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# Anthropometric evaluation of public institution sitting furniture designs

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## Abstract

Musculoskeletal symptoms are one of the health problems among institution workers in Ghana. In Ghana, ergonomics principles important in the design and selection of office furniture to ensure that it will avoid any undue strain on the user have not been addressed and documented. Whether or not these strains are related to institution furniture has yet to be determined and published data on furniture size are lacking. The purpose of the study was to

determine whether the design of furniture in institutions is appropriate for workers' anthropometry. The work included a sample of 261 working population (163 males and 98 females) having the age range of 24 – 59 years from six public institutions in Ghana. The data collected included demographic information, data on perceived health and body and furniture measurements. The females' BMI was higher than that of the males. The females had wider hip breadth measurements in the sitting position. Only few of the participants had a chair with an appropriate seat height. Seat depth was found appropriate for large groups of workers. The study recommended that the design, manufacture and procurement of the office furniture should be based on body measurements of users. **Copyright © WJSTR, all rights reserved.**

**Keywords:** Institution workers; Furniture; Anthropometry, health problems and Musculoskeletal.

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## 1. Introduction

Musculoskeletal symptoms have been studied among adult populations at their workplace (Punnett and Wegman, 2004; Carnide *et al.*, 2006). Workplace furniture design and user anthropometry have become an important consideration in designing ergonomically appropriate furniture (Van Wely, 1970; Harris *et al.*, 2005). Murphy *et al.* (2009) said a mismatch between the physical requirements of a job and the physical capacity of a worker can result in musculoskeletal disorders. Musculoskeletal back problems are the largest cause of disability amongst people of working age. Back pain does not discriminate and there are sufferers throughout the office hierarchy (Back problem, 2009). In Ghana, ergonomics principles important in the design and selection of office furniture to ensure that it will avoid any undue strain on the user have not been addressed and documented. Whether or not these strains are related to institution furniture has yet to be determined and published data on furniture size are lacking. A survey was therefore conducted with 261 institution workers to determine whether the design of their institution furniture was appropriate for their anthropometry.

Schlender (2007) reported that office-workers are at higher risk of neck pain than others. Of this, female workers were three times more likely to develop neck pain than their male counterpart. Furthermore, Professor Hetinger's research published in the journal *Ergonomics* show that apart from the hard, physical jobs, administrative work is the major cause of the spine deformations. The reason for this is modern living, an increased IT and Internet usage, with users spending more time at the computer desk, be it at work or at home. Research has shown that inappropriate sitting, caused by poorly designed furniture, accounts for headaches (14%), pain in the neck and shoulders (24%), back pain (57%), backside (16%), lower leg (19%) and pain in knees and feet (2%). The findings showed that 96%, 72%, 97%, 89%, 84% and 94% participants of institutions I, II, III, IV, V and VI respectively had inappropriate chairs. The authors concluded that an inappropriate chair was one of the factors for the lower back pain. However, the study failed to provide the actual measurements of the chairs.

Inappropriately designed furniture results in accidents, injury and ill health resulting in a reduction of productivity performance (Morag 2003, Piegorsch *et al.* 2006). The use of appropriate furniture is critical to working efficiently. Mismatches between human anthropometric dimensions and equipment dimensions may be a contributing factor to increase accident rates and health problems (Kayis and Ozok, 1991; Prado-Leon *et al.*, 2001; Imrhan *et al.*, 1993; Kar *et al.*, 2003; Okunribido, 2000). In Ghana there is no published work/available data on this issue so far, hence the decision to conduct this study.

## 2. Purpose

The purpose of the study was to assess any match and mismatch between anthropometric measurements and furniture measurements of sitting office furniture in the Ghanaian market. Institution workers (aged 24–59 years) were the participants in the study, whose anthropometric measurements were surveyed.

### **3. Materials and Methods**

All public workers in the studied institution were approached and consents were sought from both institutional heads and workers before the data collection. 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. A total of 261 were used in the exercise.

#### **3.1. Measurements in the study**

All measurements were taken in relaxed standing and sitting positions. The unit for all the measurements was millimetres and kilogram. There were three main groups of measurement: anthropometry (stature); anthropometry (sitting); and furniture design. Measurements were taken as follows.

##### **3.1.1. Anthropometry – stature.**

Body height: measurement was taken while the worker was standing erect (i.e. barefoot on the part of the females and wearing of socks on the part of the males) against the wall.

**3.1.2. Anthropometry – sitting.** Workers were asked to sit on an adjustable chair with their elbows bent at 90° across the chest.

1. Popliteal to Floor Height or Popliteal Height: Popliteal height is the distance, taken vertically, from the floor to the underside of the portion of the thigh just behind the knee while the subject is seated with the body erect. The knees and ankles are usually perpendicular, with the bottom of the thigh and the back of the knees barely touching the sitting surface.
2. Buttock to Popliteal Length: Buttock-popliteal length is the horizontal distance from the rearmost surface of the buttock to the back of the lower leg.
3. Elbow to Seat Height: Elbow to seat height is the height from the top of the sitting surface to the bottom of the tip of the elbow.
4. Sitting Shoulder Height or Shoulder Height: Shoulder height is the distance taken vertically from the top of the shoulder at the acromion process to the subject's sitting surface.
5. Knee height: Knee height is the vertical distance from the floor to the midpoint of the kneecap.
6. Width of bitrochanter or Hip Width: Width of bitrochanter is the maximum width/breadth of the lower torso.

#### **3.2. Measurements of furniture design**

Seat height (i.e. popliteal height), seat depth (i.e. buttock popliteal length), desk clearance (the vertical distance from the floor to the bottom of the front edge of the desk), maximum functional elbow height and maximum acceptable desk height are the common measurements considered in furniture design based on ergonomic principles (Parcells et al. 1999). The chairs and desks used by the public workers were measured. Descriptions of measurements taken in this study, formulas for calculation and the criteria for a mismatch decision are listed in table 1 (Parcells et al. 1999).

#### **3.3. Procedure**

The data collected included demographic data, information on perceived health and body and furniture measurements. The demographic characteristics included gender, age, body weight and height. Questions on perceived health asked for the presence of lower back pain, upper back pain, neck pain, shoulder pain, leg pain, arm pain, hand pain and wrist pain in the previous 12 weeks and over. Body measurements and measurements of a chair and desk were also collected. All the participants were in their working clothes during the procedure and shoes were removed. Participants sat on an adjustable chair for all the anthropometric sitting measurements. On the furniture measurements, only chairs made in Ghana and patronized by participants were used in the data collection

## 4. Results

### 4.1. Demography

There were 163 males and 98 females participating in the study. The mean age was 40 (SD 8.80) years (table 2). They all lived and worked in Kumasi, in the Ashanti region of Ghana.

**Table 1:** Description of measurements in furniture design

Measurement	Calculation	Mismatch decision
Popliteal height- seat height	Office work chair Popliteal height 88 – 95%	Chair too low if measurement < 88%; Fit (88.01 – 95%); Chair too high > 95%
Buttock popliteal length – seat depth	Office work chair Buttock popliteal length 80 – 95%	Seat too shallow < 80%; Fit (80.01 – 95%); Seat too deep > 95%
Knee height and desk clearance	Office desk Desk clearance minus knee height from floor	No room for leg movement if desk – knee < 20mm; Fit if > 20mm
Maximum functional elbow height	For all subjects Vertical elbow height x0.8517+shoulder height x0.1483	
Maximum acceptable desk height (MADH)	Chair Maximum functional elbow height + seat height	MADH – desk height negative value = desk too high

**Table 2:** Distribution of gender by age category (n = 261)

Age category (years)	Gender				Total (n)
	Males		Females		
	n	%	n	%	
24 – 29	22	13.50	15	15.31	37
30 – 35	31	19.02	24	24.49	55
36 – 41	29	17.79	21	21.42	50
42 – 47	49	30.06	20	20.41	69
48 – 53	20	12.27	14	14.29	34
54 – 59	12	7.36	4	4.08	16
Total	163	100.0	98	100.0	261

## 4.2 Anthropometry

Table 3 shows the body measurements of workers. 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 ( $t = 12.74, p = 0.00$ ), weight ( $t = 3.62, p = 0.00$ ), popliteal to floor height ( $t = 4.73, p = 0.00$ ) and knee height ( $t = 2.68, p = 0.01$ ). In these measurements, males were larger than females. There was also significant difference in width of bitrochanter ( $t = -3.03, p = 0.00$ ). Females were larger in this measurement.

To estimate the proportion of the segment length to the body, the means of the ratio of each segment length to stature were calculated for males and females (table 4). The results show that there were significant differences in the ratios of their respective segments. These included popliteal to floor height ( $t = -2.51, p = 0.01$ ), buttock to popliteal length ( $t = -7.23, p = 0.00$ ), elbow to seat height ( $t = -3.33, p = 0.00$ ), sitting shoulder height ( $t = -4.28, p = 0.00$ ), knee height ( $t = -5.11, p = 0.00$ ) and width of bitrochanter ( $t = -7.40, p = 0.00$ ).

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

Body measurement	Males	Females
	Mean (SD)	Mean (SD)
Height (mm)	1728.55 (65.34)	1627.08 (56.94)
Weight (kg)	75.66 (10.49)	70.81 (10.47)
BMI (kg/m <sup>2</sup> )	24.81 (3.13)	26.29(4.02)

Popliteal to floor height	468.1(29.7)	450.0(30.4)
Buttock to popliteal length	495.7 (37.8)	497.5 (32.0)
Elbow to seat height	195.6(16.8)	192.3(19.7)
Sitting shoulder height	516.9(43.8)	508.4(37.4)
Knee height	612.2(33.6)	600.8(32.8)
Width of bitrochanter	355.3(32.7)	370.1(45.8)

**Table 4:** Ratios of segment length to stature (n = 261)

Body measurement	<u>Males</u>		<u>Females</u>	
	Mean	SD	Mean	SD
Popliteal to floor height	270.95	17.32	276.67	18.64
Buttock to popliteal length	286.90	21.76	305.75	17.91
Elbow to seat height	113.28	11.03	118.17	12.18
Sitting shoulder height	299.22	25.77	312.51	21.64
Knee height	354.13	22.54	369.20	23.92
Width of bitrochanter	205.64	18.69	227.70	29.49

Tables 5 and 6 show the correlation coefficients between measurements for males and females. It was found that there was high correlation between weight and body mass index for males. For females, there was also high correlation between weight and body mass index.

**Table 5:** Correlation coefficients between males' measurements (n = 163)

Correlation	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1 Height (mm)	-	0.47**	-0.08	0.28**	0.26**	-0.08*	0.18*	0.11	0.23**
2 Weight (kg)	0.47**	-	0.83**	0.13	0.07	-0.04	0.10	0.07	0.32**
3 Body mass index (kg/m <sup>2</sup> )	-0.08	0.83**	-	-0.02	-0.09	0.01	0.10	0.00	0.23
4 Popliteal-floor height	0.29**	0.13	-0.02	-	0.26**	-0.16	0.03	0.28**	0.01
5 Buttock-popliteal length	0.26**	0.07	-0.09	0.26**	-	-0.12	-0.04	0.06	-0.07
6 Elbow-seat height	-0.08	-0.04	0.01	-0.16*	-0.12	-	0.07	-0.07	0.16*
7 Sitting shoulder height	0.18*	0.10	0.01	0.03	-0.04	0.07	-	-0.019*	0.16*
8 Knee height	0.11	0.07	0.00	0.28*	0.06	-0.07	-0.19*	-	0.10
9 Width of bitrochanter	0.23*	0.32**	0.23**	0.01	-0.07	0.16*	0.16*	0.10	-

\*\*p < 0.01, \*p < 0.05



**Table 6:** Correlation coefficients between females' measurements (n = 98)

Correlation	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1 Height (mm)	-	0.26**	-0.20	0.28**	0.43**	0.18	0.36**	-0.00	-0.03
2 Weight (kg)	0.26**	-	0.89**	0.09	0.19	-0.00	0.19	-0.05	0.27**
3 Body mass index (kg/m <sup>2</sup> )	-0.20	0.89**	-	-0.05	0.00	-0.09	0.03	-0.07	0.29**
4 Popliteal-floor height	0.28**	0.09	-0.05	-	0.33**	0.07	-0.02	0.27**	-0.02
5 Buttock-popliteal length	0.43**	0.19	0.00	0.33**	-	0.05	0.16	-0.01	0.16
6 Elbow-seat height	0.18	-0.00	-0.09	0.17	0.05	-	0.15	0.23*	0.17
7 Sitting shoulder height	0.36**	0.19	0.03	-0.02	0.16	0.15	-	0.08	0.12
8 Knee height	-0.00	-0.05	-0.07	0.27**	-0.01	0.23*	0.08	-	0.00
9 Width of bitrochanter	-0.03	0.27*	0.29**	-0.02	0.16	0.17	0.12	0.00	-

\*\*p < 0.01, \*p < 0.05

### 4.3 Measures of office chairs and desks

Authors found one main model of office work chair and four main models of desks. In fact, the difference in the desks was based on the style of construction. However, the process of measurements is the same in all the styles. Some measures of interest in this study are shown in Appendix 1.

#### 4.3.1 Matching of body measurements and the size of the chairs/desks

Workers used in the study have their assigned office work chairs and desks in their respective offices. All the computations were done according to the sizes of the office furniture in the institution. The appropriateness of the chairs was evaluated according to the recommended criteria in the equations. Taking the mismatch criteria for judging appropriateness, comparisons of the height and depth of the office work chairs are shown in table 7. The findings indicate that most of the chairs were too high.

**Table 7:** Comparison of the height and depth of the office work chairs

	Recommended criteria	Office work chair	
		n	%
Seat height	Chair too low (< 88%)	3	1.15
	Appropriate	37	14.18
	Chair too high (> 95%)	221	84.67
Seat depth	Seat too shallow (< 80%)	18	6.90
	Appropriate	145	55.56
	Seat too deep (> 95%)	98	37.55

The mean maximum functional elbow heights for males and females were 243.2 (SD 16.1) and 239.1 (SD 18.4) respectively. The maximum acceptable desk heights were 717.9 (SD 30.3) and 707.5 (SD 36.2) for males and females respectively. Acceptable desk height was then calculated, which is the difference between the maximum acceptable desk height and the desk height. A negative value resulting from the subtraction indicated that the desk was too high, while a positive value denoted an acceptable desk height. Table 8 shows the extent of mismatch of the desk height for males and females with chairs respectively. More males and females had a higher desk when chair was given to the participants. Generally, both genders were affected by the given set of furniture.

**Table 8:** A mismatch in the acceptable desk height for males and females ( n= 261)

Description	Males		Females	
	Office work chair		Office work chair	
	n	%	n	%

Desk too high	130	79.75	77	78.57
Appropriate	33	20.25	21	21.43

#### 4.4. Perceived health condition

Participants were asked whether they had experienced lower back pain, upper back pain, leg pain, arm pain, wrist pain, shoulder pain, neck pain or hand pain as at the time data were collected. Table 9 summarizes the prevalence of the perceived problems, which was below average overall. Lower back pain had the highest prevalence of 44.5% (53.4% and 52.0% for males and females respectively).

**Table 9:** Prevalence of perceived problems as at the time of data collection (261)

Problem	<u>Male (n=163)</u>				<u>Females (n=983)</u>			
	<u>Yes</u>		<u>No</u>		<u>Yes</u>		<u>No</u>	
	n	%	n	%	n	%	n	%
Lower back pain	87	53.37	76	46.63	51	52.04	47	47.96
Upper back pain	36	22.09	127	77.91	28	28.57	70	71.43
Leg pain	25	15.34	138	84.66	20	20.41	78	79.59
Arm pain	31	19.02	132	80.98	28	28.57	70	71.43
Wrist pain	44	26.99	119	73.01	32	32.65	66	67.35
Shoulder pain	45	27.61	118	72.39	40	40.82	58	59.18
Neck pain	67	41.10	96	58.90	54	55.10	44	44.90
Hand pain	12	7.36	151	92.64	14	14.29	84	85.71

#### 5. Discussions

The results confirm that both vertical and horizontal measurements are correlated to stature for both sexes. Majority of the participants had a chair with too high seat height. For seat depth, it was found that seats were appropriate above average for the group of workers. Even the highest prevalence for lower back pain is considered low compared with that of the previous literature. The study revealed that there were high mismatches between seat height and popliteal height. In this case some of the workers will not be able to support their feet on the floor, generating increase tissue pressure on the posterior surface of the knee (García-Molina et al., 1992; Gutierrez and Morgado, 2001).

Both shallow and deep seats were encountered in the study. For shallow seats, workers' thighs would not be supported enough and would generate discomfort (Pheasant, 2003), while in too deep seats, workers cannot avoid the compression on the posterior surface of the knee and workers will place their buttocks forward on the edge of the seat (Panagiotopoulou et al., 2004), causing kyphotic postures due to the wrong

use of the backrest (Khalil et al., 1993; Orborne, 1996; Pheasant, 1991). According to researchers, a good backrest, fitting the natural spinal curves, stabilizes the spine, facilitates lumbar lordosis and reduces kyphotic postures (Yanto, 2008).

The situation of match does not produce mobility constraint because of no contact of the knees with the desk (Parcells et al., 1999; Sanders and McCormick, 1993). In this particular study, the considered match criterion for the desk clearance was the knee height plus 20 mm.

As a result of mismatch between desk height and elbow rest height, workers are required to work with shoulder flexion and abduction or scapular elevation, causing more muscle work load, discomfort and pain in the shoulder region (García-Molina et al., 1992; Szeto et al., 2002). Furthermore, due to the fact that the height of the desk exceeds their elbow rest height workers are forced to lift their arms and shoulders while writing.

## 5.1 Measurements of acceptable office furniture for male and female workers

Popliteal height (seat height), buttock to popliteal length (seat depth), desk clearance and knee height, maximum functional elbow height and maximum acceptable desk height are the common measurements considered in furniture design based on ergonomic principles (Parcells et al., 1999). By using body measurements of the workers according to gender in table 3, calculations of the minimum and maximum limits of popliteal height (seat height), buttock to popliteal length (seat depth), desk clearance and knee height, and the maximum acceptable desk height can be obtained. The actual calculations leading to the minimum and maximum accepted dimensions with zero seat slope are shown below:

### 5.1.1 For males

Popliteal height (seat height):

$$\text{Maximum height } 46.81 \times 9.5 \text{ mm} = 444.7 \text{ mm}$$

$$\text{Minimum height } 46.81 \times 8.8 \text{ mm} = 411.9 \text{ mm}$$

Buttock popliteal length (seat depth):

$$\text{Maximum depth } 49.57 \times 9.5 \text{ mm} = 470.9 \text{ mm}$$

$$\text{Minimum depth } 49.57 \times 8.0 \text{ mm} = 396.6 \text{ mm}$$

Knee height and desk clearance:

$$\text{Minimum } 612.2 + 20 \text{ mm} = 632.2 \text{ mm}$$

Maximum acceptable desk height:

Since the maximum functional elbow height was

$$(0.8517 \times 195.6) + (0.1483 \times 516.9) = 243.2 \text{ mm,}$$

Therefore, the maximum acceptable desk height should range from

655.1 (243.2 + 411.9 – 0 mm inclination) for minimum seat height at 411.9 mm to

687.9 (243.2 + 444.7 – 0 mm inclination) for maximum seat height at 444.7 mm.

### 5.1.2. For females

Popliteal height (seat height):

$$\text{Maximum height } 45.0 \times 9.5 \text{ mm} = 427.5 \text{ mm}$$

$$\text{Minimum height } 45.0 \times 8.8 \text{ mm} = 396.0 \text{ mm}$$

Buttock popliteal length (seat depth):

$$\text{Maximum depth } 49.75 \times 9.5 \text{ mm} = 472.6 \text{ mm}$$

$$\text{Minimum depth } 49.75 \times 8.0 \text{ mm} = 398.0 \text{ mm}$$

Knee height and desk clearance:

$$\text{Minimum } 600.8 + 20 \text{ mm} = 620.8 \text{ mm}$$

Maximum acceptable desk height:

Since the maximum functional elbow height was

$$(0.8517 \times 192.3) + (0.1483 \times 508.4) = 239.2 \text{ mm},$$

Therefore, the maximum acceptable desk height should range from

635.2 (239.2 + 396.0 – 0 mm inclination) for minimum seat height at 396.0 mm to

666.7 (239.2 + 427.5 – 0 mm inclination) for maximum seat height at 427.5 mm

## 6. Conclusion

It is believed that the appropriate use of anthropometry in design may improve well-being, health, comfort, and safety (Pheasant, 1998 and Field, 1985). The results of the study highlight the extent of the ergonomic problems in institution furniture and the anthropometry of institution workers, although the extent of perceived health problems resulting from the mismatched chairs and desks used is below average. Recommendations on the size of chairs and desks to be used by males and females suggested that the design, manufacture and procurement of the office furniture should be based on body measurements of users. From time to time institutional heads should liaise with health workers to examine the health status of their staffs to avoid musculoskeletal disorders, improve workers morale and increase productivity. Institution workers should be educated on sitting posture.

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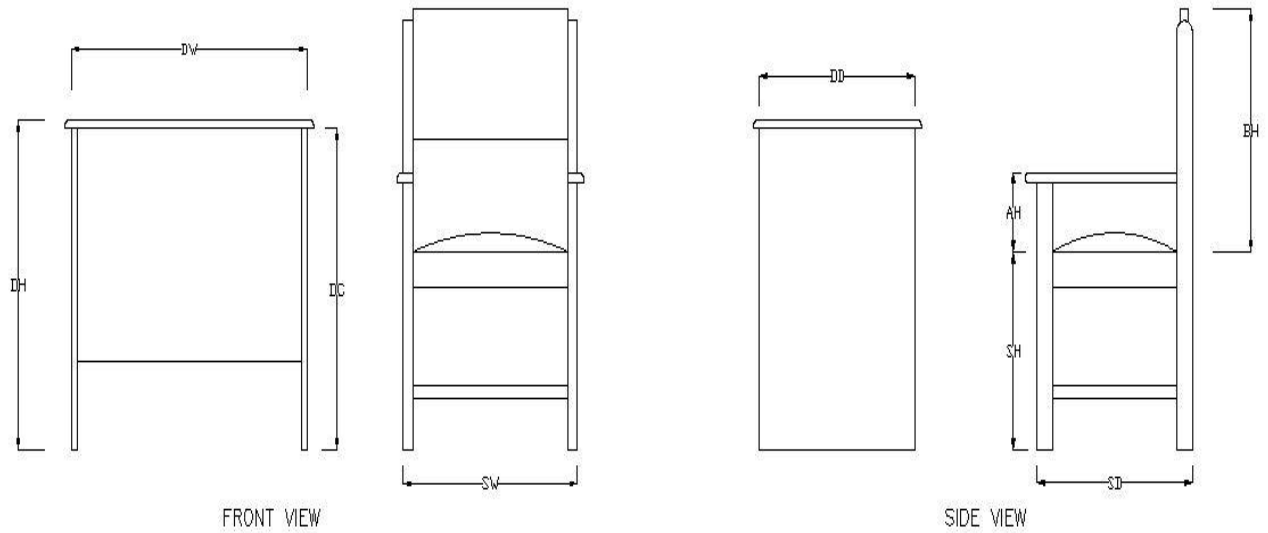
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### Appendix 1: Representation of the office furniture measures



DW = DESK WIDTH, DH = DESK HEIGHT, DC = DESK CLEARANCE, DD = DESK DEPTH, SW = SEAT WIDTH, SD = SEAT DEPTH, SH = SEAT HEIGHT, AH = ARMREST HEIGHT, BH = BACKREST HEIGHT