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Investigation of the Relationship between Stature and Popliteal Height Sitting of Nigerian Bus Drivers

Fajobi, Moses Oluwatobi[*, 1], Awoyemi, Elijah Ayodeji [2], Odedele, Deborah Tosin[3], Adesope, Waliy Adeola[4] and Adio, Teslim Adekunle[5]

[1] Mechanical Engineering Department, Ladoke Akintola University of Technology, Ogbomoso, Oyo State, Nigeria.
[2] Works and Maintenance Department, Osun State University, Osogbo, Osun State, Nigeria.
[3]Accounting and Marketing Department, Online Distance Learning Centre, Ladoke Akintola University of Technology, Ogbomoso, Oyo State, Nigeria.
[4]Mechanical Engineering Department, Oyo State College of Agriculture and Technology, Igboora, Oyo State, Nigeria.
[5]Mechanical Engineering Department, The Polytechnic Ibadan, Oyo State, Nigeria.

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ABSTRACT

The aim of this study was to establish the relationship between the Stature and Popliteal Height Sitting, PHS. 161 male occupational bus drivers were randomly selected for anthropometric characterization of Stature and PHS using standard measuring equipment. The data were analyzed using SPSS 16.0 and Design-Expert 6.0.8. Then regression model was used to estimate PHS. The model shows that there is a linear relationship between the Stature and PHS with coefficient of determination (R^2) of 0.8258 ($p < 0.0001$). The model mitigates time required for gathering anthropometric data. Designers would find this as a huge working tool for adequate productions.

1. Introduction

Development and changes evoked as a result of globalization in automotive manufacturing technology have demanded that bus design should conform to the anthropometric characteristics requirements of the users. The major objectives of ergonomics application to the design of goods, products, processes and workstations that has strong agreement with ergonomic characteristic demand of the users' anthropometry is to enhance natural working posture. In achieving this, the use of anthropometry becomes necessary. Anthropometric data is a collection of the dimensions of the human body and are useful for apparel sizing, forensics, physical anthropology and ergonomic design of process, gadgets and the workstation (Chou and Hsiao, 2005; Ismaila *et al.*, 2012; Onawumi *et al.*, 2016a). Considerable variation in individual's anthropometric data within a family, ethnic group, nation and among nations has been reported. Consequent upon this, it becomes of paramount importance to hold on to a reliable anthropometric data for a targeted workforce as necessary tool in designing for such population if the products were to be adequately suitable for the potential users. The use of anthropometry in design has been found to have a very high impact on/and enhances the physical and psychological well-being, comfortability, health status as well as safety of the product user (Barroso *et al.*, 2005; Pheasant and Haslegrave 2005). Occupational driving among all other professions has been acknowledged across the world as a means of livelihood out of which most individuals make hands meet for the purpose of sustenance (Okunribido *et al.*, 2007) and the case of Nigeria is not an exception. The fleet of vehicles used for this purpose include buses, cars, special utility vehicles, SUVs; pick- up, vans and heavy duty vehicles among others (Onawumi *et al.*, 2016b). Bus is one of the main alternatives of mass public transportation acknowledged as it is cheaper and has better coverage area than any other modes of public transportation. Buses are used mainly for conveying luggage and passengers from one location to other specific locations. Driver plays an important role in the operation of this highly technological system as he interacts with the various in-vehicle components manoeuvring them with a view to making necessary judgments at appropriate time (Fajobi *et al.*, 2016; Stana *et al.*, 2010; Bucciaglia *et al., 1995*). The prominent position often assumed by the driver for these operations is sitting and this substantiates the need for a well appropriated and ergonomically suitable seat for the driver (Pachling and Chaitany, 2013; Vetrivel *et al.*, 2012; Van-Niekerka *et al.*, 2003). Prolong sitting is one well known risk factor responsible for the development of body pain, numbness, tingling, fatigue and other forms of musculoskeletal disorders (both biomechanically and physiologically), particularly in the lower and thoracic extremities of the drivers (Teshome, 2017; Schmidt *et al.*, 2014). For this reason, consistent change in posture is recommended in prolonged sitting especially for drivers who tour far distances to overcome the effect of imposed stresses (Mohamad *et al.*, 2010; Noor *et al.*, 2013). The measurements necessary to determine the dimensions of bus driver's seat that will enable the subject to maintain the correct sitting posture are amongst others; Popliteal Height Sitting, PHS,

Tele: 08035226126
E-mail address: mofajobi54@lautech.edu.ng

knee height, buttock to popliteal length, elbow height, seated hip breadth and shoulder height (Reed 2000; Panagiotopoulou *et al.,* 2004). PHS is the main anthropometric dimension used in vehicle and other seat design as it remains the noble specification to determine appropriate seat height (Fai *et al.,* 2007; Tuttle, 2004).

In designing such a seat to suit a population, the PHS is used to ensure that members of the population are able to sit with their feet supported on the floor, and without undue pressure behind the knees. Similarly, comparing the PHS of an individual to the seat height of the available seats can assist in selecting the most suitable size for that individual (Mandal *et al.,* 2015). Gathering anthropometric data involves a lot of resources which vary from; required workforce, equipment, to funds expenditure. The use of only one dimension to predict other body dimensions for the design of vehicle seat would therefore be cheaper (Chao and Wang, 2010). Two approaches to determine a specific dimension are to measure the Stature and then multiply with a given ratio (Chao and Wang, 2010; Pheasant and Haslegrave 2005) and the use of linear regressions (Asafa *et al.,* 2010). These practices may be erroneous, as these dimensions may have low correlation (r) as well as low coefficient of determination (R^2) with or be a fraction of the independent dimension (Oladapo and Akanbi, 2015). Hence this study therefore aimed at establishing the model that best determine the relationship between Stature and PHS of occupational bus drivers in Nigeria using Response Surface Methodology (RSM).

2. Materials and Methods

2.1 Sampling

One hundred and sixty one, 161 subjects (all males) whom have been licensed by the Federal Road Safety Commission, FRSC to engage in public transportation service and with no cases of deformity were randomly selected from six prominent motor park units within the metropolitan city of Ogbomoso, South Western Nigeria for this study. Their ages range from 18 to 60 years.

2.2 Instrumentation and Anthropometry Characterization

Designing for any population requires the incorporation of the targeted population's anthropometric data if the product were to be suitable (Ayodeji *et al.,* 2008; Oguntona and Kuku, 2000), hence, the need for a highly reliable anthropometric data. Sequel to consent permission and sensitization of the subjects as to the importance of the exercise, two anthropometric dimensions (Stature and PHS) (Figures 1 and 2) were characterized by measurements through the instrumentation of Standiometer (model-Health Scale ZT-160, Micro field, England), Anthropometric Seat and Vernier Calipers. The procedure for anthropometric characterization of subjects is quite technical and it requires the use of two or more trained investigators as well as reliable anthropometric equipment. Standard procedures for anthropometric data gathering were observed. Subjects were asked to be on simple, light clothing and barefooted while measurements were taken to the nearest centimetres (cm). Each dimension was taken in triplicate by a single investigator and their means were recorded. In order to rule out the effect diurnal variation, all measurements were made in the morning and to ensure consistency and accuracy in doing this, flat wooden piece was used as foot rest to accommodate subjects of different heights and a perpendicular wooden angle to fix the elbow at 90^0 as required for the measurements of PHS.

Stature: The subject stands with his shoes removed, heels together and the weight evenly distributed between both feet. The subject stands erect with the Frankfort plane (line pass horizontally from the ear canal to the lowest point of the eye orbit) of his head parallel to the floor, the shoulder and arms relaxed and enough pressure is exerted to compress the hair. The measurement was then taken at the maximum point of quiet respiration. The Stadiometer was then used to measure the Stature as the vertical distance from the vertex to the floor. (Figure 1)

PHS: The subject sits erect on the anthropometric seat having adjusted the chair to allow his knees to be at right angle and the bottom of his thigh and the back of his knees barely touching the surface. The Vernier Calipers was used to measure the vertical distance from the floor to the thigh immediately behind the knee. (Figure 2)

2.3 Data Analysis

The data harvested was presented in Microsoft Excel Spreadsheet and subsequently exported into Statistical Products and Services Solution (SPSS) 16.0 software where descriptive statistics which included mean, median, standard deviation, maximum and minimum dimensions; and 5th, 50th and 95th percentiles were ensued. Regression analysis was used to model the data using Historical Data Design package embedded in Design-Expert 6.0.8 Software Version and analysis of variance, ANOVA for the response was examined to test for statistical significance. The Stature was considered as the independent (factor) variable considering its ease of measurement while the PHS was regarded as the dependent (response variable) because, it is rigorous to be measured accurately but pertinent to in-vehicle design geometry (Onawumi *et al.,* 2016b). The adequacy of regression model was checked by lack-of fit test, R^2, AdjR^2, Pre R^2, Adeq Precision and F-test (Oladapo and Akanbi, 2015). The highest coefficient of determination was then selected as the best model to establish the relationship(s) between the Stature and PHS. The significance of F value was judged at 95% confidence level and p-value less than 0.05 was considered significant.

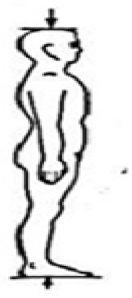

Figure 1. Stature.

Figure 2. Popliteal Height Sitting.

3.0 Results and Discussion

3.1 Descriptive summary of the drivers' anthropometric data

Table 1 presents the descriptive summary of the drivers' anthropometric data in terms of mean, median, standard deviation, maximum and minimum dimensions as well as the 5th, 50th and 95th percentiles.

Ergonomics has found a huge application in determining design values through the instrumentality of anthropometry presented in the forms percentiles for a number of dimensions. For instance, design of an ergonomically suitable vehicle seat and any other form of seat requires the use of 5th percentile of the PHS for the seat height to be adequate for a larger number of the workforce and consequently give room for a short person to be able to use the seat comfortably.

3.2 Relationship between Stature and PHS

3.2.1 PHS

To better investigate the variation between the dependent with independent variable and to establish its adequacy, the design programme suggested a linear model which represents their relationship. The Model F-value of 284.44 means the model is significant (Table 2). There is only a 0.01% chance that a "Model F-Value" this large could occur due to noise (Oladapo and Akanbi, 2015). Values of "Prob > F" less than 0.0500 indicate model terms are significant and this suggests case A is a significant model term. Values greater than 0.1000 indicate the model terms are not significant. If there are many insignificant model terms (not counting those required to support hierarchy), model reduction may improve the model. The non-appearance of "Lack of Fit F-value" implies that the model perfectly (100%) fit relative to the pure error (Onawumi *et al.*, 2016b).

3.2.2 Model Equation and Interpretation

In order to justify the kind of relationship betweeen the Stature and PHS of the subjects, a response surface methodology was put into use as it gives room for more than one relationship models (linear, quadratic and cubic) to be investigated simultanouesly and therefore suggesting the best model based on embedded validation principles in the software (Table 3). The "Pred R-Squared" of 0.8156 is in reasonable agreement with the "Adj R-Squared" of 0.8229. "Adeq Precision" measures the signal to noise ratio. A ratio greater than 4 is desirable. (Table 3). The ratio of 40.767 indicates an adequate signal. This model can be used to navigate the design space. CV < 10% has been suggested suitable in predicting the response surface models (Aremu *et al.*, 2014; Montgomery 1997). Hence CV ≤ 1.58% for the model implied that the model exhibited very high predictive ability and very efficient.

3.2.3 Analysis of Variance, ANOVA

The design suggested the best model that describes the relationship between the Stature and PHS as linear model (Table 3). A very low probability value [(p model > F) < 0.05] indicated that the model was highly significant. Since it displayed the coefficient of determination (R^2) of 0.8258 (< 0.0001) which is a capable measure to know the percentage variation between Stature and PHS, and it shows a high positive and strong relationship. By way of implication, this means that 82.58% of variation in PHS can be explained by Stature and the remaining 17.42% of variation in PHS may be due to other factors which may affect PHS of the subjects such as; nutritional status, physiological build, environment and genetic factors, diurnal effects, gender, age, muscular exercise and some other anthropometric dimensions of the body (Table 3). The adjusted determination coefficient (Adj. R^2 = 0.8229) was also satisfactory for confirming the significance of the model. The adjusted correlation coefficient (Adj. R^2 = 82.29%) of 0.8229 was very close to correlation coefficient which confirmed agreement between the predicted and actual values. The relationship between Stature and PHS is also presented in Scatter graph (Figure 3), and line-of-fit including 99% of points for the plot were observed to be roughly linear. This suggests a directly proportional relationship between the two dimensions as both increases simultaneously. However, considering the agreements R^2 and adj. R^2 values for the other equation models (Quadratic and Cubic) in Table 3, they are also reasonably significant enough to explain the relationship between Stature and PHS (Ismaila *et al.*, 2012) but of low C.V values compared with the linear model. Hence, linear regression analysis was thus deemed to be most suited for the investigation. Therefore, the PHS can be estimated using the following relationship:

PHS=49.55+3.14×STATURE ___________ Equation 1

Table 1. Anthropometric Description of the Drivers.

Anthropometric Variable Parameters Estimates	Stature	PHS
Population, N	161	161
Mean ± SD	176.12 ± 6.17	49.39 ± 2.02
Minimum Value	165.3	46.11
Maximum Value	187.1	52.98
Range	21.8	6.87
5th	167.6	46.3
50th	175.6	49.3
95th	185.9	52.3

S: Stature (cm), PHS: Popliteal Height Sitting (cm), SD: Standard Deviation

Table 2. ANOVA for response surface linear model.

Source	Sum of Squares	DF	Mean Square	F Value	Prob > F	
Model	173.98	1	173.98	284.44	<0.0001	Significant
A	173.98	1	*173.98*	284.44	*<0.0001*	
Residual	36.70	160	0.61			
CorTotal	210.67	161				

Table 3. Model Validation Summary.

Parameter	Linear	Quadratic	Cubic
R-Squared	0.8258	0.8263	0.8311
Adj R-Squared	0.8229	0.8204	0.8224
Pred R-Squared	0.8156	0.8108	0.8113
Adeq Precision	40.767	32.925	25.313
Std Dev.	0.78	0.79	0.78
Mean.	49.59	49.59	49.59
C.V	1.58	1.59	1.58
PRESS	38.85	39.85	39.75

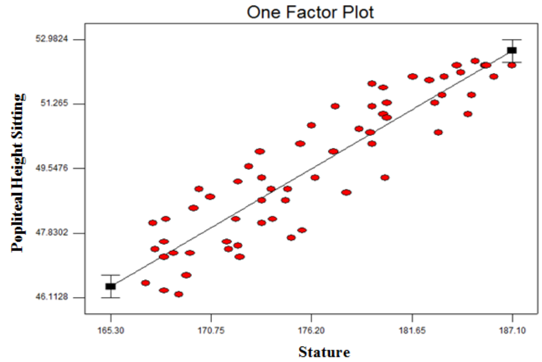

Figure 3. Correlation between Stature and PHS.

4.0 Conclusion

This study has established that there is a significant linear relationship between the Stature and PHS using HDD. It has also proposed an effective, efficient and reliable mathematical model which can be used to estimate PHS with Stature as the independent dimension with a view to mitigating the cost implication, time consumption and workforce required. Also developed a standard anthropometric database from where automobile manufacturers and other designers could draw the appropriate dimension for seat design.

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