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Ergonomic Investigation of Occupational Drivers and Seat Design of Taxicabs in Nigeria

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ABSTRACT

Repetitive trauma disorder and other work related musculoskeletal problems are prevalent among occupational drivers worldwide. This justifies the continue research and development efforts in the area of design of comfortable, safe and effective seat system by the automotive industry. The misfit seat variables are traceable to the difference between the adopted anthropometric measurement and that of the user population in the affected countries where the vehicle are exported. The objective of this paper is to investigate the ergonomic suitability of imported technological system specifically taxicab driver seat in Nigeria. Particular focus was placed to identify seat features that contribute to discomfort and work related MSDs of the operator. The application of participatory ergonomic intervention (PEI) approach is explored to achieve the objectives of this paper.

Keywords: *Taxicab, driver's seat, MSD, PEI, anthropometric data.*

1. INTRODUCTION

Ergonomics of facility has become an area of particular concern due to it's impact on safety, health, productivity and economy of users as well as the competitiveness of products, machine, process and equipment, Driver seat has moved from mere add-on or afterthought component fitted among some instrumentations and firebox to become an important component of automobile operator's workstation whose design, features and manufacture determine the level of comfort, safety and performance of driver accommodated in the workspace envelop. Sitting which is the work posture of driver should be properly done to avoid backaches, strain, excess fatigue and extra stress on the neck and back [1, 2]. Also compounding the musculoskeletal disorder (MSD) on driver is the inclusion of vibration, aging and bad suspension system of the vehicle and poor road conditions (potholes, road debris, damages expansion joints, etc.). Comfort is generally associated with the short-term sensation of seating while fatigue is associated with the long-term effects of driving. This means that the measurement of fatigue can best be achieved by performing subjective study of different seats types and designs using participatory ergonomic intervention (PEI) approach due to the fact that comfort is relative [3,4]. The interaction, use and combination of driver's seat, pedals, and steering column and wheel were identified as what influence the operator's posture [5]. Seat comfort has attracted much research focus and continue to receive more support of automotive industry. Seating discomfort can be highly subjective as different people may assess it differently based on factors like environment, nature of task at hand and other internal conditions[2,15].

The cumulative effect of MSD is more pronounced in business driver who are frequently

involve long distance (>1hour) journey. The adjustable limits of the seat must be able to accommodate the extremes of human characteristics with the distribution of the user population [6]. According ISO 2631 human body is most sensitive to seat vibrations between 4 and 8Hz [7]. Used vehicles with damaged seat damper and or spring exposes driver to excessive vibration aids unsafe shock events and other safety risks. With the increasing number of manufacturer of vehicles of different brands and types concerted efforts are required to develop user friendly, comfortable and save automobile seat system that take into account human capabilities and limitations [8, 9, 10]. Among such efforts made in this area are the introductions of adjustable seat to allow individual driver to work at his preferred space, armrest, headrest and thigh support. The challenging task in scope of the application of ergonomics is the significant variation in human capabilities with ethnicity, age, sex and race. Also, lack of "world anthropometry data" poses enormous task for ergonomists and designers. Although studies have been carried out on driver fatigue and low back disorder as a matter of research and development however the need for users assessment of seat design is inevitable [11].

In Nigeria road transportation is major form of transportation with varieties of buses, taxis, omnibus, vans and motorcycles being used to move material and people from one place to the other. Heavy Lorries and trucks are used to transport larger tones of good within short and long distances. Three distinct categories of public transportation systems operating taxicabs noticeable in Nigeria are:

- ❖ Private vehicle operators (commonly called *kabukabu*): These are public vehicle operators who use different types and brands of private vehicles. Most of these vehicles are four passenger cabs which are run on either full time or part-time basis within a particular Municipal area.

- ❖ Organized transport companies: These are transportation establishments owned by Corporations, Cooperative societies and Unions. They provide public transportation using varieties of vehicles ranging from four passenger cabs to eighteen passenger buses. The vehicles provide transport between Cities and States.
- ❖ Government owned mass transit: These are Local and State Government-owned public establishment which operate fixed route or chartered cab services and using single type of vehicle [12].

These are all imported as either used or new vehicles from different countries some of which has established human anthropometric databank. *Kabukabu* is a collection of different makes of taxicabs irrespective of where, who and for who the vehicles are produced owned and operated by individuals on commercial basis. They are preferably the old type of vehicle that runs on back axles. This choice is because of the bad condition of roads which the front wheel vehicles are not capable to run for commercial purpose. Road side fabricators have assisted in modifying seats and work place of some of these vehicles without recourse to any design specifications but simply based on based on individual users suggestion. Due to the low level of education and lack of technical know-how in the area of ergonomics on the part of the fabricators and users of these *kabukabus* most of the vehicle has be turn into state of disused which create health and safety risks for both driver and the passengers.

In the absence of appropriate legislation and standards relating to ergonomics of means of transportation, report of pains at different body segment markers and general work related illness will continue unabated [13]. In order to join in establishing a legislation framework for user friendly industrialization and technological awakening of the developing nation as Nigeria, this work consider the evaluation of ergonomic suitability of driver seat of six commonly used taxicabs in Nigeria with the view of establishing the level of matching between seat variable and human anthropometric measurements.

This study is essentially relevant now that government of Nigeria has lifted ban on the importation of vehicles that are less than ten years of manufacture couple with ever increasing brands of four passenger vehicles are used as taxicab.

2. METHODOLOGY

Personal characteristics collected include age, sex, state of origin, religion, educational background year of experience, license statures.

Anthropometric Measurement

Anthropometric variables of 1406 taxicab drivers randomly selected from five Urban Centres in Nigeria were measured. The sample size was derived from ISO15535 and twenty-one variables of the subjects in sitting posture were considered [14]. The anthropometric dimensions of subjects were measured using stadiometer, clipboard, measurement form, pencil, eraser, steel tape, and small and large wooden vernier caliper. Eight enumerators were trained on the standard method for taking anthropometric measurements. Twenty-one (21) body dimensions for sitting posture were measured and characterized. The procedure for taking anthropometric measurement of subjects is quite technical and it involves the use of eight trained enumerators and reliable anthropometric equipment. All measurements were taken with subject putting on simple, light vest without shoe on. Linear measurements are taken in centimeters while weight and age are measured and recorded in kilograms (kg) and years (yr) respectively.

Model of each of the anthropometric description of seated operator is divided into three groups for easy identification. The groups are: Sagittal Plane – Vertical Dimensions Sagittal Plane – Horizontal Dimensions and Frontal Plane as shown in figure 1. The instrument used in this study includes Data collection forms; Traditional anthropometric instruments - anthropometric chair (figure 2), stadiometer, large anthropometer, small anthropometer, standard tape-weighing scale and digital camera. The enumerators were trained on the use of the mentioned instruments, the method of positioning the subjects in correct sitting posture required for the measurement and identification of distinct body parts. Measurement of one subject was done twice to enhance the reliability of the measuring process.

Measurement of Seat Variables

From preliminary investigation six make of vehicles were found to be commonly used as taxicabs. These are Nissan, Mazda, Toyota, Mitsubishi, Peugeot and Opel. Observational studies together with linear and angular measurement were also carried out on the sampled driver's seats. The physical measurement of nineteen seat variables that was carried out on the sampled taxicabs include: Seat height, Seat depth, Backrest seat plane height, Backrest height, Distance from edge of seat to application of force point, Lumber support height, Lumber support depth Lumber support extension, Rounded front edge seat width, Armrest clearance, Backrest width (Lumber level), Backrest width (Thoracic level), Horizontal lumber concavity (Radius), Horizontal Thoracic concavity (Radius), Headrest length, Headrest width, Armrest surface length, Armrest surface breadth, Backrest angle and Seat plane angle.

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A three dimensional macro-ergonomics evaluation technique (3D-MET) was used to analyze the interrelationship between the subject (automobile driver), the object (vehicle type) and the object condition (in-vehicle element).

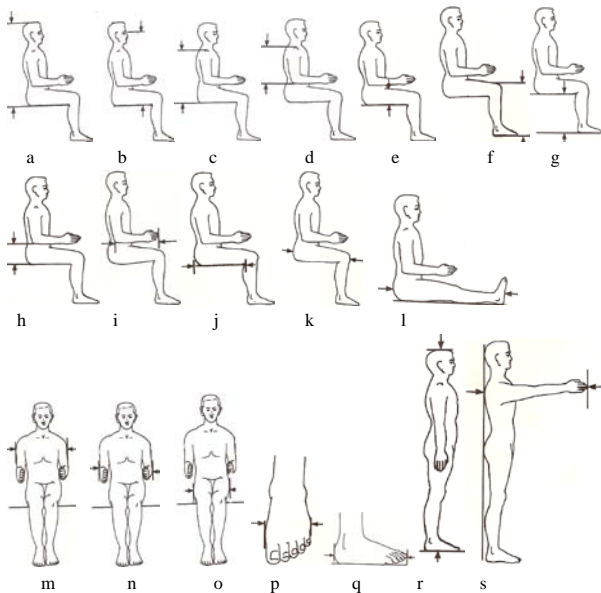


Figure 1: Anthropometric dimensions

- (i) Sagittal Plane – Vertical Dimension: a-Sitting height erect, b-Sitting eye height, c-Sitting shoulder height, d-Shoulder elbow length, e-Thigh clearance height, f-Sitting knee height, g-Sitting popliteal height, h-Sitting elbow height, s-Stature.
- (ii) Sagittal Plane – Horizontal Dimension: i-Elbow fingertip length, j- Buttock-popliteal depth sitting, k-Buttock- knee depth sitting, l- Buttock leg length, t-Forward grip reach, p- Foot breadth.
- (iii) Frontal Plane: m-Shoulder breadth (bideltoid), n- Elbow-to-elbow length, o-Hip breadth sitting, q- Foot length,



Figure 2: Automotive Seat

3. RESULTS AND DISCUSSIONS

The operators are generally male and are between 20 and 65 year among which 92% are married. 67% of the respondents have valid driver license. 85% of

them have engaged in business driving as means of living. The highest educational qualification of the operators is ordinary level. 42% work more than 8hr a day. Driver's work space has common feature for all the sampled vehicles consisting i. steering wheel, ii. Dashboard, iii. Gear control knob, iv. Foot pedals (clutch, break and trouble pedals), v. Knobs (for control of pointers and head lights and wiper), central mirror and side mirrors at both the driver's and front seat passenger. The control of all the mention elements of driver workplace become the primary function of the driver whose level of vigilance increases with the traffic intensity, unsafe road condition, general level of disuse of the vehicle, adverse climate, drivers experience and other environmental factors.

From figure 4 the most common vehicle found on Nigeria is Toyota brand (28.1%) while Benz (0.2%) is least found brand used as taxicab. This depicts the large variation of



Figure 3: Side View of Driver's Work Space including Seat of a Taxicab

the countries from which this fleet of cab types has been imported into the country as used vehicle. This is also a partial reflection of the availability and acceptability of the vehicle makes for such commercial purposes. The large variation in the brands and makes of vehicles used in business driving in Nigeria which remain a large consuming nation and indeed the largest population in Africa open up room for competition among manufacturers of commercial vehicles. Eighty one percent of these vehicles are four passenger types. However 95% of the operators use their cab to transport more than 5 passengers especially at peak periods. Table 1 shows the mean (\bar{x}) and standard deviation (SD) of five replicated measured in-vehicle elements in relation to driver's seat. The variability in the measurement which is less than 1inch (2.54cm) could be traced to manufacturing defects. This may not be responsible for musculoskeletal problem of the population of user for who it was designed but could pose significant health and safety treat to operators outside the designed user

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population. The physical measurement of eighteen seat variables that was carried out on sampled taxicabs within the workspace typically shown in figure 3.

The descriptive statistics used which include mean, standard deviation Skewness, range and percentile values (5th, 50th and 95th) of anthropometric data for twenty-one different body dimensions, weights and ages are presented in Table 2. These data could be used in the design of driver's workplace which includes the seat, pedals, control buttons, gear lever, and other facilities within the vehicle. Also in the design of automobile tools and accessories like the car jack, wheel spanner and manual tire pump.

The measured anthropometric data were compared with that Adult population of six other countries namely Chinese, Japan, Britain, France, Germany, Russia. Table 3 shows that the studied population is smaller than British, Russian and France in almost all dimensions while it on the contrary it is bigger than Chinese, Japanese and Germans.

In all the difference in the mean statures between the studied population and other locations ranges between -3.6cm and 2.3cm. Sitting height and sitting eye height of the taxicab operators is practically significantly smaller to all other location considered (Marras and Karwowski, 2006). Table 4 presents the area of application of anthropometric data in the design of comfortable, safe and user-friendly taxicab workspace.

A misapplication of anthropometric data is noticed in the design of the operator's seat especially as it affects the studied user population at some points. The level of mismatch is significant to trigger musculoskeletal trauma on the drivers studied.

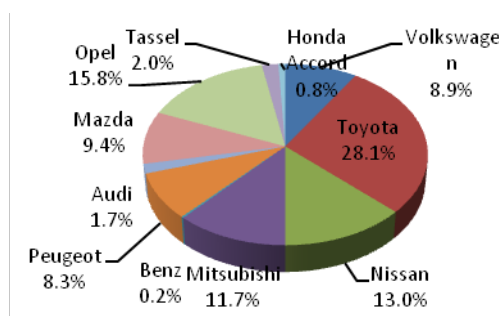


Figure 4: Taxicab brands

4. CONCLUSION

This study has been able to open up the need to conduct an anthropometric survey for user population in Nigeria. It is also evident that there is no explicit limitation on the model, brand and make of cabs that is allowed into the country. This is a reflection of lack of consciousness ergonomic implication of the large variation in vehicles used for public transport and a show of slack in legislative framework to control the incessant importation of cabs in Nigeria. Continue accumulation of repetitive trauma disorder which by extension could lead to loss of productive time and shortage in transportation services in the Nation. A conscious effort is required to develop ergonomic data of Nigeria working class and application of the same in design and arrangement of in-vehicle components of automobile for local population. Manufacturer of products where vehicle are imported from should be properly informed and mandated to produce to specifications arrived at using the Nigerian anthropometric database. Other classes of Nigerian population who also make used of taxicab as means of transportation should also be studied for possible collection of their anthropometric data.

Table 1: Comparison of values of driver seat variables of taxicabs brands used in Nigeria

<i>SEAT CHARACTERISTICS</i> (cm)	<i>Nissan</i>		<i>Toyota</i>		<i>Mitsubishi</i>		<i>Peugeot</i>		<i>Mazda</i>	
	\bar{X}	SD	\bar{X}	SD	\bar{X}	SD	\bar{X}	SD	\bar{X}	SD
Seat height	31	0.35	28.3	0.35	30.4	0.55	31.7	0.45	31.1	0.22
Seat depth	43.4	0.55	38.8	0.55	44.2	0.45	43.2	0.27	44.8	0.27
Backrest seat plane height	56.5	0.50	56.9	0.50	58.5	0.50	57.6	0.89	58.3	0.45
Backrest height	51.8	0.57	54.9	0.57	55.6	0.55	51.8	0.84	56.4	0.42
Lumber support height	20.6	0.55	17.6	0.55	14.4	0.55	21.2	0.27	14.5	0.35
Lumber Support depth lumber support extension	8.4	0.55	8.4	0.55	5.3	0.45	8.8	0.27	5.7	0.27
Rounded front edge seat width	16.1	0.22	22.8	0.22	23.3	0.45	16	0.35	23.7	0.27
Armrest clearance	58	0.00	59.2	0.00	58.2	0.45	58.9	0.22	58.5	0.35
Backrest width (lumber level)	31	0.35	50.6	0.35	30.7	0.84	31.3	0.27	31.4	0.55
Backrest width (Thoracic level)	53.2	0.45	47.3	0.45	53.1	0.74	53.4	0.22	53.8	0.27
Horizontal lumber concavity (Radius)	44.7	0.45	55.5	0.45	56.3	0.45	45.1	0.22	56.2	0.27
Horizontal Thoracic concavity (Radius)	39.3	0.45	48.5	0.45	48.6	0.55	39.5	0.50	48.6	0.42
Headrest length	20	0.00	17	0.00	17.1	0.22	21.1	0.22	16.7	0.27
Headrest width	27	0.00	26	0.00	24.1	0.22	26.1	0.22	24	0.00
Armrest surface length	6	0.00	5.3	0.00	5	0.00	5	0.00	5	0.00
Armrest surface breadth	31.1	0.22	30	0.22	29	0.00	32.9	0.22	29.5	0.00
Backrest angle(in degree)	112.2	1.79	110.6	1.79	108.2	2.77	109.6	1.14	109.6	1.67
Seat plane angle (in degree)	109.4	1.95	108	1.95	104.4	2.88	106.6	1.52	107	1.87

Table 2: Relevant anthropometric data of taxicab operator in Nigeria

Anthropometric Measurement (cm) (N=1406)	Nigeria						
	Mean	SD	Skewn-ess	Range	Percentiles		
					5th	50th	95th
Stature	172.38	6.32	-0.28	53.60	162.00	172.60	182.0
Sitting Height Erect	83.41	4.02	-0.37	29.40	77.00	83.60	88.90
Sitting Eye Height	71.36	4.38	-0.07	33.50	63.34	71.60	78.30
Sitting Shoulder Height	56.41	4.54	0.15	29.70	49.30	56.45	63.20
Shoulder-elbow Length	38.15	2.31	0.53	20.00	34.80	38.10	42.10
Sitting knee Height	54.36	2.84	-0.63	19.70	49.50	54.50	58.70
Thigh Clearance Height	13.93	1.79	0.49	10.60	11.40	13.70	17.20
Sitting popliteal Height	42.67	2.66	-0.02	20.00	38.44	42.80	47.40
Sitting elbow Height	17.25	2.20	0.56	14.00	13.94	17.00	21.30
Elbow fingertip length	49.12	4.20	-0.73	34.80	42.20	49.20	55.70
Buttock-popliteal depth sitting	47.83	3.98	0.08	31.30	41.04	48.10	54.00
Buttock-knee depth sitting	59.88	3.34	-0.34	23.80	53.70	60.10	64.53
Forward grip reach	85.42	6.68	0.07	28.60	75.60	85.20	95.80
Foot Length	26.08	1.38	-0.34	9.50	23.74	26.20	28.17
Buttock-Leg Length	105.17	5.08	0.71	41.70	98.00	104.65	113.2
Shoulder breadth (bideloid)	44.36	2.80	0.62	20.60	40.10	44.10	49.20
Elbow-to-elbow length	46.51	4.11	0.40	30.80	40.20	46.10	53.80
Hip Breadth Sitting	35.66	2.52	0.51	23.90	31.90	35.60	39.30
Foot Breadth	9.96	0.55	0.91	5.10	9.20	9.90	10.80

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Table 3: Comparison of relevant anthropometric variables of male adults in Germany, Japan, China, Britain and Russia,

Anthropometric Measurement	Germany (East)		Japan		China (Taiwan)		Britain		Russia	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Stature	171.5	6.6	168.8	5.5	170.5	5.9	174.0	7.0	173.6	6.1
Sitting Height Erect	90.3	3.4	91.0	3.0	91.0	3.0	91.0	3.6	90.9	3.2
Sitting eye Height	77.5	3.4	79.0	2.9	79.1	2.9	79.0	3.5	79.1	3.2
Sitting shoulder Height	60.1	3.1	59.1	2.6	60.2	2.6	59.5	3.2	Nda	Nda
Sitting elbow Height	24.4	2.9	25.4	2.3	26.4	2.4	24.5	3.1	24.1	2.6
Thigh Clearance Height	15.1	1.5	15.6	1.2	nda	Nda	16.0	1.5	14.6	1.6
Sitting knee Height	53.1	2.7	50.9	2.2	52.1	2.9	54.5	3.2	55.0	2.5
Sitting popliteal Height	45.2	2.6	40.2	1.9	41.1	1.9	44.0	2.9	45.0	2.2
Shoulder Elbow Length	Nda	nda	33.7	1.8	33.8	1.9	36.5	2.0	nda	Nda
Elbow fingertip length	46.5	2.0	44.8	1.8	42.7	2.7	47.5	2.1	45.3	Nda
Forward grip reach	76.3	3.7	Nda	nda	71.0	3.6	78.0	3.4	60.1	3.6
Buttock-knee depth sitting	60.3	2.7	56.7	2.3	55.8	3.1	59.5	3.1	Nda	3.1
Buttock-popliteal depth sitting	48.6	2.5	Nda	nda	nda	Nda	49.5	3.2	45.0	Nda
Shoulder breadth (bideltoid)	47.1	2.4	Nda	nda	46.0	2.3	46.5	2.8	34.8	2.2
Hip breadth sitting	36.9	2.2	34.9	1.9	36.0	2.7	36.0	2.9	27.0	2.4
Foot length	26.4	1.3	25.1	1.1	Nda	Nda	26.5	1.4	28.0	1.2
Foot breadth	10.2	6.0	10.4	0.5	Nda	Nda	9.5	0.6	Nda	5.0

NDA: no data available

Source for Anthropometric Measurements for Male Adult in Chinese. Japan and Britain Marras and Karwowsk (2006).

Table 4: Application of Anthropometric Data in Design of Taxicab In-vehicle

Anthropometric Parameters	Applications in Vehicle Seat Design
Sitting height erect	Backrest seat plane height, and headrest height
Sitting shoulder height	Backrest seat height
Sitting elbow height	Armrest height, Armrest depth Armrest clearance
Sitting eye height	Backrest seat plane height and headrest height
Shoulder elbow length	Backrest height
Buttock-knee depth sitting	Seat depth
Sitting knee height	Distance from edge of seat to application of force point
Elbow fingertip length	Armrest surface length
Buttock-popliteal depth sitting	Seat depth
Shoulder breadth (Bideltoid)	Backrest width(Thoracic level)
Sitting popliteal height	Distance from edge of seat to application of force point
Hip breadth sitting	Backrest width(Lumber level)

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