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Ergonomics assessment of locally fabricated passenger seats in trotro vehicles in Accra, Ghana

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ABSTRACT

Trotro vehicles constitute one of the major means of transportation in Ghana by way of ferrying people and goods. Most trotros are originally brought into the country as load carrying vehicles, which are then converted into passenger vehicles. Locally designed seats are then fabricated and secured into the vehicles. The study explored the ergonomic evaluation of the locally fabricated passenger seats with anthropometric measures of passengers and also compared the seat dimensions to required standards. The study was undertaken at seven selected bus stations in Accra, the capital city of Ghana. The study composed of 307 volunteer passengers comprising 175 females and 132 males with ages spanning from 18 to 60 years. The dimensions of ninety locally fabricated seats were collected from ninety randomly selected trotro vehicles. Ergonomic assessment was performed to determine match or mismatch between the anthropometric measures and vehicle seating dimensions. In addition, the fabricated seat dimensions were compared to both local and international vehicle seat standards. High mismatches indicating that the passenger seats were probably too deep or too high were observed for seat height – popliteal height, seat depth – buttock popliteal length, and seat breadth – hip breadth. A low mismatch was observed between the sitting height and backrest height for 99.4% of participants. Only four and ten out of the ninety seats complied with specified standard seat length and backrest to backrest distance, respectively. The high prevalence of mismatch is a possible indication that most locally fabricated seats do not adequately accommodate majority of passengers. Furthermore, it appears that anthropometric measures and standard vehicle seat dimensions are not considered during seat design, with potential health ramifications pertaining to the safety, comfort and sitting posture of passengers.

1. Introduction

Trotros are privately-owned multipurpose commercial minibuses used in the informal mass transportation system in Ghana (Fouracre et al., 1996). Similar buses being used in Nigeria are popularly referred to as Tokunbo (Ismaila et al., 2010). The term trotro originates from “tro” meaning three pence in reference to the fares charged in the past in a local Ghanaian dialect. Trotro serves

Abbreviations: AMVCB, Australian Motor Vehicle Certification Board; BMI, Body mass index; BPL, Buttock Popliteal length; BRH, Backrest height; BRW, Backrest Width; ISO, International Standard Organization; LI, Legislative Instrument; LTO, MVIS - Land Transportation Office Motor Vehicle Inspection system; PH, Popliteal Height; PNS, Philippine National Standards; SB, Seat Breadth; SD, Standard Deviation; SDa, Seat Depth; SH, Seat Height; SHa, Sitting Height; SPSS, Statistical Program for Social Sciences.

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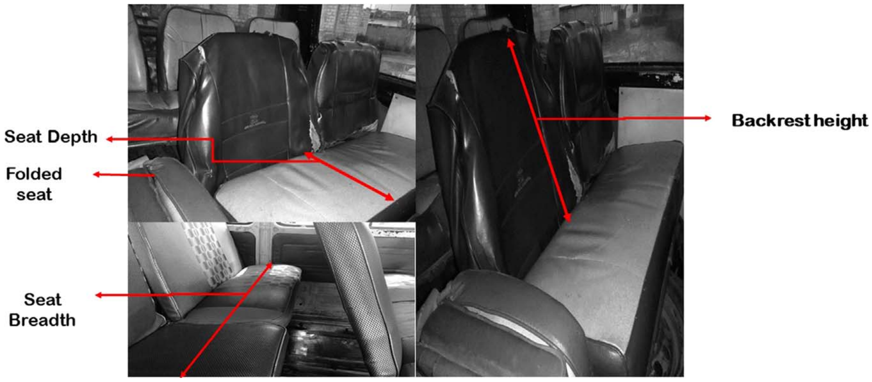

Fig. 1. Locally fabricated seats and interior view of the trotro vehicle.

as one of the major and preferred means of commercial transport in Ghana (Abane, 1993, 2011) and accounts for almost 70.0% of the means of transportation in Accra according to the World Bank's consultative citizens report card for the city of Accra (World Bank, 2010). Most minibuses have designated routes they ply, along which they can stop to allow passengers to board and alight. Sometimes, they veer into other non-designated routes to find passengers to board their vehicles. The trotro vehicle is operated by a driver and a conductor usually referred to as the “mate”. The driver controls the operation and movement of the trotro from one stop to the next, whilst the mate collects the fares, publicises to attract passengers, as well as mediate between the driver and passengers.

The vans used for trotro are imported into the country either as second-hand or new and most are originally manufactured as load carrying vehicles, which are later modified into commercial passenger vehicles. As part of the redesigning into passenger vehicles, seats are locally fabricated and installed, as well as incorporation of new features such as side windows to enhance ventilation and lighting. Some of the local automotive artisans or technicians who design and fabricate trotro seats have little or no formal vocational training in automotive seat designing, but rather informal apprenticeship. It appears that most trotro seats are designed without considering any approved or standard dimensions. Also, most artisans do not incorporate any engineering design concepts or principles during vehicle alterations (Amedorme and Agbezudor, 2013). Some artisans design the seats to suit the vehicle owners’ specifications or dimensions specified by the drivers’ unions. Interestingly, little attention may be given to the comfort and safety of passengers, as the design and fabrication are undertaken not according to any known accepted safety standards (Dzebre, 2012; Dzebre et al., 2013). The local manufacturers assume that design of seats is an art rather than science (Ismaila et al., 2010). One of the primary goal of these artisans is to derive optimum number of seats for profit maximisation by the vehicle owners (Agyemang, 2013; Ismaila et al., 2010; Saba et al., 2013). Usually, seating capacities in trotros can range from about 10 to 25 and may consist of about 3 to 5 rows of seats with each row having a seating capacity of about 3 to 5. Some of the rear right seats are foldable to enhance movement of passengers during boarding and alighting as shown in Fig. 1. Most locally fabricated seats are bench seats supported by metallic frames and upholstered.

Trotro seats constitutes a major component of the vehicle occupant protection system and their design must comply with both local and international standards to ameliorate the effects of crash-related injury severity. The essence of standards is to decrease the rates of deaths and injuries to motor vehicle users (Federal Motor Vehicle Safety Standards and Regulations, 2015). The use of anthropometric data in design may constitute improvement in the health and comfort of the users (Barroso et al., 2005; Jung and Lee, 2000). The aim of seat design is to alleviate or decrease factors that pose discomfort rather than to elicit feelings of well-being (Reed et al., 1994). In Ghana, vehicle reconstruction or modification is regulated by the Road Traffic Regulation, Legislative Instrument, 2012 (L.I. 2180), which also provides the required seat dimensions. Elsewhere, the Australian Motor Vehicle Certification Board (AMVCB) provides vehicle standards for the manufacture and installation of seats (National Code of Practice, 2013). In Hong Kong, Guide for Measuring of Passenger Seats is provided as part of the regulation of standards (Guide for Measuring Passengers on Public Light Bus, 2004). Similarly in India, automotive industry standards are available as part of the code of practice for bus body design (Automotive Industry Standards, 2014).

In order to consider seat ergonomics, there is the need to determine seat fit parameters for anthropometry. Therefore, there is the need to investigate the match or mismatch between the passenger seats and the general population anthropometry. Various studies have reported varying degrees of incompatibility between anthropometric data and local vehicle seating dimensions. A study conducted in Ibadan Metropolis, Nigeria, which compared relevant anthropometric measurements obtained from 200 passengers with mean age of 37.9 years to dimensions of locally manufactured seats obtained from 30 randomly selected Toyota Hiace minibuses, established a mismatch between anthropometric and passenger seat dimensions (Ismaila et al., 2010). It was observed that significant differences existed between the means of popliteal height and seat height; buttocks to popliteal length and seat depth; and hip breadth and seat width. Similarly, a study undertaken in Malaysia sought to determine the degree of compatibility of seat fit parameters by comparing the anthropometric dimensions of 216 participants to two local automobile seats (Daruis et al., 2011). Mismatches were observed between the anthropometric dimensional variables which are important for seat fit parameters and dimensions of the two seats. In addition, both seats were too long to fit the 5th percentile female driver, as well as too high for the 5th percentile woman and yet not high enough for the 95th percentile man. To buttress the aforementioned studies, when locally manufactured passenger seat dimensions from 30 minibuses were compared to 144 anthropometric dimensions of passengers around

Mekelle city, Ethiopia, (Saba et al., 2013), the study established that anthropometric dimensions of passengers were not employed in the design and manufacturing of the passenger seats.

In addition, a comprehensive study in the Philippines ascertained if jeepney complied with the Philippine National Standards (PNS) by comparing the anthropometric dimensions of jeepney passengers and seat space (Bacero and Vergel, 2009, 2010). If the hip breath of jeepney passengers derived from anthropometry is considered as 357 mm, only 5 jeepney models passed the seat space requirement whilst 13 jeepney models failed. Furthermore, by using the Land Transportation Office (LTO) regulations on seat space of 350 mm, only 8 jeepney models passed the seat space regulations whilst 10 jeepney models failed.

Some of the studies pertaining to vehicle seats in Ghana comprises the design of optimised seating for cargo vehicles that have been converted to commercial passenger vehicles (Addae et al., 2010); impact test investigation of locally fabricated vehicle seats in minibuses (Moghalu, 2013); and computer simulation to identify accident injuries that can be attributed to the design of locally fabricated vehicle-seats (Dzebre et al., 2013). Other studies have focused on the local design modifications of vehicles (Adedamola, 2009; Amedorme and Agbezudor, 2013). However, it appears that little attention has been focused on ergonomics studies that investigates incompatibility between anthropometric measurements of passengers and dimensions of locally fabricated trotro seats in Ghana.

Therefore, the study reported here assessed the ergonomics suitability of selected locally fabricated passenger seats in trotro vehicles in Accra, Ghana. Specifically, we assessed mismatch or match between the seat dimensions and the anthropometric measures of passengers. In addition, the measured seat dimensions were compared to local and foreign standards to ascertain if they complied with required specifications.

2. Methods

2.1. Study design & settings

The study site was Accra, the capital of Ghana. The study participants (passengers) and vehicles were sampled from seven major bus terminals. The data collection was done during a five week period commencing in June 2014.

2.2. Study populations & sampling

Convenient sampling technique was employed in this study and the participation of passengers was voluntary. Overall, 307 participants consented to participate in this study comprising 175 females and 132 males within the age range of 18 – 60 years. Participants were eligible to participate in the study only if they were residents of Accra for at least a minimum of one year and use public transportation at least 20 times in a year. Vulnerable populations such as pregnant women, the sick and disabled were exempted from participating in this study.

For the purpose of this study, only trotro vehicles with locally fabricated seats were utilised. A total of 90 locally fabricated seat dimensions were measured from ninety randomly selected trotro vehicles with the permission of the trotro vehicle driver.

The details of the vehicle seat and anthropometric dimensions employed in this study are shown in Fig. 2. All measurements for this study were taken by trained junior year undergraduate biomedical engineering interns and two biomedical engineers, comprising a faculty member and a teaching assistant. The undergraduate biomedical engineering interns and the teaching assistants undertook a

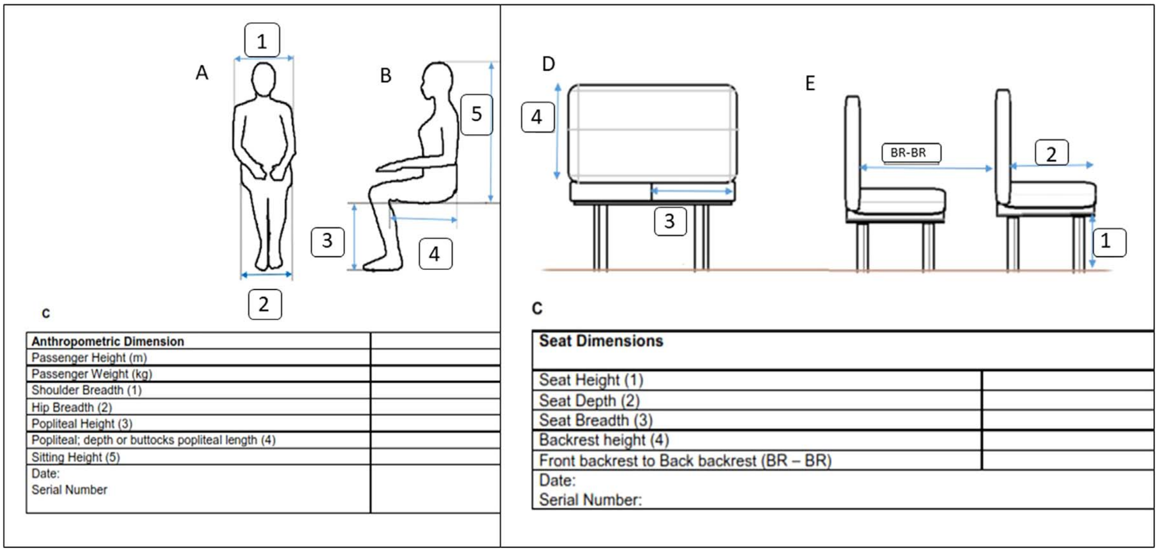

Fig. 2. Instrument used to collect anthropometry data from passengers and vehicle seat dimensions. The frontal view (A), side view (B) and the anthropometric measures used for the study; the frontal view (D), side view (E) and the vehicle seat dimensions used for the study.

pilot study prior to the data collection period.

2.3. Ethical approval

The study was approved by the Ethics Committee of our institution with protocol identification number of ECH 065/13–14. Prior to participation in the study, benefits, risks and procedures were comprehensively explained to the participants, trotro drivers and bus terminal managers. In addition, all participants who agreed to participate provided informed consent.

2.4. Anthropometric measurements

Anthropometric data was collected using traditional methods of standardised postures (Sims et al., 2012). All anthropometric measurements were obtained with a 5 m measuring tape measure with 0.1 cm measurement division and a mechanical bathroom weighing scale (Pure Pleasure BSM01) with a maximum capacity of 120 kg and a 1 kg measurement division. Due to the tropical weather climate in Accra with average temperature of about 30 ˚ C, measurements were taken with the participants wearing their usual or day-to-day clothing. All anthropometric measures for this study were taken at the right side of the participants' body with the exception of the stature and weight. Each of the participants was required to assume a relaxed sitting position on the passenger seat; where their back is fully supported, knees positioned at right angle and thigh fully supported while both legs hang freely.

The anthropometric data measured (Fig. 2) comprises: (1) shoulder breadth (biacromial) - the horizontal distance across the shoulders measured between the acromia (bony points); (2) hip breadth, sitting - the breadth of the body measured across the widest portion of the hips; (3) popliteal height- distance from the floor to the crease of the popliteal fossa; (4) buttock to popliteal length- the distance from the posterior surface of the buttock to the crease of the popliteal fossa; and (5) sitting height – the vertical distance from the sitting surface to the vertex. The anthropometric data taken adhered to ISO 15355 and ISO 7250 standards (International Standards Organization, 2012a, 2012b).

2.5. Vehicle measurements

The seat dimension were taken from the trotro vehicles with no passengers sitting on the seats. The dimensions of the locally fabricated seat recorded (Fig. 2) are: (1) seat height- distance from the vehicle floor to the highest point on the front of the seat; (2) seat depth- distance measured horizontally on the seat surface from the back to the front of the seat; (3) seat breadth- the distance measured horizontally across the farthest points on the front edges of the seat surface; and (4) backrest height- the distance measured vertically from the seat pan to the topmost portion of the seat. Additionally, the distance from the front of the back of one seat and the back of the seat immediately in front (BR-BR) was measured.

2.6. Data analysis

Data collected was analysed using R statistical software version 3.0.3 and SPSS version 20.0. Descriptive statistics such as the means, standard deviations, and 5th, 50th and 95th percentiles variables were computed for both anthropometric and passenger seat dimensions. The passenger seat dimensions measured were the seat height (SH), seat depth (SD_a), seat breadth (SB) and backrest height (BRH). The seat breadth dimensions were considered the same as backrest width (BRW) due to the nature of the seat design. The anthropometric data measured comprises hip breadth (HP), shoulder breadth (SB), sitting height (SH_a), buttock popliteal length (BPL) and popliteal height (PH). Other additional data obtained were age, weight and height. An independent t-test was used to determine if there were any significant differences in the anthropometric measures in male and female passengers. A Pearson correlation was performed as well to determine associations amongst the anthropometric measures of all the passengers. Additionally, the measured seat dimensions were compared to recommended standards of automotive seating in Ghana and other places such as India, Hong Kong and Australia. The specific details of the techniques adopted for computing the percentage mismatch or match between anthropometric data and seat dimensions (Gouvali and Boudolos, 2006) are provided in Table 1. The combinational equations in Table 1 were used in analysing the ergonomic compatibility between the anthropometry and the locally fabricated seat dimensions. A match is when a comparison between the anthropometry and seat dimensions is within the limits of the combination equation. Meanwhile, a low mismatch occurs when the minimum limit of the combinational equation is higher than the seat dimension, possibly indicating the seat is low, narrow or shallow. Whilst a high mismatch occurs when the maximum limit of the combinational equation is lower than the seat dimension, indicating the seat is too high, wide or deep.

3. Results and discussion

3.1. Anthropometric parameters

The analysis of the anthropometric data indicated that the 5th and 95th percentile data represented extremes of the data collected, comprising the "smallest person in size" and "largest person in size". As shown in Table 2, the mean male height of 1.70 m (SD = 0.07) was greater than that of the female of 1.60 m (SD = 0.09). Also, the mean weight and age of the females were greater than those of males. For mean sitting anthropometric measures of passengers Table 2, it was noted that males had larger measurements in comparison to females in respect of shoulder breadth, popliteal height and sitting height. However, the mean hip breadth of females

Table 1
A Summary explaining the techniques and concepts used to assess mismatch or match between anthropometric measures and locally fabricated seat dimensions.

Combinational equation	Incompatibility measures		
	High mismatch	Match	Low mismatch
Popliteal Height (PH) & Seat Height (SH)	When SH & PH is > 95%	When SH & PH are within 88% – 95%	When SH & PH is < 88%
$0.88\ PH \leq SH \leq 0.95\ PH$ A seat height that is either > 95% or < 88% of popliteal height (Parcells et al., 1999)	Unsatisfactory	Satisfactory & Appropriate	Unsatisfactory
Buttock Popliteal Length (BPL) & Seat Depth (SD)	When BPL & SD is > 99%	When SH & PH are within 80% – 99%	When SH & PH is < 80%
$0.80\ BPL \leq SD \leq 0.99\ BPL$ Defined as mismatch the case when depth was ≤ 80% or ≥ 99% of the buttock popliteal length (Gouvali et al., 2006)	Unsatisfactory	Satisfactory & Appropriate	Unsatisfactory
Hip Breadth (HB) & Seat Width (SW)	when HB & SW is > 130%	when HB & SW are within 110% − 130%	when SH & PH is < 110%
$1.1\ HB \leq SW \leq 1.3\ HB$ Seat width should be at least 10% (to accommodate hip breadth) and at the most 30% larger than hip breadth (for space economy). (Gouvali et al., 2006)	Unsatisfactory	Satisfactory & Appropriate	Unsatisfactory
Backrest height and sitting height	when Backrest height & sitting, height is > 80%	when backrest height & sitting, height is within 60% − 80%	when backrest height and sitting, height is < 60%
$0.6\ S \leq B \leq 0.8\ S$Equation recommends keeping the backrest lower than the scapula, or at most on the upper edge of the scapula (60–80% of shoulder height) (Gouvali et al., 2006)	Unsatisfactory	Satisfactory & Appropriate	Unsatisfactory

was greater when compared to those of males, but both male and female participants had the same average buttock popliteal length of 0.48 m (SD = 0.04). Generally, male measurements are larger than those of females in all dimensions except those related to soft tissues (Daruis et al., 2011). Similarly, all male measurements were larger than females in this study, except female mean hip breadth measurement which was greater when compared to the male passenger.

An independent t-test was performed to ascertain if there were significant differences between male and female anthropometric measures and their respective body mass index (BMI). Prior to performing the independent t-test, the anthropometric data was tested for normality to determine the suitability for use in the parametric test. There were significant differences ($p < 0.010$) between the male and female data for passenger height, shoulder breadth, popliteal height, buttock popliteal length, hip breadth, weight, age and sitting height. However, no significant differences were observed between the popliteal height of males and females as shown in Table 3.

The results of a Pearson correlation coefficient analysis between the various anthropometric measures of the passenger

Table 2
Display of descriptive statistics computed from the anthropometric data of passengers; age weight and height.

(All units in meters)	Female							Male						
	Mean	SD	Percentiles			Min	Max	Mean	SD	Percentiles			Min	Max
			5th	50th	95th					5th	50th	95th		
Shoulder Breadth	0.43	0.04	0.37	0.43	0.50	0.34	0.58	0.45	0.04	0.40	0.44	0.52	0.37	0.56
Hip Breadth	0.37	0.05	0.29	0.36	0.45	0.22	0.56	0.34	0.05	0.30	0.34	0.43	0.25	0.62
Popliteal Height Sitting	0.42	0.03	0.38	0.43	0.46	0.33	0.54	0.46	0.03	0.41	0.46	0.51	0.40	0.52
Buttock to Popliteal Length	0.48	0.04	0.42	0.48	0.54	0.39	0.58	0.48	0.04	0.42	0.48	0.54	0.38	0.60
Sitting Height	0.79	0.07	0.73	0.80	0.86	0.33	0.92	0.83	0.06	0.77	0.83	0.91	0.36	0.94
Weight (kg)	72.31	19.13	46.70	70.00	106.00	32.00	165.00	66.11	11.86	50.28	65.00	87.45	44.00	110.50
Height	1.60	0.09	1.50	1.61	1.71	88.0	1.88	1.70	0.07	1.60	1.71	1.81	1.52	1.86
Age (years)	33.4	11.10	19	32	50	18	58	28.6	9.38	19	25	50	18	57

Table 3
An independent t-test between the anthropometric measures of male and female passengers.

	t	Sig. (2-tailed)	Std. error difference	95% confidence interval of the difference	
				Lower	Upper
Age	−4.11	0.000	1.17	−7.12	−2.51
Height	11.40	0.000	0.89	8.43	11.95
Weight	−3.49	0.001	1.78	−9.70	−2.71
Shoulder Breadth	3.78	0.000	0.45	0.81	2.57
Hip Breadth	−3.91	0.000	0.57	−3.34	−1.10
Popliteal Height	10.77	0.000	0.31	2.77	4.01
Buttock Popliteal Length	−0.422	0.673	0.44	−1.05	0.68
Sitting Height	5.61	0.000	0.78	2.86	5.95
BMI	−5.04	0.000	1.21	−8.47	−3.70

participants, BMI and age are shown in Table 4. It was observed that there was a strong correlation between the shoulder breadth and passenger weight ($r = -0.534$, $p > 0.010$); popliteal height and passenger height ($r = 0.583$, $p > 0.010$); BMI and height ($r = -0.510$, $p > 0.010$); and BMI and weight ($r = 0.701$, $p > 0.010$), suggesting that these parameters have some degree of association. Likewise, moderate correlations were also observed with sitting height to passenger height ($r = 0.310$, $p > 0.010$); age and weight ($r = 0.384$, $p > 0.010$); sitting height to shoulder breadth ($r = 0.311$, $p > 0.010$); sitting height and popliteal height ($r = 0.327$, $p > 0.010$); popliteal depth and passenger weight ($r = 0.362$, $p > 0.010$); popliteal depth and shoulder breadth ($r = 0.438$, $p > 0.010$); hip breadth and passenger weight ($r = 0.480$, $p > 0.010$); and hip breadth and shoulder breadth ($r = 0.312$, $p > 0.010$). Additionally, modest correlation relationships were detected for BMI and shoulder breadth ($r = 0.224$, $p > 0.010$); age and BMI ($r = 0.276$, $p > 0.010$); age and hip breadth ($r = 0.279$, $p > 0.010$) BMI and hip breadth ($r = 0.262$, $p > 0.010$); popliteal height and shoulder breadth ($r = 0.288$, $p > 0.010$); and passenger height and shoulder breadth ($r = 0.248$, $p > 0.010$).

3.2. Vehicular seat fit parameters & regulations

When designing a seat a major criteria should be the comfort of the sitter in the vehicle and this comfort depends on thigh support, cushion parameters, seatback lateral support and the adjustability of the lumbar region (Kolich, 2003; Reed et al., 1994). A summary of vehicle seat fit parameters and regulations compared to results obtained in this study is shown in Table 5. The backrest width of a car seat needs to be wider as compared to an office chair to provide more lateral stability during cornering manoeuvre due to the dynamic movements of the vehicle while in motion (Reed et al., 1994). Shoulder breadth is normally measured at 95th percentile of male, which represents the “largest male” shoulder dimension from the population. The shoulder breadth dimension at 95th percentile male and average backrest width computed in this study were 0.52 m (SD = 3.68) and 0.43 m (SD = 0.043), respectively as seen in Table 6. The locally fabricated passenger backrest width does not satisfy the suggested recommended ranges of ≥ 0.514 m (Kolich, 2003) and 0.471 m (Reed et al., 1994). Furthermore, the locally fabricated passenger seat conforms to recommended backrest width of 0.406 – 0.56 m (Tilley, 2002) as mentioned elsewhere (Daruis et al., 2011). The mean backrest width is lower than the suggested 0.50 m (Pheasant, 2002) as mentioned elsewhere (Daruis et al., 2011).

The mean sitting height parameter is usually measured at 5th percentile for female and 95th percentile male. For this study, the backrest height for the 5th percentile for female and 95th percentile male as well as average backrest height were recorded as 0.73 m (SD = 0.07), 0.91 m (SD = 0.06) and 0.56 m (SD = 0.065), respectively. Standard seat fit parameters suggested for backrest height are 0.414 – 0.551 m (Reed et al., 1994), 0.545 – 0.595 m measured from a depressed seat (Tilley, 2002) and 0.500 m according to Heath Safety Executive, UK 1991 (Pheasant, 2002) as cited elsewhere (Daruis et al., 2011). The mean backrest height of the locally manufactured seats does not conform to those suggested (Pheasant, 2002; Reed et al., 1994) but agrees with that recommended

Table 4
Pearson correlation matrix between the anthropometric measures and body mass index (BMI) of passengers.

Correlation matrix of anthropometric measures	Age	Height	Weight	Shoulder breadth	Hip breadth	Popliteal height	Popliteal depth	Sitting height	BMI
Age	1								
Height	−0.105	1							
Weight	0.384**	0.010	1						
Shoulder Breadth	0.245**	0.248**	0.534**	1					
Hip Breadth	0.279**	0.040	0.480**	0.312**	1				
Popliteal Height	−0.050	0.583**	0.049	0.288**	−0.005	1			
Popliteal Depth	0.095	0.269**	0.362**	0.438**	0.217**	0.245**	1		
Sitting Height	−0.075	0.310**	0.154**	0.311**	0.088	0.327**	0.168**	1	
BMI	0.276**	−0.510**	0.701**	0.224**	0.262**	−0.101	0.112	0.019	1

** Correlation is significant at the 0.01 level (2-tailed).

Table 5
A summary of standard seat dimensions compared to the results obtained.

	Seat fit regulations					Literature source			
	Ghana Legislature L.I. 2180; Ghana	LTO –MVIS Philippines	AMVCB; Australia	Guide for measuring Passengers on Public Light Bus; Hong Kong	Automotive Industry; India	Kolich, 2003	Reed et al.; 1994	Darius et al.; 2011	
								Tilley, 2002	Pheasant,1996
Backrest width [95th Percentile male]	–	–	–	–	–	≥ 0.514 [m]	0.471 [m]	0.406 – 0.560 [m]	0.50 [m]
Study results	–	–	–	–	–	No	No	Yes	No
Backrest Height [5th percentile female to 95th percentile male	–	–	–	–	–	–	0.414 −0.551 [m] above the H point	0.545 −0.595 [m] depressed seat	0.550 [m] as per HSE 1991
Study results	–	–	–	–	–		No	Yes	No
Seat Depth [5th percentile female]	≥ 0.40 [m]	0.60 [m]	0.464 [m]	≥ 0.35 [m]		≥ 0.362 [m]	< 0.305 [m] from H point OR ≤ 0.44 [m]	0.406 [m]	≤ 0.435 [m]
Study results	No	No	No	Yes		Yes	Yes		Yes
Seat Spacing	≥ 0.70 [m]	–	–	–	–	–	–	–	–
Study Results	–	–	–	–	–	–	–	–	–
Seat Width [95th percentile female]			Minimum seat width of 0.429 [m]	0.40 [m]	0.20 – 0.23 [m]	0.446 −0.483 [m]	0.500 [m]	0.406 −0.506 [m]	0.435–0.500 [m]
Study Results			Yes	Yes	No	No		Yes	Yes

Table 6
Descriptive statistics computed from the dimensions of the locally fabricated seat dimensions.

Locally fabricated seat dimension (Units in meters)	Mean	SD	Percentiles			Min	Max
			5th	50th	95th		
Seat Height	0.34	0.063	0.24	0.35	0.45	0.22	0.55
Seat Depth	0.36	0.033	0.32	0.36	0.39	0.31	0.56
Seat Breadth	0.43	0.043	0.39	0.41	0.49	0.27	0.55
Backrest Height	0.56	0.065	0.45	0.50	0.66	0.41	0.74
Front backrest to Back backrest	0.66	0.067	0.59	0.65	0.93	0.57	0.95

(Tilley, 2002).

The comparison of seat depth dimension relates to buttock popliteal length and should fit the "smallest person" that is the 5th percentile female population. Buttock popliteal length measurements from this study for 5th percentile female and 95th percentile male, as well as mean seat depth of the locally fabricated passenger seat are 0.42 m (SD = 0.04), 0.54 m (SD = 0.04) and 0.36 (SD = 0.033), respectively. The proposed seat fit parameters recommended are ≥ 0.362 m (Kolich, 2003), ≤ 0.440 m or < 0.305 m from the H point (Reed et al., 1994) and ≤ 0.435 m (Pheasant, 2002) as cited previously (Daruis et al., 2011). The mean measured seat depth dimensions for this study seems to agree with the proposed recommended seat fit parameters (Kolich, 2003; Pheasant, 2002; Reed et al., 1994).

In Ghana, L.I. (2180), details regulations and guidelines for the construction of passenger carrying vehicles. It states that the width of the seat from the front to the back is at least forty centimetres or as required by the Licensing Authority. It further states that in the case of seats facing the same direction there is a space of at least seventy centimetres provided between the front of the back of one seat and the back of the seat immediately in front (Road Traffic Regulations L.I. 2180, 2012). When compared to the mean passenger seat depth dimensions of the locally fabricated passenger seat it seems to pinpoint that current seat depth dimensions in the trotro are less. Further analysis of the locally fabricated seat data indicates that only four out of the ninety locally fabricated passenger seats complied with seat length regulations as per the Road Traffic Regulations (L.I. 2180) Ghana. Also, only 10 out of the 90 passenger seats satisfied the criteria of having at least seventy centimetres provided from the front of the back of one seat and the back of the seat immediately in front. Furthermore, the Land Transportation Office Motor Vehicle Inspection system (LTO – MVIS) in the Philippines states that minimum seat passenger seat depth and width should be 0.60 m and 0.35 m, respectively (Alfonso et al., 2007; Bacero and Vergel, 2009). Comparing seat depth dimensions by LTO- MVIS standards of 0.60 m to mean seat depth dimensions of the locally fabricated passenger seat revealed that the mean seat depth dimensions is less than the LTO- MVIS standards in Philippines. Similarly, in Philippines, only 8 out of 18 jeepney models complied with seat space requirements of the LTO (Bacero and Vergel, 2009, 2010). The maximum standard seat depth recommended by the Australian Motor Vehicle Certification Board (AMVCB) in Australia suggests that seat depth for category 1 seats should be 0.464 m (National Code of Practice, 2013). The mean seat depth from this study compared to the AMVCB seems to suggest that locally fabricated passenger seats in trotro are less indicating noncompliance with AMVCB. Also in Hong Kong, the minimum seat depth should be at least 0.35 m (Guide for Measuring Passengers on Public Light Bus, 2004), which the locally fabricated seat depth is greater than.

Seat breadth dimension should have some amount of allowance for little movements and also for comfort. Female sitting hip breadth are normally higher values than male hip breadth and the 95th percentile female was recorded in this study as 0.45 m (SD = 0.05). Mean seat breadth of the locally fabricated passenger seat were calculated as 0.43 m (SD = 0.043). For good thigh depth, the

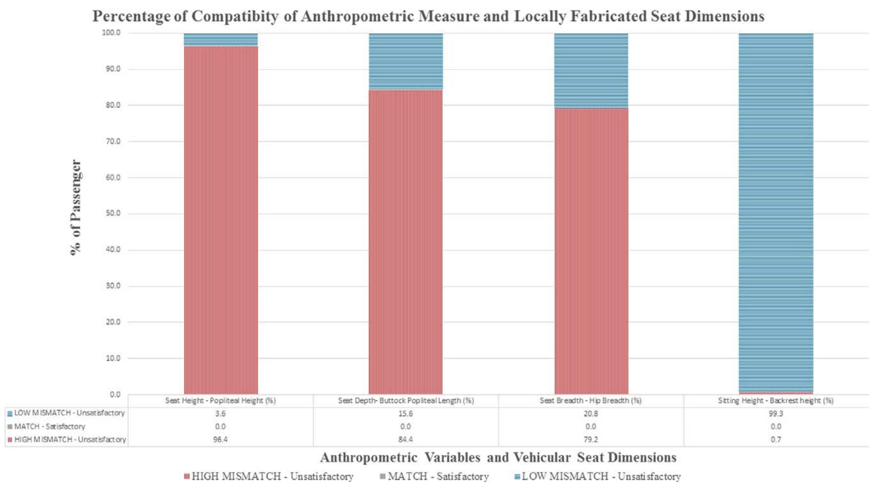

Fig. 3. Percentage of passengers whose anthropometric measures match or mismatch the vehicle seat dimensions.

seat depth should be adequate. The mean seat breadth of the locally fabricated passenger seat does not comply with recommended seat breadth parameter fit of 0.446 – 0.483 m (Kolich, 2003). However, the mean seat breadth from this study appears to be in conformance with the proposed seat fit parameters of 0.406 − 0.550 m (Tilley, 2002) and 0.435 – 0.500 m (Pheasant, 2002) as mentioned elsewhere (Daruis et al., 2011). The specified mean seat breadth of locally fabricated passenger seat is greater than 0.20 m – 0.23 m, which is the range specified the by the Automotive Industry in India (Automotive Industry Standards, 2014). In Hong Kong, the minimum seat width should be at least 0.40 m (Guide for Measuring Passengers on Public Light Bus, 2004), which the locally fabricated seat depth is greater than. Likewise, standard acceptable seat dimension by AMVCB suggests a minimum seat width of 0.429 m (National Code of Practice, 2013), which the locally fabricated seat seems to comply to.

3.3. Compatibility of anthropometric measure & vehicular seat fit parameters

Fig. 3 show details of the assessment of compatibility between the anthropometric measures and local seat dimensions. There was high mismatch 96.4% between the seat height and popliteal height. This high mismatch indicates that the locally fabricated passenger seat height were high for most passengers, hence the feet of passengers would not be supported by the floor of trotro vehicle which could lead to discomfort. Whenever the seating surface is too high, the underside of the thigh could become compressed leading to discomfort and restriction in blood circulation (Parcells et al., 1999). To compensate for this, a sitting person usually moves his buttocks forward on the chair seat, which can result in a slumped, kyphotic posture due to lack of back support (Parcells et al., 1999) or find a footrest to elevate the feet (Reed et al., 1994). A low mismatch of 3.6% representing 11 out of 307 participants was obtained, suggesting that the mean seat height was less in comparison to the popliteal height. Low seat height is likely to cause one to assume a position of greater hip flexion than 90° to accommodate this mismatch, which would increase the degree of lumbar flexion involved in sitting (Milanese and Grimmer, 2004). Further implications of the low seat could cause the user's weight to be transferred to small areas at the ischial tuberosities and hence cause a lack of pressure distribution over the posterior thighs (Gouvali and Boudolos, 2006; Parcells et al., 1999).

Seat depth and buttock popliteal length comparison indicated a high mismatch and low mismatch of 84.4% and 15.6% of the study participants respectively. Results from this study seems to suggest that majority of the locally fabricated passenger seat are deep. When the seat is too deep, the front edge of the seat will press into the thigh just behind the knees, thereby restricting circulations to the legs and feet (Gouvali and Boudolos, 2006; Reed et al., 1994). In order to decrease the discomfort, the seat occupant will slide forward (Saba et al., 2013), resulting in occupants of the seats not being able to utilize the backrest of the seat that supports the lumbar spine in sitting posture (Milanese and Grimmer, 2004; Reed et al., 1994). Also, seats which are deep will restrict leg splay by interfering with knee movement and may impede posture changes that alter pressure distributions under the buttocks and upper thighs (Reed et al., 1994). Furthermore, a low mismatch of 15.6% was observed amongst study participants seems to imply the seats were shallow. When the seat depth is too shallow, it may cause the user to have sensation of falling off the front of the chair as well as result in a lack of support of the lower thighs (Parcells et al., 1999).

Seat breadth and hip breadth compatibility assessment yielded a high mismatch of 79.2% amongst the study participants. A high mismatch indicated that most of the passengers had enough support of their ischial tuberosities in order to achieve stability and allow space for lateral movements (Parcells et al., 1999). A 20.8% low mismatch was also observed amongst the study participants.

The compatibility of sitting height with backrest height indicated a low mismatch of 99.3% of the passengers. Low mismatch of backrest has been stated to be less harmful but may lead to discomfort and uneasiness (Gouvali and Boudolos, 2006). 0.7% of high mismatches was obtained between the sitting height and backrest height. Results from this study suggest that the locally fabricated passenger seats and the anthropometric dimensions seem to be at variance, which appears to corroborates with the results of earlier studies conducted in Ethiopia, Nigerian and Malaysia (Daruis et al., 2011; Ismaila et al., 2010; Saba et al., 2013).

4. Conclusion

The study established that the locally fabricated passenger seat in the country is discordant to some degree with the anthropometric data of passengers. Mismatches in anthropometric and seat dimensions were observed in seat depth, seat height and seat breadth with the locally fabricated trotro passenger seats. Incompatibility between seat dimensions and anthropometry could result in sitting discomfort, impediment of body sitting posture and could have other public health implications pertaining to the restriction of blood circulation, particularly to the feet and hands. The results illustrate that anthropometric dimensions are not probably considered when designing seats. Since the study was undertaken in only Accra, it needs to be extended to various part of the country to obtain a nationwide overview of how anthropometric data of passengers correlates with trotro seat dimensions. The inferences deduced from this study could be used to consolidate existing policies and strategies to enhance the design of locally fabricated seats. We further suggest that the local artisans must be encouraged to use standard seat dimensions and consider anthropometric data of the population when designing seats. Perhaps, a nationwide campaign on education and enforcement of the standard seat dimensions pertaining to trotro could be undertaken.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

ST initiated the concept and design. ST, LBD and SKK contributed to the collection, analysis and interpretation of data, as well as co-wrote the manuscript. All authors read and approved the final manuscript.

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