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STATISTICAL APPROACH TO UNDERSTANDING STANDING POSTURE AND ITS LINKS TO ELBOW HEIGHT SEATED, EYE LEVEL SEATED AND HUMAN SITTING POSTURE FOR ERGONOMIC DESIGN

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Abstract: This study delves into the intricate relationship between human sitting posture (HSP), elbow height seated (EHS), eye level seated (ELS), and standing posture (SP), focusing on their pivotal role in ergonomic design. The research addresses a pressing issue in Nigeria, where imported products often disregard end-users' anthropometric measurements, leading to complaints and musculoskeletal disorders. The study meticulously analyzes the vital measurements of HSP, EHS and ELS, integral components in estimating SP. Through statistical analyses and regression modeling, data from 380 young adults in Nigeria are examined, considering diverse factors such as age, gender, and regional demographics. The precision and variability of these measurements, influenced by factors like race and ethnicity, are meticulously explored, emphasizing the need for tailored design solutions. This research underscores the imperative of incorporating anthropometric data, especially HSP, EHS and ELS, in product design. The findings reveal the profound impact on healthcare, industrial design, and societal inclusivity. Integrating these measurements into design processes will fostered collaboration between designers and healthcare professionals with enhancing public awareness. This study is a cornerstone in reshaping ergonomic design paradigms; ensuring products are universally accessible and beneficial, heralding a future of inclusive and comfortable living.
Keywords: standing posture, ergonomic design, product design, statistical modeling, user comfort

1. INTRODUCTION

Several products such as vehicle, chairs, table etc requires the anthropometric measurements of the end users for its design. Most of these products were imported to Nigeria without recourse to the end-users anthropometric measurements and this gives to the complaint of product mismatch leading to musculoskeletal disorders among the population. Most of the products require the standing height or stature of the end-users. For example, design of wheelchairs require the measurement of the standing height of the users but majority of the wheelchair users are vulnerable with disabilities such as paralyzed patients, cripples, bedridden patients etc that cannot stand erect.

Incorporation of ergonomic design principles into account of anthropometric dimensions, workplaces has the potential to minimize the occurrence of musculoskeletal disorders (MSDs) while enhancing worker comfort and productivity. Ergonomics design is considered as a process of creating products, equipment, and work environments that are designed to fit the needs of individual who use them. The objective of ergonomics design is to optimize human performance and minimize discomfort, injury, and fatigue. Ergonomic design holds significance across diverse fields, encompassing industrial design, product design, architecture, and workplace design.

Ergonomics design includes office chairs with adjustable seat height and lumbar support to accommodate different body types and reduce back pain, keyboard and mouse with an ergonomic shape to reduce hand and wrist strain, standing desks with adjustable height to allow for changes in posture throughout the day, tools with handles designed to fit the user's grip to reduce hand fatigue and improve precision.

Human Sitting Posture (HSP), sitting eye height (eye level seated) and elbow height seating (elbow seated height) are very important measurements in the estimation of standing posture (SP), which is the total height of an individual when standing upright (Yeasmin et al., 2020). Human sitting posture (HSP) refers to the height of a person from floor to the center of their head while seated and eye level seated (ELS) also refers to the height of the individual from the floor to the centre of the eye when a person is seated, while elbow height seated (EHS) is the height of an individual from the floor to the point on an armrest where the elbow is bent at a 90-degree angle.

Identifying human standing postures involves utilizing regression equations based on anthropometric measurements like arm span length, leg length and foot length (Musa et al., 2023, 2022a, 2022b, 2022c,

ISSN 1584 – 2665 (printed version); ISSN 2601 – 2332 (online); ISSN-L 1584 – 2665

Esomonu et al., 2016, Singh et al., 2013). Determination of standing height for Kori population in North Indian was performed from different anthropometric measurements (Kamal and Yadav, 2016). The study anthropometric parameters measured include knee length, foot breadth, finger length, arm length and head length. The study thereafter established regression equations separately to determine the standing height of individual for the Kori population. Similarly, a cross sectional research was performed utilizing anthropometric parameters such as hand and foot length as predictor of standing height for two different ethnic groups in Nigeria (Igbigbi et al 2018).

Nevertheless, it is very necessary to acknowledge the precision of this regression model equation fluctuates, reference to the specific population under evaluation and it might not yield the same level of accuracy for particular demographics like children and older adults. (Yeasmin et al., 2022).

Research findings have additionally demonstrated that anthropometric dimensions exhibit population-specific variations based on factors such as race, ethnicity, age and gender, all of which can impact the precision of the estimation (Musa et al., 2023, 2022a, Siqueira et al., 2015). In view of this, the research took into account the factors, as these can affect the accuracy of the estimation of SP using HSP ELS and EHS.

Ergonomics design is important for promoting health and productivity by creating products, systems, and environments that are safe, efficient, and comfortable to use. Human sitting posture (HSP), eye level seated (ELS) and elbow height seated (EHS) are very important measurements and should be taken into account along with other factors when making height-related assessments or designing products such as chairs or desks (Yeasmin et al., 2020). Most of the products imported to Nigeria without recourse to the end-users anthropometric measurements and this gives to the complaint of product mismatch leading to musculoskeletal disorders among the population (Ismaila et al., 2013, Musa et al., 2014). Several of the products require the standing height (standing posture) or stature of the end-users.

This present study intends to determine the Standing Posture (SP) using human sitting posture (HSP), eye level seated (ELS) and elbow height seated (EHS) and give a fundamental, reliable anthropometric data and employ in the anthropometric studies for the widespread extension and occurrence of ergonomic design of products such as chairs or desks, systems, workstation, workplace, machine and environments for conformability.

2. RESEARCH METHODOLOGY – SAMPLE COLLECTION

A cross sectional study was conducted among 380 young adults (190 males and 190 females) in Abeokuta South and Abeokuta North local government areas of Ogun State, Southwestern Nigeria, participants aged between 17 and 25years were selected through random snowball sampling techniques. The methods also included selective and purposeful judgmental approaches due to the rarity of specific traits caused by insecurity in Nigeria.

The study focused on measuring the standing posture (SP), human seated posture (HSP), eye level seated (ELS), and elbow height seated (EHS) of the participants, with all measurements recorded in centimeters. Individuals with limb deformities were excluded from the research.

Data analysis was conducted using Statistical Package for Social Sciences (SPSS) 21.0, including calculations for average mean values, standard deviation (SD), percentiles, coefficient of determination (R^2), correlation coefficient (R), and standard error of estimates (SEE). Linear regression analysis was employed to establish the model equation for determining SP based on HSP, ELS, and EHS.

3. RESULTS AND DISCUSSIONS

The study assessed 380 young adults (190 males and 190 females) in Ogun State through random snowball sampling techniques. Table 1, Table 2 and Table 3 shows the socio-demographic characteristic (mean, SD, minimum and maximum values) of male, female and for both gender. Similarly, 5^{th}, 25^{th}, 50^{th} (median), 75^{th}, and 95^{th} percentiles were also analyzed for the study. In ergonomics design, utilizing 5^{th}, 25^{th}, 50^{th} (median), 75^{th}, and 95^{th} percentiles is vital for crafting products that suit a diverse user base. The 5^{th} percentile signifies the size below which only 5% of the population falls. Designing products around this percentile ensures comfort for smaller individuals. The 95^{th} percentile represents the size surpassed by only 5% of the population. Designing products for this percentile prevents discomfort for larger individuals, providing ample space and support.

Table 1: Socio-demographic characteristics of the Male participants

		Age (years)	SP (cm)	HSP(cm)	EHS (cm)	ELS(cm)
N		190	190	190	190	190
Mean		21.97	166.79	82.87	62.69	73.94
Std. Deviation		2.41	8.26	6.41	3.44	6.05
Minimum		17.00	154.00	70.00	57.00	62.00
Maximum		25.00	183.00	92.00	69.00	83.00
Percentiles	5	155.00	155.00	71.00	58.00	62.00
	25	160.00	160.00	77.00	59.00	68.00
	50	166.00	166.00	84.00	62.50	74.00
	75	173.50	173.50	88.00	66.00	78.25
	95	180.00	180.00	91.00	68.00	82.00

SP: Standing posture; HSP: human seated posture; ELS: eye level seated; EHS: elbow height seated.

Table 2: Socio-demographic characteristics of the Female participants

		Age (years)	SP (cm)	HSP (cm)	EHS (cm)	ELS (cm)
N		190	190	190	190	190
Mean		22.93	158.37	74.94	55.89	65.48
Std. Deviation		1.54	3.32	2.37	2.65	2.44
Minimum		19.00	152.00	69.00	50.00	60.00
Maximum		25.00	166.00	78.00	60.00	69.00
Percentiles	5	152.00	152.00	70.00	51.00	62.00
	25	156.00	156.00	73.00	54.00	64.00
	50	158.50	158.50	75.00	56.00	66.00
	75	160.50	160.50	77.00	58.00	68.00
	95	164.40	164.40	78.00	60.00	69.00

SP: Standing posture; HSP: human seated posture; ELS: eye level seated; EHS: elbow height seated.

Table 3: Socio-demographic characteristics of the both participants

		Age (years)	SP (cm)	HSP (cm)	EHS (cm)	ELS (cm)
N		380	380	380	380	380
Mean		22.43	162.58	78.91	59.29	69.71
Std. Deviation		2.09	7.56	6.25	4.58	6.26
Minimum		17.00	152.00	69.00	50.00	60.00
Maximum		25.00	183.00	92.00	69.00	83.00
Percentiles	5	153.00	153.00	70.05	53.00	62.00
	25	157.50	157.50	74.00	56.00	65.00
	50	160.00	160.00	77.00	59.00	68.00
	75	166.00	166.00	84.00	62.75	74.00
	95	179.50	179.50	91.00	68.00	82.00

SP: Standing posture; HSP: human seated posture; ELS: eye level seated; EHS: elbow height seated.

The 50th percentile (median) is the dataset's midpoint. Designing products based on this percentile caters to the average user, ensuring comfort for a significant portion of the population. Considering the 5th and 95th percentiles helps design for extremes, accommodating individuals at both ends of the size spectrum.

By incorporating 25th and 75th percentiles, products can accommodate a wide range of body sizes, fostering inclusivity and making the product suitable for a larger percentage of the population. Integrating these percentiles in ergonomic design ensures products are comfortable, safe, and usable for diverse users, enhancing satisfaction and reducing the risk of injuries or discomfort.

Table 4 and Table 5 show the linear regression analysis and model equations and coefficient correlation model summary analysis of the study. The research findings highlight the critical importance of incorporating anthropometric measurements into product design, especially for items like vehicles, chairs, and tables. The absence of considering end-users' anthropometric data in imported products has led to complaints and musculoskeletal disorders among the population, particularly affecting vulnerable individuals like paralyzed patients and bedridden individuals.

Table 4: Linear regression analysis and model equations

Gender	Model	Unstandardized Coefficients		Equation $Y=\alpha+\beta x_1+\beta x_2+\beta x_3..+\beta x_n$ where Y = SP	Sig.	95.0% Confidence Interval	
		B	Std. Error			Lower Bound	Upper Bound
Male	Constant	113.790	6.283	SP = 113.79+0.717ELS	0.000	101.396	126.183
	ELS(cm)	0.717	0.085		0.000	0.550	0.884
	Constant	131.644	9.243	SP = 131.644+0.934ELS-0.545EHS	0.000	113.410	149.877
	ELS(cm)	0.938	0.119		0.000	0.703	1.173
	EHS (cm)	-0.545	0..210		0.010	-0.959	-0.132
	Constant	131.589	9.270	SP = 131.589+0.074HSP-0.560EHS+0.867ELS	0.000	113.302	149.876
	HSP(cm)	0.074	0.332		0.823	-0.581	0.730
	EHS (cm)	-0.560	0.220		0.012	-0.993	-0.127
	ELS(cm)	0.867	0.337		0.011	0.202	1.533
female	Constant	100.996	5.828	SP = 100.996+0.464HSP-0.418EHS+0.702ELS	0.000	89.498	112.493
	HSP (cm)	0.464	0.139		0.001	0.190	0.738
	EHS (cm)	-0.418	0.090		0.000	-0.595	-0.242
	ELS (cm)	0.702	.121		0.000	0.463	0.941
Both	Constant	104.634	5.193	SP = 104.634+0.821ELS	0.000	94.389	114.879
	EHS (cm)	0.821	0.079		0.000	0.664	0.977
	Constant	110.112	5.289	SP = 110.112+0.982ELS-0.287EHS	0.000	99.678	120.545
	ELS (cm)	0.982	0.090		0.000	0.804	1.159
	EHS (cm)	-0.287	0.083		0.001	-0.450	-0.124
	Constant	100.996	5.828	SP = 110.996+0.70ELS-0.418EHS+0.464HSP	0.000	89.498	112.493
	ELS (cm)	0.702	0.121		0.000	0.463	0.941
	EHS (cm)	-0.418	0.090		0.000	-0.595	-0.242
	HSP (cm)	0.464	0.139		0.001	0.190	0.738

a. Dependent Variable: SP (cm)

b. Independent Variables: ELS (cm), EHS(cm), HSP(cm)

Table 5: Coefficient correlation model summary analysis

Model	R	R^2	Adjusted R^2	Std. Error of the Estimate	Change Statistics				
					R^2 Change	F Change	df1	df2	Sig. F Change
Male	0.549^a	0.301	0.290	6.956	0.301	26.744	3	186	0.000
Female	0.660^a	0.436	0.426	2.512	0.436	47.843	3	186	0.000
Both	0.634^b	0.402	0.395	2.579	0.039	12.033	1	187	0.001

a. Predictors: (Constant), ELS (cm)

b. Predictors: (Constant), ELS (cm),EHS (cm)

c. Predictors: (Constant), ELS (cm), EHS (cm), HSP (cm)

The integration of ergonomic design principles, focusing on anthropometric dimensions, has been emphasized as a solution to reduce the risk of musculoskeletal disorders and enhance worker comfort and productivity. Ergonomic design aims to optimize human performance, minimize discomfort, and prevent injuries, making it essential in various fields, including industrial and product design (Musa et al., 2023). The significance of percentiles in ergonomics lies in their ability to provide designers with crucial information about body dimension distribution within a specific population. People have varied body shapes and sizes. Percentiles help designers understand these differences; ensuring products cater to a diverse audience.

Considering percentiles like the 5^{th} and 95^{th} ensures inclusivity for both smaller and larger individuals. Designing around specific percentiles creates ergonomic designs that enhance user comfort (Musa et al., 2014). Well-fitted products are more comfortable for extended use. Ergonomically designed products, considering various percentiles, reduce the risk of musculoskeletal disorders and injuries, promoting user health and safety. Understanding percentiles enables tailored products for specific demographics, such as children, seniors, or people with disabilities, ensuring a comfortable fit.

Percentiles offer essential insights into human body dimensions, enabling the design of products that are comfortable, safe, and inclusive. By considering these percentiles, products can accommodate the diversity of the human population, enhancing user satisfaction and inclusivity.

The study underlines the significance of measurements such as Human Sitting Posture, Sitting Eye Height (Eye Level Seated) and Sitting Elbow Height (Elbow Height Seating) in estimating Standing Posture (SP). These measurements are crucial for designing products like chairs and desks (Musa et al., 2011, Ismaila et al., 2013). The research method involved collecting data from 380 young adults in Nigeria, considering factors like age, gender, and regional demographics. The study conducted various statistical analyses, including linear regression, to establish model equations for determining SP using HSP, ELS and EHS. It acknowledged the impact of factors like race, ethnicity, age, and gender on anthropometric dimensions, emphasizing the need to consider these factors for accurate estimations. While recognizing the precision of regression models might vary among specific populations, the research aimed to provide essential anthropometric data crucial for ergonomic product design.

Moreover, the research stressed the importance of integrating anthropometric measurements, especially SP, HSP, ELS and EHS in ergonomic design processes. By incorporating these measurements and accounting for population-specific differences, products can be customized to meet the diverse needs of users, enhancing health, comfort, and productivity. The study acknowledged the diverse nature of anthropometric dimensions influenced by genetics, ethnicity, and geographical location. These variations underscored the importance of region-specific studies to ensure the accuracy and applicability of ergonomic designs, enabling designers to create products tailored to specific demographic groups.

In healthcare settings, particularly for individuals with disabilities, precise anthropometric measurements were vital. Designing equipment like wheelchairs for patients who couldn't stand upright highlighted the necessity of accurate measurements. By integrating these measurements, healthcare facilities could offer custom-fitted equipment, improving patients' quality of life and reducing musculoskeletal issues caused by poorly designed products.

The study's Implications for industrial and product designers were substantial. Understanding measurements like SP, HSP, ELS, and EHS allowed designers to create products catering to a wider audience. Adjustable office chairs and desks accommodating various body types promoted healthier postures, reducing chronic pain associated with prolonged sitting. These considerations not only enhanced user comfort but also increased productivity and satisfaction.

The study recognized challenges, such as excluding participants with limb deformities impacting measurements. Addressing these challenges in future studies could lead to more inclusive data. Additionally, the research encouraged exploration into other population-specific factors influencing anthropometric dimensions, refining ergonomic design principles for diverse contexts and user needs.

Beyond product design, the research had broader societal implications. By promoting ergonomic designs considering diverse anthropometric measurements, it contributed to building inclusive environments in public spaces, workplaces, and educational institutions. The study emphasized the multifaceted impact of integrating anthropometric measurements, addressing healthcare challenges, design implications, research obstacles, and societal impact. It provided a comprehensive perspective on the significance of this research in shaping a more ergonomic, inclusive, and healthier world for everyone.

4. CONCLUSION

The study highlighted the vital role of anthropometric measurements, particularly SP, HSP, ELS, and EHS, in ergonomic design processes. Considering these measurements enabled designers to create products tailored to diverse end-users, enhancing comfort, productivity, and overall well-being. Incorporating precise anthropometric data into everyday items mitigated the risk of musculoskeletal disorders, especially among vulnerable populations.

The study recommended integrating anthropometric data, including SP, HSP, ELS, and EHS, into product design processes. This ensured product was ergonomically suitable for a wide range of users, including individuals with disabilities. Further research should explore additional anthropometric measurements and their implications, fostering comprehensive and inclusive design solutions. Collaboration between designers and healthcare professionals was crucial, especially in medical equipment design, ensuring functionality, comfort, and safety for patients.

ISSN 1584 – 2665 (printed version); ISSN 2601 – 2332 (online); ISSN-L 1584 – 2665

Comparative studies across cultures and regions provided insights into global anthropometric variations, essential for designing products for international markets. Longitudinal studies assessing long-term impacts reinforced the importance of ergonomic principles. Exploring emerging technologies like 3D scanning and virtual reality enhanced measurement accuracy. Additionally, investigating strategies for inclusive design, especially for individuals with severe disabilities, was essential. This research paved the way for a future where products were universally accessible and beneficial to all, emphasizing ongoing interdisciplinary collaboration and public awareness.

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ISSN 1584 – 2665 (printed version); ISSN 2601 – 2332 (online); ISSN-L 1584 – 2665