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Design and Construction of a Drafting Table and Chair using Ergonomic Principles

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Abstract

This paper presents the design and construction of a chair and drafting table for the drafting workstation of the Kano State University of Science and Technology, Wudil, Nigeria. Anthropometric data were collated from 100 students: 97 male and 3 female students and studied. The NORDIC Musculoskeletal Questionnaire (NMQ) was used to ascertain the current status of the workstation which shows severe pains in the neck, lower back, and upper back and mild pains in the other anatomical areas. The analysis of the NORDIC questionnaire together with the anthropometric data were used in designing for the dimensions of the chair and drafting table for the workstation to alleviate the intensity of musculoskeletal trouble in the affected parts of the body and other anatomical areas. A prototype of the recommended chair with the following dimension: height 85 cm, depth 56.0 cm, width 42 cm, weight 580 N, height back rest 29 cm and drafting table: width 81.8 cm, length 93.6 cm, height 79.2 cm were fabricated using locally source materials considering the engineering properties of the materials and economic value in saving cost.

Keywords: *Drafting table, Ergonomics, Anthropometry, Biomechanics*

1.0 Introduction

The word Ergonomics comes from two Greek letter words; ERGO meaning work and NOMOS meaning laws. Hence, ergonomics is a science that focuses on the study of human fit, decrease in fatigue and discomfort through proper product design, work spaces and workstations (Scott and Erin, 2006). Ergonomics played a great attention in body positioning in order to prevent physical injuries that can occur from bad posture during work and is an integral part of modern design, manufacturing and use of products (Festervoll, 1994). Researches in ergonomics had lead to the increase in the efficient use of product through proper design based on biomechanics of the human body. This research aspect of ergonomics that deals with the measurement of human body dimensions and certain physical characteristics is called Anthropometry. Thus, anthropometry is the science that measures the range of body sizes in a population. Anthropometric data are often collated, analyzed and used in ergonomics to specify the physical dimension of work spaces, workstations, and equipments as well as applied to product design (Chou and Hsiao 2005, Davis et al, 2009). The need to protect the body from muscular-skeletal pain, cumulative trauma and reduce fatigue, increase productivity and efficiency of workers or equipments users necessitates proper anthropometric data collation and analysis for designing of work spaces, workstations and products. Anthropometric data varies considerably between regional populations of the world. For example, Scandinavian populations tend to be taller, Asians and Italians tend to be shorter and Africans tend to be stronger than Arabs (Scott and Erin, 2006).

Structural anthropometric are measurements of the bodily dimensions of subjects in fixed (static) positions. Measurements are made from one clearly identifiable anatomical land mark to another or to a fixed point in space (e.g. the height of the knuckles above the floor, the height of the popliteal fossa (back of the knee) above the floor, and so on) (Davis et al., 2009). Examples of structural anthropometric data are to specify furniture dimensions, ranges of clothing sizes, vehicle dimensions etc. Deros and Mohammad (2009) proposed and recommended a chair and table dimensions surface for Malaysian citizen's using Malaysian anthropometric data.
This paper presents ergonomic principles base on structural anthropometrics variables applied to the design and construction of a chair and drafting table use in engineering drawing studio using locally sourced materials. The design focuses on user's (students) comfort during drafting technique.

1.2 Methodology

For the purpose of this study, levels 200 and 300 students of Kano State University, Wudil were used. Ninety-seven male students were randomly selected with three female students making a total of one hundred students that were studied. Eight anthropometric data's were measured using traditional anthropometric measuring tools like tapes and weight scale. These are; Popliteal height (A), Buttock to Popliteal length (B), Hip breadth (C), Sitting elbow height (D), Buttock to back length (E), and Weight of the students (F) for the design of the chair while the related anthropometry measurements for drafting table are; sitting elbow height (D), Upper arm length (G) and Lower arm length (H) Tom Albin, (2008). The mean, standard deviation, 5th percentile and 95th percentile values of the anthropometric data were then evaluated. The analysis of the NORDIC questionnaire together with the anthropometric data were used in designing for the dimensions of the chair and drafting table for the workstation to alleviate the intensity of musculoskeletal trouble in the affected parts of the body and other anatomical areas (i.e. neck, shoulders, elbows, wrist/hands, upper back, lower back, hips/thighs/buttocks, knees and ankles/feet) in designing for the chair and drafting table dimensions.

1.3 Determination of Mean and Standard Deviation

To estimate the parameters of stature in a population, the mean and standard deviation are needed. The mean is the sum of all the measurements divided by the number of measurements. Thus, the value of the mean determines the position of the normal distribution along the x (horizontal) axis. The standard deviation is calculated using the difference between each individual measurement and the mean. It is a measure of the degree of dispersion in the normal distribution (David et al., 2002). Equations 1 and 2 were used for computing the mean and standard deviation respectively.

$$\bar{X} = \frac{\sum_{i=1}^{n} X_j}{n} \qquad (1)$$

$$S = \sqrt{\frac{\sum_{i-1}^{n} (X_i - \bar{X})^2}{n-1}} \qquad (2)$$

where
$\bar{X}$ = the mean
X_j = individual measurement
n = number of measurements
S = standard deviation

2.0 Determination of 5TH, 50TH and 95THPercentiles

Anthropometric dimensions for population are ranked by size and described as percentiles. Thus, a percentile value of an anthropometric dimension represents the percentage of the population with a body dimension of a certain size for design purposes. The 5th% to 95th% range accommodates approximately 90% of the population. For determination of the percentiles, equation 3 was used while multiplication factor F was selected from table 4 at the appendix.

$$X = M + (FxS) \qquad (3)$$

where
X = percentile value
M = mean of distribution (50th percentile value)
S = standard deviation
F = multiplication factor corresponding to required percentile (which the number of standard deviation to be subtracted from or added to the mean)

3.0 Results and Discussions

Table 1 shows the evaluated standard deviation, 5th, 50th and 95th percentile of the anthropometric data measured from the 97 male students and 3 female students in the School of Engineering of the University making a total of 100 students studied. Table 2 and 3 shows the dimensions of the designed chair and drafting table respectively.

3.1 Construction of the Chair and drafting Table

Factors considered in selecting the engineering materials for the fabrication of the drafting chair and table were: cost of the fabrication, mechanical properties of materials (e.g. stress, creep, fatigue etc), corrosion resistance, ease of fabrication (e.g. forming, nailing, bending, cutting etc), and service requirement including the most economical materials. These materials could be responsible for the working life of the chair and table, thus, allowing for easy loosening, maintenance and replacement (Onigbogi, 2012). The materials used for the construction of the chair and drafting table are cheap and easily obtainable in the local market. The chair was constructed using three-quarter inches thick round pipe and painted black. The pipes were cut to dimensions using hacksaw, bend to the required safety structural anthropometrics angle with the aid of the bending machine and welded. The top assembly is made from three-quarter plywood covered with foam and leather clothing. The leather clothing is to prevent moisture penetration through the foam. The drafting table is also fabricated using three-quarter thick round pipe, three-quarter highly polish plywood with the structural frame painted black. The highly polish plywood material for the table is chosen because wood is poor conductor of heat and its smooth surface finish will also reduce friction thus, allowing proper paper movement during drafting exercise.

3.2 Discussion

The design work considered 8 anthropometric data's measured from selected 100 Nigerian University students. These anthropometric measurements are; popliteal height (A), buttock to popliteal length (B), hip breadth (C),

Table 1: Evaluated standard deviation, 5^{th}, 50^{th} and 95^{th} percentiles of the Anthropometric data

Source: Survey, 2012

ID	Dimension	5^{th} percentile	50^{th} percentile	95^{th} percentile	S.D
A	Popliteal height	41.1	49.7	58.3	5.2
B	Buttock to popliteal length	39.0	56.0	73.0	10.3
C	Hip breadth	32.6	39.8	47.1	4.4
D	Sitting elbow height	58.9	69.1	79.2	6.2
E	Buttock to back length	46.8	53.3	59.7	3.9
F	Weight of the students	48.7	60.6	72.5	7.2
G	Upper arm length	32.4	38.1	43.8	3.5
H	Lower arm length	37.5	43.7	49.8	3.8

Table 2: Dimensions of the Chair

S/No	Part of the body (Location)	Dimension (cm)
1	Height	85
2	Depth	56
3	Width	42
4	Weight	580N
5	Height Back Rest	29

Source: Survey, 2012

Table 3: Dimensions of the Drafting Table

S/No	Part of the body (Location)	Dimension (cm)
1	Width	81.8
2	Length	93.6
3	Height	79.2

Source: Survey, 2012

sitting elbow height (D), buttock to back length (E), and weight of the students (F) for the chair while the related anthropometry measurements for the drafting table are; Sitting elbow height (D), Upper arm length (G), and Lower arm length (H).

The NORDIC Musculoskeletal Questionnaire (NMQ) was applied for evaluation of drafting technique. The results of the NORDIC questionnaire shows that the neck, upper back and lower back of the body are affected with severe pains while the right hand, left and right thigh, hips/buttocks, right wrist, right and left shoulders, left and right knee all experienced some degree of pains during the drafting activity. This is evident clear that Architectural and Engineering drawings activity causes pains, discomfort and fatigue most especially if the work spaces, workstation and equipments are not properly design for comfort and higher productivity and efficiency. The pains related to shoulder, lower back, upper and forearm, wrist, and the neck are due to student's awkward posture during working. The pains in the thigh, hips and buttock, and knee are due to the stretch muscular and static load position as noted by Tom Albin (2008). Thus, the analysis of the NORDIC questionnaire was used to address the intensity of musculoskeletal trouble in the affected parts and other anatomical areas (i.e. neck, shoulders, elbows, wrist/hands, upper back, lower back, hips/thighs/buttocks, knees and ankles/feet) that could be experience pains by the students.

The choice of the materials used for the fabrication of the chair and table is governed by factors such as mechanical properties and cost of materials, workability of the materials and service requirements. The chair and drafting table were constructed using locally sourced materials and appropriate technology to save cost

Figure 1: Drafting Chair

Figure 2: The drafting table

4.0 Conclusion

The anthropometric data of 100 students of school of Engineering of the Kano State University of Science and Technology, Wudil have been determined for the design of a drafting chair and table. The measured anthropometric data are; popliteal height, buttock to popliteal length, hip breadth, sitting elbow height, buttock to back length, and weight of the students for the chair while the related anthropometry measurements for the drafting table are; sitting elbow height, upper arm length, and Lower arm length. The NORDIC Musculoskeletal Questionnaire (NMQ) applied for evaluation of the current drafting workstation shows that the activity causes pains, discomfort and fatigue due to the incorrect postures as a result of the equipments. Most affected parts the neck, upper back and lower back with other mild pains in some other parts of the body.

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