Representative Nigerian Anthropometric Data for Automotive Applications

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ABSTRACT

An automotive policy is been pursued by the government of Nigeria which is aimed at curtailing the dominance of imported vehicles in the Nigerian automobile market. The policy is designed to cater for the automobile demands of the Nigerian population. Since these vehicles would be produced for the Nigerian population and used by them over a period of time, it is imperative that the vehicles are made for the ideal fit of the target population of the end users. The automotive design practice starts with a deliberation about the proportion and category of the car and how many people that the car would accommodate. The designers take into account the proportions of the occupants and drivers and their position in the vehicle environment to ensure that the appropriate number of users can be accommodated. This study provides a representative anthropometric data of Nigerians as a guide for the ergonomic design of automobiles intended for the Nigerian market. A controlled selection of subjects reflecting the ethnic, age, gender and anthropometric spread of the Nigerian population was conducted. A total of 863 subjects comprising 460 males and 403 females participated in the exercise and 60 body dimensions applicable in automotive design, digital human modelling and vehicle occupant packaging were obtained using standard anthropometric instruments. The subjects were selected from the four major ethnic groups in Nigeria as well as 23 other ethnic groups reflecting the ethnic distribution of the Nigerian population. The data obtained were statistically analysed using Microsoft Excel and SPSS to obtain the necessary percentile values as well as the means and standard deviations. The results obtained were used to propose some recommendations for occupant packaging dimensions for use in the design of

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vehicles intended for the Nigerian market so as to ensure the safety, comfort and security of the users.

Keywords: *Anthropometry, Design, Ergonomics, Occupant Packaging, Digital Human Modelling*

Introduction

The Nigerian government is pursuing an automotive policy that is aimed at reducing the overdependence of the Nigerian population on imported vehicles. The policy is aimed at meeting the automobile demands of the country which is about 500,000 vehicles annually at present and is expected to surpass one million vehicles in the near future all things being equal[1], [2].

In designing an automobile, the foremost stage involves establishing the customer population and their anthropometric attributes. Several key proportions of the car are established from the anthropometric dimensions of the customer population. The task of the occupant package engineer is to ensure that the greatest proportion of the customer population are fitted in executing all functions concerned while using the vehicle either as a driver/passenger or when performing maintenance on the vehicle.[3]–[10]

The practice starts with outlining the car to be designed. It is very essential to specify the targeted user population at the outset, i.e. those who would purchase and use the prospective car. Their attributes, abilities, requirements and wishes should be appreciated. The human factors engineers together with the designers and market researchers should make all attempts to collect data regarding the targeted population. Applicable anthropometric proportions are captured to generate a catalogue for assessment of several vehicle proportions from a representative sample of the user population from the anticipated market.[3], [4], [8]–[10]

The word ergonomics, when employed in a vehicle design perspective, can be easily described as the system of designing for the user. By this, we mean employing an understanding of human attributes and abilities to the design of a car. Collecting information regarding humans consists of a multifaceted technique with importance on psychology, anthropometry, statistics, biomechanics, etc. The automotive human factors engineer should guarantee that the complete variety of passengers and drivers in the targeted market are examined and accommodated for in relation to safety, comfort and ease of use. It is highly significant to observe here that the principal idea of the human factors discipline is to fit the artefact to the user and not the user to the artefact. Therefore, in the automotive context, the occupants are not expected to adjust to a substandard and shoddy design but rather the car should be designed to accommodate their requirements and abilities. The initial phase of the vehicle design process is to fix the drivers

position and subsequently design the early vehicle outline around him/her. Several SAE guidelines are applied in so doing. It is imperative to remark here that the SAE specifications might be better appropriate to the US population, while cars designed for other populations would demand comprehensive information pertaining to those populations to enhance the occupant package accordingly.[3], [5], [8]

The occupants are undoubtedly the most important component in every car package, and their postures and positions determine the entire design of the vehicle architecture. The automobile bodies are scaled around the constant manikin geometries representing the customers. The occupants one way or the other influence all facets of automobile design and it cannot be overstressed how significant the passenger and driver packaging is to the entire architecture. The saying that vehicles should be designed from the inside out actually refers to the occupant packaging rather than the interior systems. The key goal is to set up the passengers and driver to be safe and comfortable, by building a shelter around them and setting up the rest of the car package using vital orientation figures within their geometries.[4]

Designers are capable of designing secure and more ideal vehicle designs quicker and for a smaller price by utilising the digital human modelling softwares. 28 of the SAE approved systems for several car design features and driver aspects are executed by the SAE packaging standard tools. Using this tool, ergonomists can build a figure in a DHM software to determine areas where physical characteristics like the fingers, head clearance and eyes would be positioned for 95 to 99 percent of the people. It is possible to collectively assess a concept automotive design for human suitability and efficiency using DHM applications. A female or male form of whichever preferred proportions can be built because the manikins are extremely extensible and the occupant packaging component will spontaneously place the model into the vehicle according to authenticated study models.[5], [7], [9], [11], [12]

Methodology

This anthropometric survey aims to obtain human body dimensions from the Nigerian population sample and evaluate it by means of descriptive statistical techniques. This was done in order to comprehend the human body differences and extents existing in the population sample. The anthropometric survey phase comprises 3 stages including preparations for fieldwork, establishing the sample size and data collection. The format presented by Zakaria and Gupta [13] was adopted for this study.

The fieldwork preparation stage involves establishing the guideline for the anthropometric study, preparing the measurers & recorders and obtaining approval from the relevant authorities. This was done by requesting official authorization from the appropriate authorities in all the places where

the anthropometric survey was conducted. The 60 body measurements (as shown in figure 1) applicable in automotive design, vehicle occupant packaging, vehicle seat design and digital human modelling were captured from the subjects based on ISO 7250-1 standard [14]. This anthropometric survey was conducted in three states in Nigeria namely; Gombe, Bauchi and Plateau states. The survey was carried out from March to May 2017.

The sample size for our survey was determined based on ISO 15535 standard [15]. Based on the general practice of accommodating the users from the 5^{th} to the 95^{th} percentile, our sample size was established to be adequate for the scope of our study. To guarantee that the data of 5^{th} and 95^{th} percentile projects the actual population 5^{th} and 95^{th} percentiles with 95% assurance and a proportion of relative certainty, the least amount of subjects sampled randomly N is given by:

$$N = \left(\frac{1.96 \times CV}{a}\right)^2 \times 1.534^2 \quad (1)$$

where 1.96 is the critical value from a standard normal distribution for a 95% confidence interval; CV is the coefficient of variation

$$CV = \frac{SD}{\bar{x}} \times 100 \quad (2)$$

where SD is the standard deviation of the population for the body measurement under study and $\bar{x}$ is the mean; a is the proportion of relative certainty wanted. Actually, the real standard deviation and mean of the population are not known, they are therefore established by means of the outcomes of a preceding survey on a corresponding population. However, since this is the first attempt at collecting a representative anthropometric data for the Nigerian population, such previous studies are not available. Hence, the values given by Pheasant [16] were used for this study.

Since every body measurement in the survey has a separate coefficient of variation, each will need a marginally distinct least sample size to guarantee that its percentile value will project the population 5^{th} and 95^{th} percentiles with a definite proportion accuracy and 95% certainty. The least sample size for our survey was established by means of the body measurement with the biggest CV, of all the 60 body dimensions for our study, weight has the largest CV (10-21). This was done so as to have an adequate sample size for a definite proportion of relative certainty and 95% assurance and be adequate enough for all the remaining body measurements.

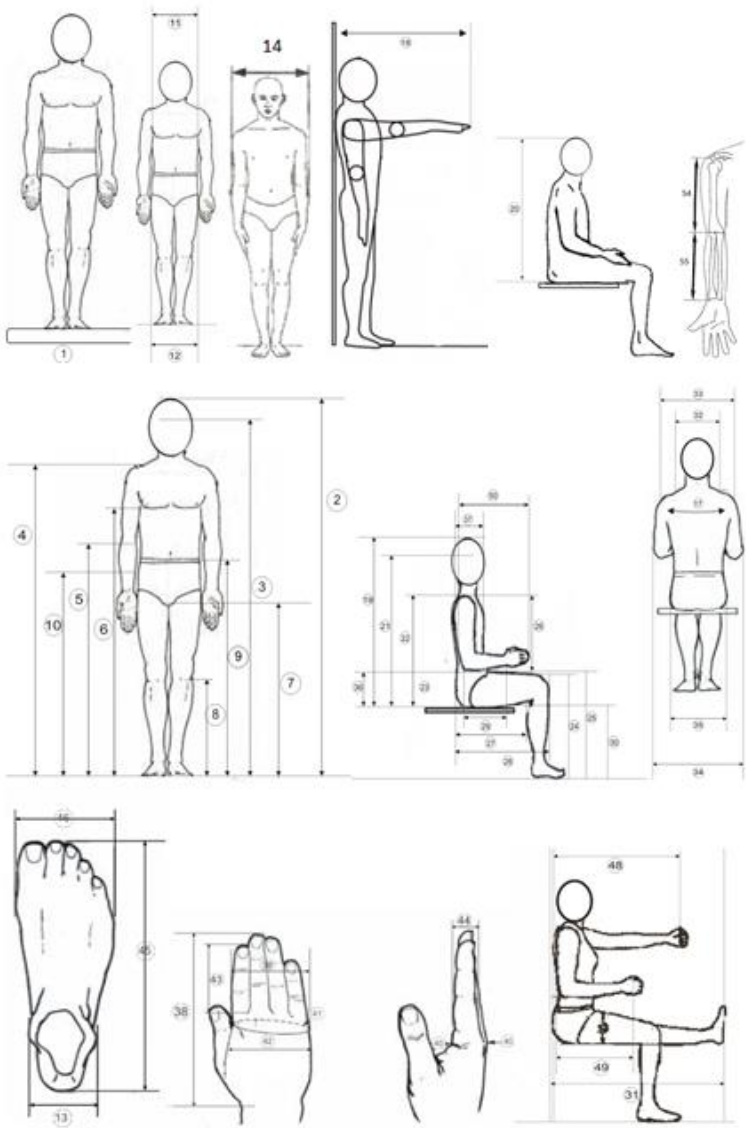

Figure 1: Human Body Dimensions for the Survey.

Based on the foregoing, the least sample size for our study for 95% assurance and 2% relative certainty was calculated as follows:

$$N = \left(\frac{1.96 \times 19.542}{2}\right)^2 \times 1.534^2 = 863.0 = 863\ subjects$$

Measuring 863 subjects will guarantee that the preferred degrees of assurance and relative certainty for all the dimensions are accomplished. This is also taking into consideration the time and budget at our disposal as anthropometric surveys require a lot of time and resources to conduct.

The proportional stratified random sampling method was adopted for this survey, through which the population was split into several strata (subgroup). After the strata were established, a simple random sample was captured from every stratum separately according to proportion. The accuracy of anthropometric data depends on the sample size. Hence, a big sample size was used based on the available time and resources. Our survey has three demographic variables namely: gender, ethnicity and age. The proportionate sampling was done in such a way that the sample size in each strata depicts the gender, age and ethnic spread of the actual population.

Results and Discussion

This section presents the statistical analysis of the data obtained. The descriptive (univariate) analysis is mostly used as the technique for statistical analysis of anthropometric data.The data collected were statistically analysed using Microsoft Excel 2010 and the statistical analysis software package IBM SPSS Statistics 24 to obtain the 1st, 5th, 50th, 95th and 99th percentile values as well as the means and standard deviations. All the measurements given are in millimetres (mm) except weight which is given in kilogramme (kg). Table 1 presents the descriptive statistical analysis results for the 460 male subjects while Table 2 presents results for the 403 female subjects, Table 3 presents the combined results for both genders.

The results show that the mean weight and stature of the males (68±12kg and 1730±88mm) are significantly higher than that of the females (64±13kg and 1664±511mm). The percentage and mean value difference of weight and stature between the male and female Nigerians are 5.9% for weight and 3.8% for stature, 4kg for weight and 66mm for stature.

The standard deviations of the anthropometric dimensions range from 8mm to 757mm for males and 2mm to 511mm for females. The biggest Standard deviation of eye height for the male subjects (757mm) shows that most of the male subjects deviate from the mean of eye height dimension while the smallest Standard deviation of hand breadth for the male subjects (8mm) indicates most of the male subjects are close to its mean. On the other hand, the highest standard deviation of stature for the female subjects (511mm) indicates that majority of the female subjects deviate from the mean of stature while the lowest standard deviation for index finger breadth

for the female subjects (2mm) shows that most of the female subjects are around the mean.

Table 1: Anthropometric Data of 460 Male Subjects (mm)

Measurement Name	1st%	5th%	50th%	95th%	99th%	SD	Mean
Weight	45	50	68	90	104	12	68
Stature	1500	1599	1730	1860	1904	88	1730
Eye Height	1400	1470	1610	1750	1813	757	1646
Shoulder (Acromial) Height	1249	1310	1445	1590	1682	94	1445
Elbow Height	968	1000	1095	1235	1321	97	1098
Chest Height	1087	1180	1300	1430	1467	107	1296
Crotch Height	596	635	790	971	1015	106	796
Knee Height	400	430	510	590	651	56	512
Waist Height (Omphalion)	770	905	1008	1120	1155	71	1008
Hip (Trochanteric) Height	670	710	868	1010	1046	97	862
Chest Breadth, Standing	211	230	270	430	539	67	293
Hip Breadth, Standing	213	256	304	410	474	51	312
Bimalleolar Breadth	51	58	69	80	94	29	71
Maximum Body Breadth	332	375	440	610	672	73	455
Buttock Circumference	760	810	940	1200	1412	122	964
Sleeve Outseam	407	470	580	650	685	56	572
Interscye Distance	198	260	365	427	603	79	358
Functional (Thumb-tip) Reach	550	715	820	950	1010	83	824
Sitting Height Erect	660	780	873	970	994	74	869
Sitting Height Normal	636	745	824	940	960	63	828
Eye Height Sitting	584	665	760	870	919	66	763
Shoulder Height Sitting	435	510	590	703	783	59	589
Elbow Height, Sitting	130	145	195	246	434	53	197
Knee Height, Sitting	430	470	553	606	660	46	550
Thigh Height Sitting	454	510	600	673	708	48	599
Shoulder - elbow Length	267	302	360	410	472	138	366
Buttock - Popliteal Length	344	434	500	580	610	48	503
Buttock - knee Length	432	530	605	690	704	52	607
Elbow - wrist Length	225	261	310	345	399	31	311
Popliteal Height	330	381	462	510	565	52	458
Functional Leg Length	730	950	1065	1200	1270	92	1065
Shoulder (Biacromial) Breadth	231	260	315	400	491	186	330
Shoulder (Bideltoid) Breadth	294	366	428	524	570	55	434
Elbow - to - elbow Breadth	320	364	425	583	600	58	437
Hip Breadth Sitting	245	282	330	449	474	48	340
Thigh Clearance	104	112	160	207	244	30	161
Abdominal Depth, Sitting	154	170	213	300	370	41	220
Hand Length	170	179	196	220	240	15	197
Hand Breadth	72	77	87	99	105	8	88
Hand Thickness	18	20	27	35	37	17	28
Hand Circumference	188	198	220	256	269	28	222
Hand Breadth at Metacarpals	62	65	77	89	96	35	79
Index Finger Length	62	65	75	84	87	9	75
Index Finger Breadth	15	16	22	26	30	14	22
Foot Length	203	220	263	293	305	22	262
Foot Breadth	74	80	94	113	117	25	96
Head Circumference	457	501	570	607	641	33	566
Forward Grip Reach	500	680	780	905	964	77	780
Elbow - grip Length	253	330	400	480	514	46	398
Forearm - Fingertip Length	364	430	510	580	647	55	508
Chest Circumference	711	780	900	1120	1540	125	924
Waist Circumference	536	660	840	1000	1150	106	838
Thigh Circumference	390	430	535	660	785	72	540
Acromion - radiale Length	237	265	320	380	410	40	324
Radiale - stylion Length	202	227	280	320	380	59	282
Axilla Height	1061	1160	1289	1400	1450	75	1285
Illiocristale Height	835	940	1075	1170	1214	67	1068
Tenth Rib Height	910	1010	1145	1300	1362	120	1149
Waist Breadth	209	234	286	380	440	43	292
Bispinous Breadth	156	180	221	301	385	36	230

Table 2: Anthropometric Data of 403 Female Subjects (mm)

Measurement Name	1st%	5th%	50th%	95th%	99th%	SD	Mean
Weight	42	46	61	89	103	13	64
Stature	1450	1516	1630	1800	1894	511	1664
Eye Height	1320	1396	1510	1691	1762	106	1525
Shoulder (Acromial) Height	1161	1242	1360	1523	1615	87	1371
Elbow Height	792	920	1044	1210	1402	103	1059
Chest Height	1005	1086	1205	1400	1440	88	1218
Crotch Height	590	630	740	967	1040	112	766
Knee Height	331	400	480	574	680	58	481
Waist Height (Omphalion)	754	803	950	1085	1125	85	951
Hip (Trochanteric) Height	655	690	800	987	1010	97	813
Chest Breadth, Standing	218	225	271	387	443	57	282
Hip Breadth, Standing	245	262	319	434	573	62	333
Bimalleolar Breadth	50	55	64	76	96	52	68
Maximum Body Breadth	310	363	430	606	704	79	444
Buttock Circumference	800	851	990	1214	1398	123	1008
Sleeve Outseam	410	475	550	619	650	46	546
Interscye Distance	230	265	358	429	489	50	351
Functional (Thumb - tip) Reach	550	662	770	919	1000	90	775
Sitting Height Erect	690	731	825	930	968	55	829
Sitting Height Normal	637	695	785	900	930	59	789
Eye Height Sitting	595	615	720	820	860	356	739
Shoulder Height Sitting	394	480	560	670	700	62	564
Elbow Height, Sitting	125	149	200	246	519	61	203
Knee Height, Sitting	412	440	524	590	649	46	523
Thigh Height Sitting	402	487	580	670	710	249	590
Shoulder - elbow Length	260	290	340	385	469	36	338
Buttock - Popliteal Length	330	394	476	550	580	53	475
Buttock - knee Length	400	490	575	654	699	308	586
Elbow - wrist Length	200	240	295	351	450	37	295
Popliteal Height	320	340	440	510	909	210	449
Functional Leg Length	720	874	990	1105	1200	101	991
Shoulder (Biacromial) Breadth	222	244	296	430	504	61	312
Shoulder (Bideltoid) Breadth	325	346	407	559	650	64	422
Elbow - to - elbow Breadth	316	340	420	584	650	67	431
Hip Breadth Sitting	270	295	360	475	558	60	370
Thigh Clearance	108	121	180	239	280	35	179
Abdominal Depth, Sitting	153	170	225	340	395	56	238
Hand Length	150	165	186	210	224	16	187
Hand Breadth	32	69	81	92	95	9	81
Hand Thickness	17	19	25	31	36	18	27
Hand Circumference	68	180	205	232	260	48	206
Hand Breadth at Metacarpals	57	61	71	82	86	6	71
Index Finger Length	54	62	69	79	84	7	70
Index Finger Breadth	13	14	19	24	27	2	21
Foot Length	190	215	243	279	295	23	243
Foot Breadth	65	72	85	105	516	53	91
Head Circumference	484	505	570	619	690	45	568
Forward Grip Reach	385	622	725	880	950	89	732
Elbow - grip Length	251	300	375	450	480	48	376
Forearm - Fingertip Length	341	400	475	550	639	59	478
Chest Circumference	720	770	915	1148	1300	126	933
Waist Circumference	560	672	870	1084	1200	122	867
Thigh Circumference	317	432	580	741	998	106	583
Acromion - radiale Length	240	260	300	360	400	57	308
Radiale - stylion Length	200	216	260	320	384	72	267
Axilla Height	399	1096	1210	1397	1450	128	1214
Illiocristale Height	790	905	1005	1129	1210	91	1008
Tenth Rib Height	729	960	1065	1269	1330	126	1078
Waist Breadth	210	240	294	400	791	82	306
Bispinous Breadth	157	187	255	301	359	57	233

Nigerian males have higher mean values than female Nigerians in 48 out of the 60 body dimensions measured. The mean values of the 48 body dimensions for the female subjects lie within 90% - 99% of the corresponding body dimensions for the male subjects with values ranging

from 1mm to 121mm. The biggest difference is found in eye height with a 121mm difference between the male mean value of 1646mm and the female mean value of 1525mm.

Table 3: Combined Anthropometric Data of 863 Subjects (mm)

Measurement Name	1st%	5th%	50th%	95th%	99th%	SD	Mean
Weight	43	48	65	89	103	13	66
Stature	1470	1540	1690	1840	1900	357	1699
Eye Height	1353	1412	1570	1740	1800	561	1590
Shoulder (Acromial) Height	1200	1270	1406	1580	1643	98	1410
Elbow Height	845	965	1080	1214	1329	102	1080
Chest Height	1023	1107	1260	1418	1450	106	1259
Crotch Height	593	635	775	968	1027	109	782
Knee Height	370	412	496	585	651	59	498
Waist Height (Omphalion)	757	845	985	1110	1140	83	981
Hip (Trochanteric) Height	670	695	835	1000	1036	100	839
Chest Breadth, Standing	215	230	270	401	538	63	288
Hip Breadth, Standing	238	260	310	420	502	57	322
Bimalleolar Breadth	50	56	67	79	93	42	70
Maximum Body Breadth	330	367	435	606	692	76	452
Buttock Circumference	763	822	960	1205	1400	125	985
Sleeve Outseam	410	474	560	640	674	53	560
Interscye Distance	223	262	360	427	500	67	355
Functional (Thumb - tip) Reach	550	685	800	940	1010	89	801
Sitting Height Erect	680	741	850	950	990	69	851
Sitting Height Normal	637	700	805	921	958	64	810
Eye Height Sitting	595	626	745	860	903	248	752
Shoulder Height Sitting	423	489	572	680	738	62	577
Elbow Height, Sitting	130	145	196	246	507	57	200
Knee Height, Sitting	429	452	540	600	654	48	537
Thigh Height Sitting	454	494	590	670	707	174	595
Shoulder - elbow Length	262	296	350	400	466	104	353
Buttock - Popliteal Length	333	400	490	570	600	52	480
Buttock - knee Length	410	494	592	680	703	214	597
Elbow - wrist Length	210	250	300	350	427	35	303
Popliteal Height	330	360	450	510	610	149	454
Functional Leg Length	720	897	1035	1180	1233	103	1031
Shoulder (Biacromial) Breadth	228	250	306	407	501	142	321
Shoulder (Bideltoid) Breadth	318	355	420	530	607	60	428
Elbow - to - elbow Breadth	319	355	421	583	613	63	434
Hip Breadth Sitting	257	288	343	459	507	56	354
Thigh Clearance	105	115	170	230	272	34	169
Abdominal Depth, Sitting	154	170	219	320	378	49	228
Hand Length	153	170	192	217	253	16	192
Hand Breadth	61	73	85	97	102	9	85
Hand Thickness	17	20	26	34	37	17	28
Hand Circumference	156	184	211	248	268	39	215
Hand Breadth at Metacarpals	60	63	74	87	94	26	75
Index Finger Length	58	63	72	82	87	8	72
Index Finger Breadth	14	15	21	25	30	18	22
Foot Length	200	216	254	290	302	24	253
Foot Breadth	67	75	89	110	157	41	94
Head Circumference	479	503	570	610	680	39	567
Forward Grip Reach	500	646	760	900	961	86	757
Elbow - grip Length	253	300	390	464	502	48	388
Forearm - Fingertip Length	364	403	492	570	640	59	494
Chest Circumference	720	778	900	1128	1336	125	929
Waist Circumference	553	663	850	1040	1150	115	851
Thigh Circumference	373	431	550	710	844	92	560
Acromion - radiale Length	239	260	310	370	404	49	316
Radiale - stylion Length	200	220	270	320	380	66	275
Axilla Height	984	1120	1260	1400	1450	109	1252
Illiocristale Height	810	915	1045	1160	1210	85	1040
Tenth Rib Height	855	970	1110	1290	1350	127	1116
Waist Breadth	211	236	290	395	472	65	299
Bispinous Breadth	157	186	224	301	369	47	231

The smallest difference is found in hand thickness and index finger breadth with just 1mm difference between the male and female mean values of 28mm and 27mm, 22mm and 21mm respectively. On the other hand, Nigerian females have higher mean values than male Nigerians in the remaining 12 body dimensions. The male mean values for these body dimensions are between 89.9% - 99.6% of the corresponding female body dimensions with values ranging between 2mm to 44mm. The biggest difference is found in buttock circumference with a 44mm difference between the female and male mean values of 1008mm and 964mm respectively. The smallest difference is found in head circumference with just 2mm difference between the female mean value of 568mm and the male mean value of 566mm.

The mean values for male and female Nigerians indicate that there is a significant difference between the two genders in some anthropometric dimensions while there is just a little difference in other dimensions.

Furthermore, the male mean values are higher than that of the combined gender in 46 out of the 60 body dimensions. The mean values of the 46 body dimensions for the combined gender lie within 95% - 99% of the corresponding male body dimensions with values ranging between 1mm to 56mm. The biggest difference is found in eye height with a difference of 56mm between the male and combined gender mean values of 1646mm and 1590mm respectively. The smallest difference is found in bimalleolar breadth with a difference of just 1mm between the male mean value of 71mm and the combined gender mean value of 70mm. Conversely, the combined gender has higher mean values than that of the male gender in 12 body dimensions. The male mean values for these body dimensions are between 95% - 99.8% of the corresponding dimensions for the combined gender with values ranging between 1mm to 21mm. The biggest difference is found in buttock circumference with a difference of 21mm between the combined gender mean value of 985 and the male mean value of 964mm. The smallest difference is found in bispinous breadth and head circumference with a difference of just 1mm between the combined gender and male mean values of 231mm and 230mm, 567mm and 566mm respectively. Both have exactly the same value in 2 body dimensions (hand thickness (28mm) and index finger breadth (22mm)).

The combined gender has higher mean values than that of the female gender in 48 out of the 60 body dimensions. The female mean values for these body dimensions lie within 95% - 99% of the corresponding mean values for the combined gender with values ranging between 1mm to 65mm. The highest difference is found in eye height with a difference of 65mm between the combined gender and female mean values of 1590mm and 1525mm respectively. The smallest difference is found in index finger breadth and hand thickness with a difference of just 1mm between the combined gender and female mean values of 22mm and 21mm, 28mm and

27mm respectively. On the contrary, the female gender has higher mean values than that of the combined gender in 12 body dimensions. The combined gender mean values for these body dimensions are between 94% - 99.8% of the corresponding female mean values with values ranging between 1mm to 23mm. The highest difference is found in thigh circumference and buttock circumference with a difference of 23mm between the female and combined gender mean values of 583mm and 560mm, 1008mm and 985mm respectively. The smallest difference is found in head circumference with a difference of just 1mm between the female and combined gender mean values of 568mm and 567mm respectively.

In automotive design, as in all other design applications in which human body measurements are applied, female and male design proportions are treated individually in order to maximise user accommodation. For instance, designing from the lowest 1^{st} or 5^{th}% value (male or female) to the biggest 95^{th} or 99^{th} percentile value (male or female) range ensures maximum user accommodation. Using anthropometric data that exclusively fulfil the maximum criteria of accuracy and representativeness is vital in developing standard design ranges. The population distribution for some anthropometric proportions is bi-modal by gender. This implies that the female and male means are distinct. Although distributions of the male and female overlap, there are substantial parts of the combined distributions which are absolutely male or absolutely female. Using the combined figures as design values can be acceptable in some particular situations, but female and male design values are commonly used individually in automotive and product/workspace design so as to guarantee that women and men are both evenly accommodated.[8], [17], [18]

Based on the foregoing, vehicle occupant packaging dimensions obtained from the combined gender values of the Nigerian population can be suitable for both genders for those body dimensions where the male and female values do not differ significantly with the combined gender values. On the other hand, for those male and female body dimensions like eye height, thigh height, buttock circumference, etc. that differ considerably from the combined gender values, individual male and female values should be used in establishing vehicle occupant packaging dimensions for the Nigerian population.

The mean of the anthropometric data obtained is compared with that of five other countries namely; Japan [16], [19], USA [3], [16], [20], Korea [17], [19], Germany [17] and France [16] as shown in Table 4. These countries are so chosen because the bulk of the automobiles imported into Nigeria come from Japan (Toyota, Honda, and Nissan), USA (Ford), Korea (Hyundai and Kia), Germany (Volkswagen, Opel, Mercedes-Benz, BMW and Audi) and France (Peugeot).[1]

From Table 4 below, it can be seen that Nigerian males have higher mean values than their Japanese counterparts in 25 out of 38 body

dimensions of which data is available. The Japanese male mean values of the 25 body dimensions lie within 82% - 99.5% of the corresponding Nigerian male mean values with values ranging from 3mm to 106mm. The biggest difference is found in eye height with a 106mm difference between the Nigerian and Japanese male mean values of 1646mm and 1540mm respectively. The smallest difference is found in hand breadth with just 3mm difference between the Nigerian male mean value of 88mm and the Japanese male mean value of 85mm. Contrarily, Japanese males have higher mean values than their Nigerian counterparts in 11 body dimensions. The Nigerian male mean values for the 11 body dimensions are between 76% - 99.8% of the corresponding Japanese male mean values with values ranging between 1mm to 63mm. The biggest difference is found in elbow height sitting with a 63mm difference between the Japanese male mean value of 260mm and the Nigerian male mean value of 197mm. The smallest difference is found in shoulder height sitting with just 1mm difference between the Japanese and Nigerian male mean values of 590mm and 589mm respectively. Both have exactly the same value in 2 body dimensions (abdominal depth sitting (220mm) and hand breadth at metacarpals (79mm)).

Table 4: Comparison of Mean Nigerian Anthropometric Data with that of 5 Key Automotive Manufacturing Countries

	Nigeria		Japan		USA		Korea		Germany		France	
Measurement Name	male	female	male	female	male	female	male	female	male	female	male	female
Weight	68	64	60	51	79	62	66	54	75	NA	73	58
Stature	1730	1664	1655	1530	1763	1622	1707	1588	1767	NA	1715	1600
Eye Height	1646	1525	1540	1425	1634	1516	1588	1480	1633	1518	1560	1500
Shoulder (Acromial) Height	1445	1371	1340	1145	1442	1334	1383	1289	1472	NA	1405	1305
Elbow Height	1098	1059	1035	955	1072	998	1036	961	1110	NA	1080	1000
Chest Height	1296	1218	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Crotch Height	796	766	748	704	846	790	757	718	843	NA	NA	NA
Knee Height	512	481	490	450	550	505	515	470	524	NA	530	495
Waist Height (Omphalion)	1008	951	NA	NA	1060	981	972	NA	1067	NA	NA	NA
Hip (Trochanteric) Height	862	813	NA	NA	915	835	842	791	919	NA	895	820
Chest Breadth, Standing	293	282	312	281	322	280	290	270	310	NA	NA	NA
Hip Breadth, Standing	312	333	339	333	360	375	322	319	363	370	340	350
Bimalleolar Breadth	71	68	NA	NA	73	64	NA	NA	77	NA	NA	NA
Maximum Body Breadth	455	444	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Buttock Circumference	964	1008	NA	NA	986	967	875	NA	966	NA	NA	NA
Sleeve Outseam	572	546	NA	NA	601	545	NA	NA	NA	NA	NA	NA
Interscye Distance	358	351	NA	NA	408	377	375	NA	438	NA	NA	NA
Functional (Thumbtip) Reach	824	775	820	751	800	731	821	760	800	NA	850	780
Sitting Height Erect	869	829	900	845	915	860	921	866	909	NA	910	860
Sitting Height Normal	828	789	NA	NA	866	820	NA	NA	NA	NA	NA	NA
Eye Height Sitting	763	739	785	735	792	739	809	758	798	NA	795	750
Shoulder Height Sitting	589	564	590	555	598	555	583	550	620	NA	620	580
Elbow Height, Sitting	197	203	260	250	232	220	265	263	289	NA	240	230
Knee Height, Sitting	550	523	NA	NA	559	515	508	470	540	NA	NA	NA
Thigh Height Sitting	599	590	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Shoulder - elbow Length	366	338	330	300	265	335	336	310	369	NA	360	330
Buttock - Popliteal Length	503	475	470	450	500	490	470	449	488	479	480	460
Buttock - knee Length	607	586	550	530	600	575	553	528	601	593	595	565
Elbow - wrist Length	311	295	274	240	NA	NA	NA	253	284	NA	NA	NA
Popliteal Height	458	449	400	360	434	389	410	384	434	NA	425	390
Functional Leg Length	1065	991	NA	NA	1081	1008	NA	NA	NA	NA	NA	NA
Shoulder(Biacromial)Breadth	330	312	380	340	400	360	391	352	374	NA	395	355
Shoulder (Bideltoid) Breadth	434	422	440	395	470	400	451	406	457	NA	470	425
Elbow - to - elbow Breadth	437	431	459	407	546	468	433	403	451	NA	NA	NA
Hip Breadth Sitting	340	370	305	305	367	384	325	330	392	NA	370	380
Thigh Clearance	161	179	135	130	160	155	152	137	199	NA	180	165
Abdominal Depth, Sitting	220	238	220	205	275	260	237	225	220	NA	270	255
Hand Length	197	187	180	165	194	180	189	175	189	NA	185	175
Hand Breadth	88	81	85	75	90	79	85	80	86	NA	85	75
Hand Thickness	28	27	NA	NA	33	28	NA	NA	29	NA	NA	NA
Hand Circumference	222	206	NA	NA	214	185	206	NA	215	NA	NA	NA
Hand Breadth at Metacarpals	79	71	79	77	90	77	83	73	NA	NA	NA	NA
Index Finger Length	75	70	NA	NA	NA	NA	74	69	87	74	NA	NA
Index Finger Breadth	22	21	18	16	NA	NA	18	17	20	18	NA	NA
Foot Length	262	243	245	225	270	244	245	225	261	NA	260	235
Foot Breadth	96	91	105	95	101	90	95	93	100	92	95	90
Head Circumference	566	568	555	545	568	545	561	542	572	NA	570	550
Forward Grip Reach	780	732	690	620	785	710	701	660	750	688	770	700
Elbow - grip Length	398	376	345	320	359	328	331	301	358	323	355	325
Forearm - Fingertip Length	508	478	440	400	484	443	460	419	475	433	470	425
Chest Circumference	924	933	913	847	993	906	903	884	951	943	NA	NA
Waist Circumference	838	867	814	791	836	718	740	740	841	NA	NA	NA
Thigh Circumference	540	583	552	537	600	579	490	552	556	578	NA	NA
Acromion radiale Length	324	308	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Radiale stylion Length	282	267	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Axilla Height	1285	1214	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Illiocristale Height	1068	1008	NA	NA	NA	NA	NA	NA	1058	NA	NA	NA
Tenth Rib Height	1149	1078	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Waist Breadth	292	306	NA	NA	NA	NA	NA	NA	282	NA	NA	NA
Bisgnious Breadth	230	233	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

On the other hand, Nigerian females have higher mean values than their Japanese counterparts in 32 out of 38 body dimensions of which data is

available. The Japanese female mean values for the 32 body dimensions lie between 73% - 99.6% of the corresponding Nigerian female mean values with values ranging from 1mm to 226mm. The biggest difference is found in shoulder acromial height with a 226mm difference between the Nigerian and Japanese female mean values of 1371mm and 1145mm respectively. The smallest difference is found in chest breadth standing with just 1mm difference between the Nigerian female mean value of 282mm and the Japanese female mean value of 281mm. Conversely, Japanese females have higher mean values than their Nigerian counterparts in 5 body dimensions. The Nigerian female mean values in the 5 body dimensions are between 81% - 98% of the corresponding Japanese female mean values with values ranging between 4mm to 47mm. The biggest difference is found in elbow height sitting with a 47mm difference between the Japanese and Nigerian female mean values of 250mm and 203mm respectively. The smallest difference is found in foot breadth with just 4mm difference between the Japanese female mean value of 95mm and the Nigerian female mean value of 91mm. Both have exactly the same value in 1 body dimension (hip breadth standing (333mm)).

American males have higher mean values than their Nigerian counterparts in 33 out of 47 body dimensions of which data is available. The Nigerian male mean values for the 33 body dimensions lie within 80% - 99.6% of the corresponding American male mean values with values ranging from 2mm to 109mm. The biggest difference is found in elbow to elbow breadth with a 109mm difference between the American male mean value of 546mm and the Nigerian male mean value of 437mm. The smallest difference is found in bimalleolar breadth, hand breadth and head circumference with just 2mm difference between the American and Nigerian male mean values of 73mm and 71mm, 90mm and 88mm, 568mm and 566mm respectively. Conversely, Nigerian males have higher mean values than their American counterparts in 14 body dimensions. The American male mean values for the 14 body dimensions are between 72% - 99.8% of the corresponding Nigerian male mean values with values ranging from 1mm to 101mm. The biggest difference is found in shoulder to elbow length with a 101mm difference between the Nigerian and American male mean values of 366mm and 265mm respectively. The smallest difference is found in thigh clearance with just 1mm difference between the Nigerian male mean value of 161mm and the American male mean value of 160mm.

On the other hand, Nigerian females have higher mean values than their American counterparts in 29 out of 47 body dimensions of which data is available. The American female mean values for the 29 body dimensions lie between 83% - 99.8% of the corresponding Nigerian female mean values with values ranging from 1mm to 149mm. The biggest difference is found in waist circumference with a 149mm difference between the Nigerian and American female mean values of 867mm and 718mm respectively. The

smallest difference is found in foot breadth and sleeve outseam with just 1mm difference between the Nigerian and American female mean values of 91mm and 90mm, 546mm and 545mm respectively. Equally, American females have higher mean values than their Nigerian counterparts in 17 body dimensions. The Nigerian female mean values for the 17 body dimensions are within 87% - 99.6% of the corresponding American female mean values with values ranging between 1mm to 48mm. The biggest difference is found in shoulder biacromial breadth with a 48mm difference between the American female mean value of 360mm and the Nigerian female mean value of 312mm. The smallest difference is found in hand thickness and foot length with a difference of just 1mm between the American and Nigerian female mean values of 28mm and 27mm, 244mm and 243mm respectively. Both have exactly the same value in 1 body dimension (eye height sitting (739mm)).

Nigerian males have higher mean values than their Korean counterparts in 33 out of 43 body dimensions of which data is available. The Korean male mean values for the 33 body dimensions are between 82% - 99.6% of the corresponding Nigerian male mean values with values ranging between 1mm to 98mm. The biggest difference is found in waist circumference with a 98mm difference between the Nigerian male mean value of 838mm and the Korean male mean value of 740mm. The smallest difference is found in index finger length and foot breadth with just 1mm difference between the Nigerian and Korean male mean values of 75mm and 74mm, 96mm and 95mm respectively. Contrarily, Korean males have higher mean values than their Nigerian counterparts in 10 body dimensions. The Nigerian male mean values for the 10 body dimensions lie within 74% - 99% of the corresponding Korean male mean values with values ranging between 3mm to 68mm. The biggest difference is found in elbow height sitting with a 68mm difference between the Korean and Nigerian male mean values of 265mm and 197mm respectively. The smallest difference is found in knee height with just 3mm difference between the Korean male mean value of 515mm and the Nigerian male mean value of 512mm.

On the other hand, Korean females have higher mean values than their Nigerian counterparts in 6 out of the 41 body dimensions of which data is available. The Nigerian female mean values for the 6 body dimensions are between 77% - 98% of the corresponding Korean female mean values with values ranging between 2mm to 60mm. The biggest difference is found in elbow height sitting with a 60mm difference between the Korean female mean value of 263mm and the Nigerian female mean value of 203mm. The smallest difference is found in hand breadth at metacarpals and foot breadth with just 2mm difference between the Korean and Nigerian female mean values of 73mm and 71mm, 93mm and 91mm respectively. On the contrary, Nigerian females have higher mean values than their Korean counterparts in 35 body dimensions. The Korean female mean values for the 35 body

dimensions lie between 77% - 99% of the corresponding Nigerian female mean values with values ranging from 1mm to 127mm. The biggest difference is found in waist circumference with a 127mm difference between the Nigerian female mean value of 867mm and the Korean female mean value of 740mm. The smallest difference is found in hand breadth and index finger length with just 1mm difference between the Nigerian and Korean female mean values of 81mm and 80mm, 70mm and 69mm respectively.

German males have higher mean values than their Nigerian counterparts in 30 out of 48 body dimensions of which data is available. The Nigerian male mean values for the 30 body dimensions are within 68% - 99.8% of the corresponding German male mean values with values ranging between 1mm to 92mm. The biggest difference is found in elbow height sitting with a 92mm difference between the German male mean value of 289mm and the Nigerian male mean value of 197mm. The smallest difference is found in hand thickness with just 1mm difference between the German and Nigerian male mean values of 29mm and 28mm respectively. Conversely, Nigerian males have higher mean values than their German counterparts in 17 body dimensions. The German male mean values for the 17 body dimensions are between 90% - 99.6% of the corresponding Nigerian male mean values with values ranging between 1mm to 40mm. The biggest difference is found in elbow grip length with a 40mm difference between the Nigerian male mean value of 398mm and the German male mean value of 358mm. The smallest difference is found in foot length with just 1mm difference between the Nigerian and German male mean values of 262mm and 261mm respectively. Both have exactly the same value in 1 body dimension (abdominal depth sitting (220mm)).

On the other hand, Nigerian females have higher mean values than their German counterparts in 6 out of 12 body dimensions of which data is available. The German female mean values for the 6 body dimensions lie within 86% - 99.5% of the corresponding Nigerian female mean values with values ranging between 3mm to 53mm. The biggest difference is found in elbow grip length with a 53mm difference between the Nigerian female mean value of 376mm and the German female mean value of 323mm. The smallest difference is found in index finger breadth with just 3mm difference between the Nigerian and German female mean values of 21mm and 18mm respectively. Equally, German females have higher mean values than their Nigerian counterparts in 6 body dimensions as well. The Nigerian female mean values for the 6 body dimensions lie between 90% - 99% of the corresponding German female mean values with values ranging between 1mm to 37mm. The biggest difference is found in hip breadth standing with a 37mm difference between the German female mean value of 370mm and the Nigerian female mean value of 333mm. The smallest difference is found in foot breadth with just 1mm difference between the German and Nigerian female mean values of 92mm and 91mm respectively.

French males have higher mean values than their Nigerian counterparts in 15 out of 30 body dimensions of which data is available. The Nigerian male mean values for the 15 body dimensions are between 81% - 99% of the corresponding French male mean values with values ranging between 4mm to 65mm. The biggest difference is found in shoulder biacromial breadth with a 65mm difference between the French and Nigerian male mean values of 395mm and 330mm respectively. The smallest difference is found in head circumference with just 4mm difference between the French male mean value of 570mm and the Nigerian male mean value of 566mm. Contrarily, Nigerian males have higher mean values than their French counterparts in 15 body dimensions as well. The French male mean values for the 15 body dimensions lie within 89% - 99% of the corresponding Nigerian male mean values with values ranging between 1mm to 86mm. The biggest difference is found in eye height with an 86mm difference between the Nigerian and French male mean values of 1646mm and 1560mm respectively. The smallest difference is found in foot breadth with just 1mm difference between the Nigerian male mean value of 96mm and the French male mean value of 95mm.

On the other hand, French females have higher mean values than their Nigerian counterparts in 12 out of 30 body dimensions of which data is available. The Nigerian female mean values for the 12 body dimensions lie between 88% - 99% of the corresponding French female mean values with values ranging between 3mm to 43mm. The biggest difference is found in shoulder biacromial breadth with a 43mm difference between the French and Nigerian female mean values of 355mm and 312mm respectively. The smallest difference is found in shoulder bideltoid breadth with just 3mm difference between the French female mean value of 425mm and the Nigerian female mean value of 422mm. conversely, Nigerian females have higher mean values than their French counterparts in 18 body dimensions. The French female mean values for the 18 body dimensions are within 86% - 99% of the corresponding Nigerian female mean values with values ranging between 1mm to 66mm. The biggest difference is found in shoulder acromial height with a 66mm difference between the Nigerian and French female mean values of 1371mm and 1305mm respectively. The smallest difference is found in foot breadth with just 1mm difference between the Nigerian female mean value of 91mm and the French female mean value of 90mm.

The proposed occupant packaging dimensions for the Nigerian population are presented in Table 5 below.

Based on the proposed occupant packaging dimensions from Table 5, a comparison is made between the recommended dimensions for the Nigerian population and that of the five countries from table 4 as shown in Table 6 below.

From Table 5, it can be seen that Nigerians will require more knee clearance and forward legroom than their Japanese, American, Korean,

German and French counterparts as the 95th percentile Nigerian male buttock – knee length of 690mm is 90mm more than the Japanese value of 600mm, 40mm bigger than the American value of 650mm, 111mm greater than the Korean value of 579mm, 35mm higher than the German value of 655mm and 50mm larger than the French value of 640mm.

Nigerians will also need more knee clearance under the steering wheel and vertical legroom than their Japanese, Korean, German and French counterparts as the 95th percentile Nigerian male sitting knee height of 606mm is 46mm larger than the Japanese value of 560mm, 72mm more than Korean value of 534mm, 21mm greater than the German value of 585mm and 26mm higher than the French value of 580mm. The American value of 606mm is exactly the same as the Nigerian value which indicates the same requirement for knee clearance under the steering wheel.

Table 5: Vehicle Occupant Packaging Dimensions for the Nigerian Population

Anthropometric Measurement	Application in Vehicle Design	Dimension	Value
Buttock - Knee length	Knee Clearance	95th%male	690
Sitting Knee Height	Knee Clearance Under Steering Wheel	95th%male	606
Hand Breadth at Metacarpals	Hand Clearance for Door Handles	95th%male	89
Sitting Height	Space Above Drivers Head (Headroom)	99th%male	994
Elbow - Elbow Breadth	Interior Shoulder Width	95th%male	583
Hand Breadth	Handle Grasps	95th%male	99
Standing Wrist Height	Height of Outside Door Handle	95th%male	971
Hand Breadth	Length of Interior Grab and Exterior Door Handle	95th%male	99
Stature	Door Height/Elbow Clearance	95th%male	1860
Maximum Body Breadth	Door Width	95th%male	610
Thigh Height Sitting	Thigh Clearance (Steering Wheel to Seat Height)	95th%male	673
Functional Thumb tip Reach	Dashboard to Backrest Length	5th%female	662
Buttock - Knee length	Forward Legroom	95th%male	690
Foot Breadth	Pedals Spacing	95th%male	113
Foot Length	Foot Clearance	95th%male	293
Sitting Knee Height	Lateral Legroom	95th%female	590
Knee Height Sitting	Vertical Legroom	95th%male	606

Table 6: Comparison of Occupant Packaging Dimensions

Occupant Packaging Parameter	Nigeria	Japan	USA	Korea	Germany	France
Knee Clearance	690	600	650	579	655	640
Knee Clearance Under Steering Wheel	606	560	606	534	585	580
Hand Clearance for Door Handles	89	NA	98	90	NA	NA
Space Above Drivers Head (Headroom)	994	NA	996	996	984	NA
Interior Shoulder Width	583	NA	620	546	515	NA
Handle Grasps	99	95	100	91	93	95
Height of Outside Door Handle	971	NA	915	843	905	NA
Length of Interior Grab and Exterior Door Handles	99	95	100	91	93	95
Door Height/Elbow Clearance	1860	1750	1870	1805	1855	1830
Door Width	610	NA	NA	NA	NA	NA
Thigh Clearance (Steering Wheel to Seat Height)	673	NA	NA	NA	NA	NA
Dashboard to Backrest Length	662	750	677	NA	NA	730
Forward Legroom	690	600	650	579	655	640
Pedals Spacing	113	115	110	103	111	105

Nigerians will require almost the same hand clearance for door handles as their Korean counterparts as the 95th percentile Nigerian male hand breadth at metacarpals value of 89mm is just 1mm less than the Korean

value of 90mm. The Americans will require more clearance for the hands as their value of 98mm is 9mm more than the Nigerian value of 89mm.

Nigerians will need almost the same headroom as their American, Korean and German counterparts as the 99th percentile Nigerian male sitting height value of 994mm is just 2mm less than the American and Korean values of 996mm while it is 10mm greater than the German value of 984mm.

Nigerians will require more interior shoulder width than their Korean and German counterparts as the 95th percentile Nigerian male elbow – elbow breadth value of 583mm is 37mm greater than the Korean value of 546mm and 68mm more than the German value of 515mm. The American value of 620mm is 37mm higher than the Nigerian value.

Nigerians will need similar handles grasps and the length of the interior grab and exterior door handles as their Japanese, American, Korean, German and French counterparts as the 95th percentile Nigerian male hand breadth value of 99mm is just 1mm less than the American value of 100mm while it is 4mm more than the Japanese and French values of 95mm, 6mm greater than the German value of 93mm and 8mm larger than the Korean value of 91mm.

Nigerians will require a higher outside door handle height than their American, Korean and German counterparts as the 95th percentile Nigerian male crotch height of 971mm is 56mm more than the American value of 915mm, 128mm more than the Korean value of 843mm and 66mm higher than the German value of 905mm.

Nigerians will need more door width/elbow clearance than their Japanese, Korean and French counterparts as the 95th percentile Nigerian male stature value of 1860mm is 110mm greater than the Japanese value of 1750mm, 55mm more than the Korean value of 1805mm and 30mm larger than the French value of 1830mm and just 5mm bigger than the German value of 1855mm. The American value of 1870mm is 10mm higher than the Nigerian value.

Nigerians will require less dashboard to backrest length than their Japanese, American and French counterparts as the 5th percentile Nigerian female functional thumb - tip reach value of 662mm is 88mm less than the Japanese value of 750mm, 15mm lower than the American value of 677mm and 68mm smaller than the French value of 730mm.

Nigerians will need similar pedals spacing as their Japanese, American, Korean, German and French counterparts as the 95th percentile Nigerian male foot breadth value of 113mm is 10mm more than the Korean value of 103mm, 8mm higher than the French value of 105mm, 3mm greater than the American value of 110mm and 2mm bigger than the German value of 111mm. The Japanese value of 115mm is just 2mm more than the Nigerian value.

Nigerians will require similar foot clearance as their American, French and German counterparts as the 95th percentile Nigerian male foot

length value of 293mm is 9mm more than the German value of 284mm, 8mm greater than the French value of 285mm and just 3mm higher than the American value of 290mm. The Japanese value of 260mm is 33mm less and the Korean value of 270mm is 23mm smaller than the Nigerian value.

Nigerians will need more lateral legroom than their Japanese, American and German counterparts as the 95th percentile Nigerian female sitting knee height of 590mm is 95mm more than the Japanese value of 495mm, 30mm higher than the American value of 560mm and 45mm bigger than the German value of 545mm.

A lot of automotive companies both local and internationally renowned OEMs have so far demonstrated a serious interest in the Nigerian automotive policy and shown their intent for manufacturing vehicles for the Nigerian market by setting up production plants in the country. At present, over 30 of these companies have been licensed to commence operation by the Nigerian Automotive Design and Development Council (NADDC) and about 10 have already begun some form of manufacturing/assembly with some already rolling out several types of vehicles into the market.[1], [2], [21]

All this is been done without any ergonomics consideration from the companies or their supervising agency the National Automotive Design and Development Council (NADDC). There is an apparent lack of user considerations in the National Automotive Industry Development Plan which is the policy that is guiding the activities of the industry as well as the individual companies' guidelines. The main concerns of both the agency and the companies operating in the country have been to produce vehicles and components to global standards and to ensure that the vehicles are adaptable to the Nigerian roads which are understandable [2], [21], [22]. However, there needs to be a serious consideration as regards to the users of these vehicles in terms of both their anthropometric and biomechanics capabilities and limitations as they interact with the vehicle as drivers/passengers or while they work on the vehicles as repair or assembly personnel.

Although there is no data available for the Nigerian situation, several studies from other countries around the world have shown the serious effects of non-fitting and non-suitable vehicles to their human users. This is evident in many cases of lower back pains and musculoskeletal disorders as well as several incidents of accidents as a result of cramped and inefficient driving postures. The health and economic burden in the affected countries run into several billions of dollars [16]. The aforementioned countries where such studies were done are the most advanced in the world with state of the art vehicles and infrastructure; as such, the economic and health burden of non-fitting and non-suitable vehicles in Nigeria can only be imagined with our current state of vehicles and infrastructure.

Conclusions and Recommendations

Based on the requirement to accommodate the maximum percentage of the Nigerian population in the vehicle environment, this work recommends vehicle occupant packaging dimensions for knee clearance (690mm), knee clearance under steering wheel (606mm), hand clearance for door handles (89mm), space above drivers head (headroom)(994mm), interior shoulder width (583mm), handle grasps (99mm), height of outside door handle (971mm), length of interior grab and exterior door handles (99mm), door height/elbow clearance (1860mm), door width (610mm), thigh clearance (steering wheel to seat height)(673mm), dashboard to backrest length (662mm), forward legroom (690mm), pedals spacing (113mm), foot clearance (design of pedals)(293mm), lateral legroom (590mm) and vertical legroom (606mm).

The anthropometric and biomechanics characteristics of the user population are very significant in the design of vehicles intended for a particular market. It is therefore recommended that the data presented in this research should be incorporated into the design of vehicles intended for the Nigerian market, as the data presented here was carefully collected to ensure that the gender, age, and ethnic distributions of the country are accurately reflected in the sample population of the subjects. Alternatively, the National Automotive Design and Development Council in collaboration with the automotive companies operating in the country and other relevant agencies should conduct a nationwide anthropometric survey of the Nigerian population to capture the anthropometric data of a truly representative sample of the Nigerian population. Such data should then be incorporated as a guideline for the design of vehicles intended for the Nigerian market so as to ensure the safety, comfort and security of the users.

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