INDIAN JOURNAL OF SCIENCE AND TECHNOLOGY

RESEARCH ARTICLE

Application of Multiple Linear Regression Analysis in Ergonomics Study for Public Institution Seat W idth

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OPEN ACCESS

Received: 12-07-2023
Accepted: 25-03-2024
Published: 21-05-2024

Citation: Adu S, Adu G, Antwi K, Appiah-Yeboah J (2024) Application of Multiple Linear Regression Analysis in Ergonomics Study for Public Institution Seat W idth. Indian Journal of Science and Technology 17(21): 2159-2165. https://doi.org/10.17485/IJST/v17i21.1741

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Funding: None

Competing Interests: None

Published By Indian Society for Education and Environment (iSee)

ISSN
Print: 0974-6846
Electronic: 0974-5645

Abstract

Objectives: To determine minimum seat width of comfortable seating for adult population, using multiple linear regression analysis on chair leg thickness, chair leg width, chair apron width, and knee height**. Methods:** Dimensions of three (3) factors were recorded using 310 adult workers. Multiple linear regression was used for statistical analysis for understanding how multiple factors (like chair leg thickness, chair leg width, chair apron width, and knee height) influence a single outcome to enhance comfortable seating. The collected data (chair leg thickness, chair leg width, chair apron width, and knee height) was analysed with the help of the analysis tool. **Findings:** The analysis used four predictors (knee height, chair leg thickness, chair leg width, and chair apron width) to obtain one predicted variable (seat width) to achieve comfortable seating based on these measurements. Subsequently, a moderate correlation existed between predictors and predicted variables, while correlations between predictors were less than 0.7 for them to be retained in the model. The coefficient of determination (R^2) is 0.3003, indicating that 30.03% of the variance in predictors could be explained by seat width. Based on the comfort assessment and analysis results, required widths that ensure comfortable seating for the target population can be recommended in public institutions. Overall, this research has the potential to improve public health, comfort, and productivity by creating data-driven design standards for seating in public institutions. **Novelty:** The study focused on elderly workers who patronise this furniture in the administration block of public institutions.

Keywords: Multiple linear regression; Ergonomics; Knee height; Chair component dimensions; Seat width

1 Introduction

Current public seating doesn't fit everyone comfortably. Chairs in libraries, waiting rooms, buses, and other public places are often sized for an average person, which can leave people feeling cramped or uncomfortable. This can be especially true for people who are larger or smaller than average. The study needs to find a seat width that works for most people. This will make the office staff that patronise this furniture in the administrative block more comfortable and inclusive for everyone.

This study aims to find the best seat width for public institutions by considering different human body and chair component sizes. The objective of this study is to determine the minimum seat width needed in public institutions to ensure comfortable seating for at least 90% of the adult population, using multiple linear regression analysis based on chair leg thickness, chair leg width, chair apron width, and knee height**.** Administrative office workers spend the majority of their time using office seats to do office work. The design of ergonomic products is dependent on human body measurements. However, the constructed seats in this current study were not designed based on users' body sizes. We know participants come in all shapes and sizes, and seat width can significantly impact comfort. This study will use a statistical technique to understand how different body measurements, like knee height, affect how comfortable people feel in seats.

Human body measurements play a significant role in producing an ergonomic product that is safe and comfortable and also ensures a healthy environment[(1)]. The match and mismatch between workers' anthropometric dimensions and chair sizes are made possible using relationship equations that compare their measures to settle on the right furniture sizes that will enhance ergonomic furniture design to address sitting problems associated with the use of furniture. For instance, Seat height is related to popliteal-to-floor height as it ought to be greater than seat height[(2)]. Also, seat width is related to the users' width of bitrochanter or hips so that enough room is created in the seat to accommodate users. In this case, there should be free movement of participants in the furniture[(3)]. Knee height is also related to desk clearance (i.e., the vertical distance from the floor to the bottom of the front edge of the desk)[(4)]. The above literature dealt with a few variables between the predictor and the predicted variables. If this paper were to follow the same trend, it would be time-consuming, expensive, and difficult. Therefore, a method to combine all four predictor variables at a goal to arrive at the predicted variable is the main concern of this present work to address those challenges. The method has the strength to investigate the dimensions that are related as factors to obtain the other dimensions relevant to the ergonomic design of furniture.

Consequently, relationships between dimensions that predict other ones are critical[(5)]. Some studies have used single variables and multiple variables in the regression equations to predict variables that are relevant to the ergonomic design of furniture[(6)]. For instance, some researchers reported that out of four measurements of factors, five other dimensions were obtained and further used for chair design[(7)]. For example, knee height is one of four critical anthropometric dimensions in the determination of the ergonomic school furniture. Also, stature in regression equations can be used to derive various body parts[(8)].

Engineering and science problems delve into exploring the relationships between at least two variables. Regression analysis is a method that studies the variation in the data on the dependent variable so that relationships between the variation and the associated independent variables can be achieved. Several regression analysis applications comprise situations in which there is more than one regressor variable. Multiple linear regression (MLR) on the other hand ensures the association between the two variables; one dependent and more than one independent[(9)]. MLR analysis is utilised to recap data and study relations between variables[(10)]. The MLR equation is:

$Y = b_0 + B_1(x_1) + B_2(x_2) + \ldots\ldots + B_n(x_n)$

Where Y equals the predicted score or the estimated value or dependent variables; $x_1, x_2, \ldots, x_n$ equals the independent variables; b_0 equals the constant and $B_1, B_2, \ldots, B_n$ equals the regression coefficients.

The ergonomic design of products, systems and environments optimise users' performance and well-being. Ergonomics plays a crucial role in ensuring comfortable and functional institutional spaces. It studies people's efficiency in their working environment[(11)]. Also, the ergonomic design of equipment with humans in mind reduces operators' fatigue and discomfort[(12)]. Public institutions often struggle to provide their staff with ergonomic seating that accommodates diverse body sizes and shapes. Sitting in an uncomfortable chair for long periods is not fun; it can negatively impact productivity and lead to health problems. In this study, we will investigate the importance of how multiple linear regression analysis can help in ergonomics studies. Previous research in the field of ergonomics has highlighted the significance of proper seating arrangements on individuals' health and well-being. Several studies have examined various ergonomic factors, such as seat dimensions, backrest design, and lumbar support, and their impact on seating comfort and performance. Designing products for designated users must involve their body dimensions for the product to fit them. The fitting of products includes their well-being, health, comfort and safety[(13)]. Further, some researchers used the right body sizes for ergonomic furniture design to help users perform their work efficiently[(14–16)].Without users' anthropometry, it will be difficult to produce ergonomic furniture[(17)].

2 Methodology

2.1 Sampling Design

Ten anthropometric measurements of 310 office staff (197 males and 113 females) and nine chair part dimensions of patronised office chairs were taken and recorded as data from three study areas (Kumasi Technical University, the Ministry of Lands and Natural Resources and Kwame Nkrumah University of Science and Technology) in Kumasi, Ghana.

2.2 Approval to Use the Participating Institutions

Registrars of the tertiary institutions (KsTU and KNUST) and the Kumasi head of MLNR gave their approval before the data collection started. Participants were assured of the confidentiality of any information concerning them. It was heartwarming that the participants from their own free will participated in the survey.

2.3 Measurement

2.3.1 Anthropometric Measurements

A precise, accurate, and dependable anthropometer, an adjustable chair (seating aid), and a steel measuring tape assisted in data collection. Table 1 and Figure 1 exhibit the descriptions of the ten body measurements of workers[18]. Apart from stature (S) where the participants were standing, the other nine body measures were collected while sitting: sitting height (Sh), sitting shoulder height (SSH), subscapular height (SCH), popliteal-to-floor height (PFH), the width of bitrochanter (WoB), elbow-to-seat height (ESH), buttock-to-popliteal length (BPL), buttock-to-knee length (BKL) and knee height (KH).

Table 1. Anthropometric measures definitions

Anthropometric dimensions	Definition
Stature	Distance is measured from the floor to the highest point of the head.
Sitting height	Distance is measured from the seat surface to the highest point of the head.
Sitting shoulder height	Distance measured from the seat surface to the top of the shoulder.
Popliteal-to-floor-height	Distance measured from the floor to the area behind the knee back.
Width of bitrochanter	Extreme horizontal distance between the hips in the sitting position.
Elbow-to-seat height	Distance measured from seat surface to flexed 90^{o} elbow bottom.
Buttock-to-popliteal length	Distance measured from buttock back to popliteal area behind the knee.
Buttock knee length	Distance measured from buttock back to the front of the knee cap.
Subscapular height	Distance measured from the seat surface to the underside of the scapula.
Knee height	Distance measured from the floor to the topmost part of the kneecap.

The study office furniture was without armrests (Figure 2). Local manufacturers constructed them by not sticking to any standards. The variables considered include:

- Seat width (SW): measured as the horizontal distance between the lateral edges of the seat. Seat width is the measured lateral horizontal distance of seat edges. Seat width formed the predicted variable[19]. When the weight of the seat user is evenly distributed, it allows the individual to move freely on the seat[20].
- Chair leg thickness (CLT): It is measured as the distance through the chair leg.
- Chair leg width (CLW): It is measured as the extent of the chair leg from side to side.
- Chair apron width (CAW): It is the extent of measurement from side to side of the flat part underneath the seat. Chair apron width provides structural strength and support in chairs.

2.4 Data Analysis

Dimensions of participants' knee height and chair parts sizes in centimetres are shown in Table 2.

3 Results

The correlations between variables are provided in Table 3. A moderate correlation existed between predictors and predicted outcomes. The correlation between predictors reported values less than 0.7. The correlation between the independent variables

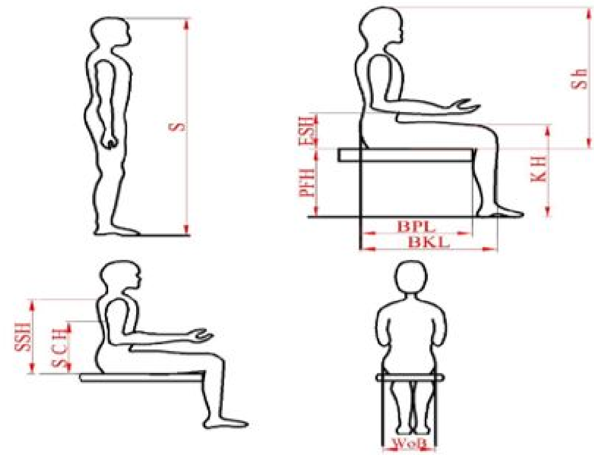

Fig 1. Anthropometry of the Office Staff

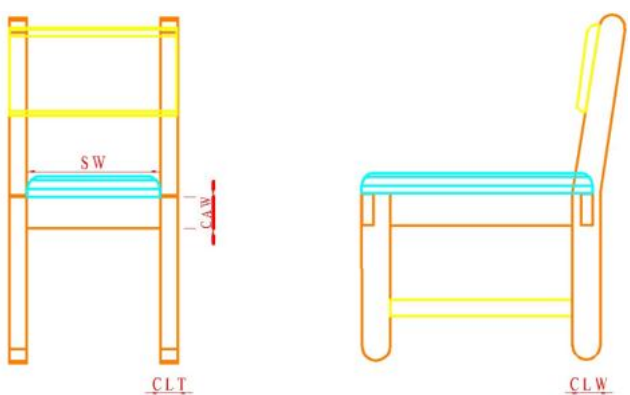

Fig 2. Chair design used in the offices

Table 2. Descriptive statistics for predictor variables like Knee height (KH), Chair leg thickness (CLT), Chair leg width (CLW), and Chair apron width (CAW)

Variable	Min	Max	SD	Mean	5^{th}	50^{th}	95^{th}
KH	49.0	70.0	4.40	60.3	50.6	60.0	67.0
CLW	4.0	6.0	0.62	4.7	4.0	5.0	6.0
CLT	2.0	3.0	0.47	2.3	2.0	2.0	3.0
CAW	4.0	8.0	1.13	5.9	5.0	5.0	8.0

is not too high to be retained in the model. In Table 4, the coefficient of determination (R^2) of 0.3003 indicates that 30.03% of the variance in seat width can be explained by the predictor variables (knee height, chair leg dimensions).

Table 3. Correlation between seat width (SW) and the predictors, knee height (KH), chair leg width (CLW), chair leg thickness (CLT), and chair apron width (CAW)

			1	2	3	4	5
Pearson correlation	1	SW	1.000	0.344	0.376	0.394	0.505
	2	KH	0.344	1.000	0.224	0.335	0.442
	3	CLW	0.376	0.224	1.000	0.264	0.590
	4	CLT	0.394	0.335	0.264	1.000	0.564
	5	CAW	0.505	0.442	0.590	0.564	1.000
Sig (1 – tailed)	1	SW		0.000	0.000	0.000	0.000
	2	KH	0.000		0.000	0.000	0.000
	3	CLW	0.000	0.000		0.000	0.000
	4	CLT	0.000	0.000	0.000		0.000
	5	CAW	0.000	0.000	0.000	0.000	
N	1	SW	310	310	310	310	310
	2	KH	310	310	310	310	310
	3	CLW	310	310	310	310	310
	4	CLT	310	310	310	310	310
	5	CAW	310	310	310	310	310

Table 4. Output of predictor variables, knee height (KH), chair leg width (CLW), chair leg thickness (CLT), and chair apron width (CAW) by predicted variable, seat width (SW)

Predictor	Estimate (B)	Std. Error	Beta	Confidence value (T)	Sig.	Tolerance	Variance inflation factor (VIF)
Constant	259.073	31.635	-	8.189	0.000	-	-
KH	0.126	0.048	0.140	2.594	0.000	0.793	1.262
CLW	0.910	0.377	0.144	2.414	0.016	0.644	1.554
CLT	2.208	0.827	0.157	2.671	0.008	0.666	1.501
CAW	0.923	0.250	0.270	3.699	0.000	0.432	2.317
R = 0.548			R^2 = 30.03 %			R^2(adjusted) = 29.10%	

The study model equation applied the dependent variables like knee height (KH), chair leg width (CLW), chair leg thickness (CLT), and chair apron width (CAW) with their regression coefficients:

Model Equation: SW = 25.907 + 0.126KH + 0.910CLW + 2.208CLT + 0.923CAW

4 Discussion

In one of the existing researches titled "Neural network and multiple linear regression to predict school children dimensions for ergonomic school furniture design". Students in their research were 600; who voluntarily participated in the study. The students ranged between 6 and 11 years old and were randomly selected from five UNRWA-UNESCO primary male schools. Four input variables (stature, shoulder-grip length, lower arm length, and shoulder breadth) were used to obtain five outputs (sitting shoulder height, elbow-to-seat height, buttock-to-popliteal length, popliteal-to-floor height, and knee height) for the design of school furniture [7]. However, knee height was used as one of the inputs instead of output in this present study to obtain the predicted variable. Adult office workers who were less than those in the existing study participated in the present study. The study areas in the present study were few compared to the existing ones. Subsequently, another study entitled "The estimation of different body dimensions from stature in the Bangladeshi male population", reported that there was a relationship between stature and other body dimensions that can be used to derive various body parts for the Bangladeshi male population. In all, 348 male volunteer participants; aged 19 to 25 years were involved in this study. Out of the 14 anthropometric parameters measured and analysed, a meaningful relationship existed between stature and other body dimensions like knee height [8]. Consequently, knee height became output in the existing study while it became input in the present study. Males were found in the existing work while both sexes participated in the present study. Participants in the existing study were younger than in the present study.

4.1 Anthropometric Dimensions of Workers

Firstly, the design of products to accommodate workers with large dimensions applies the 95^{th} percentile value of male body measurements. Secondly, the design of products to accommodate workers with varying dimensions applies 5^{th} and 95^{th} percentiles of females' and males' body measurements, respectively. Thirdly, the design of products to accommodate workers with the lowest dimensions uses the 5^{th} percentile of female body sizes [21].

4.2 Assessment of Correlation Between Predicted and Predicting Variables

In Table 3, a moderate correlation between independent and dependent variables suggests that when one changes the independent variable, it often leads to a change in the dependent variable, but not all the time and not by a fixed amount. There are other factors at play besides the independent variable. Seat width significantly influences the level of discomfort experienced by individuals during prolonged sitting [22]. Another study revealed that wider seats provide better support for individuals with larger body sizes, reducing the likelihood of developing posture-related musculoskeletal problems [23]. Understanding the impact of seat width on workers' comfort and well-being can assist in designing seating arrangements that promote proper posture and reduce the risk of musculoskeletal disorders. Generally, to sit for a lengthy period, the width of the seat should not go below 432mm [24]. A seat width of 432mm - 508mm is the standard. A correct seat width ensures that a reasonable range of the population gets into and out of the chair easily.

4.3 Output of Independent Variables by Dependent Variable

In Table 4, very high Tolerance values of the four variables refer to how much variability or uncertainty there is in a result. A very high tolerance means there's a lot of wiggle room in the findings. Very high tolerance indicates a lot of flexibility or leniency in how much something can vary and still be considered acceptable. The coefficient of determination (R-squared) of 0.3003 indicates a weak to moderate relationship between the dimensions of the chair (knee height, chair leg width, chair leg thickness, and chair apron width) and the width of the seat. The adjusted (R^2) statistic essentially penalises the analyst for adding variables to the model. Therefore, the adjusted (R^2) is a guide not to include variables that are not required [22].

4.4 Estimated minimum Seat Width (SW_{min}) Using the Model Equation

$$
\begin{aligned}
SW_{min} &= 25.907 + 0.126\,(Knee\ height)_{min} + 0.910\,(Chair\ leg\ width)_{min} + \\
&\quad 2.202\ Chair\ leg\ thickness)_{min} + 0.923\,(Chair\ apron\ width)_{min} \\
&= 25.907 + 0.126(49) + 0.910(4) + 2.202(2) + 0.923(4) \\
&= 25.907 + 6.174 + 3.640 + 4.404 + 3.692 \\
&= 43.817\ cm \\
&= 44\ cm
\end{aligned}
$$

Concerning the maximum, mean, 5^{th}, $50^{th,}$ and 95^{th} percentile values in centimetres, the same procedure that was used in calculating the minimum value is followed.

4.5 Challenges or Limitations Encountered in the Study

The challenges may be due to correlated predictors as regression analysis might struggle to tease apart how much knee height affects seat width versus how much the chair leg measurements do, and omitted variables that could estimate how much seat width truly contributes to comfort.

5 Conclusion

This scientific report has demonstrated the application of multiple linear regression analysis in providing insights into the relationship between independent variables to obtain dependent variables in an ergonomic study.

There is a usable relationship as the moderate correlation between the predictors and the predicted outcome displays a connection between user size (knee height) and chair design (leg and apron dimensions) that influence seat width. This can be valuable for chair design. On the other hand, there is limited accuracy as the prediction will not be exact. Other factors not considered (such as chair style, and target user population) can affect seat width.

This research has the potential to improve public health, comfort, and productivity by creating data-driven design standards for seating in public institutions.

Acknowledgement

With sincere gratitude and deep appreciation, we would like to thank Heads of institutions for the permission to conduct the study in their institution premises and to all workers who were involved in the data collection. To other data recording assistants who helped with the data recording, we say thank you very much.

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