Office Furniture Design – Correlation of Worker and Chair Dimensions

George Adu[1], Sylvia Adu[2], Bernard Effah[3], Kwasi Frimpong-Mensah[4], Nicholas Albert Darkwa[5]

[1, 3]Department of Interior Architecture and Furniture Production
Faculty of the Built and Natural Environment, Kumasi Polytechnic

[2, 4, 5]Department of Wood Processing and Marketing
Faculty of Forest Resources Technology
Kwame Nkrumah University of Science and Technology

Abstract: ***This study aimed at determining the relationship of anthropometric dimensions of workers from several offices in public institutions with the dimensions of institution chairs. Three dimensions of the chairs in daily use were evaluated to ascertain whether the fit is sufficient and the effect on workers' sitting posture. The study comprised of a sample of 261 workers from six public institutions in Ashanti Region, Ghana and one type of furniture. Dimensions of institution chairs were compared with three anthropometric variables of the workers. Descriptive statistics were analyzed for all variables. The study results show that furniture of appropriate dimensions is not available to a large number of workers in Ghana. Currently supplied office furniture is provided in several sizes and do not fit the users. It is recommended that work chairs may be acceptable if they are issued in four heights or individually adjustable chairs be introduced in Ghanaian institutions. Furthermore it is strongly recommended that institutions actively promote appropriate active sitting behavior.***

Keywords: public institution, office furniture, anthropometry of workers, chair dimensions, sitting.

1. Introduction

Public institution is the name that is applied to a school, college, courthouse, library, hospital and other place that is run for the public to use. The office furniture is an important part of the office environment, which plays a decisive role on the quality of the office environment. In today's office environment a worker is required to do office work with the office furniture (desk and chair) for at least six to eight hours per day. Thus, eight hours a day in office is likely not only to cause physical fatigue and disease, but also to have negative psychological effects. Modern office furniture must be designed to reflect the "human-centred" design values. It must also focus on improving working conditions and office efficiency. The applications of ergonomics knowledge, study human and office furniture as a whole, to create not only be able to ensure the environment fit for the characteristics of the physical body, but to make people work in scientific, healthy and reasonable way, and appreciate the fun of work in the efficient way[1]. Anthropometry is the science that measures the range of body sizes in a population. When designing products it is important to remember that people come in many sizes and shapes [2]. Recent trends in globalization and free trade agreements have forced some developing countries to import tools and other equipment from the Industrialized Countries without considering the anthropometric dimensions of the importing countries. Researchers have therefore stressed an urgent need to collect anthropometric data for the populations of industrialized developing countries (IDC) in order to introduce changes in equipment design and use [3]. Reach distances, work surface and chair heights, visual display unit (VDU), monitor heights and many other features of workstations should all be based on anthropometric data [4].The bodily dimensions of the user population are of primary importance in the design of workstations to accommodate healthy and comfortable posture [5] and [6]. Appropriate use of anthropometry in design may improve well-being, health, comfort, and safety [7], [8] and [9].

Mismatches between human anthropometric dimensions and equipment dimensions may be a contributing factor to increase accident rates and health problems, including musculoskeletal strains and cumulative traumas [10],[11],[12],[13] and[14]. The body dimension should match with furniture and equipment in a workstation. A mismatch in the work environment leads to users' discomfort, low productivity, work hazards, and accidents. Body dimensions of workers are important for the design of furniture. The mismatch is closely related to incorrect sitting posture and may be a predictor of back pain and future disorders. Disorders developed during working years may have permanent consequences to the human body and subsequently lead to significant problems during sitting and office work[15].[16] found that "poor sitting habits" were statistically associated with low back pain. According to [17], seating is a contributory cause of back injuries and the need for seating which adjusts both to tasks and people is paramount.

1.1 Office Furniture

Office furniture exists to enable people to carry out their work efficiently. Office furniture from manufacturers is typically not designed to accommodate the dimensions of the individual user. While all desks do not offer an overall height adjustment and chairs of different sizes, individual adjustments for the seat, arm and back are not offered. Instead, a one-size-fits-all philosophy has been adopted in the industry, because such furniture is less costly to manufacture and easier to sell at a lower price, and lessens the inventory problems for manufacturers and institutions. When some major institution furniture manufacturers in Ghana were asked what research they relied on for their furniture designs, the response was that they did not rely on

any. Instead, each company based their designs on specifications from the British Standards to decide "seat height, seat depth and seat width". Existing designs have basically been unaltered for years. Non-ergonomically dimensioned furniture, unsuited to body dimensions, increases physical strain, and commonly results in irregular posture [15].

1.2 Anthropometric dimensions of workers

[8] defined anthropometrics as a science that studies comparative dimensions of the human body, to arrive at the initial scale and dimensions of a piece of furniture. Specific measurements such as popliteal to floor height, buttock to popliteal length and width of bitrochanter are necessary in order to determine the dimensions of office furniture that will enable workers to maintain the correct sitting posture. Anthropometric data is one of the essential factors in designing machines and devices [18]. Incorporating anthropometric data would yield more effective designs. The designs are more user friendly, safer, and enable higher performance and productivity. According to [9], static anthropometric data on the other hand, are widely used in determining the dimensions of furniture. They said anthropometric data are used in ergonomics to specify the physical dimensions of work spaces, equipment, furniture, and clothing.

1.3 Chair dimensions

According to [19] a seat pan that is too wide or too deep may prevent the sitter from taking advantage of armrests and backrest. [20]saida chair is the main item of a workstation that provides adjustability for comfort and enables the work heights to be controlled. [21]said a deep seat will prevent the chair back from being used as a backrest or, if the backrest is used, the seat edge puts pressure on the legs. Such pressure can reduce circulation in the blood vessels and restrict the nerves close to the surface in the sensitive area behind the knee. A deep seat presses on the back of the legs, while a shallow seat may make the chair unstable. For deep office chair, one will need to adjust the backrest forward, insert a low back support (such as a lumbar support cushion, a pillow or rolled up towel), or get a new office chair.

1.4 Sitting

[22] said sitting is a means of changing posture and bringing rest. Sitting on an office work chair plays an important role in the field of work. It is estimated that about 75% of work in industrialized countries is performed while sitting [23]. Volume of work to the individual worker has the tendency to contribute to pain. It follows that the more the volume of work, the longer the worker sits resulting in low back pain or worsens an existing back or neck problem [24] and [25].Adopting good sitting posture will enhance comfort and will not put a lot of stress and strain on the user's buttocks, back or arm muscles, and will allow the user's feet to be on the floor [2]. Good posture will protect the supporting structures of the body against injury or progressive deformity [26]. Generally in normal office environments, many factors can influence workers' sitting posture; these include the anthropometric dimensions of office workers, the measurement and design features of the office furniture [16].

1.5 Present study

This study is aimed at determining to what extent the available institution chairs in the studied public institutions meet the needs of a specific population from institution groups I to VI, and to point out possible misuse of work furniture in their offices. The purpose of the study was to examine whether the dimensions of furniture, notably of chairs affect workers' sitting posture and appropriate for efficient productivity.The purpose of the study was to determine the difference between the six institution groups on a linear combination of the three anthropometric measurements (i.e. popliteal to floor height, buttock to popliteal length and width of bitrochanter).Differences in gender are analyzed. Given the scope of the available data, this work shows analytical results of the variables for height, depth and width of the used work chairs and the applied anthropometric dimensions (popliteal height, buttock-popliteal length and width of bitrochanter) considered as competent variables for establishing seat dimensions, in determinations whether the furniture dimensions are adequate for workers' posture.

2. Materials and Methods

The study was carried out from 2010 to 2012, with a sample of 261 workers (163 males and 98 females) from six institutions at two government ministries in Ashanti Region, Ghana. The selected public ministries differed in their job schedules, In the institutions, measurements were collected in the administration building from administrative staffs given that most or all the office furniture produced in Ghana were concentrated there. Workers were contacted during working hours, because all workers were required to be at work, and this setting offered easy access to data collection. Approval to conduct the study in these institutions enabled the researcher to visit the offices during working hours from 8am to 5pm within the 5 working days.

2.1 Dimensions of office work chair

Dimensions of institution work chairs were taken in the offices (at the point of use). Functional dimensions were recorded according to the standard [27]. Three ergonomic parameters (variables) important for proper design of the chair seat were recorded and labeled as shown in Figure 1, and were measured as the following:

- Seat height (SH): was measured as the distance from the highest point on the front seat to the floor.
- Seat depth (SD): was measured from the back of the sitting surface of the seat to its front.
- Seat width (SW) was measured as the distance from the left to the right point of the sitting surface of the seat.

All dimensions are expressed in millimetres.

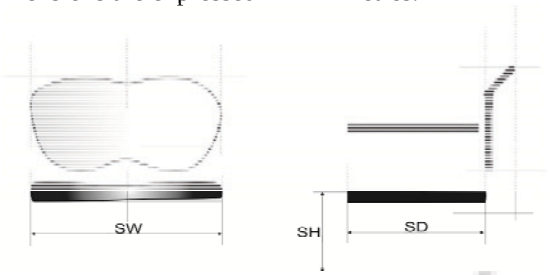

Figure 1: Functional dimensions of the seat of an institution work chair. SH - seat height, SD - seat depth, SW – minimum seat width (according to [27])

2.2 Anthropometric dimensions of the workers

Anthropometric dimensions, with the exception of height, were taken in sitting position [28], on the usually used adjustable chair, on a flat horizontal floor surface. The workers were sitting in relaxed and erected posture; wearing their own clothes; with their upper body vertical to the sitting surface; upper legs horizontal to the floor and the seat, perpendicular to the body and with the upper arms and elbows horizontal to the floor. Static anthropometry reference points for sitting variables were measured as the following:

- Popliteal to floor height (PFH): is the underside of knee to floor (body seat height) or is the distance, taken vertically with knee flexion from the foot resting surface to the posterior surface of the knee or popliteal space.
- Buttock to popliteal length (BPL): is the buttock to underside of knee or is the maximum length of the seat from front to backrest (seat length) or Seat length is the horizontal distance from the posterior surface of the buttock to the posterior surface of the knee or popliteal space with knee flexion.
- Width of bitrochanter (WOB): was measured as the maximal distance between the outside points at hips when seated.
- Stature (H): body height was measured as the vertical distance from the floor to the top of the head, while the worker stood erect, looking straight ahead.

Figure 2 shows the variables selected and analyzed. All dimensions are expressed in millimetres.

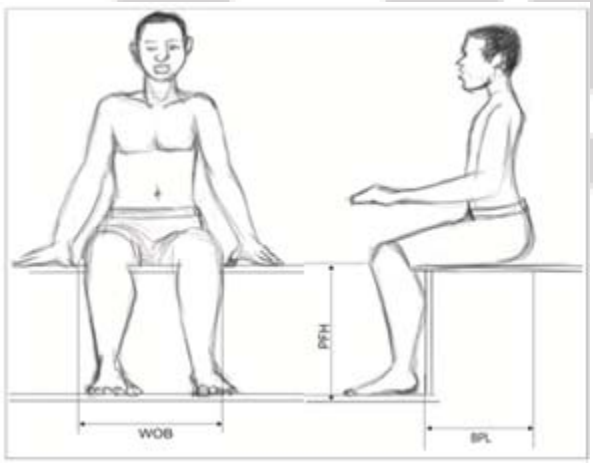

Figure 2: Anthropometric dimensions of the workers

Measured variables: BPL - buttock to popliteal length, PFH - popliteal to floor height, WOB - width of bitrochanter, maximum when seated

2.3 Statistical Methods

In order to find out how much the main parameter of institution work chairs and the workers' dimensions match or mismatch each other in ensuring ergonomically proper posture, we analyzed and tested the following variables of the chairs and the subjects.

- Seat height and Popliteal to floor height
- Seat depth and Buttock - popliteal length
- Seat width and Width of bitrochanter

Descriptive statistics was made for all analyzed variables. 5% was considered statistically significant. Seat height (i.e. popliteal to floor height), seat depth (i.e. buttock to popliteal length) and seat width (width of bitrochanter) are the common measurements considered in furniture design based on ergonomic principles [29]. The differences in the workers' popliteal to floor height, buttock to popliteal length and width of bitrochanter in the institutions were tested by independent t-test. Wherever the differences were statistically significant, Duncanpost hoc test was applied to determine between which institutions they existed. Statistical analyses and graphs have been made in the statistical package for Social Scientists (SPSS 16).

3. Results

3.1 Dimensions of office work chair

The analysis of office work chair in every institution included in this study identified one chair type. The chair was compared with the workers' dimensions. Analysis on the sizes seat height, seat depth and seat width are shown in Table 1.

Table 1: Measured Parameters of the Studied Office Work Chair (Dimensions in mm)

	Chair Type	*Height*	*Depth*	*Width*	*Description*
	Office Work Chair	472	457	477	Not fully upholstered chair. The angle of inclination of the backrest is not suitable for office use. There is no seat slope. No support for lower back.

3.2 Anthropometric dimensions of the workers

The data regarding anthropometric dimensions popliteal to floor height (PFH), buttock to popliteal length (BPL) and width of bitrochanter (WOB) were analyzed according to the institutions. Table 2 shows descriptive statistics (Mean, Standard deviation, Standard Error of the Mean, Lower 95% CI and upper 95% CI) of all the three analyzed variables. The results showed that the mean of popliteal to floor height, buttock to popliteal length and width of bitrochanter increased with gender, having more marked inclination in

institutions II and V. However, because it was not economical to produce different chairs for males and females, furniture dimensions which fit both sexes are used to produce an acceptable office work chair.

Table 2: Anthropometric Dimensions of the Variable PFH, BPL and WOB

			PFH						BPL		
	N	MV	SD	SE	L95% CI	U95% CI	MV	SD	SE	L95% CI	U95% CI
Total	261	461.30	31.13	1.93	457.52	465.08	496.34	35.68	2.21	492.00	500.67
Male	163	468.09	29.67	2.32	463.54	472.64	495.67	37.81	2.96	489.87	501.47
Female	98	450.00	30.35	3.07	443.98	456.02	497.45	31.96	3.23	491.12	503.78
Institution											
I	53	463.00	25.91	3.56	456.02	469.98	495.04	31.37	4.31	486.59	503.49
II	90	472.44	33.78	3.56	465.46	479.42	501.22	33.98	3.58	494.20	508.24
III	29	461.90	31.49	5.85	450.43	473.37	498.90	27.15	5.04	489.02	508.78
IV	36	445.28	29.42	4.90	435.68	454.88	481.81	41.04	6.84	468.40	495.22
V	19	451.05	22.83	5.24	440.78	461.32	506.84	46.97	10.78	485.71	527.97
VI	34	451.32	25.86	4.44	442.62	460.02	492.79	36.97	6.34	480.36	505.22

			WOB			
	N	*MV*	*SD*	*SE*	*L95%CI*	*U95%CI*
Total	261	360.88	38.74	2.40	356.18	365.58
Male	163	355.33	32.72	2.56	350.31	360.35
Female	98	370.10	45.80	4.63	361.03	379.17
Institution						
I	53	358.94	33.72	4.63	349.87	368.01
II	90	375.89	42.32	4.46	367.15	384.63
III	29	367.59	32.91	6.11	355.61	379.57
IV	36	349.72	37.07	6.18	337.61	361.83
V	19	340.79	29.26	6.71	327.64	353.94
VI	34	341.47	30.76	5.28	331.12	351.82

PFH – Popliteal to floor height, BPL – Buttock to popliteal length, WOB – Width of bitrochanter, MV- Mean value, SD – Standard deviation, SE – Standard error, L95%CI – Lower 95.00% Confidence interval, U95%CI – Upper 95.00% Confidence interval

3.3 Results of Statistical Evaluation

Comparison results in the parameters were tested among the workers from institution 1-VI. Independent t-tests were performed to examine the differences in measurements between males and females. The results show that there were significant differences in body height ($t = 12.74$, $p = 0.00$) and popliteal to floor height ($t = 4.73$, $p = 0.00$). In these measurements, males were larger than females. There was also significant difference in width of bitrochanter ($t = -2.64$, $p = 0.01$). Females were larger in this measurement (Table 3). The difference in popliteal to floor height when seated between the workers from II, IV and VI institutions showed a statistically significant difference $F(5,255) = 5.86$, $p < 0.001$) (Figure 3).

Table 3: Body Measurements of office workers (n= 261)

Body measurements	*Male*	*Female*
	Mean (SD)	Mean (SD)
Height (mm)	1728.55(65.34)	1627.08(56.94)
Popliteal to floor height	468.09(29.67)	450.00(30.35)
Buttock to popliteal length	495.67(37.81)	497.45(31.96)
Width of bitrochanter	354.84(31.71)	366.58(39.28)

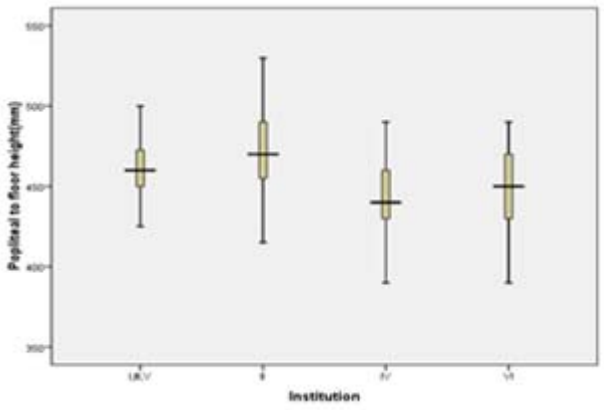

Figure 3: The differences of popliteal-floor height of the seated II, IV and VI institution workers

This information is in support of equipping public institution offices with four different height chairs, of which three heights are different among office workers in institutions II, IV and VI. Testing of the same height chairs in both institution groups of workers separately (from I-VI) showed a statistically significant difference in the popliteal to floor height when seated $F(30,1002)=9.45$; $p < 0.001$) (Figure 4).

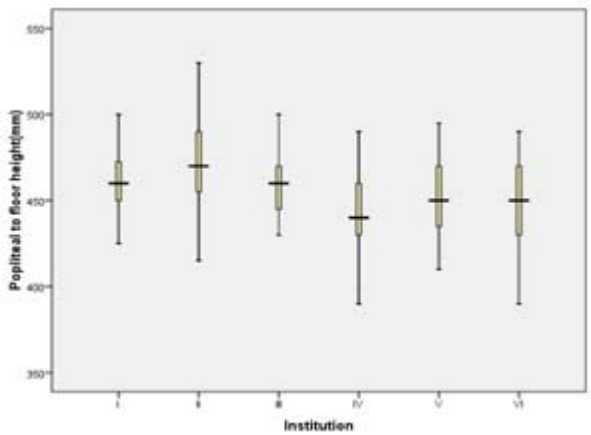

Figure 4: Differences in popliteal to floor height of I –VI institution workers when seated

Duncan's post hoc test (Table 4) showed statistically significant differences between institution II workers and other institutions. Consequently, these workers formed a separate, distinguished group. Institution II workers were statistically different in popliteal to floor height from IV, as well as those in the II and VI institution groups. Institution I

workers were not statistically different from institution III, and the latter was also not statistically different from institution V. This suggests that it might be necessary to design for four different seat heights for workers in those institutions.

Table 4: Multiple comparisons using Duncan Multiple Range Test for variable PFH

		Institution				
Anthropometric dimension	I	II	III	IV	V	VI
Popliteal to floor height	463.0^{ab}	472.4^{a}	461.9^{ab}	445.3^{c}	451.1^{bc}	451.3^{bc}

Means sharing the same letter are not statistically different

4. Discussions

Based on our study results the following were discussed:

Test results of PFH and SH. Popliteal-floor height between six groups of workers, institution I-VI, show and confirm sufficiency of four statistically significant height groups i.e. institution groups II, IV, VI and one for either I, III, or V (Figure 3). From a statistical point of view, this entirely meets the needs of both groups in that Ghana-made furniture is available for the respective groups of users. However, according to the collected data, seat height for the group of I, III, V should be seat height = 429mm and for the groups II, IV and VI are 449mm, 423mm and 429mm respectively. The above office work chair seat heights conform to the ones proposed by furniture designers as [22], [30], [31], [32], [28] and [33].The results (Table 3) show that male workers are slightly larger in stature and popliteal to floor height. The differences between the groups are statistically significant since the estimated p-values are less than the α-level of significance 0.05. For male adults the standard deviation (SD) of stature is 65mm which is slightly different from the one reported by [34], which was approximately 67mm. The difference was as a result of the age differences, where [34]looked at those aged 65 years and over while the study considered ages between 24 to 59 years.

Test results of BPL and SD. Test results of the seated buttock to popliteal length (BPL) and seat depth (SD) show that all furniture groups, were sufficiently deep and fitting. In connection with this result it must be noted, however, that only variables BPL and SD were taken into consideration, with no account of other variables e.g. height and slope of the seat or reference points of the backrest for the low back. Further studies should focus on the relations between these variables because the data for appropriate depth of the seat vary significantly, relevant to the seat height, backrest slope and the slope reference point for specific anthropometric dimensions of users. Test results of WOB and SW. Seat width of the studied chair complies with the analyzed width of bitrochanter (hip breadth). Hence, it can be concluded that all chairs are of appropriate dimensions.

Duncan's post hoc test for variable PFH; given significant difference of institution II from other institutions, it comprises a separate group which should use smaller size mark (i.e. height) of furniture. By harmonization of the mean PFH variable, institution II can get a better fitting seat height of SH (II) = 449 mm. Institutions I, III and V can be grouped together and get SH (I, III,V) = 429 mm. According to the results, SH for group IV would be SH (IV) = 423 mm, while that of SH for group VI would be SH (VI) = 429mm. Such data classification shows that the existing four height groups are sufficient.

Testing of all institutions (I–VI).Testing of the variable PFH in every institution separately (I–VI) gives a better picture of the required seat heights (Figure 4). According to the obtained values of the variable SH for the office work chair, 28% of the chairs is appropriate in Institution II, 11% in institution IV and 16% in institution V. Furthermore, the obtained values of the variable SH for chairs in institutions I, III and VI from the study reported less than 6% each that fits the institutions. The problem lies in majority of workers using too high office work chairs in their respective institution. The sitting posture of the six institution workers is improper, the feet are not at the floor and the shoulders are raised. Therefore, reading and writing is aggravated.

In an ideal world, offices should be equipped with the most suitable equipment, regardless of cost. The bodily dimensions of the user population are of primary importance in the design of workstations to accommodate healthy and comfortable posture [5].

According to [15], anthropometric dimensions of pupils should determine the standards and functional dimensions of school furniture, and this also applies to office workers. Popliteal to floor height and buttock to popliteal length measurements are much more relevant for chairs. The popliteal to floor height is a better measure of the appropriate seat height than the standing height of a person because of the variation in the trunk/leg ratio [21]. [35] Emphasized that the popliteal to floor height, after adjusting for heels, clothing and other issues is used to determine the height of the chair seat. Width of bitrochanter is used for chair width and space between armrest. [8] also saidthe length of a person's thigh (or buttock to popliteal length) determines the depth of a chair seat. The approach to sitting problem must take into account that human body is not designed to remain in a sedentary position for long periods of time.

Irrespective of new theories that are still under consideration, present work takes into account the available methods frequently applied in designing of institution work chairs or equipping public institution offices. The aim is to prove that many institutions in the chain (starting from designers, manufacturers, decision-makers in procurement of the equipment) neglect them by frequently failing to apply them. Comparison of the aforementioned parameters has shown that not even a small number of key parameters in design and finishing are respected by many, while one of the critical ones is compliance of anthropometric dimensions with dimensions of institution chairs. Although there were statistically significant difference in measured anthropometric variables between males and females, it was difficult to separate sex in the offices, especially because both genders always use the same type of the chairs and desks. With the omitting of this, the study has confirmed the assumption that there is almost few segment of the studied population, which has used the chairs of appropriate dimensions. The result is incorrect sitting posture.

5. Conclusion

In summary, this study suggests a substantial mismatch between the workers' dimensional variables, which are important for sitting, and dimensions of the work chairs in offices. These study findings are based only on the data from a convenience case in one region and institution district (Kumasi). Systematic anthropometric variations in gender and body dimensions may vary between other regions, which our study has not captured. These data must be included in future research and harmonized with international standards. Finally, our results are focused on three basic anthropometric variables for sitting positions, which are applied in static anthropometry. If sitting is defined as an active working position, our measuring system requires different approach and dynamic anthropometric values, including other (furniture and body) variables.

We recommend the introduction of the compulsory biannual anthropometric measurements in all public institutions for provision of preliminary data that will help the authorities and manufacturers equip offices with appropriately dimensioned furniture. In the real sense, chairs of very different sizes should be made available to fit different workers. However, this is often difficult to do for a variety of organizational reasons. Providing adjustable chairs, for example, might appear a suitable solution, but most of them might have great difficulties in adjusting such furniture to their size and liking [36]. Moreover, adjustable seats and desks are more costly than the ordinary one. Health professionals should liaise with institutional authorities to actively promote basic understanding of appropriate sitting position, of sitting behavior and of correct usage of adjustable furniture (where available).

The outcome of this study has added to the stock of knowledge already established about ergonomics of office furniture and their related health implications in Ghana. On the industrial level, the outcome of the study will alert companies and shops to take proactive measures to ensure that they design with variations to suit the users of the various offices to save lost production hours, legal proceedings and so on. To our fellow researchers, this study will pave way for further research to be carried out on office furniture designs in Ghana.

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Author Profile

Adu, G received his BSc. Degree in Agricultural Engineering and MSc. Degree in Wood Technology and Management from Kwame Nkrumah University of Science and Technology, Kumasi, Ghana in 1992 and 1997 respectively. During 1997 – 2005, he worked as Production and Quality Control Officer in the Company of A.G. Timbers, Kumasi, Ghana before joining Kumasi Polytechnic as Lecturer with the Department of Interior Architecture and Furniture Production and currently doing his PhD in Kwame Nkrumah University of Science and Technology Kumasi, Ghana and also asa lecturer at Kumasi Polytechnic, Kumasi in Ghana.

Sylvia Adu (Mrs.) is a Research Fellow at the Department of Wood Processing and Marketing, Faculty of Forest Resource Technology, Kwame Nkrumah University of Science and Technology (KNUST) – Kumasi, Ghana. She has worked with the Department since 2006 with expertise in Sawmilling & Machining and Timber Grading. She holds BSc. and MSc. degrees in Natural Resources Management and Wood Technology and Industrial Management respectively from the Kwame Nkrumah University of Science and Technology and is currently on a PhD. Programme in Wood Technology, KNUST. In 2010, she won a Canadian scholarship (The Canadian Bureau for International Education, on behalf of Foreign Affairs and International Trade Canada), to pursue a programme in Environmental Science – Agro-forestry. Her research interests include Wood Anatomy, Wood Processing, Wood Residue Utilization, Industrial Safety, and Assessment of sitting office furniture in the Ghanaian market, Wood Residue Management and basic research in Wood Science. She is currently the Head of the Department of Wood Processing and Marketing.