Advanced Engineering Forum *Online: 2013-12-30*
ISSN: 2234-991X, Vol. 10, pp 331-335
doi:10.4028/www.scientific.net/AEF.10.331

Ergonomics Assessment of Seat Design Based on Buttock Pressure and Anthropometrics Data

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Keywords: Low back pain (LBP).

Abstract: Today's global competition has prompted many automotive manufacturers to design their products based on consumer's preference and satisfaction. A car driver controls the vehicle and his/her comfort and safety is important to avoid any road injury or unfortunate accident. There are three main objectives for this paper. This paper is to investigate the relationships between car drivers' anthropometric characteristics, comfortable postural angles and seat adjustment, to analyze the force distribution on the car seat and to design a driver car seat that gives comfort and safety ergonomically to the driver. In this case, the measurements need to be taken for both car and the driver and also to propose a design a driver car seat that provides comfort and safety to the driver. This design should be based on ergonomic factors including design, materials used and safety. These findings enhance our understandings of car drivers' perceptions of posture comfort and safety. The data findings and relationship discussed will assist the manufacturers in designing a drivers' car seat with ergonomics value.

Introduction

One of the most important contributions that ergonomics can provide to the automobile design process is information of the physical size of driver and his/her preferred postures [1]. An experiment conducted by Costanzo detected the different levels of muscular fatigue between correct and incorrect postures [2]. Awkward postures and high vibration exposure while in driving position might result in high risk condition for musculoskeletal disorders [3]. There have been many past research and experiments conducted in driver's car posture [4, 5, 4, 6, 7, 8, 9, 10, and 11] but none was conducted for the Malaysian population. So, this study is aiming to publish comfortable and safe driving postures as preferred by Malaysian car drivers.

The objectives is to investigate the relationships between car drivers' anthropometric characteristics, comfortable postural angles and seat adjustment, to analyze the force distribution on the car seat and to design a driver car seat that gives comfort and safety ergonomically to the driver. There are two categories of ergonomics criteria that are physiological and anthropometric. The physiological categories deal with muscles, vertebral discs, joints, and skin while ergonomics criteria mostly related to physiology. Anthropometrics, the study on human dimension such as measurement, shape, mass, center of gravity, inertia of the human body and work capacity is necessary for ergonomic application. In determining the shape and dimension of a product, the features of the human body form the basis in determining size measurements. This is known as the human factors study that is concerned with the interaction of human and products.

This is a concern, because in today's environment, interior space is at a premium. Due to this mismatch, automobile seats may be consuming valuable space in the vehicle interior; space that could, otherwise, is used for other features. The standard car seat is designed to support thighs, the

buttocks, lower and upper back, and head support. The front driver and passenger seats of most vehicles have three main parts: the seat back (squab), seat base (cushion), and the headrest. When sitting in the car seat your posture is the most important factor when considering your comfort. The positions that drivers assume depend on their anthropometric characteristics, the range and type of adjustments available in the seat package, and each driver's preferred driving position. Common available adjustments deal with concerns such as providing legroom, supplying back support, and giving head support. Available amenities include electric adjustments, choice in fabric covering, and temperature control. An integral dimension to any seat design is the aspect of safety.

Methodology

Participants. The numbers of participants involved in this experiment was 3 Malaysian citizens which comprise of 3 males. The participants' age ranged from 20-23 years old. Minimum driving experience is one year to ensure the drivers have adequate experience in driving. As a token, the participants were given some incentives for their contribution.

Parameters. The measured dimensions for this study were chosen based on literature studies and direct relation with the parameter needed in the experiment. There data that are important for the study are stature, sitting height, hip height, knee height, shoulder to elbow length, sitting shoulder height, sitting waist height, hip breadth, and elbow to grip length and shoulder breadth. Two parameters for the seat adjustment were measured; they are the sliding distance and the seatback angle. These seat parameters were used to investigate the correlation between the anthropometric data and comfortable driving postural angles. The car chosen is from compact and entry midsize segment cars.

Procedure. Prior to the data measurement process, the objectives and procedures of the study were explained in detail and participants were required to fill in their personal information in a form given to them. The data includes personal information such as age, gender, race, state of origin, date of birth and occupation. The measured anthropometrics dimensions were recorded in the same form. Before the postural angle measurement process was carried out, each participant anthropometric data was photographed and recorded. Participant is then required to sit on the driver's seat in their comfortable driving postures. The picture are photographed every step that the participant do to make something from entering the car, using equipment in the car, adjusting site position, adjusting side mirror, driving, out of the car, open bonnet, until open the fuel tank. The side view of subject comfortable driving posture was photographed. Data were recorded manually into the form sheet provided. These seat adjustment parameters were taken after the seat had been adjusted by the participant according to their preference on driving comfort. For anthropometric data, the participants were measured for 62 measurements which being taken using measuring tapes. The participants were measured strictly to ensure the data are accurate and precise. For an easy analysis to compare of the anthropometric data with the test car, the car has been divided into six different sections. These sections are divided as follows:

i. Entering the car.
ii. Seating posture.
iii. Seat belt & head rest.
iv. Pedal & steering.
v. Compartment 1 (right-hand control).
vi. Compartment 2 (left-hand control).

Each and every section will be discussed in detail based on ergonomics factors include providing comfort and safety to the driver

Results and Discussion

For an easy analysis to compare of the anthropometric data with the test car, the car has been divided into six different sections. These sections are divided into six parts. The six parts are (i) Entering the car, (ii) Seating posture, (iii) Seat belt & head rest, (iv) Pedal & steering, (v) Compartment I (right-hand control) and (vi) Compartment II (left-hand control). Seat design and also pressure distribution also will be discussed here.

Entering the Car. Design for the maximum (95^{th} percentile). The position of the door handle was design to be at preferable height which is easy to be reach without stretching the arms too much. The height of the car from the ground is 140 cm and the driver is 170 cm height. In this case, for the driver to enter the car would be a bit difficult since his need to bend his head. This situation could cause stiffness to the neck when repeated frequently. There is enough space for the driver to seat comfortably. The height from the driver seat to the roof is suitable for people with sitting height less than 90 cm. The car door could be open to degree angle of 75^0, which provide enough space for the driver to enter the car comfortably. The interior door handle reach the maximum when the door is open wide. The driver needs to stretch their hand which can cause stress to the shoulder and arm muscle.

Seating Posture. Design for adjustability. The car seat is place at 95^0. The driver body is almost straight and the hands are bending. In this range of position can make the driver alert while driving. However this sitting is not comfort to the driver after driving for few hours. This could cause back pain to the driver. Moreover, for a driver with a big body, the distance between his chest and steering wheel is close and it is dangerous when an accident occur, where an impact could cause fatality. The car seat is place at 120^0. The driver is in relaxed and comfort position. The driver body weight is support by the seat cushion, giving space for the back to lean and rest. The hands are also in comfort position where it's not bending or stretch too much. The distance between the chest and the steering wheel is in safer condition in which, if collision occur, the seat belt could hold the impact avoiding the chest from hitting the steering wheel. The car seat is place exceed 130^0. The seat is lowered too much, in which it reduce the driver scope of visibility. Therefore, in this case the driver need to raise their head to get better sight and this could cause pain to the neck and shoulder. The knee bends at almost 90^0, in which uncomfortable to the driver after few hours driving and the legs can move freely. The seat position have been adjust backward and the new positions give more space for the legs to move freely and the knee now at 110^0 which at angle of comfort.

Seat Belt & Head Rest. Design for Adjustability. The position of the seat belt is a bit far backward, the driver needs to bend his hand backward and twist the wrist a bit to reach and pull the seat belt. However, the seat belt is easy to pull and wear. It gives good support of safety since the belt strap and holds the driver at the waist and chest to the seat fully. At first the head rest is place to lower; it gives partially support to the head. However, after the adjustment, the head rest providing better support to the head. The angle of comfort for head rest is between $0\text{-}15^0$.

Pedal & Steering. Design for adjustability. The seating posture at knee gives an optimal angle of 120^0 while the ankle rest on pedal position at position of $90^0\text{-}100^0$ which provide comfort to the legs of the driver. The pedals are also covered with rubber pad which provide comfort and grip for safety to the feet. The steering wheel controls which at an optimal and comfort condition can be provided. The handling when cornering (left or right), favors the maximum hands control to the steering.

Compartment I (Right-Hand Control). Design for the maximum (95^{th} percentile). The control panel consist an equipment of ignition keyhole, signal, side mirror controller, power window controller, and door handle. These panels are place higher from the driver seat where it is reachable by arm and easy to control. The control panel consist equipment for seat adjustment, bonnet, and cargo hold. This panels are place lower since it was used when the car not moving and still it is reachable by arm but need body movements to handle this panels.

Compartment II (Left-Hand Control). Design for the maximum (95^{th} percentile). This control panel consist equipment for air-conditioner, radio, and clock. It's located higher and near the driver seat so it can be reachable by arm an easy to control while driving. This portion consist equipment

for back mirror, interior lamp, and sun-screen. It place higher due to its function and also can be reachable by arm. The dashboard is place at front of the passenger seat beside the driver. It was place exceed the maximum reach from the driver seat. Therefore, it is not recommended to open the dashboard while driving because it too dangerous since the driver sight on road will be influence. This part consists of gear and handbrake. It's place lower near to the driver seat. Since there is signal indicator at the meter, therefore this control panel could be control easily even without looking.

Seat Design. By using sensors, posture and physical movements can be accurately recorded and documented. Therefore the actual ergonomic quality can be determined. This seat design is considerably better than standard seat systems with counting in the seat cushion and backrest criteria. In particular, the pronounced side bolsters and the individually adjustable lumbar support on the seat provide the driver with more support and hold to facilitate the correct posture in the vehicle. When driving become strenuous work and the driver needs long-lasting stamina, the seats help take the strain. The seat design is ergonomically shaped seat contour itself provides the framework for a comfortable sitting experience. Supplemented by the most important adjustment options – such as adjustable side bolsters on the backrest and seat cushion, extendable seat cushion, a lumbar support and comfort features. For a better seat, the seat should have lumbar support, extendable seat cushion, electric height adjustment, tilt adjustment, easy-to-operate switch pack, and backpack adjustment on both sides, adjustable headrest, backrest tilt-forward release on sides, seat back packet, and universal side airbag.

Force Analysis on the Driver's Seat. An experiment was conducted to perform an analysis on the driver's seat by using FSA4.0 (Force Sensing Application Version 4.0). The data collected shows the force distribution on the seat by applying load from the driver weights.

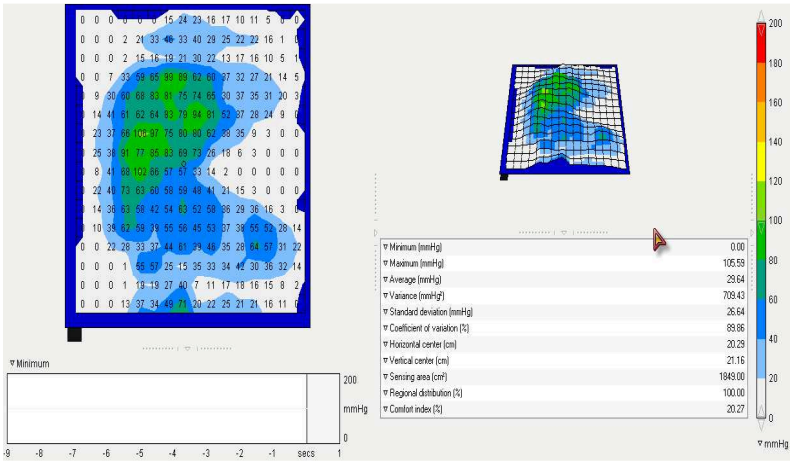

Figure 1: Force distribution on the driver's seat.

Figure 1 to shows the distribution on the driver's seat for only one sample. From the data collected shows that the force distributions cover the maximum area at around the center of the driver's seat. It covers the sensing area of 1849.00 cm^2 with the maximum comfort index of 46.24%.

Conclusion

This study has explained the importance of providing comfort in driver's car seat design. Base on the objectives of this study are: First, to investigate the relationships between car drivers' anthropometric characteristics, comfortable postural angles and seat adjustment and second, is to design a driver car seat that gives comfort and safety ergonomically. In this study, three Malaysian healthy male students with age range in early 20's have been chosen as experimental model. From the experiment analysis and data gathered performed on selected vehicle have produced several conclusions. The finding that emerges from the relationship can be summarized as follows:

i. Person with greater height usually have long arms and legs, therefore the seat need to be adjust further back from the steering wheel to give more space for the arms and legs to stretched and thus provide comfort and safety to the driver. The opposite adjustment needs to be applied to smaller person.
ii. The car choose to be studied generally was design and built based on the maximum percentile and could be adjustable in order to fit with the driver variety conditions and factors. However, the design was not perfectly ergonomics to the users since there are too much variables that influence the ergonomics factors.

These findings enhance our understandings of car drivers' perceptions of posture comfort and safety. The data findings and relationship discussed will assist the manufacturers in designing a drivers' car seat with ergonomics value.

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