Impact of Anthropometric Parameters on Pressure Variables for Determining Comfort and Safety of Automotive Seat: A Systematic Review

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Abstract

Background: A good quality of seating comfort requires integration of capabilities and limitations of the human body and the occupant’s preferred posture in different seating environments and tasks. This study provides a systematic and comprehensive review of past research related to the correlation between anthropometric parameter to seat pressure variables to determine the impact on comfort and safety in seat design.

Methods: This systematic review consisted of PRISMA flow diagram guidelines searched in Web of Science, Scopus, Sciencedirect and Google Scholar from 2009 till January 2020 related to keyword lists.

Results: As a result, 26 articles which addressed the correlation between anthropometric parameters and pressure variables were selected. Body mass index and weight were the most influence anthropometric parameter towards the pressure variables. In addition, almost all studies showed that there were medium to strong correlation between the lower body parts and the pressure variables, with R as above 0.5.

Conclusion: Comfort and safety depend on the design and ergonomics of the seat to maintain the body posture under complex roads, driving conditions and changing environment. In essence, seat and geometry functions help to reduce fatigue level and improve comfort, safety and health among drivers based on user, task and environment of driving activities.

Keywords: Anthropometric; Pressure variables; Car; Condition

Introduction

In recent decades, some studies have focused on the ergonomics and sitting comfort to ensure the users’ safety, health and wellbeing (1). Debates related to sitting comfort in recent studies not only focused on chairs as the sitting component, but also concentrated on the vehicles seat (2–11). The vehicle seat mainly determines comfort and safety amongst drivers. Several factors, such as...
anthropometry, body posture, seat properties and environment can influence the driver’s car seat characteristics. Therefore, designing a car seat that can contribute towards the comfort, safety and seating adjustability is important (12). Designing vehicle seats should not only involve selecting the best materials or features for a seat but should also considered road surfaces factors and interactions between occupant, driving task and road surfaces factors in static and dynamic conditions (13). Drivers tend to experience pain frequently during driving because they remain seated and have difficulty in changing positions whilst driving. Posture is one of the major factors of discomfort and contributes to several musculoskeletal disorder injuries, such as at lower back, neck and shoulder (14–16). Other than poor seating posture, long driving duration, poor seating conditions, and stress also affect the comfort and safety of drivers (17,18).

Meanwhile, characteristics of seat design, such as seat shape, adjustability, thermal properties, aesthetics properties, materials, exposure to whole-body vibration and duration of driving can lead to discomfort (19–21). Hence, by adhering to the anthropometry parameters, driving and seat characteristics can influence the comfort, safety level and convenience of drivers (22–25).

Anthropometric greatly influences the development of comfort and safety of automotive seats. Driving for a prolonged period creates interface pressure between the seat and the human body. The variation of pressure distribution on the seat surface is influenced by several factors, namely, seat stiffness (condition), shape, material and driver buttock’s physique characteristics (26-28).

Thus, ergonomic terms, such as safety, health and comfort play important roles in developing an automotive vehicle’s seat that is reliable, efficient and beneficial for user’s selection. This study provides a systematic and comprehensive review of reported studies concerning anthropometric parameter and their relationship with pressure distribution for the comfort and safety of seats.

**Methods**

This review paper aimed to present the relationship between anthropometric parameters and pressure variables, along with their influence on the comfort and safety level. The systematic selection process was performed using guidelines retrieved from Cochrane method and Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (29,30). Using PRISMA, the relevant articles from the different databases were merged and subsequently, the duplicates were removed. The articles were selected and defined based on priority, relevance, impact and quality using Grades of Recommendation, Assessment, Development and Evaluation Working (GRADE) (31).

**Designation of Research Questions**

This study target to improve the knowledge related to the effects of anthropometric parameter and pressure variables on comfort, safety and health. The questions focus on physical characteristic and posture which contributes to discomfort, fatigue and pain. The research questions for this study are shown as below:

- Are anthropometric parameter required in car seat development?
- What factors influence the pressure variables?
- To what extent do anthropometric parameters affect pressure variable?
- How does driver, driving task and driving environment impacts the seat comfort?

**Identification Keywords**

The database of Web of Science, Scopus, ScienceDirect and Google Scholar were searched, using related keywords and their synonyms. Table 1 lists the key terms used to identify and select related articles.

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Table 1: Key terms used in selecting articles

| Keyword  | Synonyms                                                                 |
|----------|--------------------------------------------------------------------------|
| Anthropometry | Anthropometric, weight, height, stature                                  |
| Pressure | Pressure variables, pressure distribution, interface pressure, contact area |
| Car      | Seat, driving, automotive, vehicle, car seat                              |
| Condition | Comfort, discomfort, safety, static, dynamic                              |

Screening and Selecting Articles

The screening and selection were based on the most significant terms and then were refined in the title, abstracts and keywords. This paper requires the latest studies to build awareness of the purpose not just a great implementation and the significance but the contribution and impact for further and advanced research. Table 2 presents the summary of study components regarding the inclusion and exclusion criteria of selecting papers for this review.

Table 2: Summary of inclusion and exclusion criteria for selecting papers

| Study components | Inclusion specification                                                                 | Exclusion criteria                                                                 |
|------------------|----------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|
| Type of paper    | Original research paper, SAE papers and conference proceedings.                        | Review paper or systematic review paper were excluded.                             |
| Seat             | All type of seat was included (automotive and chair). Seat pan and seat back also included. | Motorcycle seat, airplane seat, train seat and passenger seat were excluded.         |
| Detection        | All measurement of anthropometric was included. Height, weight and BMI as a standard measurement of anthropometric. | Measurement of seat and/or chair were excluded.                                     |
| Outcome measures | All pressure variables related to interface between human body and seat surface.        |                                                                                     |
| Publication date | Paper from 2009 till January 2020.                                                      |                                                                                     |
| Study design     | Study design regarding any type of experiment procedure, equipment used, and SPSS analysis. | Paper without anthropometric parameter and pressure variable data were excluded.    |
| Language         | All papers were published in English only.                                              | Paper with other languages were excluded.                                           |

Eligibility and extracting relevant information

Relevant information from the selected articles were extracted and categorized into a summary. The weighted score for each element was based on the significance and noteworthiness to the study. The assessment gave the values ranged from “Yes” [1], “Partial” [0.5] and “No” [0]. The highest quality assessment possible was a weighted score of 26 for the eleven factors listed.

Analysis of the articles

Analysis of the relevant evidence sources was carried out after the evaluation process. Fig. 1 illustrates the methodological process of the systematic review.
The quality assessments of the 26 articles were represented by strong relevance for the comprehensive overview of the study. The GRADE guidelines helped to developed and summarizing the criteria of each elements and aspects for analyzing the strengths and potential flaws of the study. Table 3 presents the quality assessment of each article selected and analysed.

Table 3: Quality assessments of selected articles

| Authors               | Precise objectives/hypothesis | Sample size | Follow up/Comparison past study | Control group | Real environment | Subjective evaluation | Anthropometry parameter | Pressure variables analysis | Detailed statistical method | Consistent conclusion | Scope, coverage and depth | Qualification |
|-----------------------|-------------------------------|-------------|---------------------------------|---------------|------------------|-----------------------|------------------------|--------------------------|--------------------------|-----------------------|-------------------------|---------------|
| Akgunduz et al (32)   | Y                             | N           | N                               | N             | N                | N                     | N                      | Y                        | Y                       | Y                      | P                       | L             |
| More & Bindu (33)     | Y                             | N           | N                               | N             | Y                | Y                     | Y                      | Y                        | N                       | P                      | N                       | L             |
| Kilincsoy et al (34)  | Y                             | N           | N                               | N             | N                | N                     | Y                      | Y                        | Y                       | Y                      | P                       | L             |
| Ismail et al (35)     | Y                             | N           | N                               | N             | Y                | Y                     | Y                      | Y                        | Y                       | Y                      | Y                       | M             |
| Jin et al (36)        | Y                             | N           | N                               | Y             | N                | Y                     | N                      | Y                        | Y                       | Y                      | Y                       | M             |
| Daruis et al (37)     | Y                             | Y           | N                               | N             | Y                | Y                     | N                      | Y                        | Y                       | Y                      | Y                       | M             |
| Study                      | Y | Y | N | Y | Y | N | N | Y | Y | Y | P | M |
|---------------------------|---|---|---|---|---|---|---|---|---|---|---|---|
| Makhsous et al (38)       | Y | Y | N | Y | Y | N | N | Y | Y | Y | P | M |
| Paul et al (39)           | Y | Y | N | Y | N | Y | N | Y | Y | Y | P | M |
| S. J. Park et al (40)     | Y | Y | N | Y | N | Y | N | Y | Y | Y | P | M |
| Rahayu & Firdaus (41)     | Y | Y | N | Y | Y | N | Y | N | Y | Y | P | M |
| Zuska et al (42)          | Y | Y | N | N | Y | N | Y | Y | N | Y | Y | M |
| Zemp et al (25)           | Y | Y | N | Y | Y | N | N | Y | Y | Y | P | M |
| Ren et al (43)            | Y | N | N | Y | N | N | Y | Y | Y | Y | P | M |
| Khamis et al (44)         | Y | Y | N | Y | N | Y | N | Y | Y | Y | P | M |
| Vink & Lips (45)          | Y | Y | N | Y | Y | N | Y | Y | Y | P | Y | M |
| Ab.Rahman et al (46)      | Y | Y | N | N | Y | Y | N | Y | N | P | Y | M |
| Khamis et al (47)         | Y | Y | N | Y | Y | N | Y | N | Y | Y | M |
| Khamis & Deros (48)       | Y | Y | N | N | Y | N | Y | N | Y | Y | P | M |
| Mitsuya et al (49)        | Y | Y | N | N | N | Y | N | Y | N | Y | Y | M |
| Chae et al (50)           | Y | Y | N | Y | Y | Y | N | Y | Y | Y | P | M |
| Vincent et al (28)        | Y | Y | N | N | N | Y | Y | Y | Y | Y | Y | H |
| Kyung & Nussbaum (51)     | Y | Y | N | Y | Y | Y | N | Y | Y | Y | Y | H |
| Cengiz et al (52)         | Y | Y | N | Y | Y | Y | Y | Y | Y | Y | Y | H |
| Fang et al (53)           | Y | Y | Y | N | Y | N | Y | Y | Y | Y | Y | H |
| Jones et al (54)          | Y | Y | N | N | N | Y | Y | Y | Y | Y | Y | H |
| Heckler et al (55)        | Y | Y | N | N | Y | Y | Y | Y | Y | Y | P | H |

% of studies complying with the factors: 100%, 77%, 4%, 65%, 58%, 54%, 50%, 100%, 69%, 94%, 73%

## Results

This study identified 1,470 articles using the keywords search strategy from four search databases. At the primary assessment level, this study excluded 526 articles as they were irrelevant and duplicated articles. A total of 287 articles related to anthropometric were unrelated to pressure description and vice versa based on their...
abstracts. Conclusively, this study included 26 articles in the meta-analysis because of their relation to the objective of the current study.

**Why is Anthropometric Measurement Needed?**

Anthropometry is a human individual measurement involving physical properties, that is, the dimensional descriptor of body size and shape. To develop a seat that provides great comfort and safety, anthropometric parameters should be considered as one of the affecting factors in the seat improvement. Three common methods exist to measure anthropometric parameter, namely, traditional measurement (anthropometer, weighing scale, measuring tape), 2D (photographic image) and 3D (scanning body).

Past studies mentioned that traditional method produces low accuracy and precision results for a complex anatomy and curvature landmark of the human body, whereas 2D and 3D methods are affected by the numerous images captured, viewing angles and lighting. Recently, the 3D method has high accuracy in measurement repeatability but the cost for equipment installation, practicing and maintenance are higher for body scanner (56,57). An accurate and relevant data can be collected and recorded using the appropriate, precise and rigid equipment monitored by the technical expertise. The measurement of the human body, particularly for Malaysian anthropometric data, should be followed on the basis of Malaysian Standards (MS ISO 7250:2003) (58).

There are 14 countries that have conducted an experiment on the basis of anthropometric related to pressure distribution. The diversity of the population in each country reflects the various dimensions of physical characteristics. Kyung and Nussbaum, (2013) have a perception that age could affect the interface between seat and human body (51). The variations in body dimension of each population in different countries, such as age, gender, body type and ethnicity could contribute significantly to the collection of anthropometric data (59-63). Several factors influence the process of designing a car seat, namely, human anthropometry, material, shape, seat geometry, and adjustability.

**Factors that Influence Pressure Variables**

Pressure distribution is a process to identify the discomfort between the human body and car seat. Objective assessments commonly use interface pressure value as the variable associated with subjective rating scales to evaluate car seat comfort or discomfort (64). Seat design weaknesses could be recognised from the analysis of the pressure distribution measurement. The pressure distribution results illustrate the effects of different factors, such as anthropometric parameters, venue, seat design, driving posture, seat material and driving condition (12,51,65-68).

Table 4 shows that almost all studies analyse the contact area between the human body with the seat pan and back. Muralitharan et al. pointed out that the softer material for the seat had a lesser impact and interface pressure transferred to the entire seat (69).

Comfort and safety seat should be designed to be flexible and adaptable to fit the different body shape and features. Na et al, reported the body pressure variables for subjective rating and objective assessment in which discomfort of the body parts occurred at the neck, shoulder, hip/buttock and thigh were identified (70). Another study indicated a relative low correlation between human body and seat pressure distribution as comfort assessment but seat material, demographics and anthropometric parameters significantly affected the seat pressure testing (28).
Table 4: Relationship between anthropometric parameter and pressure variables

| Reference | Anthropometric parameter | Position | Pressure variable |
|-----------|--------------------------|----------|------------------|
|           | Height                   | Weight   | BMI              |
|           | Upper body               | Lower body| Seat             | Seat back         | Contact Area | Mean Pressure | Peak Pressure | Pressure Ratio | Pressure Gradient|
| (36)      | ✓                        | ✓        | ✓                |
| (50)      | ✓                        | ✓        | ✓                |
| (37)      | ✓                        | ✓        | ✓                |
| (28)      | ✓                        | ✓        | ✓                |
| (38)      | ✓                        | ✓        | ✓                |
| (39)      | ✓                        | ✓        | ✓                |
| (35)      | ✓                        | ✓        | ✓                |
| (51)      | ✓                        | ✓        | ✓                |
| (32)      | ✓                        | ✓        | ✓                |
| (40)      | ✓                        | ✓        | ✓                |
| (52)      | ✓                        | ✓        | ✓                |
| (33)      | ✓                        | ✓        | ✓                |
| (41)      | ✓                        | ✓        | ✓                |
| (42)      | ✓                        | ✓        | ✓                |
| (25)      | ✓                        | ✓        | ✓                |
| (34)      | ✓                        | ✓        | ✓                |
| (53)      | ✓                        | ✓        | ✓                |
| (44)      | ✓                        | ✓        | ✓                |
| (43)      | ✓                        | ✓        | ✓                |
| (47)      | ✓                        | ✓        | ✓                |
| (45)      | ✓                        | ✓        | ✓                |
| (46)      | ✓                        | ✓        | ✓                |
| (48)      | ✓                        | ✓        | ✓                |
| (55)      | ✓                        | ✓        | ✓                |
| (49)      | ✓                        | ✓        | ✓                |

Correlation and Impacts of Anthropometry Parameters against Pressure Variables

To initiate and enhance the design to the global standards, three main design objectives must be fulfilled, that is, to plan and produce; (i) comfort (human factors and ergonomics consideration), (ii) safety (the seat capabilities–accident) and (iii) health (long-term spinal support, seat ergonomic and terrain-induced vibration attenuation). The interaction between human body and product due to the anthropometric factors could impact and lead to injury risks if an incompatibility exists between the product and the user (28,71).

During vehicle operation, the driver needs a comfortable and supporting workplace for various irritating postures caused by postural stress, muscular effort, vibration, impact and shock as well as affected upper and lower body of the drivers. Safety factors must be considered without compromising comfort factors whilst evaluating the design of the automotive seat (72). Hence, users comfort and safety is supposedly related to sitting postures, likewise, static and dynamic anthropometry data must be considered for a proper design of a safe and comfortable vehicle seat (73). The ergonomic seat design compatible with the human body contour could increase the comfort level for an effective workspace, efficient driving and avoidance of various pain and injuries (74). The ergonomic intervention for an automotive development particularly car seat during the preliminary design stages is based on the physical size of the driver, predicted posture and driving control space (75).
The relationship between anthropometric parameters and pressure distribution may lead to pain, safety factor and discomfort when driving. Past studies confirmed that a strong correlation exists between the buttock area and buttock–popliteal length ($R=0.804$). Meanwhile, the highest correlation coefficient at the buttock area was influenced by BMI ($R=0.89$) and quotient of weight and height ($R=0.78$); the higher the indicators, the larger the interface between buttock and seat (42,70). As mentioned by Vergara and Page, (2002), anthropometry, subjective assessment and objective evaluation are the best ways to evaluate comfort namely postural, biomechanics and physiological parameters (12). This indicates that almost all studies showed that there are moderate to very high correlation between the human body and the pressure variable, particularly on the lower body part with $R$ value for all pressure variables are in between 0.6 to 0.9. Anthropometry and postural variations cause differences distribution of pressure on the seat pan and seat back that requires asymmetric posture to increase the balanced between bilateral body parts for an ergonomic and comfortable human-seat interface.

**Discussion**

Car seats can be influenced by the overall ergonomic seat design, which includes material, stiffness, pressure distribution, force shear and shapes and dynamic factors in causing instantaneous environment, such as vibrations and shock (76-78). Regarding the anthropometric dimension, weight and BMI significantly impact the changes in total contact area of body with the seat (42,79). In addition, the settings of the experimental venue indicated effects of pressure variables during sitting. Hence, performing the test separately under static and dynamic circumstances is advisable. Fig. 2 depicts the interdependency of each factor affecting the comfort and safety of the drivers. The user factor affected by physical characteristics (height, BMI), physiological factor (demographic, health status) and psychological criteria (mental state, experience). Meanwhile, driving, activities and operation skills could affect the comfort and safety of the drivers. Perception of drivers concerning environment factors such as dynamic factors (vibration, shocks, and acceleration), ambient factors (thermal comfort, noise, pressure gradients), and spatial factors (workspace, operation control) as well as the ergonomics of the passenger’s position (80,81).

![Fig. 2: Factors contributing to seating comfort and safety](image-url)
Conclusion

Ultimately, the correlation between anthropometry parameter and pressure variables is slightly but statistically significant to the comfort and safety level evaluation. This was validated by a correlation analysis between body parts, particularly lower body and pressure analysis with R-values above 0.50. Age, gender, anthropometric parameters and body posture have an effect on the pressure variables under static and dynamic conditions. The anthropometric parameters are influenced by the body posture and seat adjustability, whereas the pressure variables depend on the road condition, time duration, design, driving posture and material of the seat. Human body parameter, such as BMI, weight and height are common measurements used to evaluate the impact of anthropometric parameter on car seat. Hence, ergonomically good seats would greatly reduce musculoskeletal pain and enhance the comfort, safety and competency amongst drivers. Finally, future research should concentrate on different road tasks at a maximum driving period and increase the number of subjects to predict strong correlation results that will validate the comfort and safety in real-driving performance. Statistical analysis and evidence are important to strengthen the outcome, such as the effect of different road surfaces, conditions and prolonged duration of driving with a variety of anthropometry parameters of the subjects.

Ethical considerations

Ethical issues (Including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc.) have been completely observed by the authors.

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Conflict of interest

The authors declare that there is no conflict of interests.

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