ISSN: 2449 - 0539
BAYERO JOURNAL OF ENGINEERING AND TECHNOLOGY (BJET) VOL.13 NO.2, AUGUST, 2018

ANTHROPOMETRIC COMPARISON OF NIGERIAN MALE ADULTS AND CRASH TEST DUMMIES

Rafukka, Ibrahim Abdullahi

Department of Mechanical Engineering, Bayero University, PMB 3011, Kano, Nigeria
Email: ibrahimrafukka@yahoo.com

ABSTRACT

Crash test dummies, otherwise known as anthropometric test devices (ATD), are surrogates used in the evaluation of vehicle safety performance to predict injury risk during crash. ATDs such as Hybrid III dummy that are applied currently in automotive crash testing were produced based on U.S. adult anthropometry. The aim of this study is to assess the difference between the anthropometric dimensions of Nigerian male adults and ATDs based on the reported data in the literature. Anthropometric dimensions of adults from three major ethnic groups of Hausa, Igbo and Yoruba were utilized in the study. Comparison was made between stature and weight of Nigerian male adult and 50th percentile (midsize male) and 95th percentile (large male) Hybrid III dummy. The results revealed critical difference varying from 10.4% to 23.4% for body weight and 1.5% to 3.5% for the stature. It was also found that 50th percentile Hybrid III dummy corresponds to 77th, 76th, and 67th percentiles in stature for Hausa, Igbo and Yoruba adults respectively. 95th percentiles Hybrid III dummy corresponds to 99th, 99th and 100th percentiles in body weight for Hausa, Igbo and Yoruba adults respectively. The comparison shows that ATDs are not representing Nigerian population. This lead to different injury outcomes in vehicle crash and vehicles tested using the ATDs might not be safe for Nigerian male adults. Car designers and manufactures have to consider the anthropometric differences in future designs to ensure that vehicle used by Nigerians are evaluated using crash dummies that truly represent the population.

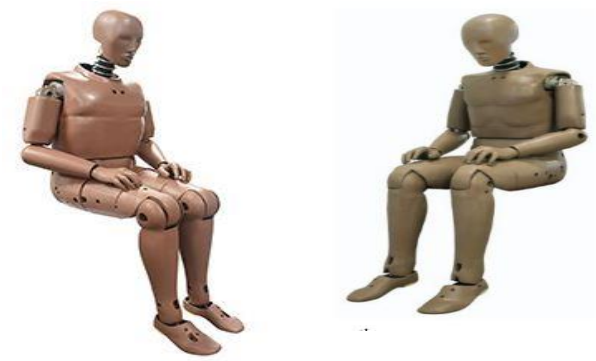
Keywords: Anthropometry; ATD; Crash dummy; Crash test; Vehicle safety.

1.0 INTRODUCTION

Road traffic accident claims about 1.2 million lives annually worldwide; hence it is considered to have high impact on the health and development of any society (WHO, 2013). It is high in developing countries because of weak safety regulations and poor infrastructures. Nigeria being the African most populous country, has been reported to have the highest road traffic accident rate in Africa, and second in the world (Atubi, 2010; Ukoji, 2014). There are recently efforts by automobile manufacturers and Nigerian government of producing made in Nigeria vehicles. Some companies have started assembling cars sold in Nigeria. To provide effective protection in car crashes, Nigerian adults' anthropometry must be taken in to consideration in evaluating safety performance of vehicles used in Nigerian.

Crash test dummies are devices used to evaluate human injuries in vehicular crashes. They are

designed to represent human attributes such as dimensions, shape, weight and articulation of joints. Dummies are instrumented to measure the accelerations, moments and forces experienced by head, neck, chest and femur during crash. The dummy biomechanical responses are compared with standards to ensure that vehicle is safe for the occupants. Crash dummies are important in vehicle production as they remain the only tool to conduct crash test on vehicle because real human being is not applicable. Vehicle developers rely on the crash tests for the assessment of vehicles crashworthiness and occupant protection systems. Figure 1 shows the two male crash test dummies in vehicle sitting posture. They are human surrogates that are globally accepted for frontal crash testing of vehicles.



95th Percentile (large male) **50th Percentile (midsize male)**

Figure 1: Hybrid III Male Crash Test Dummies (Humanetics, 2017)

Nigeria depends on imported used and new vehicles that were produced based on safety standards of other countries. Safety performance of these vehicles was evaluated using crash dummies representing other countries' population. The most common crash dummy used in crash test is Hybrid III dummy which is produced based on 50th (mid size male) and 95th (large male) percentiles U.S. adult anthropometry collected more than three decades ago (Reed & Rupp, 2013). Injury parameters such as head injury criteria and chest acceleration vary for vehicle occupants of different anthropometries under the same impact condition (S. Kim & Son, 2003; J.-E. Kim et al., 2015;). Hence, current ATDs might produce injury responses that are different from that of Nigerian adult due to differences in anthropometric characteristics. Figure 2 shows a mid size vehicle crashed in to rigid concrete barrier with an unbelted 50th-percentile Hybrid III dummy driver during a crash test.

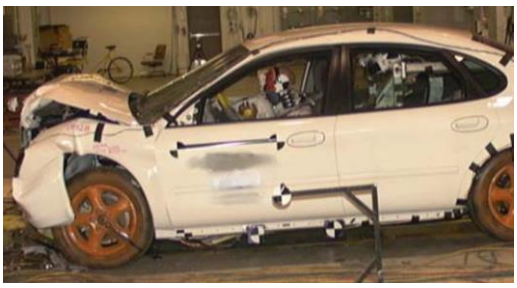


Figure 2: Crash test of midsized vehicle against a full rigid barrier with 50th-percentile Hybrid III dummy as a driver (Bois, Chou, Fileta, King, & Mahmood, 2004)

There have been many studies recently on comparing various populations of the world and ATDs with the aim of determining the validity of using the ATDs in crash test. Reed & Rupp (2013) compares current U.S. adults' anthropometry with Hybrid III dummy dimensions. It was found that secular trends in U.S. anthropometry affect the relationship between ATDs and the population. Isa et al. (2016) studied the difference in anthropometry between ATD and Malaysian adults and reported that current ATDs do not represent Malaysian adults. Chinese adults were found to be smaller than ATDs in terms of stature and body weight which makes it necessary to consider the differences in developing new vehicles used in

China (Cao, Zhang, Lv, & Yan, 2015). Study by Serre et al. (2006) revealed that French three- and six-year old child's anthropometry differs from crash dummies in various anthropometric dimensions. A significant difference in anthropometric dimensions between three year old Nigerian child and crash dummies was also reported by Rafukka et al. (2016). There is no study on assessment of anthropometric differences between Nigerian adult and crash dummies despite the fact that Nigeria is one of the major vehicle users in Africa. The current study is aimed at assessing the difference in anthropometry between Nigerian male adult and ATDs which are widely used in the evaluation of vehicle safety performance.

Studies on anthropometric comparison between crash dummy and adults for Malaysia, U.S. and China were carried out using data from national anthropometric database (Reed & Rupp, 2013; Cao et al., 2015; Isa et al., 2016) . However, there is still no anthropometric database for Nigerian population (Onawumi & Lucas, 2012; Samuel, Israel, & Moses, 2016).Studies for anthropometric data of Nigerian adults especially for weight and stature were for medical research involving blood pressure (Anyanwu, Ekezie, Danborno, & Ugochukwu, 2010; Chinedu & Emiloju, 2014; Chukwujekwu, Ezejindu, & Nwosu, 2014; Okamkpa, Nwankwo, & Danborno, 2016). Some research are for ergonomic applications for school furniture and vehicle seat (Onawumi & Lucas, 2012; Ismaila, Musa, Adejuyigbe, & Akinyemi, 2013; Samuel et al., 2016). Other studies deal with anthropometric characteristics of particular ethnic group (Oladipo, Coker, Anugweje, & Abidoye, 2005; Goon, Lamina, Musa, & Akusu, 2011; Taura, 2012; Egbe, Asuquo, Ekwere, Olufemi, & Ohwovoriole, 2014;; Ogunlade & Adalumo, 2015; Alabi, Oladipo, Didia, & Aigbogun, 2017).

2. MATERIALS AND METHODS

2.1 Materials

The data used in this study was obtained from previous studies in which stature and body weight of three major ethnic groups in Nigeria was published. This is done in order to ensure that every part of the country is represented. Three recent studies that have high number of subjects were selected for each of the three major ethnic groups of Hausa, Igbo and Yoruba. Stature obtained from the three studies were further confirmed by a very recent anthropometric study by Alabi et al. (2017). The difference between stature from Alabi et al. (2017) and that of the three studies was found to be within 1.2%. Number of samples from the selected studies was in accordance with recommendation of WHO which requires anthropometric studies to have at least 200 samples (Bridger, 2003).

This study is limited to weight and stature because the two parameters are considered as reference dimensions. Other dimensions of ATD are obtained from individual that has similar size with the reference dimensions (Cao et al., 2015). Also weight and stature significantly affect the biomechanical response of the crash dummy than any other anthropometric dimension. Table 1 shows stature and body weight of Nigerian adults from the three selected studies. The data was obtained in terms of mean and standard deviation.

Table 1: Anthropometric Data of Nigerian Male Adults

Source	Anthropometry	No. of Subject	Age	Mean	Standard deviation
Taura (2012) (Hausa)	Stature	599	18-60	1690.0	±82.0
	Weight	599	18-60	62.1	±10.7
Okamkpa et al. (2016) (Igbo)	Stature	258	28-74	1689.9	±87.5
	Weight	258	28-74	70.1	±12.0
Ogunlade & Adalumo (2015) (Yoruba)	Stature	242	18-41	1720.0	±70.0
	Weight	242	18-41	63.4	±9.1

2.2 Methods

Various percentiles can be computed using mean and standard deviation because most of linear dimensions of the human body are normally distributed (Pheasant & Haslegrave, 2016). Though body weight shows modest skew distribution in some populations, the errors of approximating it to normal distribution are considered negligible (Pheasant & Haslegrave, 2016). Thus, assuming normal distribution, the 50th and 95th percentiles were calculated using the equation:

$$X = \mu + Z\sigma \quad \ldots \quad (1)$$

Where μ is the mean, Z is the value from standard normal distribution and σ is the standard deviation.

Midsize (50th) and large (95th) male percentiles for each of the three ethnic groups was computed using equation (1) by substituting mean and standard deviation from Table 1. Z values of the 50th and 95th percentiles were obtained from the standard normal distribution table.

The percentage difference between Nigerian male adult and ATDs was calculated as follows:

$$Percent.diff.(\%) = \frac{Nigeria\ male\ data - ATD\ data}{ATD\ data} \times 100 \quad \ldots \quad (2)$$

3. RESULTS AND DISCUSSION

3.1 Results

The weight and stature of mid size and large male ATD were obtained from (Mertz, Jarrett, Moss, Salloum, & Zhao, 2001). Table 2 shows the anthropometric comparison of Nigerian male adult anthropometry with ATDs. Negative percentage difference value indicates that Nigerian male adult is lower than ATDs in stature or body weight.

Table 3 presents stature and weight targets of two male ATDs together with their associated percentiles. Percentiles to which the target values correspond was also computed and presented for the three ethnic groups.

Table 2: Anthropometric Differences between Nigerian Male Adults and ATDs

Variable	Mid size ATD	Midsize male (Hausa)	Difference (%)	Large ATD	Large male (Hausa)	Difference (%)
Stature (mm)	1751.0	1690	-3.5	1864.0	1824.9	-2.1
Body weight (kg)	78.2	62.1	-20.3	102.5	79.9	-22.0

	Mid size ATD	Midsize male (Igbo)	Difference (%)	Large ATD	Large male (Igbo)	Difference (%)
Stature (mm)	1751.0	1690	-3.5	1864.0	1883.9	-1.6
Body weight (kg)	78.2	70.1	-10.4	102.5	89.9	-12.3

	Mid size ATD	Midsize male (Yoruba)	Difference (%)	Large ATD	Large male (Yoruba)	Difference (%)
Stature (mm)	1751.0	1720	-1.8	1864.0	1835.2	-1.5
Body weight (kg)	78.2	63.4	-18.8	102.5	78.5	-23.4

Table 3: Comparison of Percentiles between ATD and Male Adults for Three Ethnic Groups

ATD	Stature			Body weight		
	Reference Values ATD (mm)	Nominal percentile ATD	Corresponding percentile (Hausa)	Reference Values (kg)	Nominal percentile ATD	Corresponding percentile (Hausa)
Mid size male	1751.0	50	77	78.2	50	93
Large male	1864.0	95	98	102.5	95	99

	Reference Values ATD (mm)	Nominal percentile ATD	Corresponding percentile (Igbo)	Reference Values ATD (kg)	Nominal percentile ATD	Corresponding percentile (Igbo)
Mid size male	1751.0	50	76	78.2	50	75
Large male	1864.0	95	98	102.5	95	99

	Reference Values ATD (mm)	Nominal percentile ATD	Corresponding percentile (Yoruba)	Reference Values ATD (kg)	Nominal percentile ATD	Corresponding percentile (Yoruba)
Mid size male	1751.0	50	67	78.2	50	95
Large male	1864.0	95	98	102.5	95	100

3.2 Discussion of Results

It is evident from Table 2 that male ATDs are different from Nigerian adults. Comparison revealed that Yoruba, Hausa and Igbo male are relatively lower than ATDs in both weight and stature. Large difference can be seen in the body weight rather than stature. The biggest difference of 23.4% is observed between ATD and large Yoruba male in body weight. The Nigerian male adults are slightly shorter in stature than ATD for three ethnic groups with difference ranging from 1.5% to 3.5%.

It is observed from Table 3 that corresponding percentiles values for both weight and stature are higher than nominal ATD percentiles values for the three ethnic groups. For example, the 50th nominal percentile of mid size ATD is equivalent to 77th percentiles of Hausa male in stature. The 95th nominal percentiles of large male ATD correspond to 99th percentiles of Hausa male in body weight. The difference in percentiles is larger in weight than stature for all the three ethnic groups. The target value for midsize male ATD is now about 75th percentiles; only one fourth of the Igbo male have stature and body weight greater than reference value of the 50th percentile male ATD. However, only 5% of Yoruba midsize male have weight greater than 50th percentile Hybrid III dummy.

The main purpose of this study is to compare the anthropometry of Nigerian male adults and ATDs. The ATDs are designed to have similar response with an individual in a given crash scenario. The results demonstrate that reference ATDs are different from the male adult of three Nigerian major ethnic groups in stature and body weight, hence cannot represent Nigerian male adults in the evaluation of vehicle safety performance. Large difference in body weight between Nigerian adult and ATDs ranging from 10.4% to 23.4% can be noticed in Table 2. Percentage difference of 1.5% to 3.5% is recorded for the stature. The 50th percentile Hybrid III dummy corresponds to 77th, 76th, and 67th percentiles in stature for Hausa, Igbo and Yoruba adults respectively. 95th percentiles Hybrid III dummy corresponds to 99th, 99th and 100th percentiles in body weight for Hausa, Igbo and Yoruba adults respectively as shown in Table 3. It was also found that a single crash dummy could be developed to represent Hausa and Yoruba male adults because the percentage difference in anthropometric characteristics between the two ethnic groups is close for both stature and weight as observed in Table 2. Igbo male is however about 10 kg lower in weight than Hausa and Yoruba adults.

Injury parameters could be different for occupants of different sizes hence there is need to take in to account the occupant size in restraint system and vehicle design (Happee, Haaster, Michaelsen, & Hoffmann, 1998). If the size of occupant is different from that of ATDs, the position of head and neck relative to the airbag and restraint system will be different from the one intended in the design. Head and neck injuries in vehicle crash depends on the airbag trigger time and position of the head relative to airbag on contact (Melvin et al., 1993). Sitting position has tremendous effect on the injury outcomes in vehicle crash. Airbag cannot effectively absorb impact energy from small driver that sits far from steering wheel as compared to midsize male. Since Nigerian male adult is smaller than ATD, seat belt routings would be close to their neck than hybrid III dummy which lead to high neck moments and forces. Occupants that are smaller than the crash dummies were reported to have higher neck injuries due to closeness of dummy neck with seat belt (Isa et al., 2016). Weight plays an important role in injury severities sustained by the occupant in crash because it is related to the energy absorption of

airbag, seat belt and knee bolster. A heavier ATD will result in high impact force which drives higher output airbag inflators. Large differences in weight between Nigerian male adult and ATD shown in Table 2 indicate that injury mitigation systems may not provide optimum protection to Nigerian adults.

Table 4 shows the difference between male adults and ATDs for some populations of the world. Interestingly, the percentage difference in stature and weight for Hausa male adults from current study is close to that of Malaysia adults while that of Igbo is close to Chinese adults. For all the populations considered the percentage difference is high in body weight than in stature. In summary, current ATDs may not sufficiently represent U.S., Malaysia, China and Nigerian populations in crash test.

This work is important considering the new vehicles being assembled and sold in Nigeria. Crash testing using correct ATDs should become a requirement for manufacturers to sell their cars in Nigeria and Africa in general. As we have New Car Assessment Program (NCAP) for some countries around the world such as Euro NCAP, US NCAP and China NCAP there is need to come up with vehicle crash test standards that will suit Nigerian population.

Table 4: Anthropometric Differences between ATDs and Male adults for Some Countries

Country	Difference between mid size male and ATD	
	Stature (%)	Body weight (%)
U.S. (Reed & Rupp, 2013)	0.57	9.21
China(Cao et al., 2015)	-3.5	-11.9
Malaysia (Isa et al., 2016)	-3.5	-19.4
Nigeria Hausa (current study)	-3.5	-20.3
Nigeria Igbo(current study)	-3.5	-10.4
Nigeria Yoruba(current study)	-1.8	-18.8

4. CONCLUSIONS

It is shown in this work that there is considerable difference between Nigerian male adults with most widely used male ATDs. Nigerian adult from three major ethnic groups are generally lower in stature and weight than mid size and large male ATDs with ifference ranging from -3.4% to -1.8% for the stature and -23.4% to -10.4% for body weight. This indicates difference in biomechanical response and injury level in vehicular crashes which signifies that current ATDs are not truly representing Nigerian male adults. Difference between Hausa and Yoruba mid size adults were very close (-20.3% and -18.8% for body weight and -3.5% and -1.8% for stature). The differences in stature and weight were also close for Hausa and Yoruba large male. Hence, a single ATD could represent the two populations. Globally however, percentage difference in body weight and stature for Hausa was close to Malaysian male adult while that of Igbo was close to Chinese adult. It is imperative therefore to put consideration into the differences in anthropometry between Nigerian adult and ATDs in design of new vehicles used in Nigeria in order to provide

effective protection against injuries to the occupants. New vehicles should be certified using crash dummies of Nigerian anthropometry. Small sample size is used in the current study as compared to studies of China and Malaysia who employed data from their national database which is not currently available in Nigeria. For further improvement on this work it is recommended that a standardize Nigerian database be established in the future to enable research on automotive safety to be conducted. Also the effect of anthropometric data on injury outcome during crash should be studied. Research should be carried out to incorporate Nigerian anthropometric data to existing ATDs.

REFERENCES

Alabi, A., Oladipo, G., Didia, B., & Aigbogun, E. (2017). Regression Equations for Stature Prediction in Nigerian Hausas, Igbos and Yorubas From Toe Length and Toe-Length Ratios. *Anthropology*, *05*(01), 1–5. http://doi.org/10.4172/2332-0915.1000176

Anyanwu, G. E., Ekezie, J., Danborno, B., & Ugochukwu, A. I. (2010). Impact of education on obesity and blood pressure in developing countries: A study on the Ibos of Nigeria. *North American Journal of Medical Sciences*, *2*(7), 320–4. http://doi.org/10.4297/najms.2010.2320

Atubi, A. (2010). Road Traffic Accident Variations in Lagos State, Nigeria: A Synopsis of Variance Spectra. *African Research Review*, *4*(2), 197–218.

Bois, P. Du, Chou, C. C., Fileta, B. B., King, A. I., & Mahmood, H. F. (2004). *Vehicle and Occupant Protection*. (P. Prasad & J. E. Belwafa, Eds.). American Iron and Steel Institute.

Bridger, R. (2003). *Introduction to ergonomics* (2nd editio). London: Taylor & Francis.

Cao, L., Zhang, K., Lv, X., & Yan, L. (2015). Comparison of Current ATDs with Chinese Adults in Anthropometry. *Traffic Injury Prevention*, *9588*(February), 00–00.

Chinedu, S., & Emiloju, O. (2014). Underweight, overweight and obesity amongst young adults in Ota, Nigeria. *Journal of Public Health and Epidemiology*, *6*(7), 235–238. http://doi.org/10.5897/JPHE2014.0638

Chukwujekwu, I. E., Ezejindu, D. N., & Nwosu, N. M. (2014). Anthropometric study of weight, height and blood pressure in children from Nnewi north local government of Anambra state, south east Nigeria. *International Journal of ScientifIC and Research Publications*, *4*(4), 1–4.

Egbe, E. O., Asuquo, O. A., Ekwere, E. O., Olufemi, F., & Ohwovoriole, a E. (2014). Assessment of anthropometric indices among residents of Calabar, South-East Nigeria. *Indian Journal of Endocrinology and Metabolism*, *18*(3), 386–93. http://doi.org/10.4103/2230-8210.131196

Goon, D. Ter, Lamina, A., Musa, D. I., & Akusu, S. (2011). the Relationship Between Arm Span

and Stature in Nigerian Adults. *Kinesiology*, *43*, 38–43.

Happee, R., Haaster, R. Van, Michaelsen, L., & Hoffmann, R. (1998). Optimisation of Vehicle Passive Safety for Occupants With Varying Anthropometry. *Methods*, (98), 1919–1924.

Humanetics. (2017). Hybrid III 50th Male. Retrieved November 8, 2017, from http://www.humaneticsatd.com/crash-test-dummies/frontal-impact/hiii-50m

Isa, M. H., Deros, B., Jawi, Z. M., Anwar, K., & Kassim, A. B. U. (2016). An Anthropometric Comparison of Current Anthropometric Test Devices (ATDs) WITH Malaysia Adults. *Malaysian Journal of Public Health Medicine*, *Special Vo*(1), 15–21.

Ismaila, S. O., Musa, A. I., Adejuyigbe, S. B., & Akinyemi, O. D. (2013). Anthropometric Design of Furniture for Use in Tertiary Institutions in Abeokuta, South- Western Nigeria. *Engineering Review*, *33*(3), 179–192.

Kim, J.-E., Hsieh, M.-H., Shum, P. C., Tubbs, R. S., & Allison, D. B. (2015). Risk and injury severity of obese child passengers in motor vehicle crashes. *Obesity*, *23*(3), 644–652.

Kim, S., & Son, K. (2003). Construction and Evaluation of Scaled Korean Side Impact Dummies. *KSME International Journal*, *17*(12), 1894–1903.

Melvin, J., Horsch, J., McCleary, J., Wideman, L., Jensen, J., & Wolanin, M. (1993). *Assessment of airbag deployment loads with the small female hybrid III dummy*.

Mertz, H., Jarrett, K., Moss, S., Salloum, M., & Zhao, Y. (2001). The Hybrid-III 10-year-old Dummy. *Stapp Car Crash Journal*, *45*, 319–328.

Ogunlade, O., & Adalumo, O. A. (2015). Mean values , normal limits and sex differences of anthropometry of young adults in a University Community in Nigeria. *American Journal of Clinical and Experimental Medicine*, *3*(1), 44–47. http://doi.org/10.11648/j.ajcem.20150301.16

Okamkpa, C., Nwankwo, M., & Danborno, B. (2016). Predicting high blood pressure among adults in Southeastern Nigeria using anthropometric variables. *Journal of Experimental and Clinical Anatomy*, *15*(2), 111. http://doi.org/10.4103/1596-2393.200912

Oladipo, G. S., Coker, T., Anugweje, K. C., & Abidoye, A. O. (2005). Study of Some Anthropometric Parameters of Itsekiri and Okpe Ethnic Groups of Delta State , South-South Nigeria. *International Journal of Community Research*, 77–80.

Onawumi, A. S., & Lucas, E. B. (2012). Ergonomic investigation of occupational drivers and seat design of taxicabs in Nigeria. *ARPN Journal of Science and Technology*, *2*(3), 214–220.

Pheasant, S., & Haslegrave, C. M. (2016). *Bodyspace: Anthropometry, ergonomics and the design of work* (Third Edit). CRC Press.

Rafukka, I. A., Sahari, B. Bin, Nuraini, A., & Manohar, A. (2016). Anthropometric Comparison of Three-Year-Old Nigerian Child and Crash Dummies. *Journal of Transportation Technologies*, *6*(4), 192–199.

Reed, M. P., & Rupp, J. D. (2013). An anthropomorphic comparison of current ATDs

with the U.S adult population. *Traffic Injury Prevention*, *14*(7), 703–705.

Samuel, O. A., Israel, D., & Moses, F. (2016). Anthropometry Survey of Nigerian Occupational Bus Drivers to Facilitate Sustainable Design of Driver ' s Workplace, *5*(May), 176–182.

Serre, T., Lalys, L., Brunet, C., Bartoli, C., Christia-Lotter, A., & Leonetti, G. (2006). 3 and 6 Years Old Child Anthropometry and Comparison with Crash Dummies. *SAE Technical Paper*.

Taura, M. (2012). Evaluation of Anthropometric Status of Hausas of Northern Nigeria. *Bayero Journal of Pure and Applied Sciences*, *4*(2), 80–82. http://doi.org/10.4314/bajopas.v4i2.15

Ukoji, V. N. (2014). *Trends and patterns of fatal road accidents in Nigeria (2006-2014)* (No. 35).

WHO. (2013). Global status report on road safety 2013. Retrieved July 13, 2016, from http://www.who.int/violence_injury_prevention/road_safety_status/2013/en/