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Anthropometric Evaluation of University Classroom Furniture

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ABSTRACT

The objective of this study is to evaluate four types of university classroom furniture. The methods of evaluation included the individual comparisons equations method and the percentile values method; both are anthropometric methods. The third method is a questionnaire-based subjective evaluation method aiming at studying students' satisfaction. The evaluated furniture dimensions were seat height, seat depth, seat width, backrest height, desk height and under desk height. The measured anthropometric dimensions were stature, hip breadth sitting, elbow height sitting, shoulder height sitting, knee height, popliteal height and buttock-popliteal length. They were collected from 80 students (half males, aged between 20 to 39 years). The individual comparisons method showed relatively lower percentages of match between the furniture dimensions and student anthropometry. While, the percentile values method showed relatively high percentages of accommodation. Results of the questionnaire showed that the majority of students were satisfied with their preferred designs.

Keywords: University students, Anthropometrics, University furniture, Classroom furniture, Students anthropometry

INTRODUCTION

School and university students spend long hours sitting on classroom furniture while performing their everyday learning-related tasks, such as reading, writing, etc. A poorly designed furniture may force students to sit in restricted and uncomfortable postures. This may lead to dissatisfaction and stress that affects students' performance negatively and may lead to musculoskeletal problems in the long run. Classroom furniture designs that confirm with related students anthropometrics should reduce such problems, help to achieve comfort and improve students' performance (Parcells, Stommel and Hubbard, 1999; Agha, 2010; Parvez, Rahman and Tasnim, 2019; Obinna, Sunday and Babatunde, 2021).

The main objective of this study is to collect the related anthropometric data for students at the Industrial and Manufacturing Systems Engineering department at University of Benghazi, and use it to evaluate the existing classroom furniture designs. The objectives also include the study of students' satisfaction with the existing classroom designs.

Three methods of evaluation were used to achieve the study objectives. The first two are the individual comparisons equations method and the percentile values method; both are anthropometric evaluation methods that utilize students' anthropometric data to evaluate the furniture designs. The third method is a questionnaire-based subjective evaluation method, involving the use of a questionnaire to study students' level of satisfaction and comfort with the furniture designs.

METHOD

The Classroom Furniture

Four types of classroom furniture designs were evaluated, two designs consist of tablet armchair desks (designs 1 and 2), in which the desktop is attached to the chair with a metal frame book storage beneath the chair. The other two designs (designs 3 and 4) consist of separated chairs and tables.

Six dimensions of the classroom furniture were evaluated; namely seat height, seat depth, seat width, backrest height, desk height and under desk height. Measurements of these six dimensions for the four designs are shown in Table 1.

Anthropometric Measurements

The study included collecting anthropometric dimensions for 80 students (half males, aged between 20 to 39 years). They were randomly selected out from 326 students enrolled in the department at the time of conducting the study.

Seven anthropometric dimensions were measured: stature, hip breadth sitting, elbow height sitting, shoulder height sitting, knee height, popliteal height and buttock-popliteal length. Measurements were taken at a lab using measurement tapes. The measurements were taken according to procedures described in (Bridger, 2018; Pheasant and Haslegrave, 2018). All measurements were taken on the sitting position (except stature) with students wearing light cloths and no shoes.

Evaluation Methods

Individual Comparisons Equations

Six equations were used to test the mismatch between anthropometric measures of the students and the dimensions of furniture. These questions are given

Table 1. Measurements of the dimensions of the existing furniture designs (in cm).

Type of design	Seat Height (SH)	Seat Depth (SD)	Seat Width (SW)	Backrest Height (BH)	Desk Height (DH)	Under Desk Height (UD)
Design 1	37	42	45	41	61	59
Design 2	44	45	47	50	70	68
Design 3	48	36	32	50	70	61.5
Design 4	45	40	43	41	77	74

Table 2. Individual comparisons equations (SA=shoes allowance).

Disk Dimension	Equation		Related Body Dimensions
Seat Height (SH)	(PH + SA) cos30 ≤ SH ≤ (PH + SA) cos 5	(1)	Popliteal Height (PH)
Seat Depth (SD)	80% BPL ≤ SD ≤ 95%BPL	(2)	Popliteal-Buttock Length (BPL)
Seat Width (SW)	110% HB ≤ SW	(3)	Hip Breadth Sitting (HB)
Desk Height (DH)	EH + (PH + SA) cos30 ≤ DH ≤ ((PH+SA) cos5)) + ((0.8517EH) + (0.1483SH))	(4)	Elbow Height (EH) / Popliteal Height (PH)
Seat Backrest height (BH)	60% S ≤ BH ≤ 80% S	(5)	Shoulder Height Sitting (SH)
Under Desk Height (UD)	KH + SA ≤ UD	(6)	Knee Height (KH)

in Table 2. These equations are the most widely used method for anthropometric evaluating of classroom furniture as reported in the literature (Parcells, Stommel and Hubbard, 1999; Gouvali and Boudolos, 2006; Agha, 2010; Castellucci, Arezes and Viviani, 2010; Macedo *et al.*, 2015; Yanto, Lu and Lu, 2017; Parvez, Rahman and Tasnim, 2019; Obinna, Sunday and Babatunde, 2021).

Each equation produces, individually for each student, a range in which the furniture dimension in question is considered suitable for this student. This range is determined for each student per each furniture dimension by using the related equation to calculate either acceptable two limits (upper and lower), or one acceptable limit (upper or lower). The furniture dimension in question is considered suitable for the student if it falls within the calculated range. It is considered inappropriate if it falls outside the range.

As an example, consider using equation (1) in evaluating a fixed seat height of 44.5 cm. Suppose that the popliteal height (PH) of a student is 42 cm and shoes allowance (SA) is 2 cm, then the lower acceptable limit is ((42+2) COS 30 = 37.6 cm) and the upper acceptable limit is ((42+2) COS 5 = 43.3 cm). Comparing this range (37.6-43.3) with the fixed seat height of 44.5 cm; one sees that it falls outside of the range and it is larger than the upper limit (44.5 > 43.3), indicating that the seat height is not suitable for this student (it is high for them).

Percentile Values

A percentile value of an anthropometric dimension represents the percentage of the population with a body dimension of a certain size or smaller (Lee *et al.*, 2017). The mean and standard deviation of the relevant anthropometric dimension were used to determine the corresponding percentile values for the furniture dimensions and percentages of accommodation of the populations. Similar procedures were used in (Yanto, Lu and Lu, 2017; Parvez, Rahman and Tasnim, 2019).

Students Satisfaction

A questionnaire was designed and used to study students' satisfaction and comfort with the four existing furniture designs. The questionnaire consists

of nine questions; eight about preference and satisfaction and one about discomfort.

The questionnaire first asks each participated student to indicate which furniture design they preferred, then, it asks the students to indicate if they were satisfied/dissatisfied with their preferred design. In case of dissatisfaction, the student was asked to identify with which specific design feature they were dissatisfied (e.g. seat height is high or low).

Students discomfort with the preferred design was determined using a Nordic questionnaire body map (Kuorinka *et al.*, 1987) with twelve body regions outlined in the map (head, neck, shoulders, chest, elbows, low back, forearms, wrists/hands, thighs, knees, legs and feet).

RESULTS

Results of Anthropometric Measurements

Table 3 gives means (M) and standard deviations (SD) of the collected anthropometric data.

Results of Individual Comparisons Equations

The percentages of match between the classroom furniture dimensions and the students' anthropometry for each design are shown in Table 4. The results are summarized as percentages of match or mismatch (above the upper acceptable limit and/or below the lower acceptable limit).

From numbers in Table 4, the only case where a 100% match was found is with under desk height in design (4). Relatively higher percentages of match were also found with backrest height in designs 1 and 4. Likewise, relatively higher percentages of match were found with seat width in design 2 and desk height in designs 2 and 3. In all the other cases relatively lower percentage (less than 70%) of match were found.

Results of Percentile Values

First, the normality of students' anthropometric data was checked by using histograms; no considerable deviations from the normal distribution were found.

Table 3. Summary of anthropometric measurements (in cm).

Anthropometric dimension	Female		Male		All	
	M	SD	M	SD	M	SD
Stature	162.5	5.9	174.5	5.3	168.5	8.2
Elbow height sitting	19.9	1.9	22.2	3.1	21.0	2.8
Shoulder height sitting	54.1	2.9	56.1	4.0	55.3	3.6
Knee height	52.7	2.4	60.4	4	56.5	4.7
Popliteal-buttock length	45.4	4.4	51.7	4.7	48.6	5.5
Popliteal height	44.3	1.8	49.9	3.4	47.1	3.9
Hip breadth sitting	41.1	3.1	35.7	4.9	38.4	4.9

Table 4. Percentages (%) of match and mismatch.

Furniture dimension		Design1	Design2	Design3	Design4
Seat height	Match	0	52.5	46.28	50
	Mismatch	100	47.5	53.75	50
	Above	1.25	7.57	48.75	18.75
	Below	98.75	40	5	31.25
Seat depth	Match	46.25	37.5	37.5	50
	Mismatch	53.75	62.5	62.5	50
	Above	26.25	50	0	12.5
	Below	27.5	12.5	62.5	37.5
Seat width	Match	66.25	81.25	2.5	55
	Mismatch	33.75	18.75	97.5	45
	Above	0	0	0	0
	Below	33.75	18.75	97.5	45
Backrest height	Match	85	2.5	2.5	85
	Mismatch	15	97.5	97.5	15
	Above	15	97.5	97.5	15
	Below	0	0	0	0
Desk height	Match	28.75	72.5	72.5	45
	Mismatch	71.25	27.5	27.5	55
	Above	0	11.25	11.25	53.75
	Below	71.25	16.25	16.25	1.25
Under desk height	Match	57.5	98.75	68.75	100
	Mismatch	42.5	1.25	31.25	0
	Above	0	0	0	0
	Below	42.5	1.25	31.25	0

Table 5 contains calculations of the corresponding percentile values for the existing furniture dimensions of the four designs and hypothetical percentages of accommodation of the populations. The mean and standard deviation of the relevant anthropometric dimension -after adding the allowance – were used in the calculations.

As an example, from Table 1, the value of the seat height dimension for design 1 is 37 cm, and from Table 3, the mean of the popliteal height is 47.1 cm and the standard deviation is 3.9 cm. Adding the value of the shoes allowance of 2 cm to the mean (modified mean = 49.1 cm), then utilizing the normal distribution probability density function, the result is a percentile of 0.10 %. Since seat height is an upper limit dimension (Lee *et al.*, 2017) that designed based on a lower percentile, the corresponding hypothetical percentage of accommodation is (1-0.0010)*100 = 99.9. This was repeated for all the other dimensions. Percentages of accommodation for seat depth and backrest height were calculated based on lower percentiles since they are upper limit dimensions. Seat width, desk height and under desk height are lower limit dimensions and higher percentiles were used in calculating their percentages of accommodation.

The numbers in the Table 5 show relatively high percentages of accommodation for most dimensions across all designs. However, still some cases of relatively low percentages of accommodation were found (especially in design 2 and design 3).

Table 5. Corresponding percentiles and percentages of accommodation for the existing furniture dimensions.

Furniture dimensions	The relevant anthropometric dimension		Design 1	Design 2	Design 3	Design 4
Seat height	Popliteal height	Percentile	0.10	9.71	38.69	14.79
		Percentage of accommodation	99.90	90.28	61.30	85.20
Seat depth	Buttock popliteal length	Percentile	6.05	15.62	0.42	2.80
		Percentage of accommodation	93.94	84.37	99.57	97.19
Seat width	Hip breadth	Percentile	62.19	76.25	1.02	46.27
		Percentage of accommodation	62.19	76.25	1.02	46.27
Backrest height	80% of shoulder height	Percentile	3.35	90.15	90.15	3.35
		Percentage of accommodation	96.64	9.84	9.84	96.64
Desk height	Elbow height	Percentile	38.7	43.15	39.5	80.38
		Percentage of accommodation	38.7	43.15	39.5	80.38
Under desk	Knee height	Percentile	53.44	97.57	72.92	99.93
		Percentage of accommodation	53.44	97.57	72.92	99.93

Table 6 shows a comparison between the results of the individual comparisons equations method and the percentile values method. The table lists the percentages of the match of each furniture dimension in each design (given in Table 4) and the percentage of accommodation of each furniture dimension in each design (given in Table 5). In general, there is some consistency between the results of the two methods. There was noticeable compatibility between the results of both methods for seat width, backrest height and under desk height. However, for seat height, seat depth and desk height no clear compatibility could be seen.

The reason why the two method were not completely compatible might be due to the fact that the percentile values method deals with the whole population and assumes that the data collected from the sample is a valid representation of the population. In addition, it uses fixed dimension of the furniture and assumes that all the population with a relevant anthropometric dimension less than (or greater than; depending on type of the dimension) the furniture dimension are accommodated by it. The individual comparison equations method, on the other hand, deals only with the individuals in the collected sample and uses a limited range for comparison for each individual for each dimension.

Results of Students Satisfaction

This section discusses the results of the questionnaire used to study students' satisfaction and comfort with the existing furniture designs. Table 7 summarizes the questionnaire results regarding students' satisfaction. These

Table 6. Comparison between the percentages of the match and the percentage of accommodation of each furniture dimension in each design.

Furniture dimensions		Design 1	Design 2	Design 3	Design 4
Seat height	Match	0	52.5	46.25	50
	Accommodation	99.89	90.28	61.30	85.20
Seat depth	Match	46.25	37.5	37.5	50
	Accommodation	93.94	84.37	99.57	97.19
Seat width	Match	66.25	81.25	2.5	55
	Accommodation	62.19	76.25	1.02	46.27
Backrest height	Match	85	2.5	2.5	85
	Accommodation	96.64	9.84	9.84	96.64
Desk height	Match	28.75	72.5	72.5	45
	Accommodation	38.7	43.15	39.5	80.38
Under desk	Match	57.5	98.75	68.75	100
	Accommodation	53.44	97.57	72.92	99.93

Table 7. Summary of questionnaire results regarding students' preference and satisfaction (as percentages (%) of responses for each item).

Item	Design				All
	1	2	3	4	
The mostly sit on design	2.5	11	42	44.5	-
The preferred design	8.75	2.5	8.75	58.75	-
Sitting hours per day (on the preferred design)					
< 2	28.6	0	0	10.6	8.8
2-3	42.9	50.0	42.9	40.4	40
3-4	14.3	50.0	57.1	44.7	47.5
> 4	14.3	0	0	4.3	3.8
Satisfaction with the preferred design	42.9	100	71.4	78.7	72.5
Dissatisfaction with the preferred design	57.1	0	28.6	21.3	27.5
Dissatisfaction is due to:-					
Desk height is high	20		50	20	27.3
Desk height is low	10		50	60	50
Seat height is high	10				9.1
Seat height is low	10		50	40	27.3
Backrest is high	20		50	20	22.7
Backrest is low			50	30	22.7
Seat width is narrow				10	4.5
Seat depth is long	20				9.1
Seat depth is short	10		50	10	13.6

results show that design 4 is the mostly sit on and preferred one with percentages of (44.5 % and 58.75 %) respectively. Results also show that 47.5 % of the students sit on their preferred design between three to four hours per day.

The results also indicate that the overall satisfaction of the students with the preferred designs is 72.5 % and that dissatisfaction is mostly due to the low desk height with 50%.

Table 8. Summary of questionnaire results regarding students' physical discomfort (as percentages (%) of responses for each item).

Item	Design				All
	1	2	3	4	
Discomfort with the preferred design	57.1		28.6	21.3	27.3
Discomfort is felt in :-					
Neck			33.3	45.5	36
Shoulder (right)			33.3	18.2	16
Shoulder (left)				9.1	8
Elbow (right)				9.1	4
Forearm (right)					4
Lower back	80		100	81.8	84
Knee (right)	20				8
Leg (left)	20				4

The questionnaire results regarding students' physical discomfort with the furniture designs are summarized in Table 8. Students were asked to show- with the help of a Nordic questionnaire body map- in what body region discomfort was felt.

The questionnaire results show that discomfort was felt in eight body regions (from the twelve regions outlined on the body map). The highest overall percentages were recorded in the low back (84 %) and the neck (36 %).

CONCLUSION

The objective of this study is to evaluate four designs of the classroom furniture at the Industrial and Manufacturing System Engineering Department at University of Benghazi. Three types of evaluation criteria were utilized; they are the individual comparisons equations, the percentile values and students satisfaction.

The results of the individual comparisons equations gave relatively low percentages of matches in most furniture dimensions. The percentile values method gave relatively high percentages of accommodations for most dimensions.

Nonetheless, some noticeable compatibility was found between the results of the two methods.

Results of the subjective evaluation questionnaire regarding students' satisfaction and comfort with the existing furniture designs showed that design 4 is the most sit on and preferred by students. Results also indicated that the majority of students were satisfied with their preferred designs and that dissatisfaction was mostly due to that the desk height was low.

Based on findings of this study, it is recommended that design 3 and design 4 or a combination from both (chair from 3 and table from 4 or vice versa) should be used for the time being. However, to obtain complete percentages of match and accommodation, this study suggests the design and use of fully adjustable dimensions classroom furniture. A less desirable, but probably more practical solution is to design and use improved fixed dimensions

classroom furniture. The data collected and results of this study could be used as basis for designing such furniture.

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