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Ergonomics Assessment of Passenger Seats of Mini-Buses in Ethiopia

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Abstract - A descriptive survey was conducted on an ergonomics assessment of passenger seats of minibus around Mekelle city, Ethiopia (Africa). The basic research questions which answered by this study are (i) to what extent the locally manufactured passenger seats of minibuses are comfortable to the passengers around Mekelle city? (ii) is there significant difference between the dimensions of locally manufactured passenger seats of minibus and the body dimensions of passengers around Mekelle city? (iii) are the passengers around Mekelle city aware of the comfort of passenger seats of minibus?. One hundred forty four passengers with ages ranging from 18 years to 63 years in the subjective evaluation and another one hundred forty four passengers with ages ranging from 18 years to 60 years in the objective evaluation participated in the study. In the subjective evaluation, passengers were asked to evaluate the dimensions and comfort of seats of minibus. Six anthropometric dimensions from one hundred forty four passengers and the dimensions of the locally fabricated seats in thirty minibuses were measured for the objective evaluation. The data collected was analyzed using descriptive statistics such as means, standard deviations, fifth, fiftieth and ninety fifth percentiles for the seat dimensions and passengers' body dimensions were calculated using Excel Microsoft Package. Moreover, the data obtained from the passenger's body dimensions was compared with the relevant dimensions of the seats using independent samples t-test (2-tailed) and chi-square test at 95 percent level of confidence. The results showed a degree of mismatch between the passengers' body dimensions and the seat dimensions. This may be an indication that the dimensions of locally manufactured passenger seats of minibus and passengers' anthropometric dimensions are at variant. It was thus concluded that the anthropometric dimensions of the passengers were not employed in the design and manufacturing of the passenger seats of minibus.

Keywords : *anthropometric, ergonomic design, minibuses, seats.*

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Ergonomics Assessment of Passenger Seats of Mini-Buses in Ethiopia

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Keywords : anthropometric, ergonomic design, minibuses, seats.

I. Introduction

In the developing countries the ownership of cars is low compared to the developed countries. In fact, Hilling (1996) observed that access to personal means of transportation, frequency of trips and choice of mode are closely related to income levels.

In Ethiopia, commercial transport operators depend largely on imported minibuses popularly called 'Mini-Bus' which in most cases do not come with passenger seats or when they do they are modified to accommodate more passengers to maximize their profits. Therefore, local manufacturers usually design or redesign the seats to suit the expectations of their customers without due consideration for the comfort and safety of the passengers.

The question of the correct design of passenger seats with emphasis on comfort as regards the Ethiopian people arises due to the fact that required anthropometric measurements are not available and the local manufacturers assume that manufacture of seats is an art rather than engineering.

Jeong & Park (1990) and Bridger (1995) noted that physical dimensions of furniture, equipment, clothing and workspaces are specified using anthropometric data to achieve proper ergonomic design. Thus the use of anthropometric data in design may constitute improvement in the health and comfort of the users (Barroso et al., 2005).

Similarly, Xiao et al. (2005) noted that anthropometric data is needed for ergonomically correct design of safe and efficient workplaces, equipment and tools.

Necessary as the anthropometric data is, the data for Ethiopian population is scant. For proper ergonomic design of passenger seats, anthropometric data for Ethiopian users of these seats is necessary and seems not reported.

The main aim of this study is to gather anthropometric data necessary for the design and manufacture of passenger seats as well as to compare the data with that of the passenger seats presently in use. The main method of obtaining anthropometric dimensions has been reported is traditional anthropometry.

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II. Materials And Methods

a) Methods, Sources of Data and Data Collection Techniques

A descriptive survey research method was employed in order to assess the current status of passenger seats comfort in minibus around Mekelle city. This study tries to demonstrate facts and findings by using primary and secondary sources of data. The primary data was obtained through subjective and objective evaluation. For the subjective evaluation, questionnaire was designed for the subjects (passengers) to assess the comfort of locally manufactured passenger seats of minibus under varying circumstances such as riding in minibuses, waiting for minibuses to come and the like. For the objective evaluation dimensional measurements of existing locally manufactured seats of thirty randomly selected minibuses and measurements of relevant anthropometric dimensions (Appendix 1) (Molenbroek et al., 2009) of available 144 users of these seats were done. The age of the subjects ranged between 18 and 63 years (mean of 32.77 years) for the subjective evaluation and between 18 and 60 years (mean of 35.4 years) were taken for the objective evaluation. All the measurements were taken from the passengers who travel from Mekelle city to different towns (Adigrat, Machew, and Samre etc.) and vice versa. The survey was carried out over a period of three months. Secondary data was obtained from such sources as published and unpublished documents collected from pertinent institutions as Mekelle road and transport bureau, taxi associations, different research papers studied by the former researchers for the development of passenger seats.

The data collected was analyzed using descriptive statistics such as means, standard deviations, and fifth, fiftieth and ninety-fifth percentiles using Excel Microsoft Package. The data obtained from the passengers was compared with the relevant dimensions of the seats using independent samples t-test (2-tailed) and chi-square at 95 percent level of confidence.

b) Subjective Evaluation

Subjective evaluation is carried out based on statistical analysis by gathering passengers' opinion towards the dimensions and comfort of minibus seats. The passengers were asked to evaluate the dimensions and comfort of the seats. Minibuses are chosen as most of the passengers choose these for transportation.

The purpose of this method is to assess passengers' evaluation on the dimensions and comfort of existing locally manufactured minibus passenger seats. The survey was carried out at the bus station where all minibuses would stop to wait passengers and riding in minibuses. It was conducted in questionnaire-based method. The researcher approached the passengers and asked for some of their time to answer the prepared questionnaires. It was necessary to explain any terms and questions that passengers might not be familiar with. They were asked to rate the seat dimensions and comfort using scale of 1 to 5. The target population for the study was adult respondents ageing from 18 to 63 years. The questionnaire was designed in such a way that the participants would respond to the questions by selecting the suitable rating scale.

All of the questions were close-ended questions to seek for participant's opinion. Such responses are useful and valuable to develop passenger seats of minibus which will reduce or minimize discomfort even during long-hour sitting. Therefore, users' point of view is very important. The questionnaire contained the following aspects:

- Demographic questions: Participants have given the rough measurement of their height, besides gender and age.
- Seat dimensions: Seat height, seat width, seat depth, backrest height, back rest width and gap between seats. Participants have been asked to assess each dimension in five rating scale.
- Overall evaluation: Participants have being asked to rate the overall comfort.

c) Objective Evaluation

i. Measurement of Seat Dimensions

Measurement for seat dimensions evaluation is important tool in the development of minibus seat to fulfill the criteria of ride comfort. The dimensions of existing locally manufactured passenger seats of minibus are assessed by taking measurements on seat height, seat width, seat depth, back rest height and back rest width using meter.

ii. Measurement of Passengers' Anthropometric Dimensions

Anthropometric dimensions (body dimensions) are important to minibus seat design dealing with the human shape. As shown in Appendix 1, the dimensions of passengers which are necessary to seat design are 1- sitting height (SH), 2-sitting to shoulder height (SSH), 3-buttocks to popliteal length (BPL), 4-popliteal height (PH), 5-shoulder breadth (SB) and 6-hip breadth seated (HB) were measured.

III. Results and Discussion

a) Subjective Evaluation-Results and Discussion

i. Statistical Summary of Respondents

In this study, there were 144 respondents, with 59% male and 41% female involved. The summary of demographic characteristics of the participants/inquired populations is depicted in Table 1.

Table 1 : Statistical summary of respondents

	Age (years)	Height (cm)
Minimum	18	160
Maximum	63	185
Mean	32.77	169.81
Standard deviation	11.22	5.45

ii. *Evaluation of Minibus Seat Dimensions*

Minibus seat dimensions were evaluated using a rating scale of 5 points numbered as 1 to 5; value of 3 represents neutral value, which is 'just nice' value, with value of 1 and 5 represent both low and high ends which are far away from 'just nice'. Mean and standard deviation (SD) value for each seat dimensions evaluation is depicted as in Table 2.

Table 2 : Mean and standard deviation value for seat dimensions evaluation

Seat dimensions	Mean	SD
Seat height	2.85	0.548
Seat width	2.63	0.632
Seat depth	2.33	0.775
Backrest height	3.10	0.707
Backrest width	2.45	1.049
Gap between seats	2.15	0.837

As shown in Table 2, mean value of evaluation on each seat dimension is ranging from 2.15 (gap between seats) to 3.10 (back rest height). Mean value over 2.50 shows that the mentioned seat dimension was more than 'just nice'. Seat height, seat width and backrest height are in this category. Seat depth, backrest width and gap between seats are slightly less than 2.50.

As each seat dimension has its own independent value representation, mean value as depicted above corresponds to this independent value. For example, evaluation of seat height; value 1 represents the seat to be too low and value 5 represents the seat to be too high for respondent, while evaluation of seat width; value 1 represents the seat to be too narrow and value 5 represents the seat to be too wide for respondent (Table 3).

It was found that most respondents did not complain much on their seat dimensions. Some of the seat dimensions were rated as 'just nice' such as seat height (78.60% rated their seat height as 'just nice), seat width (57.10% rated their seat width as 'just nice) and back rest height (70.70% rated their back rest height as 'just nice'). However, some of the seat dimensions (seat depth, backrest width and gap between seats) are rated below 'just nice'. This shows that the overall size of the passenger seats of minibus nowadays is not suitable for the passengers. Summary of respondents' rating on every seat dimension is depicted in Table 3.

Table 3 : Frequencies (%) of seat dimensions evaluation result

1	2	3	4	5
Seat dimensions:				
Frequencies (%)				
Seat height:				
TL	L	JN	H	TH
04.30	12.10	78.60	4.30	00.70
Seat width:				
TN	N	JN	W	TW
02.90	36.40	57.10	02.10	01.40
Seat depth:				
TS	S	JN	L	TL
10.70	55.70	23.60	10.00	00.00
Backrest height:				
TL	L	JN	H	TH
01.40	10.00	70.70	12.90	05.00
Backrest width:				
TN	N	JN	W	TW
17.90	43.60	16.40	20.00	02.10
Gap between seats:				
TN	N	JN	W	TW
21.40	50.00	20.70	07.90	00.00
Note: TL-Too low, L-Low, JN-Just nice, H-High, TH-Too high, TN-Too narrow, N-Narrow, W-Wide, TW-Too wide, Too short, S-Short, L-Long, TL-Too long.				

iii. *Overall Evaluation*

There was one part in the questionnaire which required the respondents to rate their overall evaluation towards the passenger seat (Figure 1).

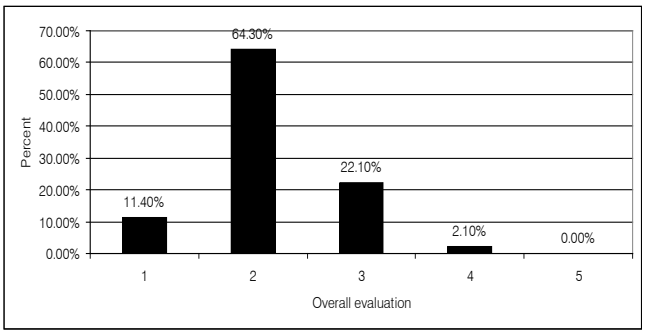

Figure 1 : Frequencies (%) of overall evaluation result (as per Table 3)

Based on Figure 1, it is clearly revealed that 22.10% of the respondents rated overall evaluation of their ride comfort as 'just nice'. 2.10% rated their ride comfort as 'comfortable' and no one rated the ride comfort as 'very comfortable'. On the other hand, 11.40% of the respondents were not satisfied with their ride comfort and rated it as 'very uncomfortable' and 64.30% rated their ride comfort as 'uncomfortable'.

b) Objective Evaluation-Results and Discussion

i. *Summary of the Dimensions of Existing Locally Manufactured Passenger Seats of Minibus*

The summary of the seat dimensions in terms of means, standard deviations, fifth, fiftieth, and ninety fifth percentiles are presented in Table 4.

Table 4 : Dimensions of existing locally manufactured passenger seats of minibus in cm

Seat dimensions			Percentile		
	Mean	SD	5th	50th	95th
Seat height	39.1	2.6	37.5	38.7	40.4
Seat width	38.4	1.3	34.0	38.2	43.5
Seat depth	38.1	6.8	34.0	37.7	41.6
Backrest height	41.6	9.5	38.0	41.3	47.0
Backrest width	37.4	6.4	33.5	37.1	41.0
Note: SD-Standard deviation					

ii. *Summary of the Anthropometric Dimensions of the Passengers*

The summary of the anthropometric dimensions of the passengers in terms of means, standard deviations, and fifth, fiftieth, and ninety fifth percentiles are presented in Table 5.

Table 5 : Anthropometric dimensions of passengers in cm

Anthropometric dimensions			Percentile		
	Man	SD	5th	50th	95th
Height	171.6	6.7	162.0	171.0	183.0
PH	44.6	3.5	37.3	42.0	48.1
HB	39.6	1.4	31.0	37.2	47.2
BPL	48.4	7.7	41.2	48.0	57.5
SH	76.0	10.7	76.5	74.4	82.4
SSH	60.7	11.3	55.0	60.1	63.8
SB	45.0	9.1	40.0	44.8	53.0
Note: SD-Standard deviation, PH-Popliteal height, HB-Hip breadth, BPL-Buthocks to popliteal length, SH-Sitting height, SSH-Sitting to shoulder height, SB-Shoulder breadth.					

iii. *T-test Analysis*

The t-test was used to assess whether the means of the seat dimensions and the means of the related anthropometric dimensions of passengers are statistically different. The t-values were calculated with the following formula (Pal & Sarkar, 2006) and the calculated values were compared with the critical t-value.

$$t = \left(\overline{X}_1 - \overline{X}_2\right) \div \sqrt{\left(\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}\right)} \qquad (1)$$

where: t =t- statistic, $\overline{X}_1$ = sample-1 mean, $\overline{X}_2$ = sample-2 mean, s_1 = sample-1 standard deviation, s_2 = sample-2 standard deviation, n_1 = sample-1 size and n_2 = sample-2 size

Table 6 shows the t-test analysis, the t-values were calculated using eq. (1) as follows:

Popliteal height and seat height:

$$t = (44.6 - 39.1) \div \sqrt{\left(\frac{3.5^2}{144} + \frac{2.6^2}{30}\right)} = 9.872$$

Hip breadth and seat width:

$$t = (39.6 - 38.4) \div \sqrt{\left(\frac{1.4^2}{144} + \frac{1.3^2}{30}\right)} = 4.537$$

Buttocks to popliteal length and seat depth:

$$t = (48.4 - 38.1) \div \left(\frac{7.7^2}{144} + \frac{6.8^2}{30}\right) = 7.370$$

Sitting to shoulder height and backrest height:

$$t = (60.7 - 41.6) \div \left(\frac{11.3^2}{144} + \frac{9.5^2}{30}\right) = 9.678$$

Shoulder breadth and backrest width:

$$t = (45 - 37.4) \div \sqrt{\left(\frac{9.1^2}{144} + \frac{6.4^2}{30}\right)} = 5.456$$

Table 6 shows that significant differences exist between the means of 'popliteal height (PH)' and 'seat height'; 'hip breadth (HB)' and 'seat width'; 'buttocks to popliteal length (BPL)' and 'seat depth'; 'sitting to shoulder height (SSH)' and 'backrest height'; 'shoulder breadth (SB)' and 'backrest width'. Thus, there is the likelihood of discomfort experienced by the passengers that use the seats due to this mismatch.

iv. *Chi-Square Test Analysis*

The chi-square test was used to evaluate whether there is an association between the dimensions of the seats and the anthropometric dimensions of the passengers. The chi-square statistic values are calculated with the following formula (Pal and Sarkar, 2006).

$$\chi^2 = \sum_{i=1}^{k} (\text{Observed} - \text{Expected})_i^2 \div (\text{Expected})_i \qquad (2)$$

where: $\sum^{k}$ = sum (of k numbers) and χ^2 = Chi square statistic

The chi-square statistic (χ^2) values for related anthropometric dimensions and seat dimensions are calculated in Table 7 and the results of the chi-square analysis are presented in Table 8.

Table 6 : T-test analysis of seat dimensions and passengers' anthropometric dimensions

Anthropometric dimensions			Seat dimensions			Difference	$t_{cal.}$	$t_{cri.}$	Criterion	Decision
	Mean	SD		Mean	SD					
PH	44.6	3.5	Seat height	39.1	2.6	5.5	9.872	1.980	± 1.77	Reject
HB	39.6	1.4	Seat width	38.4	1.3	1.2	4.537	1.980	± 0.193	Reject
BPL	48.4	7.7	Seat depth	38.1	6.8	10.3	7.370	1.980	± 2.59	Reject
SSH	60.7	11.3	Backrest height	41.6	9.5	19.1	9.678	1.980	± 7.95	Reject
SB	45.0	9.1	Backrest width	37.4	6.4	7.6	5.456	1.980	± 3.59	Reject

Note: SD-Standard deviation, PH-Popliteal height, HB-Hip breadth, BPL-Buthocks to popliteal length, SSH-Sitting to shoulder height, SB-Shoulder breadth, $t_{cal.}$ *-Calculated t-value,* $t_{cri.}$ *-Critical t-value.*

The result observed in Table 6 was corroborated by the results of the chi-square goodness-of-fit statistics which rejected any relationship between 'buttocks to popliteal length (BPL)' and 'seat depth'; 'sitting to shoulder height (SSH)' and 'backrest height'. Parcells et al. (1999) suggest that a chair whose seat height is >95% or <88% of popliteal height (PH) is a mismatch for the user. This suggests that the seat height should be between 39.9 cm and 37 cm (using the mean value of 42 cm) as compared to between 37.5 cm and 40.4 cm which makes the seats too high. Too high seats do not allow the feet to reach the floor which makes the passengers uncomfortable (Kroemer, 1971) and may result in low-back pain if the posture is prolonged (Chaffin & Anderson, 1991).

Similarly, the seat depth should be between 45.6 cm and 38.4 cm as Parcells et al. (1999) stated that a mismatch exists between buttocks to popliteal length (BPL) and seat depth when the seat depth is >95% or <80% of the buttocks to popliteal length (BPL). The existing seat depth was between 41.6 cm and 34 cm which means that the seats are shallow and may cause the user not only to have the sensation of falling off the front of the chair but may also result in the lack of support of the lower thighs (Panero & Zeinik, 1979). When dealing with a seat height and seat depth, the dimension employed needs to be smaller than the average dimension of the popliteal height (PH) and buttocks to popliteal length (BPL) (it needs to be the 5th percentile of the popliteal height (PH) and buttocks to popliteal length) (David & Oborne, 1987). As per this, the seat height and seat depth should be 37.3 cm and 41.2 cm respectively.

Table 7 : Chi-square statistic (χ^2) for related anthropometric dimensions and seat dimensions

Anthropometric dimensions and seat dimensions	Values	Percentile			Total χ^2
		5th	50th	95th	
Popliteal height and seat height	Observed values (O)	37.5	38.7	40.4	
	Expected values (E)	37.3	42.0	48.1	
	$(O-E)^2 \div E$	0.00107	0.25929	1.23264	1.49
Hip breadth and seat width	Observed values (O)	34.0	38.2	43.5	
	Expected values (E)	31.0	37.2	47.2	
	$(O-E)^2 \div E$	0.29032	0.02688	0.29004	0.61
Butocks to popliteal height and seat depth	Observed values (O)	34.0	37.7	41.6	
	Expected values (E)	41.2	48.0	57.5	
	$(O-E)^2 \div E$	1.21763	2.21021	4.39670	7.82
Sitting to shoulder height and backrest height	Observed values (O)	38.0	41.3	47.0	
	Expected values (E)	55.0	60.1	63.8	
	$(O-E)^2 \div E$	5.25455	5.88087	4.42382	15.56
Shoulder breadth and backrest width	Observed values (O)	33.5	37.1	41.0	
	Expected values (E)	40.0	44.8	53.0	
	$(O-E)^2 \div E$	1.05625	1.32344	2.71698	5.10

Table 8 : Chi-square test analysis of passengers' anthropometric dimensions and seat dimensions

Anthropometric dimensions				Seat dimensions				χ^2 Cal.	χ^2 (df=2)	Decision
	Percentile				Percentile					
	5th	50th	95th		5th	50th	95th			
PH	37.3	42.0	48.1	Seat height	37.5	38.7	40.4	1.49	5.99	Accept
HB	31.0	37.2	47.2	Seat width	34.0	41.2	43.5	1.01	5.99	Accept
BPL	41.2	48.0	57.5	Seat depth	34.0	37.7	41.6	7.87	5.99	Reject
SSH	55.0	60.1	63.8	Backrest height	38.0	41.3	47.0	15.56	5.99	Reject
SB	40.0	44.8	53.0	Backrest width	33.5	37.1	41.0	5.10	5.99	Accept

Note: PH-Popliteal height, HB-Hip breadth, BPL-Buttocks to popliteal length, SSH-Sitting to shoulder height, SB-Shoulder breadth, χ^2 Cal.-Calculated value of chi squared, χ^2 (df=2)-Critical value of chi-square at 2 degrees of freedom.

As recommended by Molenbroek et al. (2003), the seat width should be equivalent to 99 percentile value plus 15% which puts the seat width at 51.3 cm. Moreover, as recommended by Branton (1969), the backrest height and backrest width should be equivalent to the larger dimension of the sitting to shoulder height (SSH) and shoulder breadth (SB) which puts the backrest height and backrest width at 63.8 cm and 53 cm respectively. This mismatch, as noted by Ashby (1978), may mean that the seats may not be suitable for the users as the anthropometric data for the target population was necessary when designing for that population.

IV. Conclusion and Recommendations

a) Conclusion

Based on the findings of the research, the following conclusions are made.

- This research consisted of subjective and objective methods. Subjective method had been carried out in the form of questionnaire. Seat dimension and anthropometric dimension measurements were objective methods which required the results (output) in the form of data reading from the measuring instrument.
- Through subjective assessment, seat dimensions had been evaluated (Table 2). As per Table 2, although the respondents were satisfied with some of the dimensions of existing passenger seats of minibus, they still complained about certain dimensions of the seats, such as seat depth and back rest width.
- As per Table 6, the current study shows a mismatch between the dimensions of existing locally manufactured passenger seats of minibus and the anthropometric dimensions of passengers. This suggests that anthropometric data of the passengers was not employed in the design and manufacturing of the seats. This study is an indication that passenger seats of minibus and passengers' anthropometric dimensions are at variance.
- As it has been discussed in the literature review, seat design heavily relies on the anthropometric data to meet an ergonomic seat design. Therefore, the study provides anthropometric data that can be used by the local manufacturers of minibus seats for the design and fabrication of these seats.
- Therefore, the objectives of this study have been achieved and would definitely assist in an ergonomic passenger seat design of minibus. However, there are still spaces for development of the passenger seat design of minibus.

b) Recommendations

As per the result of the study, it is possible to make certain recommendations in order to improve the passenger seat design of minibus.

The overall notion of this study is not to give a detailed prescription for the design of passenger seats in minibus. However, the suggestions that are forwarded herein are aimed at giving more general guidelines to better suit this seat design in its role toward improving seat design, manufacturing and reducing the level of discomfort currently observed.

The following suggestions are forwarded as the result of the present study:

- In order to allow the passengers a sense of comfort, passenger seats of minibus should be ergonomically designed (the local manufacturers of passenger seats of minibus should use the anthropometric dimensions of passengers for the design and manufacturing of these seats).
- It is recommended that while designing seats, designers should use guidelines for seat dimensions proposed by the Society of Automotive Engineers (SAE).
- Local seat manufacturers usually design or redesign the seats to suit the expectations of their customers without due consideration for the comfort and safety of the passengers. Therefore, it is advisable if the Tigray road and transport bureau control this case.
- As this research was concentrating more on the seat dimensions, there was not much focusing on other factors for ride comfort. Therefore, in the

future, it is suggested that other interested investigators conduct more studies on other factors as well as seat dimensions.

- It is recommended if other researchers extend the present research work in order to evaluate all the segments of the public transport for ergonomic design of passenger seats.

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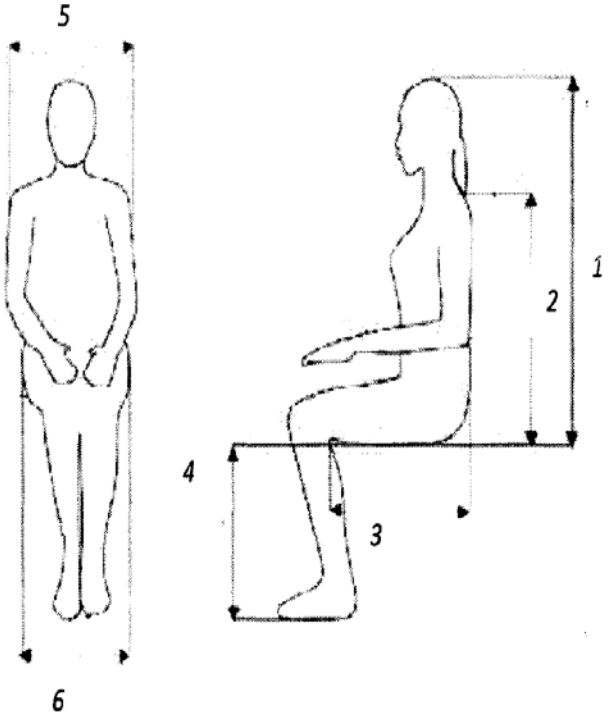
Appendix 1 : Anthropometric dimensions measured for study



1. Sitting height (SH), 2. Sitting to shoulder height (SSH), 3. Buttocks to popliteal length (BPL), 4. Popliteal height (PH), 5. Shoulder breadth (SB), 6. Hip breadth seated (HB).

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