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

Nabilah Sabri [1], *Nor Kamaliana Khamis [1], Mohd Faizal Mat Tahir [1], Jailani Besar [1,2], Dzuraidah Abd Wahab [1]

1. Department of Mechanical and Manufacturing Engineering, Faculty of Engineering & Built Environment, Universiti Kebangsaan Malaysia, Bangi, Selangor, Malaysia
2. Department of Vehicle Architecture & Integration, Proton Holdings, Shah Alam, Selangor, Malaysia

*Corresponding Author: Email: kamaliana@ukm.edu.my

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.

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.
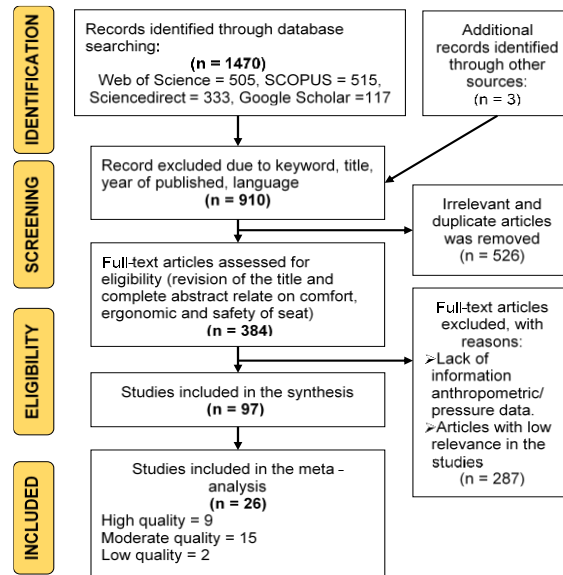
Fig. 1: PRISMA flow chart guidelines

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.

The articles were categorized into four quality groups which were "High" [80-100], "Moderate" [60-79] and "Low" [31-59] and "Very Low" [1-30]. However, for very low quality, no studies were listed and eligible for inclusion in the group. There were six articles of high quality, seventeen were of moderate quality, and three of low quality.

Table 3: Quality assessments of selected articles

Authors	Precise objectives/ hypothesis 3	Sample size 3	Follow up / Comparison past study 2	Control group 1	Real environment 1	Subjective evaluation 2	Anthropometry parameter 3	Pressure variables analysis 3	Detailed Statistical method 2	Consistent conclusion 3	Scope, coverage and depth 3	Quality 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	N	Y	P	L
Ismail et al (35)	Y	N	N	Y	Y	N	Y	Y	N	Y	P	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												
Makhsous et al (38)	Y	Y	N	Y	Y	N	N	Y	Y	Y	P	M
Paul et al (39)	Y	Y	N	Y	Y	N	Y	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	Y	N	Y	N	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	Y	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	Y	N	Y	Y	M
Khamis & Deros (48)	Y	Y	N	Y	N	N	Y	Y	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	Y	N	Y	N	Y	Y	Y	Y	H
Jones et al (54)	Y	Y	N	Y	N	N	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 pan	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)	√	√		√		√	√	√		√		
(54)	√	√	√	√	√	√	√				√	
(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 automotive 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.

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).
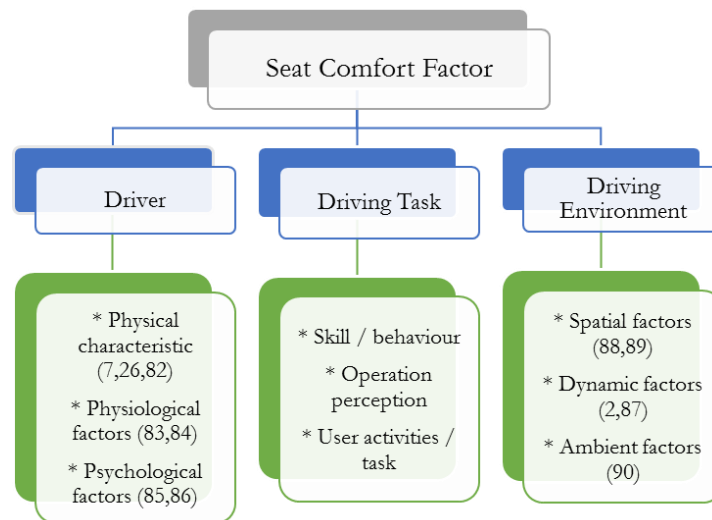
Discussion

Fig. 2: Factors contributing to seating comfort and safety

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.

Acknowledgements

Conflict of interest

The authors declare that there is no conflict of interests.

References

1. Kumar AR (2007). A Study to Investigate the Relationship Between a User's Thermal Comfort and Seat Pan Materials. Dissertations, 886.
2. Ciloglu H, Alziadeh M, Mohany A, et al (2015). Assessment of the whole body vibration exposure and the dynamic seat comfort in passenger aircraft. *Assessment of the whole body vibration exposure and the dynamic seat comfort in passenger aircraft.*, 45: 116–123.
3. de Looze MP, Kuijt-Evers LFM, van Dieën J (2003 Aug). Sitting comfort and discomfort and the relationships with objective measures. *Ergonomics*, 46 (10): 985–97.
4. Dumur E, Barnard Y, Guy B (2004). Designing for comfort. *Hum Factors Des*, 111–127.
5. Groenesteijn L, Hiemstra-van Mastrigt S, Gallais C, et al (2014). Activities, postures and comfort perception of train passengers as input for train seat design. *Ergonomics*, 57 (8): 1154–65.
6. Hiemstra-van Mastrigt S, Groenesteijn L, Vink P, et al (2017). Predicting passenger seat comfort and discomfort on the basis of human, context and seat characteristics: a literature review. *Ergonomics,* 60 (7): 889–911.
7. Khalid HM (2006). Embracing diversity in user needs for affective design. *Appl Ergon*, 37 (4): 409–18.
8. Kuijt-Evers LFM, Krause F, Vink P (2003). Aspects to improve cabin comfort of wheel loaders and excavators according to operators. *Applied Ergonomics,* 34 (3): 265–271.
9. Kyung G, Nussbaum MA, Babski-Reeves K (2008). Driver sitting comfort and discomfort (part I): Use of subjective ratings in discriminating car seats and correspondence among ratings. *International Journal of Industrial Ergonomics*, 38 (5–6): 516–525.
10. Noor NSM, Ghazalli Z, Mamat R, et al (2016). The enhancement of driver seat comfort for

small size car: A preliminary study. *Malaysian Journal of Public Health Medicine*, 16 (Specialissue1): 108–114.

11. Sheth S, Tamboli K, Raghupathi P, et al (2011). Study of the Ergonomics of a Car Seat and Its Effect on Seat Reclining Levers. In: *Proc of the 1st International Conference on Modern Trends in Industrial Engineering*, p. 1–4.

12. Vergara M, Page Á (2002). Relationship between comfort and back posture and mobility in sitting-posture. *Appl Ergon*, 33 (1): 1–8.

13. Cascioli V, Heusch AI, Mccarthy PW (2011). Does prolonged sitting with limited legroom affect the fl exibility of a healthy subject and their perception of discomfort? *International Journal of Industrial Ergonomics,* 41 (5): 471–480.

14. Grujicic M, Pandurangan B, Xie X, et al (2010). Musculoskeletal computational analysis of the influence of car-seat design / adjustments on long-distance driving fatigue. *International Journal of Industrial Ergonomics,* 40 (3): 345–355.

15. Kumar R, Sharma R, Mittal VK (2016). History of Cause - Effect Relationship Between Whole Body Vibrations and Musculoskeletal Disorders in Truck Drivers. *ELK Asia Pacific Journals*, (Special Issues).

16. Nazerian R, Korhan O, Shakeri E (2018). Work-related musculoskeletal discomfort among heavy truck drivers. *Int J Occup Saf Ergon*, 26(2):233-244.

17. Guo M, Li S, Wang L, et al (2016). Research on the relationship between reaction ability and mental state for online assessment of driving fatigue. *Int J Environ Res Public Health*, 13 (12): 1174.

18. Nævestad T-O, Laiou A, Phillips RO, Bjørnskau T, et al (2019). Safety Culture among Private and Professional Drivers in Norway and Greece: Examining the Influence of National Road Safety Culture. *Safety*, 5 (2): 20.

19. Khamis NK, Deros MB, Nuawi MZ (2018). Pattern of Muscle Contraction in Car Pedal Control Pattern of Muscle Contraction in Car Pedal Control. *Jurnal Kejuruteraan,* 30 (1): 23–29.

20. Mansfield, N. J (2004). *Human response to vibration.* CRC press.

21. Mansfield NJ, Mackrill J, Rimell AN, et al (2014). Combined Effects of Long-Term Sitting and Whole-Body Vibration on Discomfort Onset for Vehicle Occupants. *ISRN Automot Eng*, 852607:1–8.

22. Mohamad D, Deros BM, Abdul Wahab D, et al (2010). Integration of Comfort into a Driver's Car Seat Design Using Image Analysis. *Am J Appl Sci*, 7 (7): 937–942.

23. Reed MP, Manary MA, Flannagan CAC, et al (2000). Effects of Vehicle Interior Geometry and Anthropometric Variables on Automobile Driving Posture. *Hum Factors*, 42 (4): 541–552.

24. Sagot JC, Gouin V, Gomes S (2003). Ergonomics in product design: Safety factor. *Safety Science*, 41 (2–3): 137–154.

25. Zemp R, Taylor WR, Lorenzetti S (2016). Seat pan and backrest pressure distribution while sitting in office chairs. *Appl Ergon*, A: 1–9.

26. Kolich M (2003). Automobile seat comfort: Occupant preferences vs. anthropometric accommodation. *Appl Ergon*, 34 (2): 177–84.

27. Onawumi AS, Lucas EB (2012). Ergonomic investigation of occupational drivers and seat design of taxicabs in Nigeria. *ARPN J Sci Technol,* 2 (3): 214–220.

28. Vincent A, Bhise VD, Mallick P (2012). Seat Comfort as a Function of Occupant Characteristics and Pressure Measurements at the Occupant-Seat Interface. *SAE Technical Paper*, 2012-01-0071.

29. Higgins JP, Thomas J, Chandler J, et al (2019). *Cochrane handbook for systematic reviews of interventions.* John Wiley & Sons.

30. Moher D, Liberati A, Tetzlaff J, et al (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. *PLoS Med,* 6 (7): e1000097.

31. Schünemann H, Brożek J, Guyatt G, et al (2013). *GRADE handbook for grading quality of evidence and strength of recommendations.* Updated October 2013. The GRADE Working Group.

32. Akgunduz A, Rakheja S, Tarczay A (2014). Distributed occupant-seat interactions as an objective measure of seating comfort. *International Journal of Vehicle Design,* 65 (4): 293–313.

33. More R., Bindu R (2015). Comfort Analysis of Passenger Car Vehicle Seat. *Int J Eng Sci Innov Technol*, 4 (4): 95–100.

34. Kilincsoy U, Wagner A, Vink P, et al (2016). Application of ideal pressure distribution in development process of automobile seats. *Work,* 54 (4): 895–904.

35. Ismail AR, Abdullah SN, Sukadarin EH, et al (2013). Ergonomics Assessment of Seat

Design Based on Buttock Pressure and Anthropometrics *Data. Adv Eng Forum*, 10 (2013): 331–335.

36. Jin X, Cheng B, Wang B, Shen B (2009). Assessment of driver's seating discomfort using interface pressure distribution. *2009 IEEE Intell Veh Symp*, 1419–1424.

37. Daruis DDI, Deros BM, Nor MJM, et al (2012). Relationship between Objective and Subjective Methods in Evaluating Static Discomfort of Car Driver Seat. *Adv Mater Res*, 4997–5003.

38. Makhsous M, Lin F, Hanawalt D, et al (2012). The effect of chair designs on sitting pressure distribution and tissue perfusion. *Hum Factors,* 54 (6): 1066–74.

39. Paul G, Daniell N, Fraysse F (2012). Patterns of correlation between vehicle occupant seat pressure and anthropometry. *Work*, 1:2226-31.

40. Park SJ, Min SN, Subramaniyam M, et al (2014). Analysis of Body Pressure Ratio for Evaluation of Automotive Seating Comfort. *SAE Technical Paper,* doi.org/10.4271/2014-01-0456.

41. Rahayu S, Firdaus M (2015). A Comparison Study between the Road Condition with Pressure Distribution on the Seat and Car Vibration. *Journal of Public Health Medicine*, 15(1):77-82.

42. Zuska A, Jurecki R, Jaśkiewicz M. (2016). Laboratory Study About Pressure Distribution on Car Seats With People of Different Anthropometric Features Participation. *Arch Automot Eng*, 74 (4): 115–127.

43. Ren J, Du X, Liu T, et al (2017). An Integrated Method for Evaluation of Seat Comfort Based on Virtual Simulation of the Interface Pressures of Driver with Different Body Sizes. *SAE Technical Paper*, doi.org/10.4271/2017-01-0406.

44. Khamis N, Deros B, Schramm D, et al (2017). Predicting pressure level felt under the seat pan due to changes in driving position. *Pressacademia,* 5 (45): 325–334.

45. Vink P, Lips D (2017). Sensitivity of the human back and buttocks: The missing link in comfort seat design. *Appl Ergon*, 58: 287–292.

46. Ab.Rahman MH, Maidin NA, Ahmad MN, et al (2018). The study of seating pressure on car seat between two national cars. *Malaysian Journal of Public Health Medicine*, 18:135-141.

47. Khamis NK, Roslan AF, Deros BM, et al (2018). Measuring pressure interface of local car seats under static and dynamic circumstances: A comparative study. *Malaysian Journal of Public Health Medicine,* (2): 89-96.

48. Khamis NK, Deros BM (2018). Development of a statistical model for predicting seat pressure felt level in simulated condition based on direct and anthropometric measurement. *J Phys Ther Sci,* 30 (6): 764–769.

49. Mitsuya R, Kato K, Kou N , et al (2019). Analysis of body pressure distribution on car seats by using deep learning. *Appl Ergon*, 75:283-287.

50. Chae S, Kyung G, Nam K (2011). Measuring drivers' dynamic seating experience using pressure mats. In: *International Conference of Design, User Experience, and Usability* ,368–375.

51. Kyung G, Nussbaum MA (2013). Age-related difference in perceptual responses and interface pressure requirements for driver seat design. *Ergonomics*, 56 (12): 1795–1805.

52. Cengiz TG, Sari S, Günay İ (2015). Car Seat Comfort by Measuring Interface Pressure and Using Subjective Evaluation System in Road Trials. *International Journal of Automotive Engineering and Technologies,* 4 (4): 172–184.

53. Fang R, Gao J, Xie S (2015). Analysis of Pressure Distribution Between Human and Seat for Evaluation of Automotive Seating Comfort. *Proceedings of SAE-China Congress,* 383–395.

54. Jones M, Park J, Ebert-hamilton S, et al (2017). Effects of Seat and Sitter Dimensions on Pressure Distribution in Automotive Seats. *SAE Technical Paper,* doi.org/10.4271/2017-01-1390.

55. Heckler B, Wohlpart M, Bengler K (2019). Anthropometric Factors in Seat Comfort Evaluation: Identification and Quantification of Body Dimension Affecting Seating Comfort. *Congress of the International Ergonomics Association.* Springer International Publishing.

56. Lau MH, Armstrong TJ (2011). The effect of viewing angle on wrist posture estimation from photographic images using novice raters. *Applied Ergonomics*, 42 (5): 634–643.

57. Yu A, Yick KL, Ng SP, Yip J (2013). 2D and 3D anatomical analyses of hand dimensions for custom-made gloves. *Appl Ergon*, 44 (3): 381–92.

58. Standard, M. MS ISO 7250: 2003 *Basic human body measurements for technological design (ISO 7250:*

1996, IDT). Department of Standards Malaysia.

59. Deros BM, Hassan NHH, Daruis DDI, et al (2015). Incorporating Malaysian's Population Anthropometry Data in the Design of an Ergonomic Driver's Seat. *Procedia - Social and Behavioral Sciences,* 195 (2015): 2753–2760.

60. Abd Rahman NI, Md Dawal SZ, Yusoff N, et al (2017). Anthropometric measurements among four Asian countries in designing sitting and standing workstations. *Indian Academy of Sciences,* 43:10.

61. Lin YC, Wang MJJ, Wang EM (2004). The comparisons of anthropometric characteristics among four peoples in East Asia. *Appl Ergon*, 35 (2): 173–8.

62. M.Yusuff R, Hussain M, S.A.R SN (2009). Anthropometry Dimensions of Older Malaysians: Comparison of Age, Gender and Ethnicity. *Asian Social Science,* 5 (6): 133–140.

63. Oyewole SA, Haight JM, Freivalds A (2010). The ergonomic design of classroom furniture / computer work station for fi rst graders in the elementary school. *International Journal of Industrial Ergonomics*, 40 (4): 437–447.

64. Deros BM, Daruis DD, Mohd Nor MJ (2009). Evaluation of Car Seat Using Reliable and Valid Vehicle Seat Discomfort Survey. *Ind Eng Manag Syst,* 8(2): 121–130.

65. Andreoni G, Santambrogio GC, Rabuffetti M, et al (2002). Method for the analysis of posture and interface pressure of car drivers. *Applied Ergonomics*, 33 (6): 511–522.

66. Kolich M (2004). Selected car seat studies dealing with static pressure distribution. *SAE Technical Papers,* DOI:10.4271/2004-01-0377.

67. Smith J, Mansfield N, Gyi D, et al (2015). Driving performance and driver discomfort in an elevated and standard driving position during a driving simulation. *Appl Ergon*, 49: 25–33.

68. Tewari V., Prasad N (2000). Optimum seat pan and back-rest parameters for a comfortable tractor seat. *Ergonomics*, 43 (2): 167–86.

69. Muralitharan M, Helmi SA, Ismail K (2017). Design Automotive Driver Seat Ergonomically for Malaysian. *Human Factors and Ergonomics Journal*, 2 (3): 21–26.

70. Na S, Lim S, Choi HS, et al (2005). Evaluation of driver's discomfort and postural change using dynamic body pressure distribution. *International Journal of Industrial Ergonomics*, 35 (12): 1085–1096.

71. Pheasant S, Haslegrave CM (2005). *Bodyspace: Anthropometry, ergonomics and the design of work.* CRC press.

72. Mandal SK, Maity A, Prasad A (2015). Automotive Seat Design: Basic Aspects. *Asian Journal of Current Engineering and Maths*, 4 (5): 62–68.

73. Kolich M (2008). A conceptual framework proposed to formalize the scientific investigation of automobile seat comfort. *Appl Ergon,* 39 (1): 15–27.

74. Jhinkwan A, Singh J (2014). Design Specifications and Ergonomic Evaluation of Car Seat (A Review). *Int J Eng Res Technol,* 3 (5): 611–623.

75. Schmidt S, Amereller M, Franz M, et al (2014). A literature review on optimum and preferred joint angles in automotive sitting posture. *Applied Ergonomics*, 45 (2): 247–260.

76. Kim SG, Ko CY, Kim DH, et al (2017). Development of a shear force measurement dummy for seat comfort. *PLoS One*, 12 (11): e0187918.

77. Sammonds GM, Fray M, Mansfield NJ (2017). Effect of long term driving on driver discomfort and its relationship with seat fidgets and movements (SFMs). *Appl Ergon*, 58: 119–127.

78. Toward MG (2010). Factors affecting the dynamic response of the body and the vibration transmitted through seats. Doctoral dissertation, University of Southampton.

79. Fojtlín M, Psikuta A, Toma R, et al (2018). Determination of car seat contact area for personalised thermal sensation modelling. *PLoS One,* 13(12):e0208599.

80. Silva MCG (2002). Measurements of comfort in vehicles. *Meas Sci Technol,* 13: 41–60.

81. Stanković M, Mićović A, Sedmak A, et al (2018). Analysis of comfort parameters in special purpose vehicles from technological development point of view. *Technical Gazette,* 25 (2): 502–509.

82. Patel MX, Doku V, Tennakoon L (2003). Challenges in recruitment of research participants Challenges in recruitment of research participants. *Advances in Psychiatric Treatment*, 9 (3): 229–238.

83. Ellegast RP, Kraft K, Groenesteijn L, et al (2012). Comparison of four specific dynamic office

chairs with a conventional of fi ce chair : Impact upon muscle activation , physical activity and posture. *Appl Ergon*, 43 (2): 296–307.

84. Gokila P, Suresh P (2014). Parameters influenced in car seat design from Ergonomic Perspectives - A Review. *Applied Mechanics and Materials,* 592-594.

85. Fazlollahtabar H (2010). A subjective framework for seat comfort based on a heuristic multi criteria decision making technique and anthropometry. *Appl Ergon*, 42 (1): 16–28.

86. Yang Z, Sun S, Chen G (2009). Evaluating sitting comfort with questionnaire and body pressure distribution: Overview and design. *Proceeding 2009 IEEE 10th Int Conf Comput Ind Des Concept Des E-Business, Creat Des Manuf - CAID CD'2009*. p.1443–1447.

87. Mohamad D, Deros BM, Ramli NF, et al (2016). Comfortable driver's car seat dimensions based on Malaysian anthropometrics data. *Iran J Public Health*, 45(1): 106–113.

88. Skilling EJ (2016). *Chapter 12. Workstation, work area, and console design. Human Factors in the Chemical and Process Industries*. Elsevier Inc. p. 205–222

89. Fard M, Lo L, Subic A, Jazar R (2014). Effects of seat structural dynamics on current ride comfort criteria. *Ergonomics*, 57 (10): 1549–1561.

90. Ormuž K, Muftić O (2004). Main ambient factors influencing passenger vehicle comfort. *Ergonomics*,77-84.