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Ergonomic Appraisal of a Nigerian University Library

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ABSTRACT

Ergonomics considers the users of a product to design products that are safe, comfortable, and easy to use. This study appraises the academic library of a Nigerian University ergonomically. The air temperature, relative humidity, sound level and lighting intensities of various locations within the library were determined and compared with the internationally accepted standard. Anthropometric measurement of five hundred and twenty six of the library users were taken and used to determine the ergonomically supported furniture dimensions which was then compared with the dimensions of the furniture presently in use in the library. Also, questionnaires were distributed to the measured library users and evaluated to assess the user's satisfaction with the facilities available in the library. Result shows that the average air temperature in most locations is within the international standard range while the average relative humidity and the sound level are higher than (outside) the range. The average light intensity is within the international standard range for some locations while it falls below (outside) the range for some others. Finally, the dimensions of the existing furniture are generally within the value estimated from the anthropometric data of the library users.

Keywords: *Ergonomics, Anthropometry, Furniture, Body Dimension, Library, University, Nigeria.*

1. INTRODUCTION

Ergonomics is the scientific discipline concerned with the understanding of the interactions between humans and other elements of a system, and the profession applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance (IEA, 2000). Ergonomics is concerned with the "fit" between the user, equipment and their environments. It takes account of the user's capabilities and limitations in seeking to ensure that tasks, functions, information and the environment suit each user. To assess the fit between a person and the used technology, human factors specialists or ergonomists consider the job (activity) being done and the demands on the user; the equipment used (its size, shape, and how appropriate it is for the task), and the information used (how it is presented, accessed, and changed). Ergonomists draw on the principles of industrial engineering, psychology, anthropometry (the science of human measurement), and biomechanics (the study of muscular activity) to adapt the design of products and workplaces to people's sizes and shapes and their physical strengths and limitations. Armed with this complete picture of how humans interact with their environment, ergonomists can develop the best possible design for products and systems. Ergonomic application result in better job and working conditions. Benefits include reduction in work injury and ill health, improved worker's performance and satisfaction.

A library is an organized collection of information resources made accessible to a defined community for reference or borrowing. It provides physical or digital access to material, and may be a physical building or room, or a virtual space, or both (Allen, 1984). A library's collection can include books, periodicals, newspaper, manuscripts, films, maps, prints, documents, microform, CDs, cassettes, videotapes, DVDs, e-books, audio books, database and other formats. Libraries range in size from a few shelves of books to several million items. It is a place in which literary and artistic materials, such as books, periodicals, newspapers, pamphlets, prints, records, and tapes, are kept for reading, reference, or lending. Hence, the library can be generally described as an essential part of an institution which facilitates learning, study and research. It serves an academic environment (i.e. students, lecturers, etc); therefore the comfort of users of the library is paramount as this would ensure optimum output of its users such as increasing academic performances of students, encouraging effective study and research. It is therefore necessary for every institution to consider ergonomics while designing its library as this would affect its overall productivity.

2. LITERATURE REVIEW

Adapting the idea from a hierarchy of human needs developed by Abraham Maslow (1970), Jordan (1999) proposed a hierarchy of user needs in order to establish a constructive basis that can help to broaden and extend the scope of ergonomics beyond usability on the product design process. Consequently, after considering product requirements, a hierarchy of user needs, when interacting with products, was proposed as shown in Figure 1 (Bonapace, 2002).

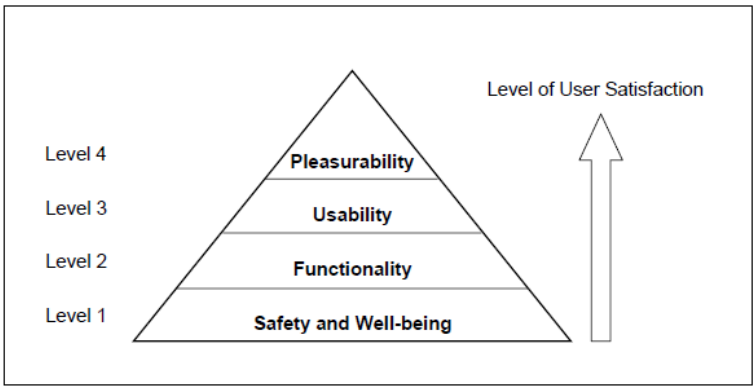

Figure 1: Hierarchy of user needs when interacting with products

While the role of ergonomists in the course of product design is to mainly focus on the functionality and usability of product, ergonomics as a scientific discipline has brought remarkable benefits to users of products in terms of safety, comfort, productivity, and easy-of-use (Wickens et al., 1998). Once appropriate functionality is satisfied, the user has tendency to need something more beyond the functionality (Jordan, 1999). In this sense, product usability can be one of them (Rubin, 1994; Rudy, 1997). In order to capture the usability, a product must be designed by adapting some or all of the ergonomic design principles related to a given product. However, it had been argued that subjective satisfaction of users should be included in the concept of usability in the consumer product domain (Nielsen, 1996) and that product usability is a function of both the user's performance and the user's subjective satisfaction (Wichansky, 2000).

Users' subjective aspects such as satisfaction, pleasure, and feelings towards a product have been greatly emphasized in the level of pleasurability (Jordan, 1999; Green and Jordan, 2002). Product pleasurability has been accepted as a new challenge in the area of ergonomics (Green and Jordan, 2002). Hence, users should derive great satisfaction from product and services rendered to them. Consequently, designer should take note of this and address it at the design stage of the product.

In a highly competitive academic environment, the library is an essential component of an institution's intellectual expression. Libraries must design their spaces and furniture in a way that meet the needs of 21st century learning, teaching, and research. Therefore considerations of ergonomic design factors which could support humans in achieving operational objectives within his/her workspace should be done during its design stage. Ergonomic factors that can have impact on the workplace include environmental factors, workstation factors, and psychosocial/organizational factors. The sound level as well as temperature and lighting intensities can have impact on the workers. It has been reported that environmental improvements such as thermal comfort, lighting, acoustics, and indoor air quality can increase worker productivity by 5% to 15% and can reduce employee absenteeism by 8% to 45%. Also, a direct correlation between noise in the workspace and performance has been found; wherein people within workspaces with fewer acoustic disruptions performed 2.6 times better than those with less acoustic control (GSA, 1999).

The library's workstations are arranged in an environment, where multiple individuals work in the same room with dividers to separate them. There are several sources of noise in this kind of environment. The noise produced by ventilation and air conditioning equipment, movement sounds such as the sounds of footsteps and conversations of co users all contribute to the sound level (ambient noise). The predominant effects of too much noise in this environment are distraction, disturbance of intellectual activities, and annoyance.

Ergonomic design standards have been established for libraries in terms of the sound level, the relative humidity and the temperature of the environment. The standard level of sound allowed in the library is 40dB (Aaberg, 2014). The relative humidity for libraries environment shall be set at a value (set point) between 35 and 50%, inclusive. The maximum acceptable total relative humidity variation or operating range shall be 5% on either side of the set point. The relative humidity therefore shall not go above 55% or below 30%. Also, the temperature of the library's environment shall be set at a value (set point) not to exceed 72ºF (21ºC). a temperature range of 5ºF on either side of the set point was established as the maximum acceptable temperature variation meaning that the air temperature shall not go below 67ºF and it shall not go above 77ºF (ANSI/NISO Z39.79-2001). These requirements (i.e. the standard values) should be considered in the design of libraries environment.

One of the most frequent subjects of ergonomics evaluations is the workstation, perhaps because so much research has linked improper workstations to work related musculoskeletal disorders (Bernard, 1995). A library chair is one of the most important pieces of equipment in the library. It should be the first priority for equipment expenditures and there should be no compromise with comfort and durability. Library patrons will sit for hours of intensive study and their comfort will determine their level of satisfaction with the library study experience. Also, work surfaces that are too high or too low can lead to awkward postures such as extending the arms to reach the surface, elbows held away from the body, and elevated shoulders, resulting in neck, arm, shoulder, and back pain. Repeated or continuous contact with hard surfaces, called contact stress, can create pressure that can inhibit nerve function and blood flow. Contact stress can be caused if the legs are press against a hard surface on a chair or elbows rest on a hard desk surface. Therefore, it can be concluded that the ergonomic factors that affect the comfort and pleasure of

library users include reading table and chair parameters, thermal factors such as relative humidity and air temperature, level of sound/noise and the light intensity. Consequently, this study evaluates a Nigerian University library ergonomically in respect of its design as it was not certain whether this important approach was considered at its design stage. Each of the ergonomic factors was reviewed against the international standard in respect of the library to appraise it ergonomically. The relative humidity, light intensity, air temperature, sound level and furniture design parameters were determined and compared with the accepted international standard. Also, the adequacy of the Library facilities was generally assessed. The existing library facilities and furniture at the Federal University of Technology, Akure, Nigeria, was used and hence served as a reference.

3. METHODOLOGY

The research work considered five major areas/locations of the library namely (1) reference section/unit, (2) circulation section/unit, (3) Reading room 1, (4) Reading room 2, and (5) newspaper reading stand. Environmental ergonomic data were measured and recorded in these areas over a period of four weeks in June to July and four weeks in December-January. These months were considered to represent the raining season and the dry season respectively. These are the two major seasons of the year in Nigeria. The ergonomic data collected in respect of the aforementioned locations include light intensity measured using Digital Luxmeter Model LX1010B, sound level measured using Sound Level Meter Model HT-80A, and relative humidity and temperature measured using Indoor/Outdoor Hygro-thermometer Model HH439. The data collected was averaged over the period of data acquisition and then compared with the international standard for industrial comfort.

The main workplace position for library users is sitting. Hence, seated anthropometric measurements of four hundred and twenty-two male and one hundred and five female students, selected at random, were taken using anthropometer and tape rule. The expected design parameters of the library workstation's chair and table in respect of the collected seated anthropometric data was estimated and compare with those of the chairs and tables presently available in the library.

Also, questionnaire was designed and administered to the library users, whose anthropometric measurements were taken, to access their satisfaction with the library facilities such as reading tables, sitting chairs, lighting, ventilation, fan, air conditional and the library's cleanliness. The Five point Likert method of summated rating (Kothari, 1995) was used to assess the responses of the respondents to questions. The respondents' responses to questions were graded as very high (excellent), high, moderate (average), low, very low with the corresponding score of 5, 4, 3, 2, 1, respectively. The data obtained were analyzed using mean score (average) and percentages. Average rating was obtained by dividing the total point score for each question by the total number of respondents. The average ratings were then interpreted as follows; Value between 4.01 to 5.00 as "very high" value between 3.01 to 4.00 as "high" value between 2.01 to 3.00 as "moderate", value between 1.01 to 2.00 as "low", and value between 0.01 to 1.00 as "very low".

4. RESULTS AND DISCUSSION

Figure 2 shows the average air temperature of the library measured at each location in comparison with the international standards during the wet and dry seasons. It can be noted that the measured air temperature at all the different locations of the library is approximately close to the standard or recommended international limit. The scenario reflected by the graph is the case and similar when all the windows in the respective locations are closed and the air conditioning units are switch on or when all the windows are opened and the ceiling fans are switch on. However, it was noted that when the air conditioning units and fans were not switched on, due to power failure, the air temperature rose to as much as 84.7 ^{o}C in the library during the dry season while it rose to about 80.1 ^{o}C during the raining season with the windows opened.

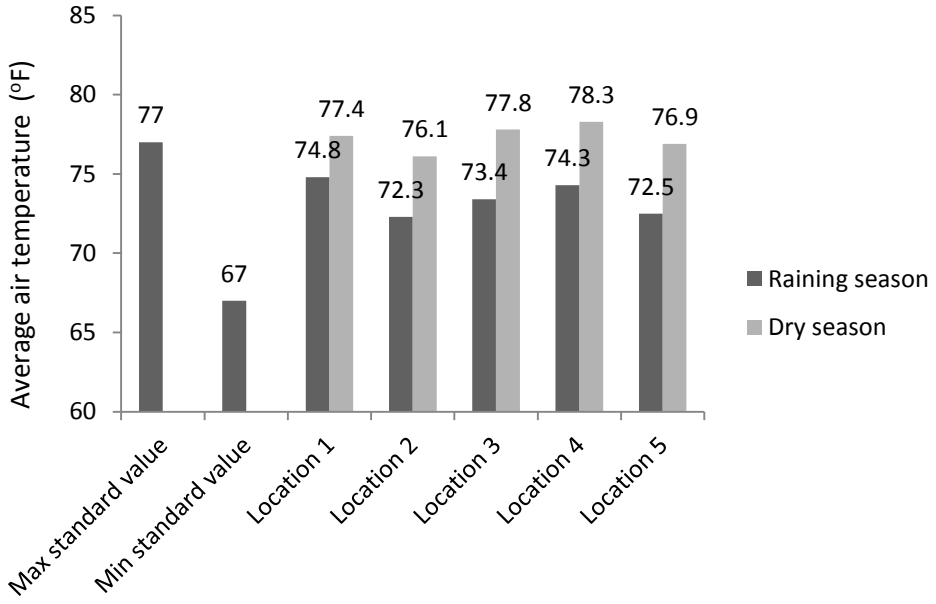

Figure 2: Comparison of the average temperature of the library with international standard

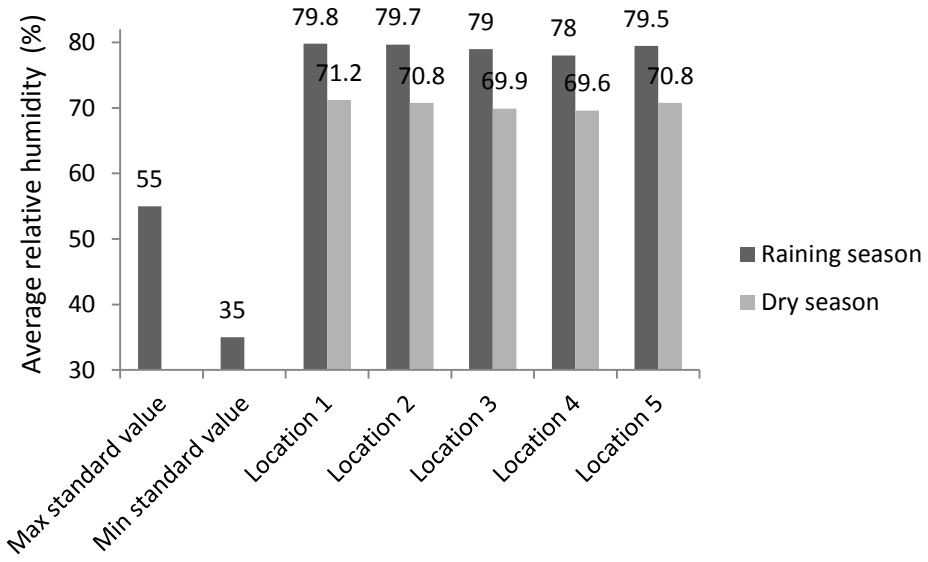

Figure 3: Comparison of the average relative humidity of the library with international standard

The values of relative humidity measured in the library were higher than the recommended international standard and this could cause a problem for library users (see Figure 3). The Figure shows that humidity was always above 69% even though the recommended value is 55%. The value of humidity measured during the dry season is lower than during the rainy season. Peoples' breathing is a primary source of moisture that causes humidity indoors. A person exhales approximately 200 milliliters of water vapour per hour while awake. However, this is easily removed during the dry season than the raining season because of the environmental condition. Humidity, determines the rate at which water can evaporate from the skin. When the air is full of moisture, it is harder for the air to absorb the sweat from our skin. The result is that we feel hot and sticky. Hence the following can be taken into consideration to improve the condition: (1) Opening of the windows preferably on opposite sides of the building to maintain a good cross air flow. This is the most effective method to remove internal moisture. (2) Keeping air at a comfortable and healthy humidity level through the use of dehumidifier is another important method when the windows are closed and the air conditioners are on.

Figure 4 provide a representation of the light intensities measured in the library compared to the international standard. There was no marked variation in the light intensities measured during the rainy season compare with the dry season hence one average value was estimated for each of the locations.

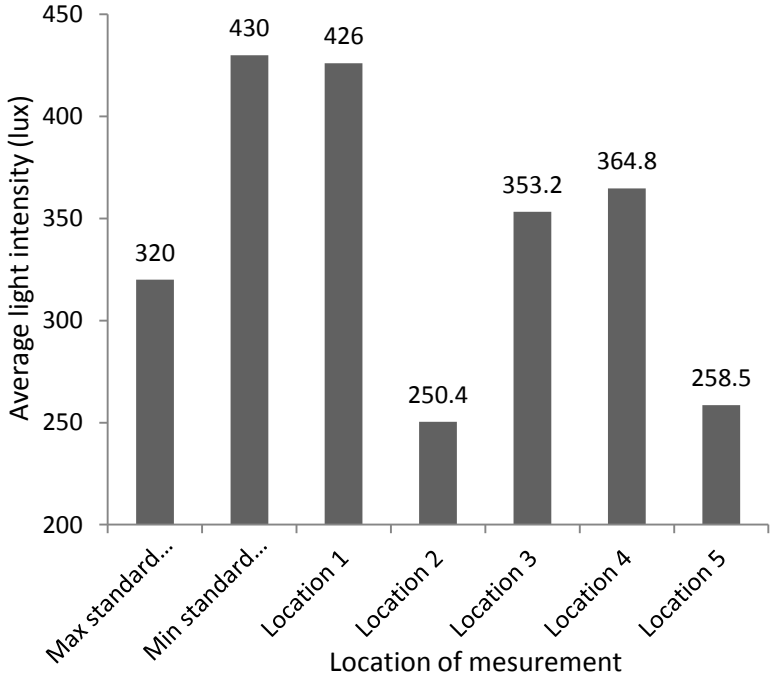

Figure 4: Comparison of the average light intensities of the library with international standard

Figure 4 showed that Location 1 (the reference section) has a high value of light intensity which falls within the international standard range. This was due to the nearness of the location and hence it's reading tables to windows. The natural light entering this location is much and is easily dispersed through the furniture. This could be the major cause of the high light intensity.

Location 2 (the circulation desk) has a very low amount of light as the average light intensity fall below the international standard range. Observation revealed that there is no window around the location. The major source of natural light is from the transparent roof which is about 25 feet away. The artificial light consists of fluorescent lights that are not appropriately positioned. They positioned at extreme end of the location and cannot disperse enough light to the entire location. Hence it is advised that the fluorescent lights be appropriately positioned possibly by suspending them to cover the entire location as any attempt to make windows around this location would be tedious and uneconomical. The average light intensity in locations 3 (reading room 1) and 4 (reading room 2) were found to be in the international standard range (see Figure 4). Hence it is good as it is.

The average light intensity obtained for location 5 (the newspaper stand) was below the international standard. This is due to its position which is at the corner of the library with just one window that is a bit away from it. The problem with artificial lighting provided here is similar to that of location 2; hence it is advised that appropriately positioned and sufficient artificial lighting be used in place of the insufficient natural lighting.

Poor lighting makes the visual system work harder and majorly leads to eyestrain. Also, poor lighting can also cause other, more indirect effects. For example the natural response to insufficient luminance is to get closer to the task or to look at it from a different direction. This can mean adopting unsuitable postures that lead to other forms of discomfort such as neck- and backache.

The data gathered and analyzed revealed that the sound level at the various locations of the library was higher than the internationally accepted standard (see Figure 5). This usually results in noise and the major causes of the noise were observed to be external and internal. These includes, automobiles movement, noise from electrical appliances like the ceiling fans and noise from generating set when there is no light which were considered external. The internal cause is chatting of users in the library which is wrong. Some people use to do group study while some walk noisily in the library. The major disadvantage of this is that the users are distracted. All this can be curbed if (1) an alternate source of electricity that is not noisy (e.g. Solar power) is used, (2) more emphasis is laid on the no noise policy of the library and offenders appropriately disciplined and (3) a group study zone which is sound proofed is created to enable group study for those who would love to have one.

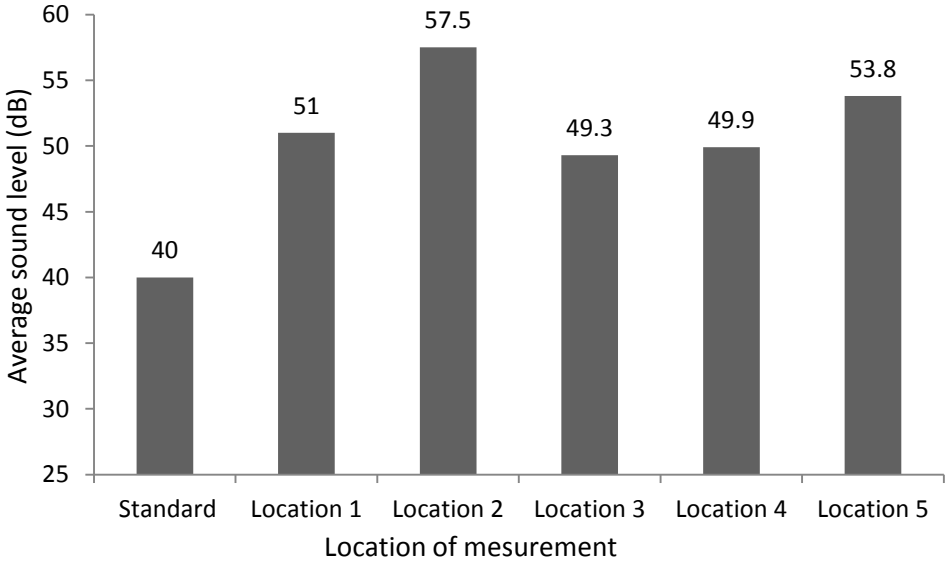

Figure 5: Comparison of the average sound level of the library with international standard

The average, 5th, 50th and 95th percentile of the anthropometric measurement taken on four hundred and twenty-two males and one hundred and five females of the library users, selected at random, are as presented in Table 1. There are three types of chairs available in the library for the users. These were named chair 1, chair 2 and chair 3 for the purpose of this study. All the three types do not have adjustable control and they do not have arm rest as well. This is considered ok as the library users mostly use them for only 2 to 4 hrs, which may not be every day. So the time of usage is short. Hence, the design for average principle is always adopted for estimating the design parameters of such furniture. Consequently, the 50th percentile of the collected anthropometric data (Table 1) was used to determine what should be the dimensions of ergonomically sound furniture for the library users and this is referred to as the estimated design parameter of the furniture. The estimation was done using existing library furniture dimension combination formulas (see Table 2).

The comparison in Table 3 shows that the design parameters of the furniture in the Library falls within the range of values estimated from the anthropometric data of the library users

except for Chair 1. The height and depth of Chair 1 fall a little above range of the estimated value. However, in both case, the value is under 1 cm which is very small therefore it could be assumed that the design parameters of all the chair types in the library as well as the table are adequate for the users.

Table 1: Measured anthropometric data of the library Users

Body dimension measured	Measured valued of anthropometric data with respect to the selected population			
	Mean (cm)	5th %ile (cm)	50th %ile (cm)	95th %ile (cm)
Sitting height	81.9	75.8	81.4	90
Sitting eye height	116.2	110.5	116	125.2
Waist depth	18	14.2	17.9	23.1
Thigh clearance	60.3	56.2	60.2	65.1
Buttock-to-knee	58.7	52	58.8	64.1
Knee height	55.5	50.7	55.3	60.7
Buttock popliteal length	48.5	41.4	48.6	54.6
Popliteal height	45.8	41.5	45.9	49.9
Hip breadth	32.3	25.6	32	41
Shoulder height	61.4	56.8	60.9	67.5
Elbow rest height	24.2	19.6	24.8	28.7

Table 2: Library furniture dimension combination formulas

	Dimension Combination	Formula	Reference
1	Chair Seat Height (CSH) and Popliteal Height (PH)	$(PH + 2)\cos 30 \leq CSH \leq (PH + 2)\cos 5$	Osquei-Zadeh et al., 2012
2	Chair Seat Depth (CSD) and Buttock-Popliteal Length (BPL)	$0.80\ BPL \leq CSD \leq 0.99\ BPL$	
3	Chair Seat Width (CSW) and Hip Breadth (HB)	$1.1\ HB \leq CSW \leq 1.3\ HB$	
4	Chair Backrest Height (CBH) and Shoulder Height (SH)	$0.60\ SH \leq CBH \leq 0.80\ SH$	
5	Table Height (TH) and Elbow-Rest Height (ERH)	$CSH + ERH \leq UTH \leq CSH + 0.852\ ERH + 0.148\ SH$	Ghazilla et al., 2010 Osquei-Zadeh et al., 2012
6	Underneath Table Height (UTH)	$(KH + 2) + 2 \leq UTH \leq (PH + 2)\cos 5 + 0.852\ EH + 0.148\ SH - 4$	

The mean score computed from the responses of the library users to the administered questionnaire in respect of their satisfaction level with regard to the considered library facilities is as presented in Table 4. This table revealed that the level of satisfaction derived by the library users is high for all the facilities considered. The mean score for each facility in all the cases falls between 3.01 and 4.00. However, a detail analysis of the table implies that the users are most satisfied with the cleanliness of the library followed by the table.

Table 3: Comparison of the estimated ergonomically sound design Parameters with the design parameters of the existing furniture for the library

	Furniture dimension/design parameters	Related anthropometric data	Representative 50th %ile value (cm)	Estimated value	Measured value (cm)		
					Chair 1	Chair 2	Chair 3
CHAIR	Chair seat height (CSH)	Popliteal height (PH)	PH=45.9	41.5≤CSH≤ 47.7	48.5	47.3	44.7
	Chair seat depth (CSD)	Buttock popliteal length (BPL)	BPL=48.6	38.9≤CSD≤ 48.1	49	47.2	43.2
	Chair seat width (CSW)	Hip breadth (HB)	HB=32	35.2≤CSW≤ 41.6	45.2	39.1	39.1
	Chair backrest height (CBH)	Shoulder height (SH)	SH=60.9	36.5≤CBH≤ 48.7	43.7	40.6	43.2
TABLE	Table height (TH)	Elbow rest height (ERH)	ERH=12 PH=45.9 SH=60.9	66.3 ≤ TH ≤ 77.9	77.3		
	Underneath table height (UTH)	Shoulder height (SH) Knee height (KH)	SH=60.9 KH=55.3	59.3 ≤ UTH ≤ 73.9	62.2		

Table 4: Mean score of ergonomic related condition and facility of the library

Ergonomic related condition and facility	Mean score
Cleanliness	3.99
Window ventilation	3.67
Lightings	3.51
Fans	3.54
Air conditioners	3.62
Chairs	3.45
Reading table	3.86

The level of users' satisfaction with the chair is 3.45. Though this is interpreted as high with regards to the tool used it falls below users' satisfaction with table. The reason could be attached to the fact that the chairs are armless, not adjustable and some dimensions of one type are slightly out of the estimated design parameters. Hence, the study takes a close look at the breakdown of the responses of users on their level of satisfaction in respect of the library chairs. The breakdown of the questionnaire responses revealed that two, fifteen, thirty-five, Forty-two and six percent of the respondents chose very low, low, moderate, high and very high respectively as their level of satisfaction. Therefore, it could be implied from this analysis that seventeen percent of the library users that chose very low and low were those affected most by the ergonomic shortcomings of the chair. However, since planning to replace all the chairs in the library may be expensive; an alternative solution is to construct new chairs of adequate design parameters with armrest, good support surface technologies and possibly with adjustability provide to replace about twenty percent of the existing chairs in the library, particularly the chair 1 types.

CONCLUSION

This study employs ergonomic knowledge to evaluate a Nigerian University library. While some of the ergonomic factors considered fall within the internationally set standard some others did not. Generally, the satisfaction level of the library users considering the facilities is high. However, it can be inferred from this study that ergonomic design consideration were not studied closely during the design of the library structure and facilities. Consequently, it should be noted that it is very important to conduct ergonomics studies and apply them to design of structure and facilities to ensure that users are not affected by musculoskeletal disorder which could hamper national manpower building process associated with the library setup.

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