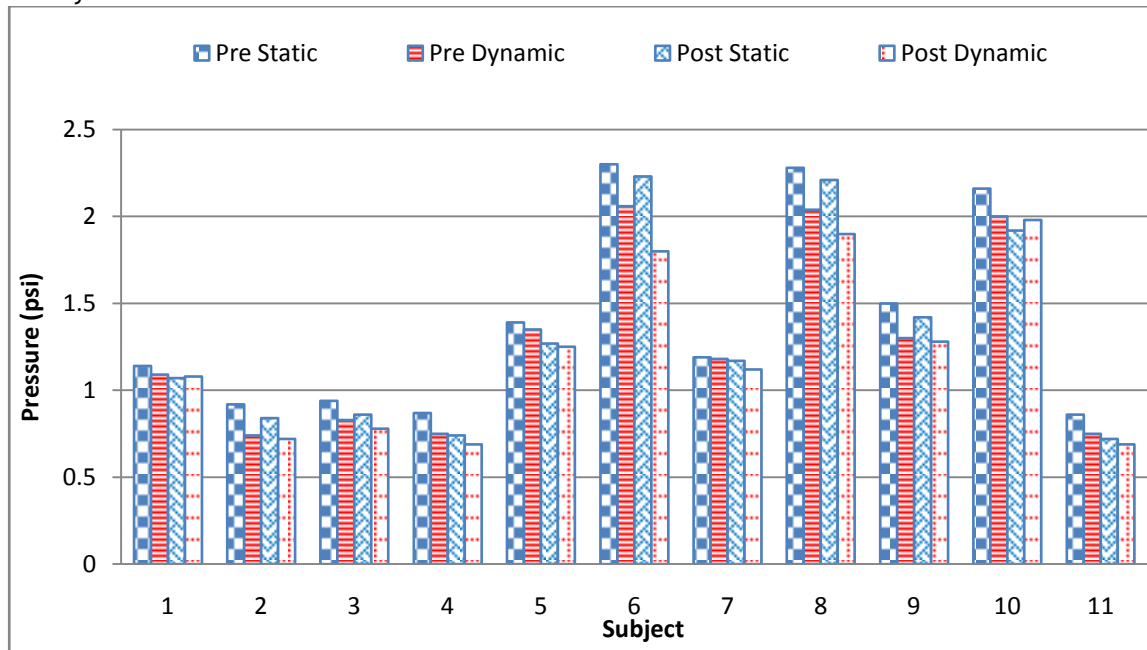


Figure 7- Pressure distribution of the sedan backrest

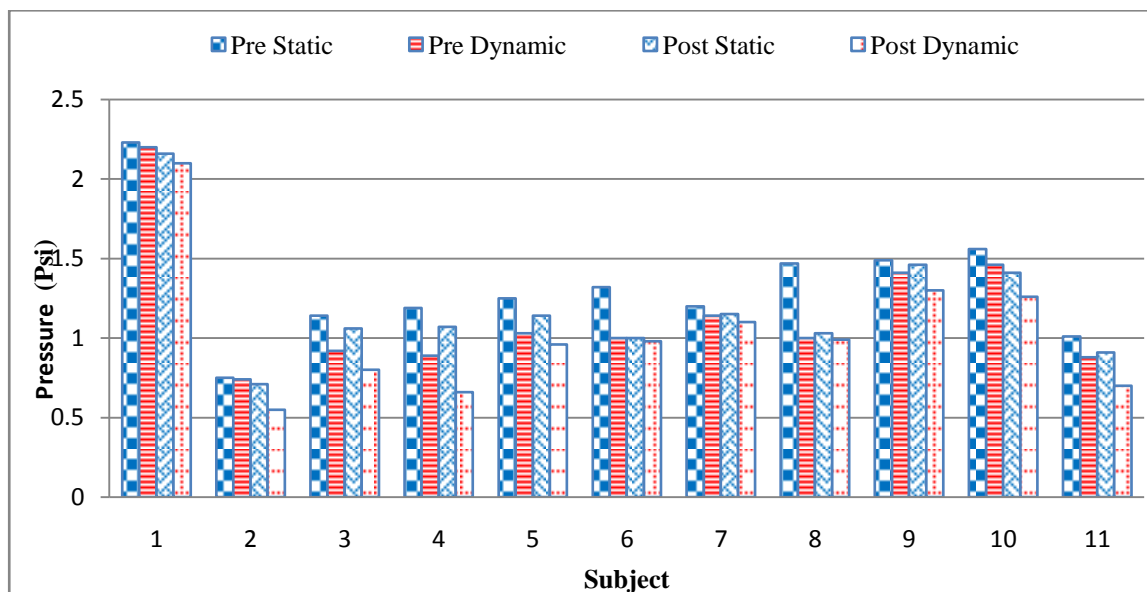


Figure 8- Pressure distribution on the compact backrest

Table 3 shows the average pressure distribution on the backrest of the sedan and compact car according to the body part areas. As shown in Table 3, the lower back recorded the lowest average pressure, which was around 0.5 psi. Low pressure in the lower back part of the body is caused by lack of support in the lumbar region of the backrest for both cars.

Table 3 - Pressure distribution of backrest on sedan and compact car

| Sedan | | Compact | |
|-----------------|------------------------|-----------------|------------------------|
| Body part | Average pressure (Psi) | Body part | Average pressure (Psi) |
| Upperback right | 0.32 | Upperback right | 0.37 |
| Upperback left | 0.60 | Upperback left | 0.46 |
| Lowerback right | 0.19 | Lowerback right | 0.18 |
| Lowerback left | 0.37 | Lowerback left | 0.34 |

DISCUSSION

Viano and Andrzejak¹⁷ stated that pressure on the car seat is one of the causes for sitting discomfort. Parakket¹⁸ in addition, determined the human tolerance toward prolonged sitting in various seat cushions. In their study, the peak seat pressure was around 1.22 to 3.22 psi. In addition, as regards seat pan condition based on previous studies, there were many values of the recommended comfortable peak pressure of the ischium tuberosity (under the buttock area) recorded, which was from 0.84 psi to 4.35 psi¹⁹⁻²⁰. However, Dunk²¹ found the comfortable peak pressure was at 2.61 psi for female and 2.94 psi for male. In addition,²² suggested that Figure 3 (a) has good pressure distribution due to the less sensitive tissue at the ischium tuberosity compared to the thigh.

With regard to the backrest condition, specifically, comfortable seats are indicated by the average pressure levels of 0.2 psi to 0.33 psi in the lower back region of the backrest^{19,23}. According to previous studies, discomfort may result from either extreme or lack of pressure on the support, which in this case is the backrest. In this study, the lower back pressure shows mean pressure around 0.5 psi. Therefore, it can be interpreted that both types of cars did not provide high comfortability for drivers. This is possibly due to lack of support in the lumbar region of the backrest.

Furthermore, if the peak pressure is at the upper back, it means the seat design has small support on the lower back region^{22,24}. According to Daruis²⁴, the human spine is naturally in the S form. Without sufficient support for the lumbar area (lower back) at the backrest, the body position of the seat occupant tends to be curved and bent. As a result, the occupant may experience discomfort at the upper back due to lack of support. In this study, the highest pressure was at the upper back for both types of car seat. This is another reason to prove that the car seats provided lack of support.

CONCLUSION

All in all, this study shows that the pressure on the car seat was slightly influenced by the weight of the seat occupant. Based on findings from the seat pan, the pressure of the heavier subject is more scattered at the buttock area, whereas the lighter subject has mild stress concentrated under ischium tuberosity. In terms of experiment circumstances, the pressure reading in a static state was higher than in the dynamic condition due to the force involved and the pressure on the seat pan in compact car is higher compared to the sedan. Overall, it was found that the backrest of sedans and compact cars had less lumbar support and could cause pain in the back of the subject's body.

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COMPETING INTERESTS

There is no conflict of interest.

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