

USER INSTITUTIONS OF OFFICE WORKERS IN GHANA: INVESTIGATING THE DIFFERENCES

Adu, G.

Department of Interior Architecture
& Furniture Production, Kumasi
Polytechnic Kumasi
GHANA

Adu, S.

Department of Wood Processing
Marketing, Kwame Nkrumah
University of Science & Technology
Kumasi, GHANA

Asare, K.P.

Department of Mathematics
and Statistics, Kumasi
Polytechnic Kumasi
GHANA

ABSTRACT

The aim was to investigate whether there are differences in the institutions of office workers based on their anthropometric measurements (such as popliteal to floor height, buttock to popliteal length, elbow to seat height, sitting shoulder height, knee height and width of bitrochanter). It follows that, anthropometric measurements of a number of office workers' from three public institutions in Ghana were studied in a survey. The study employed a Multivariate analysis of variance (i.e. a versatile multivariate statistical technique) for the data analysis. In the results, the p - values of the four different multivariate tests (Pillai's Trace, Wilks' Lambda, Hotelling's Trace and Roy's Largest Root) were all significant given $p = 0.000 < 0.050$. The finding was that, there was a significant effect of the anthropometric measurements in the three institutions considered as a group. Thus, the three institutions differed generally on the six anthropometric measurements variables. The main effects of the individual dependent variables was that four anthropometric measurements (popliteal to floor height, elbow to seat height, knee height and width of bitrochanter) significantly differ in the three institutions. The post hoc analysis was also carried out using the pairwise comparisons to know the institutions where the differences came from.

Keywords: Anthropometric measurements, office furniture, MANOVA, Public institutions, Ghana.

INTRODUCTION

Manufacturers of locally made office furniture do not consider dimensions of individual users when producing sitting office furniture for institution workers. Mismatches between human anthropometric dimensions and equipment dimensions reported by Kayis and Ozok (1991), Prado-Leon et al. (2001), Imrhan et al (1993), Kar et al. (2003) and Okunribido (2000) as quoted in Mandahawi et al. (2008), may be a contributing factor to increase accident rates and health problems.

Anthropometry is the science that measures the range of body sizes in a population (Deros et al., 2009). When designing products it is important to remember that people come in many sizes and shapes (Openshaw and Taylor 2006). The body dimensions of the user population are of primary importance in the design of workstations to accommodate healthy and comfortable posture (Helander, 1997). Also, appropriate use of anthropometry in design may improve the health and well-being, comfort, and safety (Pheasant, 1998; Field, 1985; Tunay and Melemez, 2008).

Public institution includes schools, colleges, courthouses, libraries, hospitals and other places that is run for the public to use. The six most common anthropometric measurements according to Panero and Zelnik (1979) are popliteal to floor height (PFH), buttock to popliteal length (BPL), elbow to seat height (ESH), sitting shoulder height (SSH), knee

height (KH) and width of bitrochanter (WOB). The anthropometric measurements are used to determine the dimensions of office furniture that will enable workers to maintain the correct sitting position. Addition of anthropometric measurements would yield more desire designs. The designs become safe, user friendly and increase performance and productivity.

Sheskin (2000) reported that many scientific studies analyze a single variable within the population or analyze multiple variables one at a time to reach meaningful and significant statistical and scientific conclusions. It follows that other studies require an additional level of analysis that goes beyond what simple univariate methods can provide. Multivariate statistical methods incorporate multiple variables into a single analysis (Bartoszynski and Niewiadomska-Bugaj, 2008). It is extremely helpful when there are multiple predictor variables within a population.

MATERIALS AND METHODS

Informed consent

Approval to conduct the study enabled the researcher to visit the offices during working hours. Respondents were approached during the working hours since subjects were required to be at work. Before respondents answer the questionnaire, researchers have to explain to subjects about the essence of the study. Recording started immediately after the explanation. For smooth exercise, the identity of office workers was kept private by writing codes (office code and institution code) on the data sheet instead of putting their names directly. All of the subjects participated in their own free will in the research as no compensations were given to the subjects.

Sampling design

The target population was public institutions in Ghana and the studied population was public institutions in Kumasi in Ashanti Region, including Ministries and Public Tertiary Educational Institutions. A two-stage random sampling technique helped in selecting the samples. It is required that the population elements are first divided into non-overlapping groups according to a certain criterion. In the first stage, a simple random sample of groups is selected; in the second stage, a simple random sample of elements is drawn from each of the groups selected during the first stage.

In all, there were twenty six (26) such public institutions as mentioned earlier in Kumasi Metropolis. A simple random sample was adopted to choose three institutions from the twenty six public institutions at the first stage. The selected institutions were Kwame Nkrumah University of Science and Technology (KNUST), Ministries of Lands and Natural Resources (MLNR), and Kumasi Polytechnic (KPOLY). At the second stage, KNUST recorded 186 number of administrative offices, MLNR recorded 85 number of administrative offices, and KPOLY recorded 91 number of administrative offices. This constituted a total population of 362 offices in all the three selected institutions.

A sample size of 186 number of offices was selected to carry out the study. For the calculation of the sample size (n = number of offices), the reader is referred to sample size calculation. An equal stratified sampling was adopted in allocating sample sizes to the three selected institutions and a simple random sampling used to select the offices where administrative staffs work. To this end, 62 administrative offices each were selected from the three individual institutions (KNUST, MLNR, and KPOLY). Following this, every

administrative staff from the offices was considered in the anthropometric measurements data collection. In all, 261 administrative staffs comprising of 82 from KNUST, 89 from MLNR, and 90 from K-POLY were involved in the study. In fact, these 261 workers patronize the locally made office furniture. The anthropometric measurements collected followed the same procedure as outlined in Adu and Adu (2015).

Descriptive research design was employed. The research process followed the problem statement, formulation of specific hypotheses and detailed information needs to arrive at a conclusive study. Also, the needed information was collected from a sample of the population units only once and this made the study, cross-sectional. The study applied single cross-sectional design which means that only one sample of respondents from the study population was involved in the study.

Sample size calculation

Cochran's (1977) sample size formula:
$$n = \frac{\pi}{\left(1 + \frac{\pi}{N}\right)}$$

Where:

n = Sample size

N = Population size = 362

Z = Level of confidence = 1.96

p = Baseline level for indicators = 0.5

d = Margin of error = 0.05 and,

$$\pi = \frac{Z^2 \times p(1-p)}{d^2} = \frac{1.96^2(0.5)(0.5)}{0.05^2} = 384$$

$$n = \frac{384}{\left(1 + \frac{384}{362}\right)} = \frac{384}{2.061} = 186$$

Statistical Analysis: Multivariate analysis of variance (MANOVA)

Multivariate analysis of variance (MANOVA) differs from univariate analysis of variance (ANOVA) in the number of dependent variables used. The main purpose of univariate analyses of variance is to determine the effects of one or more independent variables upon one dependent variable. Here, there arise situations in which measurements are available on more than one dependent variable.

The extension of univariate analysis of variance to the case of multiple dependent variables is known as Multivariate Analysis of Variance. This data analysis technique allows for a direct test of the null hypothesis with respect to all the dependent variables in an experiment. In the

study of MANOVA, a linear function in "y" of the dependent variables in the analysis is constructed, so that "inter-group differences" on y are maximized. The composite variable "y" is then treated in a manner somewhat similar to the dependent variable in a single ANOVA, where the null hypothesis is either accepted or rejected.

In many situations, it is further of interest how the altering of the combination of factors could explain variations, not in one, but several response variables simultaneously. The aim of conducting MANOVA is to determine how the quantitative variables can be combined to maximally discriminate between distinct groups of people, places, or things. There are several advantages of using MANOVA-models instead of many univariate ANOVA-models severally. With respect to MANOVA, it is possible to test joint hypotheses of differences for factor level means. MANOVA on the other hand takes into account the correlation between response variables and thus make better use of the information in the data (Littell et al., 2002).

In the univariate case the differences between several groups (treatments) is determined by performing analysis of variance (ANOVA). Usually data is collected on several variables in most of the studies. An interesting question here is whether overall, there is a difference between groups or treatments. For several variables, more data will be generated leading to more information. With more information, higher power is expected.

MANOVA Table

In univariate ANOVA, the total sum of squares [SS (total)] is partitioned into a sum of squares due to one or more sources and a residual sum of squares. Each source is associated with a number called the degrees of freedom representing the number of linearly independent contrasts or linearly independent parameters. In multivariate analysis, the p -variables are measured on each object or unit leading to a vector of responses for each object. Thus in p -dimensional MANOVA, p [SS (total)] s are divided, one for each variable measured. Also, there are measures of covariances between pairs of variables presented as sums of cross products. The MANOVA table construction results in the portioning of these measures of variances and covariance's which are collected in a matrix of sums of squares and cross products [written as SSPM(total)] into SSPM due to one or more sources (as in ANOVA) and a residual SSPM. Accordingly, for instance, the one way MANOVA table will be of the form as in Table 1.

In Table 1, H , R and T are $p \times p$ matrices, where p is the number of response variables, and h , r and t are the corresponding degrees of freedom values.

Table 1: Breakdown of One Way MANOVA table

Source	DF	SSPM
Between groups	H	H
Within group (Error)	R	R
Total	T	T

Testing in MANOVA

For a one way case, the statistical model for the MANOVA is of the form

$$\mathbf{y}_{ij} = \boldsymbol{\mu} + \boldsymbol{\alpha}_i + \boldsymbol{\varepsilon}_{ij} \quad (1)$$

$$i = 1, 2, \dots, t$$

$$j = 1, 2, \dots, r$$

where t is the number of groups and j is the number of observations for each group. In (1) the parameters are $(p \times 1)$ vectors and the $\boldsymbol{\varepsilon}_{ij}$ are vector random variables assumed to be distributed independently as $N_p(\mathbf{0}, \Sigma)$ where Σ is the covariance matrix of the residuals. Note

that the errors for different objects will be uncorrelated but the error within the same object may be correlated.

Under the null hypothesis $H_0: \alpha_i = 0, i = 1, 2, \dots, t$, the reduced model is

$$y_{ij} = \mu + \varepsilon_{ij}$$

A number of test statistics has been developed to test the effects in MANOVA (Anderson, 1984). All these test are based on the roots of the equation

$$|H - \theta R| = 0 \quad (2)$$

where H is the SSPM of the source to be tested and R is the SSPM residual as in Table 1. Equation (2) can also be written of the form

$$|R(H + R)^{-1} - \lambda I| = 0$$

$$\text{Where } \lambda = \frac{1}{1 + \theta}.$$

Number of solutions for θ is equal to the rank of the H matrix and the rank of H can be expressed as

$$\text{rank}(H) = \min(p, h) \quad (3)$$

Out of the statistics used the most common statistic is the Wilk's' Λ statistic which has the likelihood ratio approach, and is given by

$$\Lambda = \frac{|R|}{|H + R|} = \prod_{i=1}^p \lambda_i = \prod_{i=1}^p \frac{1}{(1 + \theta_i)}$$

An approximate distribution of Λ is the chi-square given by,

$$-\left(r - \frac{p - h + 1}{2}\right) \ln \Lambda \sim \chi_{ph}^2$$

where p is the number of response variables and h is the df of the source to be tested.

RESULTS

Test statistics of significant difference between institutions

Table 2 reported that, this test was significant using an $\alpha = 0.05$. Pillai's Trace = 0.630, $F(12, 506) = 19.48, p < 0.001$. Significantly, F indicated that there were significant differences among the Institution groups on a linear combination of the six dependent variables.

Table 2: Multivariate Tests of differences between three groups of Institutions KOLY, MLNR, KNUST

Effect	Test	Value	F	Hypothesis DF	Error DF	Sig.	Partial Eta squared (Variance of dependent variable)
Institution	Pillai's Trace	0.630	19.480	12.000	508.000	0.000	0.315
	Wilks' Lambda	0.450	20.724	12.000	506.000	0.000	0.330
	Hotellings Trace	1.047	21.985	12.000	504.000	0.000	0.344
	Roy's Largest Root	0.834	35.303	6.000	254.000	0.000	0.455

Main effects of the individual dependent variables

Because the MANOVA was significant, the univariate ANOVA results were examined (Table 3). These tests are identical to the six separate univariate one-way ANOVAs one would have performed if one opted not to do the MANOVA – provided that there are no missing data. The p values for the ANOVAs in the MANOVA output do not take into account that multiple ANOVAs have been carried out. To reduce Type I error, the study used a traditional Bonferroni procedure and tested each ANOVA at the .008 level (.05 divided by the number of ANOVAs carried out, which equated to the number of dependent variables). With the exception of buttock to popliteal length and sitting shoulder height, the ANOVA test revealed significant difference among the rest of the variables when the three institutions are considered at the $p = 0.008$.

Table 3: Test of Between-Subjects Effects

Source	Dependent variable	Type III Sum of Squares	DF	Mean Square	F	Sig.	Partial Eta Squared
Institution (KPOLY, MLNR, KNUST)	Popliteal-floor height	25179.832	2	12589.916	14.324	0.000	0.100
	Buttock-popliteal length	4363.174	2	2181.587	1.724	0.180	0.013
	Elbow-seat height	3815.337	2	1907.669	6.123	0.003	0.045
	Sitting shoulder height	11148.172	2	5574.086	3.273	0.039	0.025
	Knee height	112257.735	2	56128.867	79.218	0.000	0.380
	Width of bitrochanter	38439.648	2	19219.824	17.551	0.000	0.120

Post hoc Multiple Comparison

Figure 4 reported on post hoc multiple comparisons to see which pairs of means were different. Each comparison was tested at the alpha level for the ANOVA divided by the number of comparisons; for example, $\frac{.008}{3} = .0027$.

For test results of popliteal to floor height (PFH): There was a significant pairwise difference between Kumasi Polytechnic verses Ministry of Lands and Natural Resources.

For test results of Knee height (KH): There was significant pairwise difference between Kumasi Polytechnic and Ministry of Lands and Natural Resources, Kumasi Polytechnic and

Kwame Nkrumah University of Science and Technology, and significant pairwise difference between Ministry of Lands and Natural Resources and .

For test results of Width of bitrochanter (WOB): There was a significant pairwise difference between Kumasi Polytechnic and Ministry of Lands and Natural Resources, and Ministry of Lands and Natural Resources and Kwame Nkrumah University of Science and Technology.

Table 4: Pairwise Comparison

Anthropometric Measurements	Institutions	Significance
Popliteal to floor height	KPOLY vs. MLNR	0.000
	KPOLY vs. KNUST	0.078
	KNUST vs. MLNR	0.007
Buttock to popliteal length	KPOLY vs. MLNR	0.154
	KPOLY vs. KNUST	0.649
	KNUST vs. MLNR	0.623
Elbow to seat height	KPOLY vs. MLNR	0.893
	KPOLY vs. KNUST	0.015
	KNUST vs. MLNR	0.004
Sitting shoulder height	KPOLY vs. MLNR	0.628
	KPOLY vs. KNUST	0.232
	KNUST vs. MLNR	0.032
Knee height	KPOLY vs. MLNR	0.000
	KPOLY vs. KNUST	0.000
	KNUST vs. MLNR	0.000
Width of bitrochanter	KPOLY vs. MLNR	0.000
	KPOLY vs. KNUST	0.101
	KNUST vs. MLNR	0.001

DISCUSSION

The purpose of this study was to increase the understanding concerning office users' anthropometric measurement levels in public institutions. As a means of checking the occurrence of multicollinearity, correlation between the dependent variables should register low to moderate values. When the correlation value is 0.60 or above, one would consider either making a composite variable (in which the highly correlated variables were summed or averaged) or eliminating one of the dependent variables. This study reported low to moderate correlation. Researchers ensured that the data met the following assumptions before the MANOVA analysis: they included two or more dependent variables measured at the interval or ratio level (i.e., they were continuous); the independent variable consisted of two or more categorical independent groups; independence of observations; and adequate sample size.

Box's Test of Equality of Covariance Matrices gave Box's test = 93.759, $F(42, 195000) = 2.158$, $p = 0.000$. However, because the variance – covariance matrices is violated, Pillai's Trace test (which is very robust and not highly linked to assumptions about the normality of the distribution of the data) was used. With reference to Levene's test of equality of error variance, four (4) variables such as buttock to popliteal length, elbow to seat height, knee height and width of bitrochanter were violated.

To protect against Type I error, the study used a traditional Bonferroni procedure and tested each ANOVA at the .008 level. It followed that PFH, ESH, KH, and WOB < 0.008 . Thus, the null hypothesis that there are no differences, is rejected, hence they differ in the three institutions (Roebuck, et al., 1975). On the other hand, alpha level for BPL and SSH is > 0.008 . Thus, the null hypothesis is accepted, hence assumed equal. Because main effects of

those dependent variables were significant, one uses the post hoc test to determine where the differences lie. To ensure that Type I error is maintained, the study also needed to control the probability of committing one or more Type I errors across the multiple pairwise comparisons for the dependent variable at the .008 alpha level. With Bonferroni method, each comparison is tested at the alpha level for the ANOVA divided by the number of comparisons; for this example, $.008/3 = .0027$.

From a statistical point of view, popliteal to floor height and width of bitrochanter entirely meets the needs of two groups in locally made office chairs for the respective groups of users. Knee height on the other hand, statistically meets the needs of three groups in locally made office desks for the respective groups of users. Therefore, in order to manufacture furniture for three institutions on seat height (i.e. popliteal to floor height) and seat width (i.e. width of bitrochanter), two ranges of dimensions should be considered. Finally, for desk clearance (i.e. knee height), each institution's dimensions should be considered on its own merit.

CONCLUSIONS

Buttock to popliteal length, elbow to seat height, knee height and width of bitrochanter were not equal, while popliteal to floor height and sitting shoulder height were equal in terms of variances. From statistical point of view, popliteal to floor height, elbow to seat height, knee height and width of bitrochanter were different among office workers. The variables in which institution differences within the respective groupings were found included popliteal to floor height, knee height and width of bitrochanter. The three different institutions (Kumasi Polytechnic, Ministry of Lands and Natural Resources, and Kwame Nkrumah University of Science and Technology) dimension groups in seat width and desk clearance of locally made office furniture (chairs and desks) should be supplied to users in public institutions. Furthermore, two different institutions (Kumasi Polytechnic and Ministry of Lands and Natural Resources) dimension group (seat height) of locally made office chair should be supplied to users in the public institutions.

From the statistical point of view, knee height (desk clearance) met the needs of three groups, while popliteal to floor height (seat height) and width of bitrochanter (seat width) met the needs two groups of the patronised locally made office furniture.

RECOMMENDATION

Office chairs should be supplied in two dimensions of seat height and seat width (or individually adjustable chairs), while office desks should be supplied in three dimensions of desk clearance in order to enhance seat comfort of the individual user of the locally made office furniture.

ACKNOWLEDGEMENTS

With sincere gratitude and deep appreciation, we would like to thank Heads of institutions for the permission to conduct the study in their institution premises and to all workers who were involved in the data collection. To other data-recording assistants who helped with the data recording, we say thank you very much.

REFERENCES

- Adu, G. and Adu, S. (2015) Anthropometry Dimensions of Ghanaian Public Workers: Comparison of Age, Gender and Body Mass Index (BMI). *International Journal of Innovative Research in Science, Engineering and Technology*, 4 (5), 2670 – 2676.
- Bartoszynski, R. and Niewiadomska-Bugaj, M. (2008) *Probability Statistical Inference*, 2nd ed. Hoboken, New Jersey: Wiley-Interscience.
- Cochran, W.G. (1977) *Sampling techniques* (3rd ed.). New York: John Wiley and Sons.
- Deros, B., Mohamad, D., Ismail, A.R., Soon, O.W., Lee, K.C. and Nordin, M.S. (2009): Recommended chair and work surfaces dimensions of VDT tasks for Malaysian citizens. *European Journal of Scientific Research*, 34(2): 156 - 167
- Field, D. (1985) *Projects in Wood*. Netherlands: Mitchell Beazley Publishers, pp 11.
- Helander, M. G. (1997) Anthropometry in workstation design. In: Helander, M. (Ed.), *A Guide to the Ergonomics of Manufacturing*. London: Taylor & Francis: 17 – 28.
- Littell, R., Stroup, W. and Freund, R. (2002) *SAS for linear models*. SAS Institute.
- Okunribido, O.O. (2000) A Survey of Hand Anthropometry of Female Rural Farm Workers in Ibadan, Western Nigeria,” *Ergonomics*, 43, 282 – 292.
- Mandahawi, N., Obeidat, M., Altarazi, S.A. and Imrhan, S. (2008): Body anthropometry on a sample of Jordanian males. *Proceedings of the 2008 industrial engineering research conference* J. Fowler and S. Mason, eds.
- Openshaw, S. and Taylor, E. (2006) *Product Design Ergonomics* [Accessed 1st November 2010] Available from World Wide web: <http://www.allsteeloffice.com/NR/rdonlyres/3B6AC489-FC78-4B78-895A-OASD8A9E888A/O/ErgoHandbook.pdf>
- Panero, J. and Zelnik, M. (1979) *Human dimension and interior space*. New York: Watson-Guptill Publications.
- Pheasant, S. (1998) *Bodyspace: Anthropometry, Ergonomics and the Design of Work*, 2nd Ed. London: Taylor & Francis.
- Roebuck, J. A., Kroemer, K. H. E. & Thomson, W. G. (1975) *Engineering Anthropometry Methods*. New York: Wiley-Interscience.
- Sheskin, D.J. (2000) *Handbook of Parametric and Nonparametric Statistical Procedures*, 2nd Ed. Boca Raton, Florida: Chapman & Hall/CRC.
- Tunay, M. and Melemez, K. (2008): An analysis of biomechanical and anthropometric parameters on classroom furniture design. *African Journal of Biotechnology*, 7(8), 1081 – 1086.