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Anthropometry Evaluation Using Analytical Hierarchical Process and Independent Test Method for Hospital Bed Design: A Case Study in Nigeria

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ABSTRACT

To address the problems of errors in health care and serious safety issues, fundamental changes of health care processes, culture, and the physical environment are necessary and need to be aligned, so that the caregivers and the resources that support them are set up for enabling safe care. The study is aimed at evaluating the relationship between patient physical demands (problems) and hospital beds design using anthropometric factors and to determine which anthropometric factor is majorly responsible for patients' physical demand.

A survey was conducted using 30 patients of equal sex randomly. Independent Test was used to evaluate the relationship between patient physical demands (back pain, fatigue, poor blood circulation and sleep discomfort) and anthropometric factors (stature, elbow span, popliteal height and vertical grip reach) used in the bed design. Analytical Hierarchial Process (AHP) was also conducted for the anthropometric factors to determine which factor is most responsible for these physical demands.

The results from the Independent Test and Analytical Hierarchial Process show that patient's physical demands are extremely related to anthropometric factors. Also, stature which is equivalent to bed length in design is the major cause of back pain in patient. These physical demands were as a result of not considering anthropometric dimensions before design, leading to poor ergonomic design of hospital beds. It is therefore recommended that anthropometric data of users of any particular work station should be taken into consideration before any design is embarks on by design engineers. This will enhance the comfort and health safety of the users.

Keywords: anthropometric factors, independent test, Analytical Hierarchial Process, patient physical demands, ergonomics

INTRODUCTION

Recent attention in health care has been on the actual architectural design of a hospital facility, including its technology and equipment, and its effect on patient safety [36]. To address the problems of errors in health care and serious safety issues, fundamental changes of health care processes, culture, and the physical environment are necessary and need to be aligned, so that the caregivers and the resources that support them are set up for enabling safe care. The facility design of the hospital, with its equipment and technology, has not historically considered the impact on the quality and safety of patients, yet billions of dollars are and will be invested annually in health care facilities. This provides a unique opportunity to use current and emerging evidence to improve the physical environment in which nurses and other caregivers work, and thus improve both nurse and patient outcomes.

There is a need for ergonomic consideration in patient bed and other health care system facility design [1]. The word

"Ergonomics" comes from two Greek words "ergon," meaning work, and "nomos" meaning laws [4]. It is the interaction among man, machine and environment which focuses on the interactions between the works demand and worker capabilities [2]. Anthropometry is one of the basic parts of ergonomics that refers to the measurement of human body. It is derived from the Greek words "anthropos" means man and "metron" means measure [4]. Anthropometric data are used in ergonomics to specify the physical dimensions of workspaces, equipment, furniture and clothing to "fit the task to the man" [16] and to ensure that the physical mistakes between the dimensions of equipment and products and the corresponding user dimensions are avoided.

Recent studies have concentrated on identifying the primary risk associated with wrong and poor design of health care bed facility [1]. Improper design of health care system beds is responsible for many types of psychological and physical problems like back pain and it hampers to sleep [2]. Other

prevailing problems of poor design of health care systems beds include, but not limited to fatigue, blood circulation problem and discomfort in sleep [2], which may lead to a lot of problems and even diseases like osteochndrosis, radiculities, arthritis, insomnia, allergy, asthma etc [2].

Optimizing the anthropometric data for health care system facilities design can be stressful due to number of design parameters involved, this problem has recently been made much easier as a result of the development of some design principles like design for adjustable range, design for average sizes and design for extreme [1]. Using these designs, one can conveniently predict the level of safety in term of comfort of care givers and patients, and thus increasing the performance level of workers in the system.

The research paper aimed at study the ergonomic trends in the design of the selected health care work station with reference to the use of anthropometry. To re-design the work station, if necessary, in order to improve the productivity, health safety and comfort of the users.

Human Error and Cognitive Functioning by Design

Cognitive psychologists have identified the physical environment as having a significant impact on safety and human performance [38-39]. Understanding "the interrelationships between humans, the tools they use, and the environment in which they live and work" is basic to any study of the design a health care facility and its effect on the performance of the nurses and other caregivers who interface with the facility and its fixed (e.g., oxygen and suctioning ports on the wall of a patient room) and moveable (e.g., a patient bed) equipment and technology [40]. Humans do not always behave clumsily and humans do not always err, but they are more likely to do so when they work in a badly conceived and designed health care setting [41].

Organizational/system factors that can potentially create the conditions conducive for errors are called latent conditions. According to Reason [38], latent conditions are the inevitable "resident pathogens" that "may lie dormant within the system for a long time, only becoming evident when they combine with other factors to breach the system's defenses. Latent conditions can be identified and remedied before an adverse event occurs." Examples of latent conditions are: poorly designed facilities, including the location of technology and equipment; confusing procedures; training gaps; staff shortages or improper staffing patterns; and poor safety culture. A specific example of a latent condition effecting patient safety would be the impact of low lighting levels in the medication dispensing areas that are associated with some medication errors but not others [42]. These and other conditions are what Reason describes as the "blunt end," where administrators, the work environment, and resources determine the processes of care delivery. Latent conditions are present in all organizations and can be unintentionally created by those who are responsible for designing systems, ensuring adequate staffing, creating and enforcing policies, and so on.

The design of a facility/structure with its fixed and moveable components can have a significant impact on human performance, especially on the health and safety of employees, patients, and families [43]. In a review of more than 600 articles, researchers found that there was a link between the physical environment (i.e., single-bed or multiple-bed patient rooms) and patient (e.g., fewer adverse events and better health care quality) and staff outcomes (e.g., reduced stress and fatigue and increased effectiveness in delivering care) [44]. Efforts to improve patient and staff outcomes can target latent conditions for clinicians by using evidence-based designs to decrease distractions, standardize locations of equipment and supplies, and ensure adequate space for documentation and work areas. The research done by Reason [38] and Leape [39] describes the value of practices based on principles designed to compensate for human cognitive failings. Thus, when applied to the health care field, human factors research (i.e., an area of research that includes human performance, technology design, and human-computer interaction, "A Human Factors Framework," by Henriksen et al [45], which has emphasized the need for standardization, simplification, and use of protocols and checklists, can be used to improve health care outcomes.

By targeting human factors through facility design and ensuring that latent conditions and cognitive failures that lead to adverse events are minimized, patient safety will improve. This requires a multifaceted approach, including developing a strong safety culture, redesigning systems or facilities with their equipment and technology, focusing on eliminating the conditions of cognitive errors, and helping caregivers correct/stop an error before it leads to harm or mitigate it if it occurs.

Chou & Haiao [8] have used two-dimensional anthropometric data for developing an electric scooter in Taiwan. The developed electric scooter resulted in a significant improvement in its appearance and ergonomic performance. The hierarchical estimation method was applied to 60 anthropometric variables by using the 1988 US Army anthropometric survey data and used to design an occupant package layout in a passenger car [35]. In 2006 [33] have collected anthropometric data that were performed by 12 primary care physicians on 24 adult volunteers in Geneva, Switzerland and that was published in 2008.

Anthropometric data must contain at least some valuable information about certain aspect of person's diet and health. Cvrcek [10] have explained that the height and weight variation of adolescent boy's exhibit a pattern that is inconsistent with that for a normal healthy population.

For ergonomic product design with better safety, comfort and health consideration three-dimensional anthropometry is very important as it gather rich information. Chang et al. [7] have used three-dimensional anthropometric measurements that offer much more surface information than traditional dimension measurement and proposed methods for low cost portable hand-hell laser scanner along with a piece of glass used as a hand support to reduce scanning shadow areas. Engineering design is a strong determinant of workplace ergonomics. A survey among 680 engineers in 20 Danish enterprises indicated that engineers are not aware that they influence the work environment of other people [5]. Ergonomics had a low rating among engineers, perhaps because neither management nor safety organizations expressed any expectations in that area. The study further indicated that the effects of ergonomics training in engineering schools were very limited.

The anthropometric measurement can be used as a basis for the design of workstations and personal protective equipment that can make work environments safer and more users friendly. Currently, there is increasing demand for this kind of information among those who develop measures to prevent occupational injuries and increase the level of satisfaction. Anthropometric measurements among 1805 Filipino workers in 31 manufacturing industries showed data for standing, sitting, hand and foot dimensions, breadth and circumference of various body part and

grip strength that was the first ever comprehensive anthropometric measurement of Filipino manufacturing workers in the country which is seen as a significant contribution to the Filipino labor force who are increasingly employed by both domestic and foreign multinationals and was published in 2007 [30]. This study helps Filipino working population for the ergonomic design of workstations, personal protective equipment, tools, furniture and interface systems that aid in providing a safer, effective, more productive and user friendly workplace. Das, Shikdar and Winters [11] demonstrated the beneficial effect of a combined work design and ergonomics approach, especially for the redesign of a workstation for a repetitive drill press operation that increase both the production output and operator satisfaction. The result showed significant improvement in production quantity (22%) and quality (50%) output as a consequence of applying work design and ergonomics principles.

In Turkey, the static anthropometric measurements of 13 dimensions from 1049 students were obtained while they were standing and sitting that was published in 2008 [34]. To be used in classroom and laboratory design the necessary anthropometric data was analyzed to determine the limit value. Existing dimensions of desks and chairs were compared with the student's anthropometric measurements. It was observed that there was a mismatch between popliteal height and seat height, knee height and desk clearance, buttock to popliteal length and seat depth. Comparing Turkish students and other nation's student the result showed that there was significant difference in anthropometric measurements.

Like increased workload, flexibility efforts and productivity requirements, musculoskeletal disorders show noticeable impacts on the workers health in their own professional environment. Lanfranchi and Duveau [25] have presented a predictive model on musculoskeletal pain in relation to maneuver margin, workload and work recognition.

Metha et al. [26] have designed seat dimensions for tractor operator's based on anthropometric data of 5434 Indian male agricultural workers considering comfort ability of operators because if the operator's seat is not comfortable, their work performance may be poor and there is also a possibility of accidents. Another anthropometric survey was carried out by Dewangan, Owary and Datta [14] for female agriculture workers (age ranged 18-60 years) of two north eastern (NE) hill states of India, namely Arunachal Pradesh and Mizoram. Collected data were statistically analyzed and also compared with those of American, British, Chinese, Egyptian, Japanese, Korean, Maxican and Taiwanese female workers that showed in stature, Indian women are shorter by 9.27 cm as compared to American women.

Daneshmandi, Isanezhad and Hematinezhad [12] have shown the effect of classroom furniture on back pain, neck, and lumber and lag fatigue when the students used them. A total of 203 male students from 32 classes of 8 different schools of the urban community were randomly selected in this study. The investigation showed a significant relationship between the tired fillings of the subjects with every dispositional condition of the classroom. Necessary standards during manufacturing the equipments of schools according to anthropometric specifications and ergonomics consideration reduce tired feelings and pain of the students that increases learning and concentration.

Some students of Industrial Engineering in Mexico complained that the activities of tutors create fatigue, neck and back pain after classes [19]. After that, a research of 52 students,

46 males and 6 females between 19 to 23 years old, have estimated the anthropometric parameters of popliteal height, buttock-popliteal length, sitting elbow and wide of the hip of students as well as the dimensions of the desk and calculated relations between them and compared it with international recommendations. The research demonstrated that the desk type used by the study population have mismatches with anthropometric measures of the users and probably are the cause of fatigue and muscle aches cited. They recommended that it is required to meet student's health problem, to acquire adjustable desks or at least desks of different dimensions according to the anthropometric measurements of male and female users.

Niu, Li, and Salvendy [29] have analyzed 510 head samples of Chinese young men that help to analyze human body surfaces, sizing of shape-fitting wearing items, clinical practice. Braking and steering-assistance features of hospital bed have direct effects on task efficiency and physical demand. Thus appropriate selection of specific designs able to improve productivity and contribute to a reduction in work related musculoskeletal disorders risk among healthcare workers. Kim et al [23] have done a repeated measure experimental study considering work related musculoskeletal disorders aimed to increase effectiveness of hospital bed design features (brake pedal location and steering-assistance) in terms of physical demands and usability during brake engagement and patient transportation tasks.

Iseri and Arslan [22] have done a large survey of 4205 civilians (2263 males and 1942 female) in the year of 2007 to estimate the anthropometric characteristic of the Turkish population by geographic region, age and gender which showed 37 measurements that are commonly used in industry. Husein et al [21] have studied on facial anthropometry and aesthetic measurements to compare Indian American women with North American white women. In this study the researchers obtains 30 anthropometric measurements of 102 Indian American women and the result showed significant difference in 25 of 30 facial measurements. Laios and Giannatsis [24] have employed virtual modeling technique and the method of principle component analysis for ergonomic evaluation and redesign of children bicycles based on anthropometric data. In Greece the redesigned bicycles are now in full Production and distribution is underway in many commercial outlets as proper fitting increases cycling performance, efficiency, and comfort and injury prevention.

Unsafe medical care leads to the suffering of millions of patients every year. Human Factors and Ergonomics (HFE) is that scientific discipline which provides unique approach for examining complex socio-technical systems. System approach, roles and methods of human factors and ergonomics have been studied by Carayon and Buckle [6]. The system approach carefully developed by human factors and ergonomics specialists over the past 50 years has a vital role to play in addressing healthcare challenges [6].

Hossain and Ahmed [20] present 36 linear and static anthropometric dimensions and weight of 88 male students living in three residential halls of Bangladesh University of Engineering and Technology (BUET) for the design of five mostly used residential hall furniture (Bed, Chair, Desk table, Book shelf and Locker). They showed the different percentages of mismatches between furniture dimensions and corresponding body dimensions of individual users.

Anthropometric data varies from region to region. Chuan, Hartono and Kumar [9] were collected anthropometric data of the

Singaporean and Indonesian populations. The data were mainly from university students. In total, 245 male and 132 female subjects from Indonesia and 206 male and 109 female subjects from Singapore were measured. This study used 36 measurement dimensions. The authors made a comparison with previous anthropometric data collected in 1990 of over a thousand Singaporeans. Statistical analysis showed that Singaporeans both male and female tend to have larger dimensions than Indonesians in general. In addition, the data reveal the current sample to be significantly larger on more than 50 percent of the dimension measured for both males and females. Hafizi et al. [17] have run a large anthropometric study on primary school children in Iran that explained negative impact on human health if the use of furniture fails to fulfill anthropometric data of its users. Gathering data about anthropometric dimensions are important as anthropometric data can change by time. In many communities anthropometric data have been measured especially among school, college and university students. Study was designed to obtain anthropometric dimensions of Iranian children aged 7-11 years and data were obtained on 2030 primary school students (1015 males and 1015 females) in Yazd of Iran. Study showed a descriptive statistics as well as key percentiles for 17 static anthropometric data. The result showed some difference in anthropometric data with other studies and significant gender differences in some dimensions as well. In order to create a data bank for furniture design a study was run in Iran which measured anthropometric dimensions of Iranian university students [28]. They measured 20 anthropometric dimensions of 911 university students (475 males and 436 females), aged 18-25 years, that showed a significant difference between anthropometric dimensions of their populations with others population. Except for buttock-knee all dimensions measured were significantly different between two genders.

Hedge, James and Pavlovic-Veselinovic [18] have optimized the implementation of healthcare information technology considering risk of work related musculoskeletal disorders in ways that will benefit user performance while minimizing their injury risks. In the patient transportation study, the use of a steering lock reduced the number of adjustments and decreased perceived physical demands during bed maneuvering. Additionally, the adjustable push height reduced shoulder moments during an in-room bed start-up task. The contour feature reduced patient sliding distance with repeated bed raising/lowering, which can potentially reduce the demands placed on healthcare workers to reposition them. Metha et al. [27] have suggested that proactive ergonomic considerations in hospital bed design can reduce physical demands placed on healthcare workers. Widanarko et al. [37] have described the prevalence of musculoskeletal symptoms in New Zealand where a sample of 3003 men and women aged 20-64 were randomly selected. Musculoskeletal symptoms experienced during 12 months in 10 body regions were assessed in telephone interviews using a modified version of the Nordic Musculoskeletal Questionnaires. The highest prevalence was for low back (54%), neck (43%), and shoulder (42%). Females reported a statically significantly higher prevalence of musculoskeletal symptoms in the neck, shoulder, wrist/hands, upper back and hips/thighs/buttocks regions compared to males while males reported more symptoms of elbows, low back and knees. There were no statistically significant differences in prevalence among age groups.

International Ergonomics Association Technical Committee has been formed due to the concern of increasing prevalence and role of information and technology in the lives of children as well as the incident of back pain and heavy loads children carry in back packs [3]. A survey was sent to Ergonomics for Children and Educational Environments to describe a cross-section of international efforts to address the health and the future of children. It is possible to analyze and predict with an applied ergonomics that is sensitive to the social complexities of workplace, including power, gender, hierarchy and fuzzy system boundaries [13].

Dianat et al. [15] have evaluated the potential mismatch between classroom furniture dimensions and anthropometric characteristics of 978 Iranian high school students (498 girls, 480 boys), aged 15 to 18 years. The mismatch was varied between the high-school grade levels and between genders, indicated their special requirements and possible problems.

Adeodu and Anyaeche [1] also studied the ergonomic trends in the design of an open plan computer operator workstation, using some cyber cafes in Nigeria. The analysis of the result shows that most users of the workstation may likely suffer from musculoskeletal diseases due to not putting anthropometry into consideration in the initial design of the work station. The anthropometric dimensions of the users are used to re-design the workstation (Chair and Table) for adjustable range that can carter for 5%-95% of the user. The re-design of the workstation reflected on the improvement of the user's productivity, comfort and health safety.

METHODOLOGY

A random sample of 30 patients was selected from the clinic of Afe Babalola University, Ado-Ekiti, Ekiti State, Nigeria. The demography and anthropometric dimensions of the patients were taken to determine the relationships between patient's physical demands and anthropometric factors related to normal hospital bed through independent test. After that, Analytical Hierarchy Process was done to determine which anthropometric factor is most responsible for these physical demands.

Four anthropometric dimensions have been measured. Analytical Hierarchy Process (AHP) shows that anthropometric dimensions: stature, elbow span, popliteal height and vertical grip reach are related to bed length, bed width, bed height and bed stand height respectively for normal hospital bed [2].

RESULTS

Table 1 Demographic Factors of the respondent (patient)

Parts	Profile	Category	Frequency	Percentage
Demographic Factor	Gender	Male	15	50
		Female	15	50
	Age Limit	Below 20	11	37

		20-30	10	33.33
		30-40	5	17
		40-50	2	7
		50 and above	2	7
	Weight	30-45 kg	11	37
		45-75 kg	15	50
		Above 75 kg	4	13
	Height	Below 1.5m	18	60
		1.5-1.7m	12	40
		Above 1.7m	0	0

Table 2 Relationship between Patient Physical Demand and Anthropometric Factors

Anthropometric Factors / Physical Demands	Stature (Bed Length)	Elbow Span (Bed Width)	Popliteal Height (Bed Height)	Vertical Grip Reach (Bed Stand Height)	Total
Back Pain	25	15	0	0	40
Fatigue	20	25	10	12	67
Blood Circulation Problem	30	30	5	0	65
Sleep Discomfort	20	25	10	0	55
Total	95	95	35	12	227

ANALYSIS

Table 2 above shows that 25 patients agreed that bed length can lead to back pain. Also 15 patients agreed that bed width can lead to back pain e.t.c. It is also seen that bed length and bed width have the highest physical demands followed by bed height and the least is bed stand height.

Independent Test

Table 3 Expected and Observed Values of the Respondents

Anthropometric Factors / Physical Demands	Stature (Bed Length)	Elbow Span (Bed Width)	Popliteal Height (Bed Height)	Vertical Grip Reach (Bed Stand Height)	Total
Back Pain	25 (16.74)	15 (16.74)	0 (6.17)	0 (2.15)	40
Fatigue	20 (28.04)	25 (28.04)	10 (10.33)	12 (3.54)	67
Blood Circulation Problem	30 (27.20)	30 (27.20)	5 (10.02)	0 (3.44)	65
Sleep Discomfort	20 (23.02)	25 (23.02)	10 (8.48)	0 (2.91)	55
Total	95	95	35	12	227

Expected frequency is indicated by first bracket and calculated by the following equation:
Expected frequency = (column total) x (row total)/ (ground total)
Degree of freedom (v) = (row-1) (column-1)

Table 4 Calculated Chi-Square Values

Anthropometric Factors / Physical Demands	Stature (Bed Length)	Elbow Span (Bed Width)	Popliteal Height (Bed Height)	Vertical Grip Reach (Bed Stand Height)
Back Pain	4.08	0.18	6.17	2.15
Fatigue	2.31	0.33	0.011	20.22
Blood Circulation Problem	0.29	0.29	2.52	3.44
Sleep Discomfort	0.40	0.17	0.27	2.91
Total	7.08	0.97	8.97	28.72

$X^2 = \sum (Oi - \varepsilon i)^2 / \varepsilon i$

$X^2 \text{ cal} = 45.74$

Now

Ho = Problems are not related to anthropometric factors

Hi = Problems are related to anthropometric factors

Level of significance, $\alpha = 0.05, 0.01$

Degree of Freedom, V = 9

$X^2 = 0.05, 9 = 16.92 < X^2 \text{ cal}$

$X^2 = 0.01, 9 = 21.66 < X^2 \text{ cal}$

Decision: Ho is rejected

Hence problems of patients are related to anthropometric factors

Analytical Hierarchy Process (AHP)

Table 5 AHP Fundamental Scale [32]

Level of Preference Weights	Definition	Explanation
1	Equally preferred	Two activities contribute equally to the objective
3	Moderately	Experience and judgment slightly favour one activity over another
5	Strongly importance	Experience and judgment strongly or essentially favour one activity over another
7	Noticeably dominance	An activity is strongly favoured over another and its dominance demonstrated in practice
9	Extremely importance	The evidence favouring one activity over another is of the highest degree possible of affirmation
2, 4, 6, 8	Intermediate values	Used to represent compromise between the preferences listed above
Reciprocals	Reciprocals for inverse comparison	

Table 6 Average Random Index (RI) based on matrix size [31]

N	1	2	3	4	5	6	7	8	9	10
RCI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

Table 7 Evaluation of Attributes

Attributes	C1	C2	C3	C4	Geometric Mean	Normalized Weight
C1	1	2	5	3	2.34	0.47
C2	1/2	1	5	3	1.65	0.33
C3	1/5	1/5	1	2	0.53	0.11
C4	1/3	1/3	1/2	1	0.48	0.10
Total	2.03	3.83	11.50	9	5	

Evaluation Parameters

Geometric Mean for specific attribute = (product of the attributes) $^{1/n}$

Normalized Weight for specific attribute =

(Geometric mean for each attribute) /Total geometric mean

Eigen vector (λmax) = ∑(sum of attribute of respective column)(normalized weight of each row)

Consistency Index (CI) = (λmax – n) / (n -1) for n = 4; RI = 0.90

Consistency Ratio (CR) = CI/RI

Table 8 Evaluation of attribute for Back pain

Parameter	Stature	Elbow Span	Popliteal Height	Vertical grip Reach	Geometric Mean	Normalized Weight
Stature	1	3	3	4	2.45	0.51
Elbow Span	1/3	1	1	2	0.9	0.19
Popliteal Height	1/3	1	1	2	0.9	0.19
Vertical grip reach	1/4	1/2	1/2	1	0.5	0.11
Total	1.91	5.5	5.5	9	4.75	

Eigen vector (λmax) = ∑(sum of attribute of respective column)(normalized weight of each row) = 4.0541

Consistency Index (CI) = (λmax – n) / (n -1) (for n = 4; RI = 0.90) = 0.018

Consistency Ratio (CR) = CI/RI = 0.02 = 2% < 10%, so acceptable

Table 9 Evaluation of attribute for Fatigue

Parameter	Stature	Elbow Span	Popliteal Height	Vertical grip Reach	Geometric Mean	Normalized Weight
Stature	1	5	3	5	0.51	0.10
Elbow Span	1/5	1	1/3	1	0.51	0.10
Popliteal Height	1/3	3	1	3	1.32	0.25
Vertical grip reach	1/5	1	1/3	1	2.94	0.56
Total	1.73	10	4.67	10	5.28	

Eigen vector (λmax) = ∑(sum of attribute of respective column)(normalized weight of each row) = 4.056

Consistency Index (CI) = (λmax – n) / (n -1) (for n = 4; RI = 0.90) = 0.019

Consistency Ratio (CR) = CI/RI = 0.0211 = 2.11% < 10%, so acceptable

Table 10 Evaluation of attribute for Blood Circulation Problem

Parameter	Stature	Elbow Span	Popliteal Height	Vertical grip Reach	Geometric Mean	Normalized Weight
Stature	1	9	9	5	4.49	0.67
Elbow Span	1/9	1	1	¼	0.41	0.06

Popliteal Height	1/9	1	1	¼	0.41	0.06
Vertical grip reach	1/5	4	4	1	1.34	0.20
Total	1.42	15	15	6.5	6.65	

Eigen vector (λmax) = ∑(sum of attribute of respective column)(normalized weight of each row) = 4.11
Consistency Index (CI) = (λmax – n) / (n -1) (for n = 4; RI = 0.90) = 0.037
Consistency Ratio (CR) = CI/RI = 0.0411 = 4.11% < 10%, so acceptable

Table 11 Evaluation of attribute for Sleep Discomfort

Parameter	Stature	Elbow Span	Popliteal Height	Vertical grip Reach	Geometric Mean	Normalized Weight
Stature	1	9	5	8	4.35	0.66
Elbow Span	1/9	1	1/4	½	0.34	0.05
Popliteal Height	1/5	4	1	5	1.41	0.20
Vertical grip reach	1/8	2	1/5	1	0.47	0.07
Total	1.44	16	6.45	14.5	6.65	

Eigen vector (λmax) = ∑(sum of attribute of respective column)(normalized weight of each row) = 4.12
Consistency Index (CI) = (λmax – n) / (n -1) (for n = 4; RI = 0.90) = 0.04
Consistency Ratio (CR) = CI/RI = 0.0444 = 4.44% < 10%, so acceptable

Table 12 AHP Final Evaluation

Anthropometric Parameters	Attributes and their Weights				Composite Weight	Rank
	Back pain (0.47)	Fatigue (0.33)	Blood Circulation Problem (0.11)	Sleep Discomfort (0.10)		
Stature	0.51	0.56	0.67	0.66	0.67	1
Elbow Span	0.19	0.10	0.06	0.05	0.14	3
Popliteal Height	0.19	0.25	0.06	0.21	0.20	2
Vertical Reach Grip	0.11	0.10	0.20	0.07	0.11	4

Composite Weight = ∑(Normalized Weight of Attribute) (Normalized Weight of Anthropometric Parameters) e. g for Stature = (0.47x0.51) + (0.33x0.56) + (0.11x0.67) + (0.10x0.66) = 0.67
From the AHP final evaluation results, it shows that for all the attributes, bed length is most responsible which is related to anthropometric factor stature. This is followed by bed width (elbow span), bed height (popliteal height) and bed stand height (vertical grip reach) respectively.

CONCLUSIONS
1. For all the patient physical demands, bed length is most responsible.
2. Patients physical demands are related to anthropometric factors

RECOMMENDATIONS
Every patient deserves a safe and comfortable resting system. Hospital bed needs to be design in such a way that both the patient and other care givers feel convenience. Health care systems are to be design by putting ergonomic and human factor principles into practice. Having noting the patients physical demands in relation to bed design, hospital bed design in Nigeria should be done according to the anthropometric dimensions of the people in the region. This will increase the comfort and health safety of patients and workers in the system

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