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Anthropometry Survey of Nigerian Occupational Bus Drivers to Facilitate Sustainable Design of Driver's Workplace

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Abstract: Driving is a highly demanding and responsible job in which both the driver and passengers are exposed to several occupational risks. However, poor design of driver's workplace is a major risk factor responsible for the uncomfortable conditions which operators of this highly technological system are exposed to especially when engaged in long distance driving. This study aimed at developing anthropometric model for business bus drivers in Nigerian which will facilitate sustainable design of driver's workplace. A sample size of 161 drivers were randomly selected among strata of operators of buses in selected motor parks in the study area for the ergonomic study. Twelve anthropometric data were collected and analysed to obtain their 5th, 50th and 95th percentiles with which the anthropometric model were developed. Anthropometric model developed from 1932 data points was presented in forms of table showing measurement of sitting driver's body parts in his workspace indicating design for average as well as extremities of 5th and 95th percentiles. The model represents a database from which designers, manufacturers of equipment, machine, automobiles and household goods can obtain relevant body measurement of the population under study in relation relevant to specific product feature and for development of sustainable workspace design.

Keywords: *Anthropometry, Workspace, Bus driver, Ergonomics, Sustainable design.*

1. Introduction

Human body characteristic has become uniquely an important research area due to demand it poses on wears, furniture, workspace, engineering facilities and design of all manually operated systems. Among other study of biological systems, anthropometric survey is an area that is rarely research in spite of its significance to the comfort, safety and performance of human operator of any facility. Anthropometry is the science of measurement and the art of application that establishes the physical geometry, mass properties, and strength capabilities of the human body. It is concerned with the scientific study of human subjects for the development of standards and evolving of specific demands associated specifically with manufactured goods and services to enhance product usability and suitability for the user population [1],[2] and [3]. The applications of anthropometry in workplace design cannot be over emphasised with involve evaluation of postures, specification between controls and human operator/surrounding equipment as well as biomechanical analysis of forces and torque [4], [5] and [6]. The least expectation from ergonomic designed workplace is to be able to accommodate extreme users typically from a 5th percentile woman to a 95th percentile man. Anthropometric data have varied uses the design of virtually every equipment, tool, automobile, clothing, shoes etc. that are being used or operated upon by human being. Also in public health including the evaluation of nutritional status, cancer studies, as a risk factor for coronary heart disease (CHD) [7].

It has been found that the taxi cabs used in Nigeria for public transport exists in several variety of models sourced from advanced countries such as United State of America (USA), Germany, Japan, France, Europe and other developing countries like China, South Africa and India. These vehicles evidently were designed without due consideration for the peculiarities of anthropometric variable of Nigeria user population [8]. Ghosh *et al* [9] in their comparative study of the variability of anthropometric data among two communities found that some of the variables such abdominal disposition differs significantly which suggest the high level of sensitivity that these morphological features assume. The current ergonomic challenges faced by generally developing nations and Nigeria in particular is the absence of organize and structured anthropometric data. A number of anthropometric surveys of Nigerian available in literature were in pockets of research outputs with little or no consideration for implementation.

The automotive industry strongly encourages research in the field of objective comfort assessment, of seat and the related postures [10]. Despite the efforts of several automobile manufacturers to develop new safe and user friendly vehicle workplace which increase its usability in terms of seat comfort, ease of reach of other in-vehicle's components, there is still a prevalence of work related musculoskeletal disorders (WRMDs) commonly reported among occupational drivers. Some other important factors that should be considered in the design of in-vehicle elements are related to human body dimensions of the drivers particularly in designing of automobile seat, dashboard, steering wheel, pedals, knobs, levers, and doors [11], [12] and [13].

This work seeks to make further contribution to such efforts and to create an anthropometric database that finds useful applications in the design of bus driver's workspace. Ergonomics design of automobile is highly essential in the choice of model of vehicle that can be acceptable to Nigeria user population and in the legislation regarding importation of automobile in to the country.

2. Materials and method

A proportionate random sampling was done from each of the six major bus stations in the South western part of Nigeria. The sample size considered was determined using the procedures outlined in International Standard Organization (ISO) 15535. A sample size of one hundred and sixty-one bus drivers was selected for the study. Fifteen (15) anthropometric variables relating to seating posture were measured and characterised. The procedure for taking anthropometric measurement of subjects is quite technical and it requires the use of three trained enumerators and reliable anthropometric equipment. All measurements were taken with subject. Linear measurements considered in three dimensional plane as follows (i) Sagittal Plane – Vertical Dimensions (e.g. Sitting Height Normal, Sitting Height Erect, Eye Height Sitting, Shoulder Height Sitting, (ii) Sagittal Plane – Horizontal Dimensions (e.g. Forearm Hand Length Buttock-Popliteal Length, Buttock-Knee Length, Anterior Arm Reach, and (iii) Frontal Plane (e.g. Shoulder Breadth, Elbow-to-Elbow Breadth, Hip Breadth Sitting, Knee-to-Knee Breadth, Foot Breadth, were all measured in centimetres while weights and ages are recorded in kilograms (kg) and years (yr) respectively. Four enumerators who have received adequate training on the process and procedure as well as the use of the equipment involved were used in conduct of the study. Likewise, the subjects were given a brief but well packaged orientation just before commencement of the measurement at their bus garages to inform them on objectives and benefits of the survey. Demographic characteristics and other personal details of the subjects were collected using structure questionnaire. The equipment which were used for the measurements includes stadiometer, a variable anthropometer, anthropometric seat, graduated measuring tape, and a bathroom weighing scale. As part of the procedure the subjects were asked to stand on the platform of the stadiometer and the pointer is moved to obtain the stature of each subject and in turn sit on the anthropometric seat, its arms were adjusted according to the subject's height and measurement was recorded from the vertical scale. In a similar form, other measurements were recorded in sitting and standing postures with the help of anthropometer. The measurements were evaluated on descriptive statistics such as the mean, standard deviation (sd), range and 5th, 50th, 95th percentiles using ExcelMicrosoft and STATA 11.0 data processing tools.

3. Results and discussion

The population under study was absolutely male dominant with age range of 20-60 years, over 60 percent were 30 years and above which suggests relatively matured working population and married being 93%. Less than 1% has higher education certificate while only fifty-two percent of the driver's school certificate holder. This could have significantly adverse implication on driver's level of understanding of road safety rule, regulations and repairs and maintenance instructions. The average stature of the respondents is about 176 cm (sd = 5.16) and the 95 percentile of the standing height is 186 cm. Majority of the respondents (95%) weigh less than 85 kg with mean weight of 74 kg (sd = 6.7). Table 1 shows the anthropometric measurement of the drivers arranged according to order of planes (Sagittal Plane- Vertical Dimension (I), Sagittal Plane- Horizontal Dimension (II), Frontal Plane III) and weight (IV). This represent anthropometric model for the commercial bus drivers in the study area. A comparison of the model with similar models obtained for *molue* drivers in Ajayeoba and Orekoya [15]. taxi drivers in Onawumi and Lucas, [8] and Ismail *et al* [16] show no significant difference at p = 0.05 for all the variables considered (Table 2). It is important to note that all the subjects in the surveys were from the same geo-political zone of Nigeria. However, a further comparison of the model with those of other study areas specifically the South West [15] and South-Eastern [17] show significant differences (p = 0.05) at some of anthropometric variables as statures, sitting height normal, and elbow rest height, buttock knee length and hip length (Table 3). This suggests that the influence of ethnicity cannot be overruled in anthropometric modelling. Such effect may however, fizzle out in the face of multi-ethnic population as found in capital cities and other commercial hubs of the country.

Table 4 presents the comparison of the mean ratio of buttock popliteal length to stature of different population and group. This ratio was specifically considered because of its direct application to design of seat. The activities of automobile driver were carried out in sitting posture and for many tasks in other occupation sitting is more common and convenient than any other posture. For design of driver's seat, it necessary to consider buttock popliteal length of the operator to obtain comfortable seat depth. The mean ratio obtained for south western Nigeria are almost the same possibly because the population under consideration are drivers. Significant difference exists in the case of passenger and agricultural workers having mean rations 0.3001 and 0.2962 respectively. The case of other nations there is similar in the mean ratios of Russia and Germany however both are considerably deferent from that of the present study. This suggests the need for adjustable mechanism of the seat depth which is conspicuously missing in the seat system of the busses imported into Nigeria.

The applications of anthropometric variable in the design of in-vehicle of bus are shown in Table 5. Mismatch between the characteristics of driver workspace and demands of human operators have resulted to musculoskeletal disorders (MSDs) and associated etiological effects. For instance, a good number of the bus drivers patronises local herbals and hawkers of concussions to get medication for pains, strains and discomforts experienced after the

day's work. Cumulative Trauma Syndrome (CTS) have also been related to awkward postural challenges occasioned by poor design of seat system of the buses. About sixty-eight percent of the buses operated by the driver had failed seat adjustable features hence constraining them awkward posture which they had to maintain for as long as the driving lasts. Also noted was that eighty-five percent of the vehicles was used foreign vehicles (refers to as *Tokunbo*) some of which were in the state of disused imported into the country. Where there is no functional policy guiding importation of automobile these *Tokunbos* find easy entry into nation market. Price variation between brand new bus and *Tokunbo* of the same mode is very large enough to influence the choice of an average Nigerian majority of who live below two dollars per day. Prevalence of discomfort and other musculoskeletal disorder renders the workplace of the operator unsustainable needing modifications. Some drivers end up deforming the workspace through some form of ill-informed adjustments and reworks (through fabrication of certain attachment) done on some elements of the workspace. Result of this survey bring to light the needed database that manufacturer of automobile can use in manufacture of user friendly driver workplace.

Table 1: Anthropometric data of bus operators (n = 161)

Anthropometric Variables		Mean	Std. Dev	Range	Percentile		
					5th	5th	95th
I	Stature	176.12	6.17	21.8	167.6	175.6	185.9
	Sitting height normal	79.32	4.31	16.8	72.7	79.3	85.0
	Sitting height erect		6.65	27.4	75.0	83.2	93.6
	Shoulder Height Sitting	57.54	2.55	9.7	53.9	57.3	61.5
	Shoulder-Elbow Length	37.26	2.26	7.7	34.0	37.0	40.8
	Thigh Clearance Height	14.06	1.38	4.49	12.1	13.9	16.1
	Popliteal Height Sitting	49.39	2.02	6.79	46.3	49.3	52.3
II.	Buttock-Popliteal Length	48.97	2.57	10.5	45.7	48.6	53.2
	Buttock-Knee Length	58.89	2.88	13.6	55.0	59.0	63.1
	Anterior-Arm Reach	89.19	3.99	15.3	83.7	89.2	95.4
	Thumb-Tip Reach Sitting	81.44	3.53	12.7	76.7	80.9	87.2
III	Shoulder Breadth	45.42	3.25	10.6	40.4	45.1	50.1
	Hip Breadth	37.95	3.62	15.7	32.8	37.9	42.7
	Maximum Body Breadth	46.1	3.2	11.2	41.0	46.2	50.8
IV	Weight	74.05	6.70	31.5	61.7	73.6	85.1

All dimensions were measured in centimetres (cm) except weight which is in kilogram (kg)

Table 2: Comparison of Anthropometric Data of Bus Operators with past related works on Bus and Taxicab operators' anthropometry in Nigeria

Anthropometric Measurement	Ajayeoba and Orekoya [15]			Onawumi and Lucas [8]			Present study		
	5th	50th	95th	5th	50th	95th	5th	50th	95th
Shoulder Height Sitting	54.0	57.1	60.2	49.8	56.2	65.2	53.9	57.3	61.5
Shoulder-Elbow Length	33.5	36.2	38.9	35.14	37.90	42.90	34.0	37.0	40.8
Shoulder Breadth	40.6	42.8	45.0	40.24	44.35	50.86	40.4	45.1	50.1
Sitting height normal	NA	NA	NA	72.9	79.5	85.37	72.7	79.3	85.0
Sitting height erect	NA	NA	NA	76.2	83.4	88.87	75.0	83.2	93.6
Buttock-Knee Length	54.9	58.1	61.3	54.0	60.2	64.7	55.0	59.0	63.1
Buttock-Popliteal Length	45.8	48.9	51.9	40.04	48.05	53.80	45.7	48.6	53.2
Thigh Clearance Height	11.5	13.3	15.0	11.5	13.9	17.40	12.1	13.9	16.1
Popliteal Height Sitting	47.4	49.8	52.1	38.47	42.35	47.93	46.3	49.3	52.3
Thumb-Tip Reach Sitting	75.9	79.9	83.8	N/A	N/A	N/A	76.7	80.9	87.2
Anterior-Arm Reach	82.2	86.4	90.5	75.70	86.20	95.77	83.7	89.2	95.4
Stature	166.8	173.3	179.7	161.30	172.00	182.76	167.6	175.6	185.9
Hip Breadth	31.8	34.9	38.1	31.84	35.80	39.60	32.8	37.9	42.7
Maximum Body Breadth	41.8	44.6	47.5	42.0	47.1	54.57	41.0	46.2	50.8
Weight	N/A	N/A	N/A	58.81	68.00	88.07	61.7	73.6	85.1

All variables were measured in centimetres (cm)

Table 3: Comparison of Anthropometric Data of Automobile Operators from related works in Nigeria

Anthropometric Measurement	Ismaila et.al [16]			Onuoha [17]			Present study		
	5th	50th	95th	5th	50th	95th	5th	50th	95th
Shoulder Height Sitting	N/A	N/A	N/A	48.4	55.3	57.7	53.9	57.3	61.5
Shoulder-Elbow Length	N/A	N/A	N/A	26.8	31.0	44.5	34.0	37.0	40.8
Shoulder Breadth	N/A	N/A	N/A	38.6	44.3	55.7	40.4	45.1	50.1
Sitting height normal	N/A	N/A	N/A	N/A	N/A	N/A	72.7	79.3	85.0
Sitting height erect	76.9	83.5	93.0	69.4	83.5	92.9	75.0	83.2	93.6
Buttock-Knee Length	58.4	62.1	67.7	49.1	58.3	63.0	55.0	59.0	63.1
Buttock-Popliteal Length	44.4	51.1	60.8	42.6	49.1	53.5	45.7	48.6	53.2
Thigh Clearance Height	11.9	14.1	16.9	11.4	13.6	15.7	12.1	13.9	16.1
Popliteal Height Sitting	N/A	N/A	N/A	39.5	43.3	52.1	46.3	49.3	52.3
Thumb-Tip Reach Sitting	N/A	N/A	N/A	NA	NA	NA	76.7	80.9	87.2
Anterior-Arm Reach	N/A	N/A	N/A	75.3	81.2	91.2	83.7	89.2	95.4
Stature	158.8	172.5	190.8	158.9	163.6	176.6	167.6	175.6	185.9
Hip Breadth	29.0	36.4	46.4	28.5	30.8	35.6	32.8	37.9	42.7
Maximum Body Breadth	33.7	46.0	64.0	N/A	N/A	N/A	41.0	46.2	50.8
Weight	N/A	N/A	N/A	41.3	56.3	66.3	61.7	73.6	85.1

All variables were measured in centimetres (cm)

Table 4: Comparison of buttock-popliteal length to stature ratio with other ethnic populations of the world.

Study		Mean Ratio	Source
South Western Nigeria	Bus drivers	0.2768	Present study
South Western Nigeria	*Molue* Bus drivers	0.2822	Ajayeoba and Orekoya [15]
South Western Nigeria	Taxi cab drivers	0.2794	Onawumi and Lucas [8]
South Western Nigeria	Passengers in Busses	0.2962	Ismaila *et al* (2010)
South Eastern Nigeria	Agricultural workers	0.3001	Onuoha (2012)
Britain	Male Adult	0.2845	Marras and Karwowsk (2006)
Germany	Male Adult	0.2834	Marras and Karwowsk (2006)
Russia	Male Adult	0.2592	Marras and Karwowsk (2006)

Table 5: Applications of body dimensions in the in-vehicle design of bus

Anthropometric Variable	Mean (50^{th} percentile)	SD	Application in-vehicle variables
Popliteal height sitting	49.39	2.02	Seat height
Hip breadth sitting	37.95	3.62	Seat width
Buttock-popliteal length	48.97	2.57	Seat length
Shoulder height, sitting	57.54	2.55	Back-rest length
Shoulder breadth	45.42	3.25	Back-rest width
Anterior arm reach sitting	89.19	3.99	Dashboard-backrest length
Thumb –tip reach sitting	81.44	3.53	
Buttock-Knee length	58.89	2.88	
Anterior arm reach sitting	89.19	3.99	Steering-wheel external diameter
Thigh height sitting	14.06	1.38	Thigh clearance (steering wheel-seat height)
Stature	176.12	6.17	Driver's door height
Max. body breadth	46.1	3.2	Driver's door width
Stature	176.12	6.17	Ground-to-driver's door height Elbow clearance
Popliteal height sitting	49.39	2.02	Seat-pedal length
Popliteal height sitting	49.39	2.02	Rounded front edge seat width
Sitting height Normal	79.32	4.31	Headrest length
Sitting height Erect	83.36	6.65	
Buttock-Knee length	58.89	2.88	Seat Adjustment

Conclusion

It was observed that Nigeria has been made a dumping ground for disused items including automobiles the picture that the present government need to address with deep sense of responsibility. There is great need to enact and enforce importation policy on automobile in Nigeria. This would drive the auto manufacturers who like to trade with country to take up responsibility of supporting research in the area of ergonomic suitability of their product to Nigeria users which effort will impact positively on the comfortable, safe, and performance of operator of the engineering system. Alongside with the demographic content of the population of Nigeria, government should consider including the collection of anthropometric data of different age structure of her population. Design for sustainability of a vehicle with careful consideration of the physical limitations of the driver is a requirement for user-friendly, comfortable and effective drivers-vehicle system. This enhances acceptability, performance and productivity among bus operators as well as support competitiveness in automotive industry. A public-private partnership (PPP) arrangement is suggested for successful development of national anthropometric database which would wide acceptable to all relevant manufacturer, researchers and information scientists.

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