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# Development of Ergonomic Computer Workstation for Secondary School Children in Owo Metropolis

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***Authors' contributions***

*This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.*

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## ABSTRACT

This study evaluated existing computer workstations, which includes computer workstation tables and chairs for computer users', and developed new one for secondary school students in Owo metropolis. Questionnaire was developed and administered to support investigation of existing computer workstation in some selected secondary schools within the metropolis. Also, essential human body measurements (i.e. anthropometric measurement) that are necessary for estimating the design parameters of computer workstation were identified from literatures. Subsequently, the essential anthropometric data were collected by taking the measurements of the relevant body dimensions of boys and girls randomly selected from JSS1-SSS3 classes of the selected secondary schools in Owo metropolis. The measurements were conducted using standard anthropometer and anthropometric tape. A conceptual design of computer workstation to be developed was determined and appropriate design principle (i.e. design for extreme, design for adjustable range or design for average) was employed to determine the values of the design parameters in respect of the anthropometric data collected. The determination of the values of design parameters were done in

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due consideration of the various features associated with each parameter and appropriate clearance, where necessary. Thereafter, a full scale prototype of the designed workstation was built. Evaluation of the workstation built was conducted by having representatives of small, average and large size users from within the targeted population walk through representative task on the workstation and then assessing their comfortability in doing the task using the developed questionnaire. The responses collected from the questionnaire administered were analyzed using average rating. Also, Analysis of Variance (ANOVA) was applied to examine the effect of age, sex and height on the comfort of the users using their responses. The evaluation result revealed an average respondents rating of “4.30” and “3.99” for the Table and Chair respectively in comparison with the existing ones whose average rating is“1.79” and “1.38” respectively. This shows that the comfort experienced by the users while using the developed workstation is very high compared to the existing ones. Also, the ANOVA result revealed that age, sex and height have no effect on the comfort users perceived while using the workstation. Hence, the developed workstation would provide comfort for secondary school students in Owo metropolis and south western Nigeria thereby enhancing their performance and productivity.

*Keywords: Ergonomics; anthropometric data; computer workstation; evaluation; table; chair.*

## 1. INTRODUCTION

Ergonomics is the study of people while they use equipment in specific environments to perform certain tasks. It seeks to minimize adverse effects of the environment upon people and thus to enable each person to maximize his or her contribution to a given job [1,2]. Anthropometry is a research area in ergonomics dealing with the measurement of human body dimensions and certain physical characteristics. Anthropometric data can be used in ergonomics to specify the physical dimensions of workspaces, workstations, and equipment. This involves the application of ergonomic principles to achieve ergonomically sound design of a product [3]. Ergonomics is about matching equipment to the user and the task to the worker. To apply ergonomics, we need to know about human capabilities and of equal importance is what the person is trying to achieve. A fundamental issue in ergonomics is size. Humans come in a range of sizes. Not only those people, who are tall, short, thin or wide, there are those who have small hands, others with a long reach etc. One could imagine that there are different types of Chairs and Tables as there are people of different heights. A workstation is the place a worker occupies when performing a job or it may be one of several places where work is done. Some examples of workstations are work stands or worktables for machine operation, assembly, inspection, a worktable where a computer is operated etc. Researches had shown that good ergonomic design principles must be applied to give the operator or a range of operators the optimum man-machine interface and the adjustability required to prevent discomfort and prevent workplace injuries [4,5,6]. Sotoyama et al. [5] recommended desk height to be adjustable to the user’s height and the monitor to be set closer to the keyboard to provide a smaller ocular surface area. Khalid et al. [6] recommended the need for adjustability in school furniture, in order to accommodate the variation in anthropometric measures of different genders and ages. Also it was shown that many cases of shoulder and neck pain were caused by inappropriate design or use of furniture [7].

Momodu et al. [8] investigated ergonomic compliance in Nigeria computer workstations using a structured questionnaire backed up with oral interview. The major ergonomic deficiencies were revealed and it was shown that most of the Work Related Musculoskeletal Disorder (WRMD’s) complained injuries are: eye strain, shoulder pain, arm pain and back pain. Also, Adejuyigbe and Ali [9] identified the ergonomic problems of various furniture items used by staff and students in a Federal University in Nigeria and equally prescribed optimum design for them. However, the proposed specifications were based on foreign anthropometric data. Therefore, this study applied published ergonomic guidelines to propose adequate design dimensions based on the anthropometric data collected from the studied population thereby providing user friendly and ergonomically sound computer workstation for secondary school children in Owo metropolis, Nigeria.

## 2. METHODOLOGY

The descriptive method of research also known as statistical research, which describes data and characteristics about the population or phenomenon being studied, is adopted in this study using questionnaire and actual measurements in gathering information. Six secondary schools were selected within Owo metropolis and used for the purpose of the study. The study approached is as follows.

### 2.1 Evaluation of the Existing Workstations

Evaluation of the existing computer workstations available in the selected schools which involved a physical measurement of their relevant dimensions (design parameters) followed by the administration of a questionnaire to sixty students (thirty male and thirty females) selected from the schools was conducted. The students, who have been using the workstations before, were each given Microsoft word including graphics task to process on the workstation for twenty minutes before proceeding to fill a developed questionnaire to assess the comfort experience while carrying out the task on the workstation. This was randomly repeated three times, at different selected occasions, with each of the participants.

The questionnaire was constructed on the basis of health relevant information. It comprised of personal information and ergonomics/health questions (see Fig. 1). In response to the questions students' were asked to tick a number from 1 to 5 (representing very low to very high) that best represented their reaction to each of the questions [10]. Subsequently, the responses to the questions were analyzed.

### 2.2 Design of the New Workstations

A total of thirteen (13) anthropometric dimensions of two hundred and fifty (250) students, including one hundred and thirty eight (138) males and one hundred and twelve (112) females, selected from the six secondary schools considered for this study were measured and utilized for estimating the design parameters required to develop the workstation. The thirteen dimensions measured are; sitting height (SH), sitting eye height (SEH), sitting shoulder height (SSH), popliteal height (PH), sitting knee height(SKH), forearm hand length (FHL), sitting elbow height (SELH), thigh clearance (TC), buttock popliteal length (BPL), buttock knee length (BKL), shoulder hand length (SHL), sitting hip breadth (SHB) and shoulder breadth (SB). These were denoted as 1 to 13 respectively in Fig. 2. The participants' ages varied between 11- 18 years old. Appropriate guidelines and procedures to ensure accurate anthropometric measurement and evaluation as provide by ISAK [11], Cogil [12] and OSH [13] was followed to avoid errors.

The dimensions measured were recorded alongside the personal information, such as sex, age, sex, class and height, of each person measured. The data that were collected was analyzed to calculate the mean, the standard deviation, the 5th percentile and the 95th percentile and their values are as presented in Table 1.

Afterward, a computer workstationwas designed and developed in respect of the students' anthropometric data collected and analyzed.

The mean ( $\mu$ ), standard deviation ( $\alpha$ ), 5th percentile and 95th percentiles of the anthropometric dimensions collected from the sampled population/respondents are calculated using equations; (1), (2), (3) and (4) respectively [14].

$$\mu = \frac{\sum_{i=1}^{n} \mu_i}{n} \quad (1)$$

$$\alpha = \sqrt{\frac{\sum_{i=1}^{n} (\mu_i - \mu)^2}{n}} \quad (2)$$

$$5^{th}\text{percentile} = \mu - 1.65\alpha \quad (3)$$

$$95^{th}\text{percentile} = \mu + 1.65\alpha \quad (4)$$

Where $\mu_i$ is the data collected from the $i^{th}$ member of the sample.

#### 2.2.1 The workstation chair design

In respect of the design parameters of a workstation Chair and their determinants, Table 2 shows the values of the design parameters required for constructing workstation Chair for the studied population.

**SECTION A: Background Information of Students (Please tick/fill as appropriate)**

Name of Student: ..........................................................................................

Gender: (a) Male ☐ (b) Female ☐

Age of Student: (a) 8-12 ☐ (b) 13-17 ☐

Height of Student: (a) 145-165 ☐ (b) 166-180 ☐

Level of Education: (a) JSS 1-3 ☐ (b) SSS1-3 ☐

Weight of the Student: ..............................................

**SECTION B: Assessment of Computer Workstation Table and Chair. Please tick (√) as Appropriate from the following alternatives: 5= Very high, 4= High, 3= Moderate, 2= Low, 1= Very low**

| S/N | CRITERIA | 5 Very High | 4 High | 3 Moderate | 2 Low | 1 Very Low |
|---|---|---|---|---|---|---|
| 1 | Your most frequently used items are within easy reach. (Arm Pain Contributor) | | | | | |
| 2 | Your lower back is supported by the curved part of the chair backrest. (Back Pain Contributor) | | | | | |
| 3 | You are able to sit without feeling pressure from the chair seat on the back of your thighs or knees. (Back Pain Contributor) | | | | | |
| 4 | Your feet are fully supported by the floor or a footrest. (Leg Pain Contributor) | | | | | |
| 5 | You can easily adjust your Table and Chair when you're sitting on it. | | | | | |
| 6 | You can adjust the height of your Table and Chair to achieve a straight wrist posture. (Wrist Pain Contributor) | | | | | |
| 7 | You can reach your mouse comfortably without stretching. (Arm Pain Contributor) | | | | | |
| 8 | You can maintain a comfortable, upright head posture when using your computer without tilting your head up and down. (Neck Pain Contributor) | | | | | |
| 9 | You have enough space beneath your work surface to move your legs. | | | | | |
| 10 | You are comfortable and free of pain while working. (Arm Pain Contributor) | | | | | |
| 11 | Your shoulders are relaxed and not elevated when you work on your keyboard. (i.e. you are not experiencing shoulder pain/arm pain) | | | | | |
| 12 | You are able to read the entire screen comfortably without straining your eyes. (Eye Strain Contributor) | | | | | |
| 13 | Your head is upright & straight not severely bent or turned when viewing the monitor. (Neck Pain Contributor) | | | | | |

**Fig. 1. Details of the administered questionnaire**

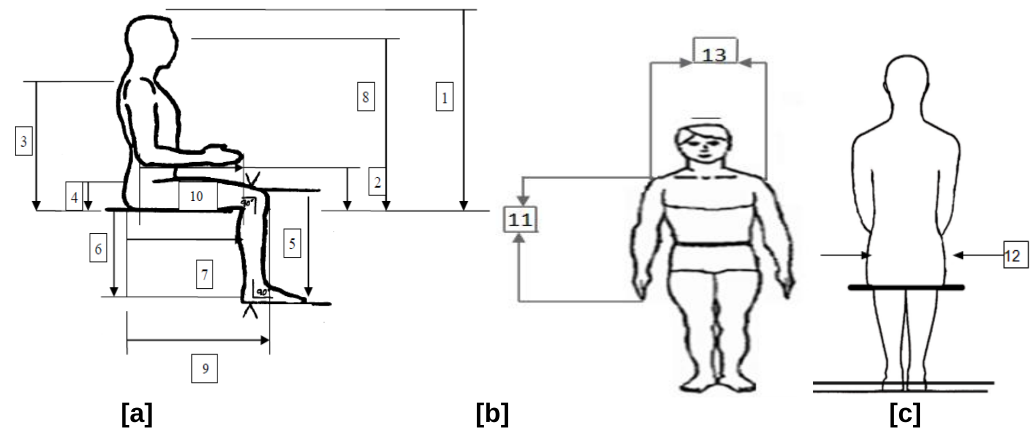


**Fig. 2. The thirteen anthropometric dimensions measured**

**Table 1. Analyzed anthropometric data, all units are in mm**

| Measured dimension | Mean | | | SD | | | 5th percentile | | | 95th percentile | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Male | Female | All | Male | Female | All | Male | Female | All | Male | Female | All |
| SHB | 350.0 | 365.0 | 357.5 | 24.5 | 15.8 | 20.2 | 309.6 | 338.9 | 324.2 | 390.4 | 391.1 | 390.3 |
| SH | 784.6 | 745.4 | 765.0 | 80.2 | 67.5 | 73.9 | 652.3 | 634.0 | 643.1 | 916.9 | 856.8 | 886.9 |
| SEH | 712.0 | 667.8 | 689.9 | 88.9 | 75.3 | 82.1 | 565.3 | 543.6 | 554.4 | 858.7 | 792.0 | 825.4 |
| SSH | 355.1 | 345.5 | 350.3 | 44.8 | 54.9 | 50.1 | 413.2 | 395.8 | 404.1 | 561.0 | 571.7 | 569.5 |
| PH | 467.7 | 467.6 | 467.5 | 31.5 | 26.3 | 29.1 | 363.7 | 371.5 | 367.3 | 467.7 | 458.3 | 463.3 |
| SKH | 494.2 | 493.1 | 493.6 | 44.6 | 53.9 | 49.5 | 420.6 | 404.2 | 411.9 | 567.8 | 582.0 | 575.3 |
| FHL | 416.1 | 412.4 | 414.2 | 22.0 | 20.6 | 21.3 | 379.8 | 378.4 | 379.1 | 452.4 | 446.4 | 449.3 |
| SELH | 198.8 | 202.1 | 200.3 | 18.2 | 24.2 | 21.4 | 119.8 | 125.5 | 122.3 | 179.8 | 205.3 | 192.9 |
| TC | 159.8 | 181.8 | 170.8 | 18.9 | 22.6 | 20.8 | 128.6 | 144.5 | 136.5 | 191.0 | 219.1 | 205.1 |
| SHL | 689.4 | 691.6 | 690.5 | 36.1 | 30.6 | 33.4 | 629.8 | 641.1 | 635.4 | 749.1 | 742.1 | 700.0 |
| BKL | 213.7 | 218.4 | 216.0 | 30.0 | 16.8 | 24.3 | 164.2 | 190.7 | 175.9 | 263.2 | 246.1 | 256.1 |
| BPL | 470.0 | 458.0 | 464.0 | 30.2 | 22.9 | 26.6 | 420.2 | 420.3 | 420.2 | 519.8 | 495.8 | 507.8 |
| SB | 377.3 | 353.1 | 365.2 | 33.3 | 30.6 | 32.0 | 322.4 | 302.6 | 312.4 | 354.2 | 350.3 | 351.8 |

**Table 2. Estimated chair design parameters**

| Design parameter | Anthropometric measure | Determinant | Design principle used/design dimension obtained |
|---|---|---|---|
| Seat height | Popliteal height | 5th percentile female and 95th male | Design for adjustable range 372 mm - 468 mm |
| Seat depth | Buttock popliteal length | 5th percentile of the overall students | Design for extreme (minimum) 420 mm |
| Seat width | Hip breadth | 95th percentile of the overall students | Design for extreme (maximum) 391 mm |
| Back rest height | Sitting shoulder height | Mean of the overall students | Design for average 350 mm |
| Arm rest height | Sitting elbow height | Mean of the overall students | Design for average 200 mm |

**Table 3. Estimated table design parameters**

| Design parameter | Anthropometric measure | Determinant | Design principle used/design dimension obtained |
|---|---|---|---|
| Table surface height | E=Sitting elbow height<br>P=Popliteal height<br>S=Sitting shoulder height | E + [(P + 2 )cos 30°] ≤ D≤ [(P+2)cos 5°] + (E0.8517) + (S0.1483) | Design for adjustable range 596 mm – 712 mm |
| Table surface depth | Shoulder hand length | 95th percentile of overall students | Design for extreme 700 mm (max.) |
| Table surface width | Shoulder hand length + Shoulder breadth | 95th percentile of overall students | Design for extreme 1050 mm (max.) |

The Table established values of the design parameters of the Chair in its 4th column using appropriate ergonomics design principle.

With reference to the data in Table 1, the dimension for seat height was taken from the 5th percentile female and 95th percentile male of the students' popliteal height to be 372 mm – 468 mm. It allows the operators to place their feet firmly on the floor or on a footrest because hanging legs put extra loads on lower back muscles. Besides, this combination with the work surface heights, allows the operators to achieve both a suitable keyboard-to-forearm relationship and adequate leg clearance.

The armrest of Chairs was also designed to be average as 200 mm, which is parallel to the floor, or held with the hand higher than the elbow. This dimension was taken from the mean of sitting elbow height of overall students. This is to ensure the wrist can be place flat on the Table and in the same plane as the forearm. The dimension of the seat width was determined using the 95th percentile of the sitting hip breadth of the overall students. The seat width should be wide enough to accommodate the user hip. In this study, the 95th percentile of hip breadth used is 390 mm. The anthropometric dimension to be considered in the design of the seat depth is the buttock-popliteal length. In this study, the 5th percentile of the buttock-popliteal length and thus the seat depth is 420 mm. For the design of the backrest height, the sitting shoulder height is considered; mean of the overall students of sitting shoulder height is adopted as the average in the current study. The mean of the overall students is 350 mm.

#### 2.2.2 The workstation table design

Parcells et al. [15] had suggested that Table height should be adjusted to elbow height measured from the floor, so that it would be minimum when shoulders are not flexed or abducted and maximal when shoulders are at 25° flexion and 20° abduction. Hence, according to Gouvali and Boudolous [16] equation (5), given as follow, was used to calculate the Table height (D).

$$E + [(P + 2)\cos 30°] \leq D \leq [(P+2)\cos 5°] + (E0.8517) + (S0.1483) \quad (5)$$

Where:

E is the sitting elbow height (SELH)
P is the popliteal height (PH)
S is the sitting shoulder height (SSH)

The value for E, P and S were taken from the 95th percentile calculation of the overall students (Table 1). Therefore, from calculation the Table height is recommended to be adjusted from 596 mm to 712 mm. Also, the Table surface depth and Table surface width were obtained from the 95th percentile of the overall shoulder hand length and shoulder hand length plus shoulder breadth respectively (see Table 1). Consequently the design parameters for the workstation Table are as given in Table 3.

#### 2.2.3 Material selection

Factors considered in selecting the engineering materials for the fabrication of the workstation were: cost of fabrication, design features, aesthetic, mechanical properties, corrosion resistance, ease of fabrication and service requirement. Generally wood, steel bars (hollow round and square angle), foam and plywood are used. Wood is mostly used in the manufacture of Table and Chair. It can be used in every part of the Table and Chair because of its comparatively low cost. Metal or steel bar is used to make the frame of the Table and Chair because it has good strength and machinability. Foam is usually used in the seat, arm rest and backrest of the Chair to produce a soft surface on the seat, arm rest and backrest. Plywood is used in seat, backrest and Chair. It is fastened to the steel by means of screw to provide a support for foam. Square bar was selected for the frame of the Table because it can be bent to a certain angle which reduces time and machining cost. Leather clothing is used on the surface of the Table and Chair to prevent moisture penetration through the foam.

##### *2.2.3.1 Parametric analysis for components' material size selection*

Three finite element models (FEMs) were developed and simulations were carried out to conduct parametric analysis for the wood and mild steel materials to be used for fabrication of components of the workstation. This is intended to minimize manufacturing cost of the workstation which, in turn, is connected with minimization of material consumption and the ability of the workstation to withstand the expected load. A Finite Element Analysis (FEA) software (ANSYS) was used for this purpose to analyze the force distribution and internal stresses in construction members. This allows verifying the strength of the workstation, which was designed and dimensioned in ANSYS to compare variants of component size, available in the market for achieving the design. The engineering properties of the materials used in the finite element model are as given in Table 4.

**Table 4. Material properties of wood and mild steel**

| Material | Wood (Birch) | Mild steel |
|---|---|---|
| Mass density | 0.55 kg/m$^3$ | 7.86 kg/m$^3$ |
| Yield strength | 56.3MPa | 207MPa |
| Ultimate tensile strength | 6.3MPa | 345MPa |
| Young's modulus | 10.3GPa | 220GPa |
| Poisson's ratio | 0.426ul | 0.275ul |
| Shear modulus | 3.6115GPa | 86.2745GPa |
| Expansion coefficient | 0.0000045ul/c | 0.000012ul/c |
| Thermal conductivity | 0.15W/(mK) | 56W/(mK) |
| Specific heat | 1200J/(kg c) | 460J/(kgc) |

## 2.3 Evaluation of the Developed Workstation

Evaluation of the workstation built was conducted by having representatives of small, average and large size users (see Table 5 for the characteristic anthropometric dimensions of the three groups) from within the targeted population walk through representative task on it and assessing their comfortability in doing the task as was done with the existing workstation.

**Table 5. Range of the main anthropometric dimensions for the small, medium and large users**

| Anthropometric dimension | Small users | Medium users | Large users |
|---|---|---|---|
| SH (mm) | 634-723 | 730-819 | 827-916 |
| PH (mm) | 364-394 | 401-431 | 437-467 |
| BPL (mm) | 421-447 | 457-483 | 493-519 |
| SHB (mm) | 310-332 | 340-362 | 369-391 |
| SSH (mm) | 396-448 | 458-510 | 519-571 |
| SELH (mm) | 120-143 | 151-174 | 182-205 |
| SHL (mm) | 630-664 | 673-707 | 715-749 |
| SB (mm) | 303-315 | 323-335 | 342-354 |

Sixty (60) students comprising of thirty (30) male and thirty (30) female students were selected at random for this evaluation. After walking through similar tasks, as with existing workstation, on the developed workstation, they were made to respond to the same questionnaire developed to assess the existing workstation using the same approach. Fig. 3 shows the constructed workstation.

**Fig. 3. The developed workstation**

### 2.3.1 Hypothesis testing

Certain hypotheses were postulate and analyzed to further evaluate the developed Table and Chair. Hypothesis testing helps to establish if a statistical difference is significant or not. In order to determine the significance, the computed value was compared with the appropriate critical value [F-Table value] at a chosen level of significance. In this case, 5% [$\alpha$ = 0.05] significant level or 95% confidence level was used to either reject or accept the hypothesis. This implies that 5% is the allowable errors for testing the hypotheses. In order to test the hypotheses, one-way Analysis of Variance [ANOVA] test was carried out to determine if the age, sex and height of the students significantly affect the comfort perceived using the designed workstation. The following hypotheses were set:

i. $H_{0(1)}$: Ages would affect the comfort perceived when using the workstation;
ii. $H_{1(1)}$: Ages would not affect the comfort perceived when using the workstation.
iii. $H_{0(2)}$: Sex would affect the comfort perceived when using the workstation;
iv. $H_{1(2)}$: Sex would not affect the comfort perceived when using the workstation.
v. $H_{0(3)}$: Height would affect the comfort perceived when using the workstation;
vi. $H_{1(3)}$: Height would not affect the comfort perceived when using the workstation.

## 3. RESULTS AND DISCUSSION

### 3.1 Existing Workstation Evaluation Result

The result obtained in respect of the comfortability of participants in using the existing workstation, revealed an average respondents rating of “1.79” and “1.38” for the Table and Chair respectively, showing that the comfort experienced in using the existing workstation is “low”. This implies that participants were not comfortable while using the existing workstation.

Work-related poor health symptoms experience by users of the existing workstation was found to be high from the response of the administered questionnaire. Fig. 4 shows the details of the distribution of poor health symptoms as estimated from the responses to the administered questionnaire.

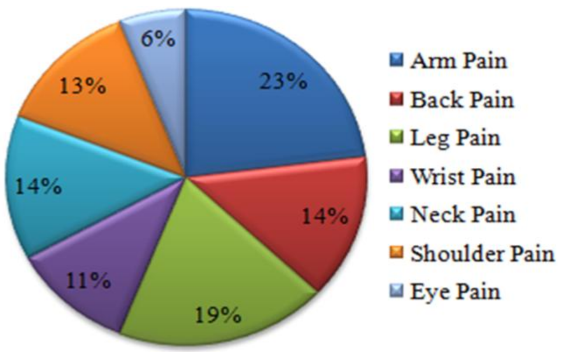


**Fig. 4. Distribution of poor health symptoms**

A wide variety of situations that could lead to health problems were reported: 6% of the respondents reported eyestrain, 13% shoulder pain, 14% back pain, 23% arm pain, 11% wrist pain, 14%neck pain, and 19% leg pain. These problems, eyestrain and musculoskeletal disorder, are indicators of ergonomic deficiencies in the school computer workstations. Eyestrain could be due to computers facing windows producing glare, user-to-monitor distance, long hours of computer use, inappropriate Table and Chair height, and inappropriate lighting. Musculoskeletal problems could be due to poor computer facilities and workstation layout, inappropriate workstation design, long hours in the same posture and inadequate rest breaks.

### 3.2 An Overview of the Collected Male and Female Anthropometric Data

Table 1 show that there are several major differences in terms of the mean values of the thirteen measured dimensions for males and females. The value for sitting height and sitting eye height are higher for male students compared to female students. These values are acceptable because normally boys are taller than girls. Meanwhile, the values for thigh clearance and sitting hip breadth of female students is larger compared to male students. Also, the Table shows clearly the differences in values of thigh clearance and hip breadth between males and females. This data shows that female has larger thigh and hip than male which can be explained by the fact that a female pelvis bone is slightly wider than male for reproduction purpose. Dlugos [17] explained that the female pelvis is more widely separated causing a widening of the hips with respect to the male.

### 3.3 Parametric Analysis Result

In respect of stress and strain analysis, the results obtained from FEA with ANSYS were compared to understand which of the materials’ dimension variant should be selected to minimize the cost of production. By applying a load of 392 N on the Table, which is the average weight of a desktop computer system with other computer accessories like documents holder, lamp stand, document, phones etc and a load of 540 N on the Chair, which is the weight of the heaviest student measured. The maximum stress and strain values for the three different FEM analyzed in respect of the three material size variants are presented in Table 6. It was observed that the thicker the material the lesser the displacement (strain) and the internal stress developed.

**Table 6. The maximum stress/strain values obtained from the FEA of the material sizes variant for the workstation**

| | Variant 1 | Variant 2 | Variant 3 |
|---|---|---|---|
| **Maximum stress (MPa)** | | | |
| Table | 2.237 | 2.368 | 2.687 |
| Chair | 255 | 256 | 257.4 |
| **Maximum strain (mm)** | | | |
| Table | 0.01166 | 0.01393 | 0.01877 |
| Chair | 12.67 | 12.71 | 12.78 |

Variant 3 with the highest maximum internal stress and strain was selected and used to construct the workstation. The reason for selecting variant 3 is that the size is the cheapest in market out of the three material variants considered and used in the simulation. Also, the simulation conducted revealed that the material size variant would carry the required loads without collapse.

**Table 7. Test of significance using analysis of variance ANOVA (Age)**

| Source of variation | SS | Df | MS | F (Ratio) | F (Critical) |
|---|---|---|---|---|---|
| Between groups | 0.8333 | 1.0000 | 0.8333 | 0.0133 | 4.0800 |
| Within groups | 2385.3330 | 38.0000 | 62.7719 | | |
| Total | 2386.1663 | 39.0000 | 63.6052 | | |

**Table 8. Test of significance using analysis of variance ANOVA (Sex)**

| Source of variation | SS | df | MS | F (Ratio) | F (Critical) |
|---|---|---|---|---|---|
| Between groups | 61.6333 | 1.0000 | 61.6333 | 0.9161 | 4.0800 |
| Within groups | 2556.5333 | 38.0000 | 67.2772 | | |
| Total | 2618.1666 | 39.0000 | 128.9105 | | |

**Table 9. Test of significance using analysis of variance ANOVA (Height)**

| Source of variation | SS | df | MS | F (Ratio) | F (Critical) |
|---|---|---|---|---|---|
| Between groups | 36.3000 | 1.0000 | 36.3000 | 0.5905 | 4.0800 |
| Within groups | 2335.867 | 38.0000 | 61.4702 | | |
| Total | 2372.167 | 39.0000 | 97.7702 | | |

### 3.4 Developed Workstation Evaluation Result

The result obtained in respect of the comfortability of the users while working with the developed workstation revealed an average respondents rating of “4.30” and “3.99” for the Table and Chair respectively. This shows that the comfort experienced while using the developed workstation on the average is “very high”. It implies that users were found to be very much comfortable while working with the developed workstation than when they worked with the existing one.

#### 3.4.1 Hypothesis testing result

The result obtained in respect of the comfortability of users while using the developed workstation, in respect of age, sex and height, using ANOVA is as presented in Tables 7, 8 and 9 respectively. From the Tables, the F critical value obtained from Table of F distribution (at 5% Significant Level) is found to be greater than the F (Ratio) value, for each of the cases/hypotheses i.e. (4.0800 > 0.0133 for Age, 4.0800 > 0.9161 for Sex and 4.0800 > 0.5905 for Height). These indicate that hypotheses $H_{0(1)}$, $H_{0(2)}$ and $H_{0(3)}$ (Null Hypotheses) would be nullified and the hypotheses $H_{1(1)}$, $H_{1(2)}$ and $H_{1(3)}$ stand. Hence, differences in age, sex and height of the students have no effect on the comfort that is perceived using the workstation. This result is a welcome development for this study as it substantiates the fact that the developed workstation is actually ergonomically sound.

## 4. CONCLUSIONS

The study focused on the suitability of workstation used for VDT according to the anthropometric data collected from students of secondary school. Chair and Table are the important furniture in the VDT’s workstation and they need to be designed ergonomically. This is important in order to fit at least 95% of the students. Suitable dimensions for the computer workstation are important to avoid musculoskeletal problems. A set of questionnaire was used to capture the experiences of the students towards the compatibility of the existing computer workstation with their body dimensions. The anthropometric data of the students were collected via measurement and utilized to design ergonomically sound computer workstation. The overall rating conducted to evaluate the performance of the developed workstation returned the calculated response to the comfortability generally experienced by the its users as “4.30” and “3.99” for the Table and the Chair respectively, showing that the comfort experienced in using the developed workstation is “very high”, compared to the existing ones whose average rating are “1.79” and “1.38” for the Table and the Chair respectively. Therefore the proposed dimensions and the developed workstation would provide a comfortable and productive workspace for secondary school students in Owo metropolis in particular, as well as in South-Western Nigeria in general.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

## REFERENCES

1. Kroemer KHE. Ergonomics on how to design for ease and efficiency. Englewood Cliffs, NJ, USA: Prentice Hall; 2003.

2. Chou JR, Hsiao SW. An anthropometric measurement for developing an electric scooter. International Journal of Industrial Ergonomics. 2005;35(11):1047-1063.
3. Bridger RS. Introduction to ergonomics. New York: McGraw- Hill Publisher; 1995. ISBN: 007007741X, 9780070077416
4. Harry CS. Ergonomic factors involved in optimum computer workstation design: A pragmatic approach; 2002.
(Accessed 15 November 2015)
Available:http://www.ergotron.com/Portals/0/literature/whitePapers/english/ERGONOMIC_FACTORS.pdf
5. Sotoyama M, Saito S, Suzuki T, Saito S, Taptagaporn S. Vertical gaze direction and eye movement analysis for a comfortable VDT workstation design. Luczak, H.; Çakir, A. E. and Çakir, G. editors. Work with Display Units. Amsterdam, the Netherlands: Elsevier. 1992;110–423.
6. Khalid SA, Mohamed ZR, Riyad AA. Ergonomically adjustable school furniture for male students. Academic Journals of Educational Research and Review. 2013; 8(13):943-955.
7. Shikdar MA, Ashraf A, Al-Kindi. Office ergonomics: Deficiencies in computer workstation design. International Journal of Occupational Safety and Ergonomics (JOSE). 2007;13(2):215–223.
8. Momodu BAI, Edosomwan JHE, Edosomwan TO. Evaluation of ergonomics deficiencies in Nigerian Computer Workstations. Journal of Ergonomics; 2014.
(Accessed 15 November 2015)
Available:http://www.omicsgroup.org/journals/evaluation-of-ergonomics-deficiencies-in-nigerian-computer-workstations-2165-7556.S4-008.pdf
9. Adejuyigbe SB, Ali DM. Ergonomic evaluation of furniture in higher institution in Nigeria: A case study of FUTA. Nigerian Journal of Industrial and System Studies (NJISS). 2004;3:24-30.
10. Kothari CR. Research methodology. Methods and Techniques, Second Revised Edition, New Delhi, India; 2004.
11. The International Society for the Advancement of Kinanthropometry (ISAK). International standards for anthropometric assessment. The International Society for the Advancement of Kinanthropometry; 2001.
(Accessed 20 October 2015)
Available:http://www.ceap.br/material/MAT17032011184632.pdf
12. Cogill B. Anthropometric indicators measurement guide. Washington, DC: Food and Nutrition Technical Assistance (FANTA) Project, FHI 360; 2003.
(Accessed 20 October 2015)
Available:http://www.fantaproject.org/sites/default/files/resources/anthropometry-2003-ENG.pdf
13. Occupational Safety and Health (OSH) Branch, Labour Department. A Guide to Work with Computers; 2010.
(Accessed 20 October 2015)
Available:http://www.labour.gov.hk/eng/public/oh/DisplayScreen.pdf
14. Deros BM, Mohammad D, Ismail AR, Soon OW, Lee KC, Nordin MS. Recommended chair and work surfaces dimensions of VDT tasks for Malaysian citizens. European Journal of Scientific Research. 2009;34(2):156-167.
15. Parcells C, Stommel M, Hubbard RP. Mismatch of classroom furniture and student body dimensions. Journal of Adolescent Health. 1999;24(4):265-273.
16. Gouvali MK, Boudolos K. Match between school furniture dimensions and children's anthropometry. Applied Ergonomics. 2006; 37(6):765–773.
17. Dlugos C. Pelvic cavity and organs, State University of New York Buffalo; 1999. (Accessed 17 July 2015)
Available:http://www.smbs.buffalo.edu/ana/newpage45.htm




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