Anthropometric Seat Design for Bus Drivers in Southwestern Nigeria

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Abstract

Most buses used in Nigeria are imported; thus, the anthropometric dimensions of the citizens of the country of manufacture were used for the seat design. Poorly designed seats due to a mismatch in anthropometric measurements may lead to musculoskeletal disorders. Hence, there is a need to design an appropriate seat for particular bus drivers. This study aimed to obtain anthropometric dimensions of Nigerian bus drivers and design an appropriate driver's seat based on the collected dimensions. Relevant anthropometric variables necessary for the driver's seat design were obtained from 150 randomly selected male bus drivers from seven towns in Ogun, Oyo and Lagos states. Seat dimensions of 50 urban buses in heavy and medium automobile categories were considered. The means, standard deviations and 5th, 50th and 95th percentiles were calculated. The existing seat dimensions were compared with the required anthropometric measurements of the drivers for the seat design. It was found that the current seat measurements differed from the suggested seat dimensions. The study highlighted that in designing and producing bus seats for Nigerian bus drivers, their anthropometric data should be considered. The study recommended that the dimensions of the driver's seat should be 46.45-50.45 cm (seat height); 39-48.26 cm (seat depth); 46.83 cm (seat front width); 53 cm (backrest height); 49-58.26 (backrest depth); and 90° to 130° (seat backrest angle).

***Keywords**:* anthropometric dimensions, professional bus drivers, vehicle seat design

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1. Introduction

Anthropometric measurements vary according to ethnicity, gender, age, race, occupation and patterns of nutrition (Ismaila, 2009; Agrawal *et al*., 2010; Guan *et al*., 2012; Spasojević-Brkić *et al*., 2014). Hence, anthropometry is needed in developing specific standards and requirements associated with manufactured goods and services to ensure the usability and suitability of products for the user population (Okunribido *et al*., 2007). Also, the safe and economical accomplishment of various tasks depends on the users' anthropometric characteristics (Ismaila *et al*., 2013). However, in the automotive industry, Nigerians depend on the imported vehicles that have been designed using the anthropometric dimensions of the people from the manufacturer's country of origin. It is also uncertain whether or not the vehicles, assembled in Nigeria, use Nigerian anthropometric data as the required anthropometric measurements for the seat design.

One of the earliest reported ergonomic assessments of vehicle seats in Nigeria was made by Ismaila *et al*. (2010). The study obtained the anthropometric data of bus users to determine a possible mismatch between their relevant dimensions and bus seats. It was found that there was an incompatibility between the anthropometric dimensions of passengers and the seat dimensions. Lucas and Onawumi (2013) conducted an ergonomic assessment of the in-automobile interface design of taxi cabs. The study established that there were fleets of disused cabs that were generally not user-friendly. Fajobi *et al*. (2019) confirmed that there was a mismatch between the anthropometric dimensions of drivers and seats in some buses (Toyota and Mazda). Similarly, Ismaila *et al*. (2021) carried out an ergonomic assessment of drivers' workstations. They discovered that the seats offered by vehicle manufacturers were not ergonomically appropriate for drivers.

Consequently, the said mismatches affect the driver's sedentary posture, which is a key risk factor for musculoskeletal illnesses and contributes to their development (Byran *et al*., 2013). It is worthy to note that for vehicle drivers, the comfort while driving is different from that of sitting on a chair at home, at the office, or in the workplace (Deros *et al*., 2015). After driving for 135 min, drivers experience increased discomfort in the driver's back, buttocks and thighs (Porter *et al*., 2003). Hence, appropriate seat design should be made to avoid the risk of developing a musculoskeletal disorder (Gouvali and Boudolos, 2006; Murphy *et al*., 2007) and obtaining severe injury under different velocities in a frontal crash (Jinhuan *et al*., 2016).

An ergonomically suitable product and physical equipment require that they be designed using the anthropometric data of the user population. Kovacevic *et al.* (2010) noted that a properly designed vehicle seat reduces the driver's fatigue and provides safe traffic. Sedentary posture should be given additional consideration throughout the design process, especially when there are other manual tasks involving the use of force (Li and Haslegrave, 1999). The availability of users' anthropometric data also enhances the seat design as this is used by manufacturers as a guide to developing products for the global market (Dawal *et al.*, 2015; Jamir *et al.*, 2015) allowing the product to be ergonomically useful to the population of certain countries (Rahman *et al.*, 2018). Jinhuan *et al.* (2016) advised to consider the differences in anthropometric dimensions between nationalities (Chinese and Americans) in the development of new vehicle models in China for Chinese drivers. Onawumi *et al.* (2016) reported the development of predictive models for some anthropometric dimensions of Nigerian professional bus operators. The study collected anthropometric data from occupational bus operators in Nigeria and provided three mathematical models to predict the anthropometric variables necessary for the design and manufacture of driver's workplace and in-vehicles elements. Lastly, Uba *et al.* (2018) proposed some measurements for the automotive seat using Nigerian representative anthropometric data to guide designers of automobiles for the Nigerian market.

The previous studies only emphasized the need to design seats of vehicles using users' anthropometric data as there were incongruences between the users and the seats. However, they only amassed relevant anthropometric data from Nigerian commercial bus drivers but did not utilize the obtained data to design appropriate seats for their use. Hence, this study aimed to collect the seat dimensions of the existing buses and anthropometric data from Nigerian commercial bus drivers. The obtained data was then used to design an ergonomically suitable seat for them.

2. Methodology

2.1 Sample Selection

The participants agreed to be part of the study after the aim was explained to them. Relevant anthropometric measurements for the driver's seat design and age were obtained from 150 randomly selected male bus drivers in seven urban centers in Ogun (Abeokuta, Ilaro, Sagamu and Ijebu-Ode); Oyo (Ibadan and Oyo) and Lagos States (Oshodi and Yaba). The mentioned locations were selected because of economic activities and bus traffic. The sample size was determined using Cochran's (1977) formula as presented in Equation 1.

$$N = \frac{Z^2 * pq}{e^2} \tag{1}$$

where e (margin of error) = 7%; p (population proportion) = 0.5; Z = 1.65 (90% confidence level); and q = 1-p.

Roscoe (1975) suggested that in determining the sample size, a sample size greater than 30 and less than 500 should be sufficient for most research. Furthermore, according to Saunders *et al.* (2000), many statisticians agree that a sample size of 30 or more usually has a mean that is very close to the normal distribution.

2.2 Measurement of Seat and Bus Driver's Anthropometric Dimensions

A total of 50 vehicles (five each in heavy and five each in medium categories were used in the study). Table 1 presents the details of these vehicles.

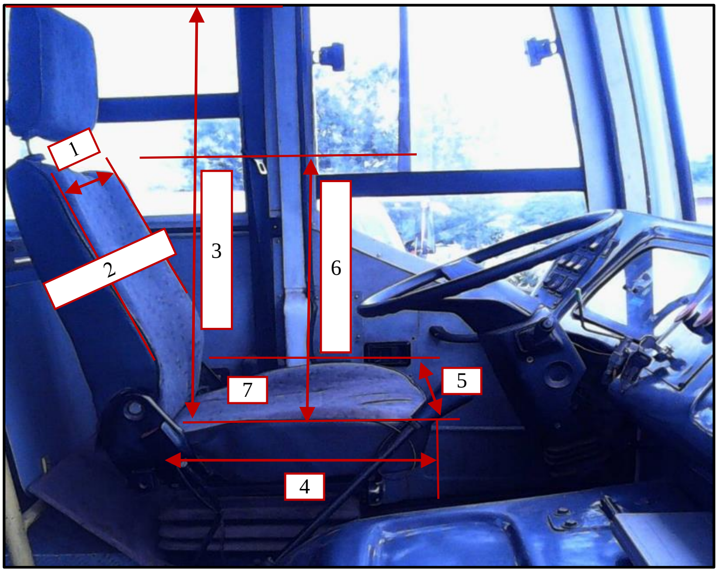
Table 1. Automobiles categories and their brand, country of manufacture and seating capacity

Heavy automobile		Medium automobile	
Brand (country of origin)	Seating capacity	Brand (country of manufacture)	Seating capacity
Foton (China)	42	Mitsubishi 1 (Japan)	14
Ashok (India)	42	Toyota-Coaster (Japan)	30
Tata (India)	42	Mazda (Japan)	10
Comil (Brazil)	54	Honda-Oddysey (Japan)	10
		Nissan-Urvan (Japan)	14
		Mitsubishi 2 (Japan)	10

The driver's anthropometric and seat variables were measured using a digital stadiometer (Detecto PD 300 M, Cardinal Scale Manufacturing Company, United Kingdom) and a Vernier caliper (0-600 mm, Mitutoyo, Japan), respectively.

2.2.1 Measurement of Seat Dimensions

The following seat dimensions were measured: seat front width, seat back width, seat depth, backrest width (shoulder level), seat height, seat back height and backrest width (lumbar level). The seat measurements were described by Chakrabortty *et al.* (2014) (Figure 1).



1 – backrest width (shoulder); 2 – backrest width (lumbar); 3 – seat height; 4 – seat depth; 5 – seat front width; 6 – seat back height; 7 – seat back width

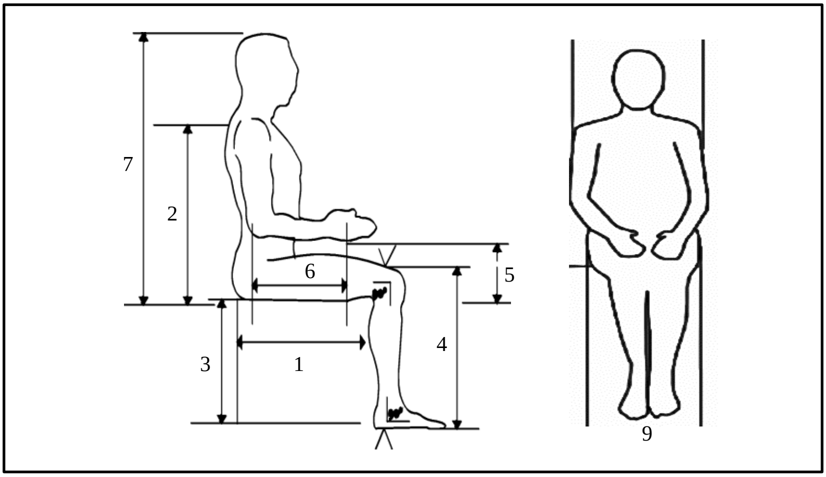
Figure 1. Measured seat variables

2.2.2 Measurement of Driver's Anthropometric Variables

The anthropometric dimensions of the driver required for the design of seat dimensions were sitting height, popliteal height, hip breadth, shoulder width, sitting shoulder height, buttock-popliteal length, elbow rest height, knee height and elbow-hand grip. The measurements were described by Halder *et al.* (2018) and Mohamad *et al.* (2016) as presented in Figure 2.

2.3 Seat Design Considerations

In the design of the bus driver's seat, seat height, depth, and width as well as backrest height, depth and angle were taken into consideration. The required anthropometric measure for seat height was the popliteal height and for adjustability, the dimensions were the 5th and 95th percentiles as the minimum and maximum dimensions, respectively. A shoe heel allowance of 0.45 cm was also added to the minimum and maximum dimensions. The required anthropometric measure for seat depth was the buttock-popliteal length; the dimensions of the seat depth were the 5th and 95th percentiles of the buttock popliteal length as the minimum and maximum dimensions, respectively. The seat width was determined using the hip breadth of the widest hip, usually that of a female. The 5th percentile of the shoulder height (sitting) was taken for the backrest height. The backrest depth was taken as the sum of the seat depth and backrest's thickness. A thickness of 10 cm was considered for the backrest. For the backrest angle, the seat backrest was inclined at an angle towards the back.



1 – buttock-popliteal length; 2 – sitting shoulder height; 3 – popliteal height; 4 – knee height; 5 – elbow rest height; 6 – elbow-hand grip; 7 – sitting height; 8 – shoulder width; 9 – hip breadth

Figure 2. Measured driver's anthropometric variables
(adapted from Ismaila *et al*., 2015)

2.4 Data Analysis

The statistical analysis of the obtained data was conducted using descriptive statistics such as mean, standard deviation, 5th, 50th and 95th percentiles in the Statistical Package for the Social Sciences (SPSS) version 16. The T-*t*est analysis was used to determine whether there were significant differences between the current seat dimensions and the recommended values at 5% level of significance.

3. Results and Discussion

3.1 Nigerian Bus Drivers' Anthropometric and Seat Dimensions

Table 2 presents the summarized anthropometric dimensions of Nigerian male bus drivers whose ages ranged from 23 to 61 years (mean of 47.7 years) while the dimensions of the driver's seat are presented in Table 3. In Table 2, the mean, standard deviation, 5^{th}, 50^{th} and 95^{th} percentiles of the anthropometric data obtained from the drivers are shown. Percentile is widely used in anthropometry to categorize anthropometric dimensions with 5^{th}, 50^{th} and 95^{th} percentiles representing small, medium and large dimensions, respectively (Zhang *et al*., 2016). The 5^{th}, 50^{th} and 95^{th} percentiles mean that at least 5, 50 and 95%, respectively, of the population will have the dimensions as specified against each. Thus, at least seven drivers would have a stature of 168 cm.

Table 2. Summarized anthropometric measurements (cm) of bus drivers

Variable	*n*	Mean	SD	5^{th} percentile	50^{th} percentile	95^{th} percentile
Stature	150	173.15	3.32	168.80	173.00	179.10
Sitting height	150	83.18	4.52	76.90	83.00	90.00
Shoulder width	150	44.50	3.25	40.00	44.00	50.00
Sitting shoulder height	150	55.40	1.97	53.00	55.00	58.15
Buttock-popliteal length	150	48.75	1.45	49.95	49.00	50.00
Hip breadth	150	37.02	1.98	34.70	37.00	40.15
Knee height	150	59.25	1.48	56.95	59.00	61.05
Elbow rest height	150	20.8	1.93	21.26	20.00	24.58
Elbow hand grip	150	30.29	1.35	28.00	30.00	31.00
Popliteal height	150	47.46	1.22	46.00	47.50	50.00

Table 3 presents the seat dimensions for the heavy automobile (HA) and medium automobile (MA) measured in the current study. It was found that the seat heights from the cabin floor were 39-43 and 27-35 cm for HA and MA, respectively. The seat depths were 40-50 and 49-50 cm for HA and MA, respectively. The seat front width range was 47-50 cm for the HA, while the MA had a value of 50 cm.

Table 3. Dimensions of driver' seat (cm) in the sampled vehicles

Variable	Heavy automobile				Medium automobile					
	Foton	Ashok	Tata	Comil	Nissan (Urvan)	Mazda	Toyota (Coaster)	Mitsubishi 1	Mitsubishi 2	Honda (Odyssey)
Seat height	43.00	39.00	43.00	40.00	33.00	35.00	27.00	42.00	34.00	25.00
Seat depth	50.00	50.00	50.00	40.00	50.00	49.00	49.00	50.00	50.00	50.00
Seat front width	48.00	50.00	48.00	47.00	50.00	50.00	50.00	54.00	48.00	50.00
Seat back width	43.00	38.00	38.00	47.00	38.00	44.00	42.00	42.00	38.00	44.00
Backrest width (lumbar)	38.00	43.87	42.00	34.00	50.00	47.00	52.00	48.00	47.00	50.00
Backrest width (shoulder)	54.00	45.68	46.00	49.00	42.00	43.00	48.00	46.00	43.00	45.00
Backrest height	43.00	50.00	50.00	46.00	54.00	55.00	55.00	50.00	50.00	58.00

There were different width dimensions of the backrest at the lumbar and shoulder levels. The backrest widths (lumbar) were 34-43 and 47-52 cm for HA and MA vehicles, respectively. These values at the shoulder were 46-54 cm (HA) and 42-48 cm (MA). The backrest height was obtained using the sitting shoulder height; the backrest height ranges were 43-50 cm for HA and 54-55 cm for MA.

3.2 Dimensions of Seat Design Considerations

As mentioned in the preceding section, the important dimensions in the seat design are seat height, depth, and width and backrest height, depth and angle. The fact that seats will cause discomfort over a period of time necessitates the provisions for adjustability of the seats to allow a change in body posture to reduce discomfort (Van Rosmalen *et al*., 2009). Adjustable design involves the use of the 5^{th} and 95^{th} percentiles of the required dimensions as the minimum and maximum values, respectively.

3.2.1 Seat Height

Park *et al.* (2013) noted that the driver's sitting height was a determinant of the sitting posture that was adopted. The appropriate dimensions for seat height are 46 cm (minimum) and 50 cm (maximum). However, there is a need to add a shoe heel allowance of 0.45 cm to the minimum and maximum dimensions as suggested by Kothiyal and Tettey (2001). The implication is that the minimum and maximum dimensions of the seat should be 46.45 and 50.45 cm (Table 4), respectively, as the measured seat height of the vehicles was between 27 and 43 cm with a mean of 37.14±5.41 cm. The recommended seat height, based on the obtained anthropometric data, should be a minimum of 46.45 cm and a maximum of 50.45 cm. This implied that the existing vehicle seats were too low for the drivers. A low seat may increase the knee and soft region pressure since the drivers may be forced to fold their legs (Halder *et al*., 2018). It may also hinder the ability of the driver to assess the road properly.

3.2.2 Seat Depth

An adjustable seat requires that the dimensions of the seat depth should be the 5^{th} (39 cm) and 95^{th} (48.26 cm) percentiles of the buttock popliteal length as the minimum and maximum dimensions, respectively. The seats were deep for the drivers as the measured seat depths were between 40 and 53 cm with a mean of 48.29±3.41 cm, while the seats are expected to be a minimum of 39 cm and a maximum of 48.26 cm. Deep seats may not allow the driver to make use of the backrest, which may cause a curvature of the spine resulting in an uncomfortable posture (Ismaila *et al*., 2013).

3.2.3 Seat Width

The seat width should accommodate the user's hip and clothing and allow for comfortable arm movement (Bridger, 1995). Ismaila *et al.* (2013) used 95th percentile of the hip breadth of the drivers with 15% of hip breadth as an allowance. The drivers' 95th percentile of the hip breadth was 40.72 cm, an allowance of 15% (6.11 cm). Therefore, the recommended seat width would be 46.83 cm as against the seat width of between 38 and 47 cm with a mean of 41.43±3.29 cm. All the vehicles had adequate dimensions for the seat front width but only the seat back width of the Comil was adequate (Table 2).

3.2.4 Seat Backrest Height

Thariq *et al.* (2010) suggested the use of the 5th percentile of shoulder height (sitting) and this was sustained in this study. Therefore, the backrest height should be 53 cm while the headrest should be 23.9 cm (since the 5th percentile of the sitting height of the drivers was 76 .9 cm).

3.2.5 Seat Backrest Depth

Drivers should be provided with structural supports for the trunk and contact with backrest influence vertical apparent mass of the body. The thickness of the backrest is essential in providing this support as it determines how well it can aid the trunk. A good backrest can assist in reducing lumbar load. It may also influence the vibration transmission through a foam cushion at the seat pan (Zhang *et al*., 2015).

Increasing foam thickness from 5 to 12 cm reduced the resonance frequency and the associated vertical vibration transmissibility of a seat cushion, with a more predictable effect than when altering the composition, density, or hardness of the foam (Ebe and Griffin, 2000). In the study by Zhang *et al*. (2015) on the effect of foam thickness at the seat and backrest with three thicknesses of foam at the backrest of 6, 8 and 10 cm, foam thickness of 10 cm provided the least transmissibility of vibration. This necessitates the choice of 10 cm as the thickness of the backrest. As mentioned, the backrest depth is the sum of the seat depth and the thickness of backrest. A seat depth of between 39 and 48.26 cm was recommended in this study; thus, the backrest depth should be between 49 and 58.26 cm.

3.2.6 Seat Backrest Angle

Driving subjects the driver to a fixed body posture with the hands on the steering wheel and one foot on the accelerator. The angle between the backrest and the seat pan determines the driver's body posture, especially the trunk-upper leg angle. A small angle of inclination of the backrest results in high sub-maximum pressures on the seat pan with sub-maximum pressure on the backrest (Hostens *et al.*, 2001).

Studies have recommended that the seat backrest should be inclined at an angle between 90° and 110° towards the rear (Cranz, 1998); Thariq *et al.* (2010) recommended 96°. Harrison *et al.* (1999) found that electric activity of the back muscles is lowest; hence, the intradiscal pressures are lowest when the backrest is inclined at between 110° and 130°. Saidu and Aghazadeh (2019) recommended a seat back inclination of 100° as myoelectric activity of the back muscles was less at this inclination. These studies showed that the seat back inclination should be adjustable from 90° to 130°.

3.3 Current Seat Dimensions and Proposed Seat Design

The current study confirmed that the anthropometric data of the user population is necessary for the proper design of an ergonomically compliant driver's seat. A review of 54 studies by Joseph *et al.* (2021) found moderate evidence that an uncomfortable seat for professional drivers is a risk factor for the development of musculoskeletal disorders. In another study by Kasemsan *et al.* (2021), it was established that bus drivers had a high level of musculoskeletal pain in the neck, back and shoulder parts of their bodies and advocated a national-wide epidemiological database to be able to monitor and report muscular pain among bus drivers.

The recommended dimensions of the driver's seat are presented in Table 4 while Table 5 shows the comparison of the values of the existing seat and the proposed seat. Figure 3 presents the proposed seat design, incorporating the recommended dimensions, for Nigerian drivers in the South West.

Table 4. Recommended seat dimensions for Nigerian drivers

Anthropometric variable	Seat variable	Recommended dimension
Sitting popliteal height	Seat height	46.45-50.45 cm
Buttock popliteal length	Seat depth	39.00-48.26 cm
Hip breadth	Seat front width	46.83 cm
Hip breadth	Seat back width	46.83 cm
Hip breadth	Backrest width (lumbar)	46.83 cm
Seat backrest angle		90°-130°
Shoulder width	Backrest width (shoulder)	48.95-57.85 cm
Shoulder height (sitting)	Backrest height	53.00 cm

Table 5. Comparison of the existing seat dimensions and the recommended ones

Anthropometric variable	Heavy automobile	Medium automobile	Proposed dimensions
Seat height (cm)	39.00-43.00	27.00-35.00	46. 45-50.45
Seat depth (cm)	40.00-50.00	49.00-50.00	39.00-48.26
Seat front width (cm)	47.00-50.00	50.00	46.83
Seat back width (cm)	38.00-47.00	38.00-44.00	46.83
Backrest width (lumbar) (cm)	34.00-43.89	47.00-52.00	46.83
Backrest width (shoulder) (cm)	46.00-54.00	42.00-48.00	48.95-57.85
Backrest height (cm)	43.00-50.00	54.00-55.00	53.00
Seat backrest angle			90°-130°

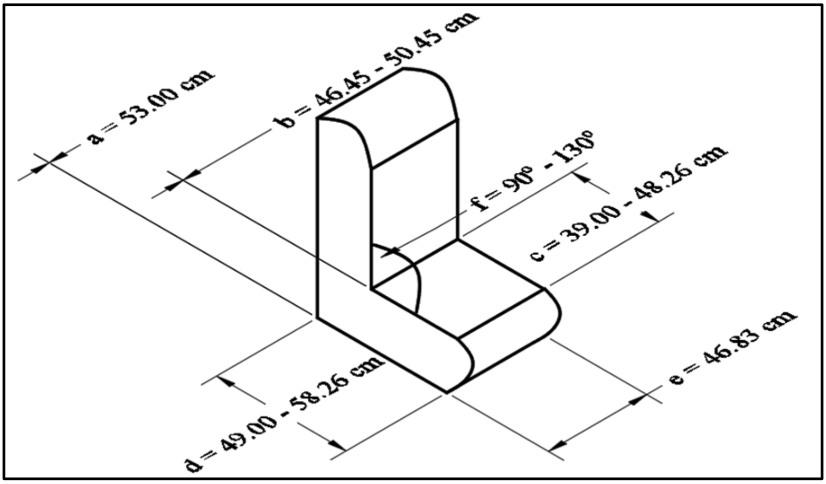


Figure 3. Proposed seat design for Nigerian drivers: backrest height (a); seat height (b); seat depth (c); backrest depth (d); seat front width (e); and seat backrest angle (f)

The T-*t*est statistical analysis showed that there were significant differences between the recommended and the existing values of the seat height with p = 0.002 (Table 5) and p = 0.000 (Table 6) for HA and MA, respectively, and seat depth of MA (p = 0.001) (Table 7) except for HA (p = 0.264) (Table 8). These further confirmed the need to use the anthropometric data of Nigerian bus drivers in the design of their seats. These results are in agreement with the work by Gowtham *et al.* (2020) on seating comfort analysis for Indian bus drivers using rapid upper limb assessment (RULA). They found out that drivers in the 77th to 94th percentile were comfortable with the seat, while others had higher RULA scores and were uncomfortable. They then suggested that the design of bus seats should consider the anthropometric data of Indians.

Table 5. Statistical difference between the existing and recommended seat height dimensions (HA)

	Existing dimension	Recommended dimension
Mean	41.25	48.2
Variance	4.25	2.916667
Observations	4	4
Pooled variance	3.583333	
Hypothesized mean difference	0	
Df	6	
t stat	-5.19226	
P(T <= t) one-tail	0.001015	
t Critical one-tail	1.94318	
P(T <= t) two-tail	0.00203	
t critical two-tail	2.446912	

Table 6. Statistical difference between the existing and recommended seat height dimensions (MA)

	Existing dimension	Recommended dimension
Mean	32.66667	48.70833
Variance	37.06667	2.400417
Observations	6	6
Pooled variance	19.73354	
Hypothesized mean difference	0	
Df	10	
t stat	-6.25472	
P(T <= t) one-tail	4.72E-05	
t critical one-tail	1.812461	
P(T <= t) two-tail	9.45E-05	
t critical two-tail	2.228139	

Table 7. Statistical difference between the existing and recommended seat depth dimensions (MA)

	Existing dimension	Recommended dimension
Mean	49.66667	43.71
Variance	0.266667	10.3286
Observations	6	6
Pooled variance	5.297633	
Hypothesized mean difference	0	
Df	10	
t stat	4.482528	
P(T <= t) one-tail	0.000587	
t critical one-tail	1.812461	
P(T <= t) two-tail	0.001174	
t critical two-tail	2.228139	

Table 8. Statistical difference between the existing and recommended seat depth dimensions (HA)

	Existing dimension	Recommended dimension
Mean	47.5	43.565
Variance	25	15.7969
Observations	4	4
Pooled variance	20.39845	
Hypothesized mean difference	0	
df	6	
t stat	1.232143	
P(T <= t) one-tail	0.131994	
t critical one-tail	1.94318	
P(T <= t) two-tail	0.263987	
t critical two-tail	2.446912	

4. Conclusion and Recommendation

The study found that the existing bus seats in Nigeria were not compatible with the necessary anthropometric dimensions of the Nigerian drivers. This may force the drivers to adopt an uncomfortable posture that will consequently put them at risk of musculoskeletal disorders. It was also revealed that were significant differences between the recommended and current dimensions of seat height and depth. Finally, the study was able to design an appropriate seat for the target population using the obtained anthropometric data. The design can be used for fabricating their seats to reduce the associated disorders. For future work, it is recommended to conduct a similar study with a larger number of participants.

5. References

Agrawal, K.N., Singh, R.K.P., & Satapathy, K.K. (2010). Anthropometric considerations of farm tools/machinery design for tribal workers of Northern India. Agricultural Engineering International CIGR Journal, 12(1), 143-150.

Byran, E., Gilad, I., & Oxman, R. (2013). Ergonomic design: Experimental studies of multi-task vehicle. Agriculture Forestry and Fisheries, 2(1), 23-32.

Bridger, R.S. (1995). Introduction to ergonomics. New York, United States: Mc Graw-Hill.

Chakrabortty, R.K., Asadujjaman, M., & Nuruzzaman, M. (2014). Fuzzy and AHP approaches for designing a hospital bed: A case study in Bangladesh. Journal of Industrial and Systems Engineering, 17(3), 315-328. https://doi.org/10.1504/IJISE.2014.062541

Cochran, W.G. (1977). Sampling techniques (3rd ed.). New York: John Wiley & Sons.

Cranz, G. (1998). The chair: Rethinking culture, body, and design (1st ed.). New York, United States: W.W. Norton.

Dawal, S.Z.M., Ismail, Z., Yusuf, K., Rashid, S.H.A., Shalahim, N.S.M., Abdullah, N.S., & Kamil, N.S.M. (2015). Determination of the significant anthropometry dimensions for user-friendly designs of domestic furniture and appliances – Experience from a study in Malaysia. Measurement, 59, 205-215. https://doi.org/10.1016/j.measurement.2014.09.030

Deros, B.M., Hassan, N.H.H., Dian, D.D.I., & Tamrin, S.B.M. (2015). Incorporating Malaysian's population anthropometry data in the design of an ergonomic driver's seat. Procedia - Social and Behavioral Sciences, 195, 2753-2760. https://doi.org/10.1016/j.sbspro.2015.06.388

Ebe, K., & Griffin, M.J. (2000). Qualitative models of seat discomfort including static and dynamic factors. Ergonomics, 43, 771-790. https://doi.org/10.1080/001401300404742

Fajobi, M.O., Onawumi, A.S., Mfon, U.M., & Awoyemi E. (2019). Mismatch between anthropometry characteristics of Nigerian occupational bus drivers and the in-vehicle measurement. Covenant Journal of Engineering Technology (CJET), 3(1), 20-37.

Gouvali, M.K., & Boudolos, K. (2006). Match between school furniture dimensions and children's anthropometry. Applied Ergonomics, 37(6), 765-773. https://doi.org/10.1016/j.apergo.2005.11.009

Gowtham, S., Ramnaath, M., Sudharsan, S., Kumar, B.V.L., Praneeth, V., Dinesh, S., & Subramaniyam, M. (2020). Seating comfort analysis: A virtual ergonomics study of bus drivers in private transportation. IOP Conference Series: Materials Science and Engineering, 912, 022018. https:// doi:10.1088/1757-899X/912/2/022018.

Guan, J., Hsiao, H., Bradtmiller, B., Kau, T.Y., Reed, M.R., Jahns, S.K., Loczi, J., Hardee, H.L., & Piamonte, D.P.T. (2012). US truck driver anthropometric study and multivariate anthropometric models for cab designs. Human Factors, 54(5), 849-871. https://doi/10.1177/0018720812442685

Halder, P., Mahmud, T., Sarker, E., Karmaker, C., Kundu, S., Patel, S., Setiawan, A., & Shah, K. (2018). Ergonomics considerations for designing truck driver's seats: The case of Bangladesh. Journal of Occupational Health, 60, 64-73. https://doi.org/10.1539/joh.16-0163-oa

Harrison, D.D., Harrison, S.O., Croft, A.C., Harrison, D.E., & Troyanovich, S.J. (1999). Sitting biomechanics Part I: Review of literature. Journal of Manipulative Physiological Therapy, 22, 594-609. https://doi.org/10.1016/s0161-4754(99)70020-5

Hostens, I., Papaioannou, G., Spaepen, A., & Ramon H. (2001). Buttock and back pressure distribution tests on seats of mobile agricultural machinery. Applied Ergonomics, 32(4), 347-355. https://doi.org/10.1016/s0003-6870(01)00013-8

Ismaila, S.O. (2009). Anthropometric data of hand, foot and ear of university students in Nigeria. Leonardo Journal of Sciences, 15(8), 15-20.

Ismaila, S.O. (2008). Research Note: Anthropometric data of the foot of Nigerian university students. Ergonomics SA, 20(2), 45-50.

Ismaila, S.O., Akanbi, O.G., Adekunle, N.O., Adetunji, O.R., & Kuye, S.I. (2010). An ergonomics assessment of passenger seats in buses in South Western Nigeria. Sigurnost (Safety), 52(4), 329-334.

Ismaila, S.O., Akanbi, O.G., Oderinu, S.O., Anyanwu, B.U., & Alamu, K.O. (2015). Design of ergonomically compliant desks and chairs for primary pupils in Ibadan, Nigeria. Journal of Engineering Science and Technology, 10(1), 35-46.

Ismaila, S.O., Musa, I.A., Adejuyigbe, S.B., & Akinyemi, O.D. (2013). Anthropometric design of furniture for use in tertiary institutions in Abeokuta, South-western Nigeria. Engineering Review, 33(3), 179-192.

Ismaila, S.O., Odunlami, S.A., Kuye, S.I., Musa, A.I., & Olayanju A. (2021). ERGO - Evaluation of urban bus driver's workstations in South West Nigeria. Journal of Engineering Science, 18(2), 51-64.

Jamir, L., Kalaivani, M., Nongkynrih, B., Misra, P., & Gupta, S.K. (2015). Anthropometric characteristics and under nutrition among older persons in a rural area of northern India. Asia Pacific Journal of Public Health, 27(2), 2246-2258.

Joseph, L., Vasanthan, L., Standen, M., Kuisma, R., Paungmali, A., Pirunsan, U., & Sitilertpisan, P. (2021). Causal relationship between the risk factors and work musculoskeletal disorders among professional drivers: A systematic review. Human Factors, 14, 1-24. https://doi:10.1177/0018720821100

Kasemsan, A., Joseph, L., Paungmali, A., Sitilertpisan, P., & Pirunsan, U. (2021). Prevalence of musculoskeletal pain and associated disability among professional bus drivers: A cross-sectional study. International Archives of Occupational and Environmental Health, 94, 1263-1270. https://doi.org/10.1007/s00420-021-01683-1

Kothiyal, K., & Tettey, S. (2001). Anthropometry for design for the elderly. International Journal of Occupational Safety and Ergonomics, 7(1), 15-34. https://doi .org/10.1080/10803548.2001.11076474.

Kovacevic, S., Vucinic, J., Kirin, S., & Pejnovic, N. (2010). Impact of anthropometric measurements on ergonomic driver posture and safety. Periodicum Biologorum, 112(1), 51-54.

Li, G., & Haslegrave, C.M. (1999). Seated work postures for manual, visual and combined tasks. Ergonomics, 42(8), 1060-1086. https://doi.org/10.1080/0014013991 85144

Lucas, E.B., & Onawumi, A.S. (2013). Ergonomic evaluation of in-vehicle interface design of taxicabs in Nigeria. International Journal of Engineering Research and Applications, 3(4), 566-572.

Mohamad, D., Deros, B.M., Daruis, D.D.I., Ramli, N.F., & Sukadarin, E.H. (2016). Comfortable driver's car seat dimensions based on Malaysian anthropometrics data. Iran Journal of Public Health, 45(1), 106-113.

Murphy, S., Buckle, P., & Stubbs, D. (2007). A cross-sectional study of self-reported back and neck pain among English schoolchildren and associated physical and psychological risk factors. Applied Ergonomics, 38(6), 797-804. https://doi.org/10.101 6 /j.apergo.2006.09.003

Okunribido, O.O., Shimbles, S.J., Magnusson, M., & Pope, M.H. (2007). City bus driving and low back pain: A study of the exposures to posture demands, manual materials handling and whole-body vibration. Applied Ergonomics, 38, 29-38. https://doi.org/10.1016/j.apergo.2006.01.006

Onawumi, A.S., Adebiyi, K.A., Fajobi, M., & Oke, E.O. (2016). Development of predictive models for some anthropometric dimensions of Nigerian occupational bus operators. European Journal of Science and Technology, 5(5), 12-27.

Park, J., Choi, Y., Lee, B., Sah, S., Jung, K., & You, H. (2013). Sitting strategy analysis based on driving postures and seating pressure distributions. Proceedings of the Human Factors and Ergonomics Society, 57(1), 1983-1986.

Porter, J.M., Gyi, D.E., & Tait, H.A. (2003). Interface pressure data and the prediction of driver discomfort in road trials. Applied Ergonomics, 34(3), 207-214.

Rahman, N.I.A, Dawal, S.Z.M., Yusoff, N., & Kamil, N.S.M. (2018). Anthropometric measurements among four Asian countries in designing sitting and standing workstations. Sādhanā, 43, 10. https://doi.org/10.1007/s12046-017-0768-8

Roscoe, J.T. (1975). Fundamental of research statistics for the behavioral science, international series in decision process (2nd ed.). New York, United States: Holt, Rinehart and Winston, Inc.

Saidu, M., & Aghazadeh, F. (2019). Impact of vehicle seat back inclination on occupational driving safety. Journal of Industrial and Systems Engineering, 12(2), 1-8.

Saunders, M., Lewis, P., & Thornhill, A. (2007). Research methods for business students (4th ed.). Essex, England: Prentice Hall.

Spasojević-Brkić, V.K., Klarin, M.M., Brkić, A.D., & Sajfert, Z.D. (2014). Designing interior space for drivers of passenger vehicle. Tehnika, 69(2), 317-325. https://doi.org/10.5937/tehnika1402317S

Thariq, M.G.M., Munasinghe, H.P., & Abeysekara, J.D. (2010). Designing chairs with mounted desktop for university students: Ergonomics and comfort. International Journal of Industrial Ergonomics, 40, 8-18.

Uba, M.A., Abdullah, K.A., & Faris, W.F. (2018). Representative Nigerian anthropometric data for automotive applications. Journal of Mechanical Engineering, SI 5(4), 68-88.

Van Rosmalen, D., Groenesteijn, L., Boess, S., & Vink, P. (2009). Using both qualitative and quantitative types of research to design a comfortable television chair. Journal of Design Research, 8(1), 87-100.

Jinhuan, Z., Jie, Y., Xin, J., Ming, S., Xiao, L., & Chunsheng, M. (2016). Differences of anthropometric dimensions between Chinese and American and the effects on drivers' injury risks in vehicle frontal crash. Journal of Automotive Safety and Energy, 7(2), 175-181.

Zhang, J., Yang, J., Jin, X., Shen, M., Luo, X., & Ma, C. (2016). Differences of anthropometric dimensions between Chinese and American and the effects on drivers' injury risks in vehicle frontal crash. Journal of Automotive Safety and Energy, 7(2), 175-181.

Zhang, X., Qiu, Y., & Griffin, M.J. (2015). Transmission of vertical vibration through a seat: Effect of thickness of foam cushions at the seat pan and the backrest. International Journal of Industrial Ergonomics, 48, 36-45. https://doi.org/10.1016/j.ergon.2015.03.006