Ergonomic Evaluation of Hospital Bed Design and Anthropometric Characterization of Adult Patients in Nigeria

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Abstract:-*The use of beds and other similar furniture are not restricted only to hospitals, but also found enormous applications in other health care facilities and settings, such as assisted living facilities, nursing homes, outpatient clinics, as well as in home health care services.The design of hospital beddepends largely on users' anthropometric characteristics to ensure comfort, safety and productivity of health care service. In this work the level of fitness of existing beds in hospitals in Nigeria to physical demands of patients'body measurements were studied with a stratified random sample size of 87 subjects (55 males and 32 females consisting of the caregivers and the caretakers) selected from subjects in the study area for analytic exploration and anthropometric characterization using the Participatory Ergonomic Intervention (PEI) approach. Structured questionnaire was administered to identify the level of ergonomic awareness and implementation with reference to existing intensive care unit (ICU) beds and medical/surgical bed designs. Following standard procedure, four anthropometric dimensions (Stature, Popliteal-Height, Vertical-Grip-Reach and Elbow Span) relevant to standard bed design were collected using calibrated anthropometric equipment. Existing workplaces were examined and analyzed under the combination of different anthropometric dimensions and design specifications. Independent test was used to determine the relationships between patient's physical anthropometric characteristics and ergonomic factors while evaluation of the functional relationships was carried out between anthropometric factors responsible for the identified users' capabilities through Analytical Hierarchy Process (AHP). Based on the design specifications and standard values from the literatures, the analyses of the results misfits resulting fromsome deficiencies in the existing designs of the workstations which factors were found responsible for back pain, fatigue, poor blood circulation and other related musculoskeletal disorders among the users. A proposed design specifications weresuggested considering the application of the design for extremities. The result of the independent test on the proposed design shows that there are strong correlations between the subject's anthropometric characteristics and ergonomic factors and that the most pertinent ergonomic factor is bed length. It is recommended that due consideration be given to users' anthropometry in the design and manufacture hospital bed for local use.*

KEYWORDS: *Hospital Bed, Ergonomic factor, Analytical Hierarchy Process, ICU, Patients, Caregivers.*

1 INTRODUCTION

Bed is a unique invention of human kind devised to ease the problem encountered in the process of sleeping. The case of hospital bed is not an exemption with beds that are designed for in-patients and individuals who give priority to some forms of health care. Huge amount of money is spent annually on development of health care facilities which has attracted much attention of both government and politicians to health care sector in relation to construction of healthcare infrastructure, the effects of which was left for ergonomists and experts/researcher to investigate and improve upon. Unsafe medical care has led to the increasing suffering of millions of patients on yearly basis. Good health is directly influenced by the way one sleeps since quality of life depends on quality of sleep [1] and [2]. Awkward posture and improper sleep may cause a lot of medical disorders and other diseases like osteochondritis, radiculitis, arthritis, blood supply disturbance, insomnia, allergy, asthma, sleep apian amongst others [3]and [4]. Due consideration of ergonomic factors is highly essential the design of hospital bed and furniture as well as the physical environment in a health care facility [5] and [6]. The inadequate design of medical bed has been identified to be a major risk factor for many physiological, psychological and other related musculoskeletal problems which compounds the health status of the users [7]. There is need to consider and resolve the inadequacies encountered in health care facilities design influenced by cultural practice, physical environment, basic safety issues, and changes in health care processes such that the patients, caregivers and other support staff in the health sector particularly those who participate in the re-engineering of the system [4], and [8]. Although, a lot of improvements have taken place in the design of hospital beds and health care workstation in recent times, but product of these efforts remain inaccessible to average citizen in developing countries. Hence the reason for the use of makeshift beddings and related facilities which further complicate health problems of the patients using them. According to Das, *et al*., (2007)combined work design and ergonomics approach, especially for the redesign of such physical environment for operations not only increase the production output but also the user's satisfaction since the features of any design contribute to its efficiency[9].Kim, *et al*., considered work related musculoskeletal disorders in their experimental study aimed at increasing effectiveness of some hospital bed design features such as brake pedal location and steering assistance, in terms of physical demands and usability during brake engagement and patient transportation tasks, it was concluded that these features have direct influence on task efficiency and physical demand [10], [22] and [23]. Appropriate selection of specific design and its parameters will improve productivity and consequently contribute significantly to the reduction in related musculoskeletal disorders among healthcare givers and the patients [2]. Hedge, *et al*., worked on development and implementation of an optimum healthcare information technology considering risk of work related musculoskeletal disorders in other to enhance users' performance while minimizing their work related injury [11]. The study observed that in the process of transporting patients, the use of a steering lock reduced the number of adjustments and decreased perceived physical demands during bed maneuvering. Also, the adjustable push height reduced shoulder moments during an in-room bed start-up task. The study also observed that the contour feature was found to reduce patient sliding distance with repeated bed raising/lowering, which can potentially reduce the demands placed on healthcare workers to reposition them. Metha, *et al*., suggested that proactive ergonomic considerations in hospital bed design can reduce physical demands placed on healthcare workers and by extension the patients [12]. System engineering approach carefully developed by human factors and ergonomics specialists over the past 50 years has a vital role to play in addressing healthcare challenges [12] and [14]. Anthropometric data optimization for health care system and similar 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 (50th percentile) and design for extremities (5th/95th percentiles) [3]. Using these approach one can conveniently ensure significant level of safety and comfort of care givers and patients, as well as improve the performance of operators of the health facility. The ergonomic trends in the design of health care workstation and facilities promised huge economic and health benefits when required anthropometric data and other relevant information are made available to ergonomist who engage in design and manufacture of facilities for the health sector. In developing countries like Nigeria, the acceptance of the product from human factor engineers depend on the level of economic consideration involve as the majority of the user population live below the poverty level and could not afford the cost of western/improved health care services that is available in the developed countries. This study therefore considers the evaluation of ergonomic factors in hospital bed design for Nigerian.

2 Materials and Method

2.1 Sample Size

A stratified sample size of 87 patients and caregivers (55 males and 32 females) was randomly selected from the Oyo State Hospital Management Board (OSHMB) for exploratory study using the Participatory Ergonomic Intervention (PEI) approach. This approach involves the collection of stakeholders' opinion as well as their anthropometric variables which will serve as necessary input in the design and manufacture of an improved workstation and general facilities arrangement in the healthcare system.

2.2 Research Instrument

2.2 Study Instrument

The instrument used in this study include structured questionnaire which was designed based on ergonomic investigation standard and administered to the randomly selected subjects. Demographic information as well as opinion on their assessment of the comfort, ease of use, adjustability, and safety of existing hospital bed workstations were harvested Also anthropometric data collection form and traditional anthropometric measuring devices (Anthropometric Seat, Stadiometer, Vernier-Callipers, Tape Rule and Bathroom Weighing Scale) were used for the collection of subjects' body measurements. In this case relevant anthropometric characteristics which include (stature, popliteal-height, vertical-grip-reach, elbow span and weight)of respondents were recorded. To ensure consistency and accuracy in doing this, flat wooden piece was used as foot rest to accommodate subjects of different heights and a perpendicular wooden angle to fix the elbow at 90^0 as required for the measurements. Each measurement was replicated thrice and the average values were recorded. The third step of the study was the ergonomic re-design of the hospital bed work station using data from the anthropometric dimensions of the patients and the standard parameters obtained from the literature. Lastly, Independent test was used to determine the relationships between patient's physical anthropometric characteristics and ergonomic factors and the most pertinent anthropometric factor responsible for these physical characteristics demand was determined through Analytical Hierarchy Process (AHP). Complete data was captured on a spreadsheet using the Word Excel programme in preparation for analysis. Data collected was processed using STATA statistical package version 11.0. to obtain the descriptive statistics was employed to summarize the demographic data of the respondents, presented using frequency tables and expressed as percentages while anthropometric data was expressed as means and standard deviations.

2.3 Anthropometric Dimensions for Hospital Bed Design

Anthropometric dimensions were measured in centimeters and consequently converted to inches to facilitate easy comparison with standard design data which came in inches. A highly reliable anthropometric data for a targeted population becomes necessary when designing for that population otherwise the product may not be suitable for the users [3]. The procedure for taking anthropometric measurement of subjects is quite technical and it requires the use of two or more trained enumerator and reliable anthropometric equipment. All measurements were taken following standard procedures and to the nearest centimetres (cm) and later converted to inches otherwise weight which was measured and recorded in kilograms (kg). A 2D diagrammatic model of each of the anthropometric descriptor of a subject are shown in Figures 1(a – d) for easy identification

The description of body measurement that were collected are presented in figure 1:

a. Stature: This was taken in sleeping mode, as this is often the posture taken by patients and not in standing [14] The horizontal distance between the centre of the head and the sole of the feet was measured.
b. Elbow Span: This is the horizontal distance between the lateral surfaces of the two elbows.
c. Popliteal Height: Taken in sitting position, the vertical distance between the floor and to the thigh immediately behind the knee.
d. Vertical Grip Reach: Either in sitting or standing position, the horizontal distance from the back of the shoulder (greatest bulge of trapezium) to the tip of the extended middle finger.

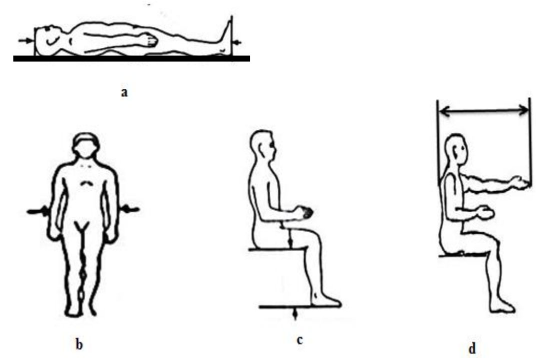

Figure 1: Description of measured anthropometric dimensions
a. Stature b. Elbow Span c. Popliteal Height Sitting
d. Vertical Grip Reach [1]. [4], [5] and [23].

3 Result and Discursion

3.1 Demography

The demographic characteristics considered included age and sex of the patients. As shown in Table 1, the ages of the patients were observed to be normally distributed around 36-39 age group. However, the average age of the subjects sampled in the hospital was ($37\frac{1}{2}$ years) which also falls in the 36-39 age group. It could be said that this age group are more active in strenuous activities and a reason to visit hospital often for medical check-ups. 12% was recorded for the 19 years and below, atmospheric condition and nutritional deficiencies might be some contributory factors to this, as patients within this age range are prone to ailment. A critical look at distribution revealed that those among the patients who are between the ages 40 and 55 years constituted 32.18% while 56 years and above was found to be 3.45%. Out of the 87 patients sampled, 55 (63.21%) of them were male while 32 (36.79%) were female.

3.2 Heights and Weights

Table 1 presents the distribution of both height and weight of respondents indicating 1% above 1.75 m and about one-fifth was above 1.45 m. This suggests negative skewness an indication that place importance on the bed length of about 1.75 m. (Table 1). The distribution of weight of respondents indicate a normal distribution among the respodnents with the average weight being 60.5 kg. The weight distribution 45 – 75kg had the highest frequency of more than two quarters (56%). Others stand at 26% and 17% for 30 - 45kg and 75kg and above categories respectively.

3.3 Educational Background

ISSN 2229-5518

Academic statures of respondents indicate that the percentage of those who are non-literates is 6%. Those who have junior secondary school certificate, ordinary national diploma, OND/national certificate examination, NCE among the sampled patients shared equal percentages (14.94%). Percentage distribution for those respondents who have higher national diploma, HND and bachelor of science was found to be about one quarter, 23% while those with other qualifications was equal to 6%. Generally, about 94% of the respondents have a minimum of primary school certificate which is necessary for the be able read and write and to be able to understand as well as appreciate the contribution of ergonomic to design and manufacture of basic facilities and the benefits in term of minimization of musculoskeletal disorders. (Table 1)

3.4 Ergonomic Evaluation

Resultsfrom the analysis of ergonomic awareness and implementation showed that 60% of the respondents always experience discomfort and this connotes that, virtually all the respondents experience pain, discomfort and other forms of musculoskeletal disorders in certain part(s) of their body segments, especially from the upper and thoracic extremities link systems which include abdomen, spinal cord, back, fore-limbs, wrist, hand and the chest when using the bed as attested to by about two-third (65.52%) of the respondents. While those affected at the head, neck and lower extremity are 9%, 17% and 8% respectively. (Table 1). More than half of the respondents rated the existing design as not conformed to ergonomic standard. 21.84% agreed with moderately and slightly conformity. The result of this study also share the opinion of other researchers within Nigeria that existing hospital bed in the country does not conform to ergonomic standard evidently from the response of the subjects as none of them agreed to strong conformity of the bed to ergonomic standards [15], [16] and [21]. On a light note, the productivity rating of the existing design by both the care givers and the patients were 25% and 18% on the fairly and average bases, succeeded by poor with 45%. While only 12% of the respondents agreed that the productivity was good.

Table1:Demographic Information, Educational Background of the respondents and Ergonomic Awareness and Implementation

	Profile	Group	Frequency	%
Demographic information	Gender (Sex)	Male	55	63.21
		Female	32	36.79
	Age Range (Years)	19 and Below	10	11.49
		20 - 25	6	6.90
		26 - 29	8	9.20
		30 - 35	13	14.94
		36 – 39	19	21.84
		40 - 45	9	10.34
		46 - 49	12	13.79
		50 - 55	7	8.05
		56 and Above	3	3.45
	Height (meters)	Below 1.45	19	21.84
		1.45 – 1.65	44	50.57
		1.65 – 1.75	23	26.44
		Above 1.75	1	1.15
	Weight (Kilograms)	30 – 45	23	26.44
		46 – 75	49	56.32
		76 and Above	15	17.24
Educational Background	Non-Literate		5	5.75
	Primary School		17	19.54
	JSCE		13	14.94
	SSCE/Modern		14	16.09
	OND/NCE	N/A	13	14.94
	HND		11	12.64
	First Degree		9	10.34
	Others		5	5.75
Ergonomic awareness and Implementation	How often do you experience musculoskeletal disorder using the bed?	Always	53	60.92
		Sometimes	24	27.59
		Rarely	10	11.49
		Not at all	0	0
	Do you experience any disorder, pain or discomfort in any of these body segments?	Head	8	9.19
		Neck	15	17.24
		Upper Limb	26	29.89
		Thoracic	31	35.63
		Lower Limb	7	8.05
	Can you evaluate the existing design of the health care system?	Strongly	13	14.94
		Moderately	12	13.79
		Slightly	7	8.05
		Not at all	55	63.22
	How can you rate the productivity of the care giver interacting with the workstation?	Excellent	0	0
		Good	10	11.49
		Fair	22	25.29
		Average	16	18.39
		Poor	39	44.83

3.5: Comparison of Existing Design with Available Ergonomic Standard

Figures 2 – 7 show the pictures of the existing design and workstation of the study area, as well as the standard hospital bed designs as found in the literature. Tables 2 and 3 compare the existing bed designs (Figures 2 and 3) for both intensive care unit, ICU bed (Figures 4 and 5) and medical/surgical bed (Figures 6 and 7) with ergonomic standards.

Considering from these tables, the bed length is 83′′ and 79.9′′ respectively for the existing designs, these does not totally conformed and completely deviated from the ergonomic standards of 89′′- 91′′ (Stryker Epic II); 92′′ without bumper and 93.5′′ with bumper (Hill-Rom Total Care) for ICU. Similarly, 94.25′′ (Stryker Gobed II) and 93′′ (Stryker Secure II bed) for medical/surgical bed are out of conformity. The stature anthropometric dimension was used as the basis for the bed length design, and such poor and inadequate design will lead to back pain fatigue and other forms of musculoskeletal disorders, MSDs for the patient while bed width was design using elbow span. The existing design is smaller compare to ergonomic standards for both work stations as observed from both tables and this inadequate design will cause hindrance to proper circulation of blood in the body system of patient. Popliteal height anthropometric dimension was applied to bed height designed. For good ergonomic design, popliteal height for any hospital bed height design should not be too high because lower bed height permits the patients to enter and exit the bed very easily and without damaging any medical procedure that they have undergone [4]. Otherwise, the legs will be suspended in air when sitting thus putting tension on the legs and definitely cause poor blood circulation and fatigue to the patient using the work station [3]. Vertical and horizontal reach grips and combination of other measured anthropometric dimensions were used in designing back rest rotation, knee elevation and trend. These mismatches between the anthropometric characteristics demands and the existing design could hamper sleep comfort and cause body pain, fatigue, similar MSDs and sometimes lead to sleep discomfort in the patient using the workstation. Owing to the above discussed specifications for both ICU and medical/surgical beds, it could be deduced that both beds share a common bond of serving purpose to be patient-friendly and user-friendly [17]. Other listed specifications are design for the comfort and safe working area of both the caregivers and care-takers [18]. Zoom technology which is an advanced feature in Stryker Epic II for ICU bed is lacking in the existing design ICU bed. The zoom technology is a bed frame that is motor driven to alleviate if not eradicate stress caused to nurse's thoracic extremity by the constant pushing and pulling of the bed during patient transport [17]. Features embedded in Epic II are; a built-in electronic scale for accurate weighing of a patient no matter what posture the patient may be in, and also radiolucent which allows for X-ray to be taken while the patient is still in bed. These often save the nurse the stress encounter in weighing and X-raying manually. It is important to note that the advance features in Total Care ICU bed standard other than the ones earlier highlighted and are lacking in the existing design renders it ergonomic unsafe for usage and exposes the patient to musculoskeletal diseases infliction.

Furthermore, incorporated in the Total Care ICU bed standard design are frame and mattress setting features aimed at alleviating aches/injuries related to back and pressure sores associated with patient transfer long term stays and repositioning. The patient could adjust himself into any desirable position all the way to an upright chair position using the easy to use point-of-care controls for tilting. To the advantage of the patient sitting in correct posture, a shear-less pivot patient position mechanism which minimize the patient's migration towards the foot end of the bed through hybrid actions of the frame, surface and patient. There is also a retractable foot mechanism which can be placed snug against a patient's feet in order to reduce the need for additional foot support devices (Table 2). The Total care ICU bed provides not only stability and easy to use controls for the patient but is also built to satisfy the needs of patient caregivers. The bed reduces the amount of stress on the caregivers' backs when transferring patients from the bed. Additionally, other capabilities of the bed include an overriding feature for CPR which, by the press of a button, overrides all manual and automatic controls to immediately put the bed into a position convenient for resuscitation in case of emergency. CPR system is an emergency procedure consisting of external cardiac massage and artificial respiration; the first treatment for a patient who has collapsed and has no pulse and has stopped breathing; attempts to restore circulation of the blood and prevent death or brain damage due to lack of oxygen [19]. Other support for the caregiver includes Graphical User Interface, GUI that records the weight of the patient, patient lighting, pre-set bed positioning, a line-of-sight angle indicator to provide the caregiver with the proper head and Trendelenburg angle articulation, side rail controls located just out of the patients reach on the outside of the rails, they can be activated only by the system's enable command which ensures patient safety from the mechanism. Similarly, in the case of medical/surgical bed, GoBed II standard there exist many features that were designed with the caregiver's interest in mind but lacking in the Nigerian existing medical/surgical bed design (Table 3). Incorporated in these beds are eight separate poles to be used for traction setup to help support proper bone healing and for suspending IV medicine and fluid bags while being administered to the patients through veins and there are also four hooks below the bed to drain and store medical and bodily waste. Two separate bed controls for the nurse, one on the side rail and one at the foot of the bed. Among other features of The GoBed II are one handed side rail releases to allow a nurse to drop the side rail simultaneously as they are helping the patient and a drop down fifth wheel to aide in mobility when the bed must be moved.

Figure 2: A view of a clustered hospital work station (Present Study, 2016)

Figure 3: Existing Design (Present Study, 2016)

Figure 4: Stryker Medicals Epic II ICU Bed (Brian and Todd, 2006)

Figure 5: Hill-Rom Total Care ICU Bed (Brian and Todd, 2006)

Figure 6: Stryker Medical GoBed II Med/Surg Bed (Brian and Todd, 2006)

Figure 7: Hill-Rom VersaCare Med-Surg Bed (Brian and Todd, 2006)

Table 2: Existing Design andSpecified Standard for ICU Bed

Bed Specification	Specification Dimension for Existing Design (Present Study)	Stryker EPIC II Standard [17] (Brian and Todd, 2006)	Hill-Rom Total Care Bed Standard [4] (Adeodu, *et al*., 2014a)
Bed Length	83′′	89′′- 91′′	92′′ (without bumper) 93.5′′ (with bumper)
Bed Width	36.7′′	40′′- 42.5′′	36′′ (side rail down) 40′′(side rail up)
Bed Height	33′′ (Fixed)	18′′ – 32.5′′	17.5′′- 36.5′′
Back rest rotation	0^0 - 90^0	0^0 - 90^0	0^0 - 75^0
Knee Gatch/Elevation	0^0 - 30^0	0^0 - 90^0	0^0 - 20^0
Trend/Lower leg elevation rotation	14^0 /- 14^0	12^0 /- 12^0	15^0 / - 15^0
Weight	N/A	500lb (maximum)	400lb – 500lb
Electronic	N/A	115 Volt, 7Amp rating, 60Hzfrequency and current leakage (100μA)	115 Volt, 7Amp rating, 60Hz frequency and current leakage (50Ma)
Chair Positioning	N/A		Seat – 0^0 - 10^0 Foot – 30^0 - 70^0 Head – 50^0 - 65^0
Wheel Track	N/A	N/A	20′′ head 23.5′′ foot
Under Bed Clearance	N/A		0.75′′
Advance Special Ergonomic Features	N/A	Zoom technology with motor driven, Built in electronic scale for weighing, Radiolucent bed for X-Ray and Manual release control feature	Point of care control mechanism Shear-less pivot patient position mechanism Retractable foot mechanism and overriding feature for CPR during emergency.

3.6: Analyses of Variances and Proposed Design Parameter

Apart from the physical comparison of the bed designs, analyses of variances, ANOVA were further performed on the design specifications and they revealed for the design parameters where data were available that, there are significant differences at p = 0.05 confidence level. Likewise the comparative analysis of the anthropometric dimensions of the patients, existing design of the hospital bed work stations and standards from the literature shows that existing hospital bed work stations are poorly designed and thus inadequate for the Nigerian patients as their anthropometric characteristics demands does not tally with the ones used for the existing design. It becomes imperative to buy into the principles of anthropometry in decision making towards designing or the purchase of bed and other gadgets [5]. Based on the results from the analyses of demographic information, educational background ergonomic awareness and implementation, comparisons of standard design data, existing design and anthropometric dimensions of the respondents, the study presents the proposed design data for hospital bed work station is presented in Table 4.

Table 3: Existing Design and Specified Standard for Med/Surgical Bed

Bed Specification	Specification	Stryker GO BED II	Stryker Secure II Bed

ISSN 2229-5518

	Dimension for Existing Design (Present Study)	Standard (Brian and Todd, 2006)	Standard (Brian and Todd, 2006)
Bed Length	79.9′′	94.25′′	93′′
Bed Width	37′′ (maximum) 19′′ (minimum)	39′′ (side rail down) 40′′ (side rail up)	40′′ (side rail down) 42.5′′(side rail up)
Bed Height	33′′ (Fixed)	14.5′′ – 29′′	16′′- 30′′
Back rest rotation	0^0 - 90^0	0^0 - 60^0	0^0 - 60^0
Knee Gatch/Elevation	0^0 - 30^0	0^0 - 28^0	0^0 - 40^0
Trend/Lower leg elevation rotation	14^0 /- 14^0	14^0 /- 14^0	12^0 /- 12^0
Weight	Undefined	500lb (maximum)	500lb (maximum)
Electronic	N/A	120 Volt, 4Amp rating, 50 - 60Hz frequency and current leakage(100μA)	115 Volt, 7Amp rating, 60Hz frequency and current leakage(60μA)
CasterDiameter	N/A	6′′	6′′Standard, 8′′ Optimal
Side Twist	0^0 - 90^0	0^0 - 90^0	0^0 - 90^0

3.7: Results from Independent Test

Following standard procedure on independent test, the result from the independent test conducted to determine the relationships between patient's physical anthropometric characteristics and ergonomic factors based on two major hypotheses:

H_o = Musculoskeletal disorders experience of patients are not related to ergonomic factors

H_1 = Musculoskeletal disorders experience of patients are related to ergonomic factors

At level of significance, $\alpha = 0.05, 0.01$

Degree of freedom, (v) = 12

$$X^2_{Cal} = 115.03$$

$X^2_{0.05,12} = 21.026 < X^2_{Cal}$

$X^2_{0.01,12} = 26.217 < X^2_{Cal}$

At $p \leq 0.05$ H_o is rejected and H_i is accepted.

Table 5 shows the result for the final and overall attribute evaluation for all the parameters indicating all the individual composite weight and the rank for scale of preference standard (Saaty, 1990). For instance;

Composite weight for Popliteal Height (Bed height)

= 0.43 x 0.190 + 0.330 x 0.250 + 0.120 x 0.062 + 0.08 x 0.210 + 0.04 x 0.432 = 0.206

3.8: Analytical Hierarchy Process

To show the interrelationship between the ergonomic factors and the patient physical demands and the influence on one another, AHP is suitable [1]. Based on this, this study employed Analytical Hierarchy Process, AHP, to determine the order in which the ergonomic factor responsible for attributes and the related anthropometric dimensions. Five attributes evaluations were considered which included; back pain, fatigue, blood circulation disorder, sleep discomfort and comfort. Consistency ratio, CR recorded for each of these attributes in terms of percentages are, 2%, 2.11%, 4.07%, 4.44% and 5.43% respectively, Table 5. Since each of the CRs is less than 10% except otherwise then, they are all acceptable [1]. The result of the final AHP evaluation of all the attributes and the most related anthropometric dimension to each showed that for, Popliteal Height (Bed Height), Elbow span (Bed Width), Vertical Grip Reach (Bed Stand Height) and Stature (Bed Length), the composite weights are 0.206, 0.130, 0.122 and 0.540 respectively. These indicate that for back pain, fatigue, blood circulation disorder, sleep discomfort and comfort of patient, bed length is the most responsible ergonomic factor which is related to anthropometric dimension, stature as it has the highest composite weight. Then, bed height is responsible ergonomic factor which is related to anthropometric dimension, popliteal height. Likewise, bed width is responsible ergonomic factor which is related to anthropometric dimension elbow span. And lastly, Bed stand height is responsible ergonomic factor which is related to anthropometric factor Vertical grip reach which had the least composite weight.

Table 4: Proposed Work Station Design Specification for Hospital Bed

Bed Specification	Stryker Standard ICU BED	Stryker Standard MED/SURG BED	Mean Anthropometric Dimensions	ICU Hospital Bed	Med/Surgical Bed
Bed Length	91′′ – 92′′	92.5′′ – 93 ′′	Stature: 66.59′′	91′′ (without bumper) 93.3′′ (with bumper)	92.5′′ – 93 ′′
Bed Width	40′′ (side rail down) 42′′ (side rail up)	39′′ – 40′′ (side rail down) 40′′ – 42′′ (side rail up)	Elbow Span: 35.16′′	40′′ (side rail down) 42′′ (side rail up)	39′′ – 40′′ (side rail down) 40′′ – 42′′ (side rail up)
Bed Height	18 ′′ (low) 32.5′′ (high)	14.5′′ – 16′′ (low) 29′′ – 30′′ (high)	Popliteal Height: 17′′	Adjustable: 18′′ (low) 32.5′′ (high)	Adjustable: 14.5′′ – 16′′ (low) 29′′ – 30′′ (high)
Litter positioning	Back rest: 0^0 - 90^0 Knee Gatch: 0^0 - 30^0 Trend: 12^0 / 12^0	Back rest: 0^0 - 60^0 (max) Knee Gatch: 0^0 - 20^0 (min) 0^0 - 40^0 (max) Trend 12^0 / 12^0 (min) 14^0 /- 14^0 (max)	FI XED	Recommended littering position: Back rest: 0^0 - 90^0 Knee Gatch: 0^0 - 30^0 Trend: 12^0 / 12^0	Recommended littering position: Back rest: 0^0 - 60^0 (max) Knee Gatch 0^0 - 20^0 (min) 0^0 - 40^0 (max) Trend 12^0 / 12^0 (min) 14^0 /14^0 (max)
Caster diameter	6′′	6′′ (mi n) 8′′ (ma x)	UNDEFINED	Recommended caster diameter: 6′′	Recommended caster diameter: 8′′
Weight	500lb	500 lb (max) 400lb (min)	178lb	500lb (max)	500lb (max)
Electronic	115 Volt, 7Amp rating, 60Hz frequency and current leakage (60µA)	115- 120 Volt, 4-7Amp rating, 60Hz frequency and current leakage (50-60 µA)	N/A	Recommended Electronics for special features: 115 Volt, 7Amp rating, 60Hz frequency and current leakage (60 µA)	Recommended Electronics for special features: 115- 120 Volt, 4-7Amp rating, 60Hz frequency and current leak(50-60 µA)

Table 5: AHP Final Evaluation

Parameter	Attributes and their weights						
	Back	Fatigue	Blood Circulation	Sleep	Comfort	Composite Weight	Rank

		pain (0.43)	(0.33)	Disorder (0.12)	(0.08)	(0.04)		
Popliteal Height	Bed Height	0.190	0.250	0.062	0.210	0.432	0.206	2
Elbow Span	Bed Width	0.190	0.096	0.062	0.050	0.144	0.130	3
Vertical Grip Reach	Bed Stand Height	0.110	0.096	0.200	0.070	0.3298	0.122	4
Stature	Bed Length	0.510	0560	0.670	0.660	0.0949	0.540	1

3.9 Predictive Model for Anthropometric Dimension ofNigerian Patients

Careful consideration must be given to potential user of any product from the design stage giving priority to the structural capacity and limitations, all of which make up the physical anthropometric characteristics demand of such user. Design for average (50th) and extremities (5th and 95th) become imperative to accommodate a larger percentage of the targeted population. As 95th percentile is normal while those who fall in the 5th percentile will experience mismatches and such could be utilized accommodated with tilting/adjustments. Since, existence of mismatch becomes a misnomer for the patient to tilt, hence, one-sided confidence bonds for bed length, width and height should be considered in such design. While for stand height most of the case health care workers help the patients to use net and nurse uses stand height, thus, one-sided confidence bonds for stand height will not be appropriate. Table 6 shows the summarized descriptive statistics of the anthropometric dimensions of the patients out of which the linear models (Equations 1 – 3) were developed from the historical data design, HDD of Design Expert 6.0.8 Version (Onawumi *et al.*, 2016b).

Table 6: Descriptive Statistics of Body Dimension

Anthropometric dimension	Mean(SD) (cm)	Mean(SD) (inches)
Stature	169.52(9.743)	66.740(3.835)
Elbow span	89.470(4.072)	35.22(1.603)
Popliteal height	47.380(2.305)	18.653(0.907)
Vertical grip reach	199.841(15.446)	78.677(6.081)

$$\text{Elbow span} = 0.950457x - 52.6587 \quad (1)$$
$$\text{Popliteal height} = 0.06378x + 34.48596 \quad (2)$$
$$\text{Vertical grip reach} = 0.3646x + 158.83163 \quad (3)$$

Where the symbol (x) in equations (1 - 3) stands as the independent variable (stature) because it is easy to measure as the factor (Onawumi *et al.*, 2016b) and dependent variables are the other anthropometric dimensions. The analyses of anova, ANOVAs of the regression models demonstrate that the models are very significant, as were evident from the F-test with a low probability value [(pmodel>F)<0.05] for all, which indicated that the model was significant. The minimum coefficient of determination (R^2) was 0.9849, indicating that 98.49% of the variability in the response could be explained by the model. Also the minimum adjusted correlation coefficient (adj. R^2 = 97.58) of 0.9758 was very close to correlation coefficient which confirmed agreement between the predicted and actual anthropometric dimensions [20]. Hence using these equations, if the stature of anyone is known, such will have proper dimensions which will enhance design of hospital bed and other products. According to Ismaila *et al.*, it can be very expensive in developing countries like Nigeria to obtain anthropometric data when needed, and as such, measuring few ease-to-measure anthropometric variables to determine others would be helpful and affordable [24]. Although economic reason is important but, at the same time, adequacy and effectiveness of the predictive models cannot be compromised [5]. The current study took these three factors; economic reason, adequacy and effectiveness into consideration and in view of the high predictive ability of the models, using them in estimating other ones are justifiable.

4.0 CONCLUSION AND RECOMMENDATION

This study has revealed the prevalence of back pain, fatigue, blood circulation disorder, sleep discomfort and other forms of MSDs among Nigerian patients and caregivers. There was low level of ergonomic awareness and applications to beds used in the studied hospitals. The existing hospital bed workstation designs were not found to be user- friendly and they do not conform to ergonomic standards as revealed by analyses of variances, ANOVAs. This may be responsible for low productivity in the health care system as well challenges relating to comfort and safety of the operators of the work systems. Independent test showed that anthropometry has strong correlation with ergonomic factors and these consequently have high influence on the patient's comfort. A secured, convenience, comfortable sleeping and bed environment is deserved by every patient. The proposed design promised significant improved performance and comfort of users.

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