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Development of an Evaluation Protocol for Ergonomic Chair Selection

Heecheon You [1], Rahul Khrakar [1], Erwin Unaja [1], Yen Mien Liu [1],
Jeffrey E. Fernandez [1], Diana Mansouri [2], Kandace Johnson [2], and Ken Arnold [2]
[1] Department of Industrial and Manufacturing Engineering
Wichita State University, Wichita Kansas 67260-0035, USA
[2] Department of Risk Management, Sedgwick County, Kansas
Wichita, Kansas 67203, USA

Abstract

A systematic evaluation protocol was developed to provide information of chairs suitable to users having different body sizes. The chair evaluation protocol includes (1) definition of user groups, (2) classification of chair uses, (3) determination of ergonomic guidelines, and (4) evaluation and synthesis. Four user groups were defined by equally partitioning 95% (2.5 to 97.5 percentiles) of the US population based on height and three categories of chair usage such as office, executive, and guest chairs were identified. Then, to identify chair dimensions appropriate to each user group, 22 chair design parameters selected and 8 anthropometric variables associated with chair design were related. Finally, evaluation and synthesis schemes for three ergonomic criteria were developed: (1) accommodability, (2) comfort, and (3) effectiveness of mechanism. Using the proposed protocol, 28 chairs (15 office, 7 executive, and 6 guest chairs) sent to a county in Kansas by several chair vendors were evaluated. The evaluations of each chair based on the three ergonomic criteria were summarized into one of three recommendation categories: *recommended*, *acceptable*, and *unacceptable*. Use of the chair evaluation information would help purchase ergonomic chairs suitable to the county's employees for better performance and quality of health of workers.

Keywords: Chair evaluation protocol, Ergonomic criteria, Anthropometry.

1. Introduction

Sitting in a chair unfit to the user for a long period of time causes fatigue, discomfort, and/or pain due to undue stress on the body [1]. To reduce the undesirable effects, a careful selection should be made for a chair that matches the user's body dimensions. However, evaluation protocols commonly accepted to determine if a chair is ergonomically suitable to the user or a group of users are not available.

The purpose of this study is to develop a systematic protocol for ergonomic evaluation and selection of chair. By using the evaluation protocol, this study provides information of proper chairs for a user group specified. The chair evaluation information is expected to facilitate acquisition of ergonomic chairs suitable to a county's employees, which will contribute to job satisfaction, quality of health, and productivity in the workplace.

2. Chair Evaluation Protocol

A systematic protocol was proposed to evaluate chairs from three ergonomic aspects: accommodability, comfort, and effectiveness of mechanism (Figure 1). Detailed procedures of the protocol include (1) definition of user groups (Q1 to Q4), (2) classification of chair uses, (3) determination of ergonomic guidelines for chair dimensions, and (4) evaluation and synthesis.

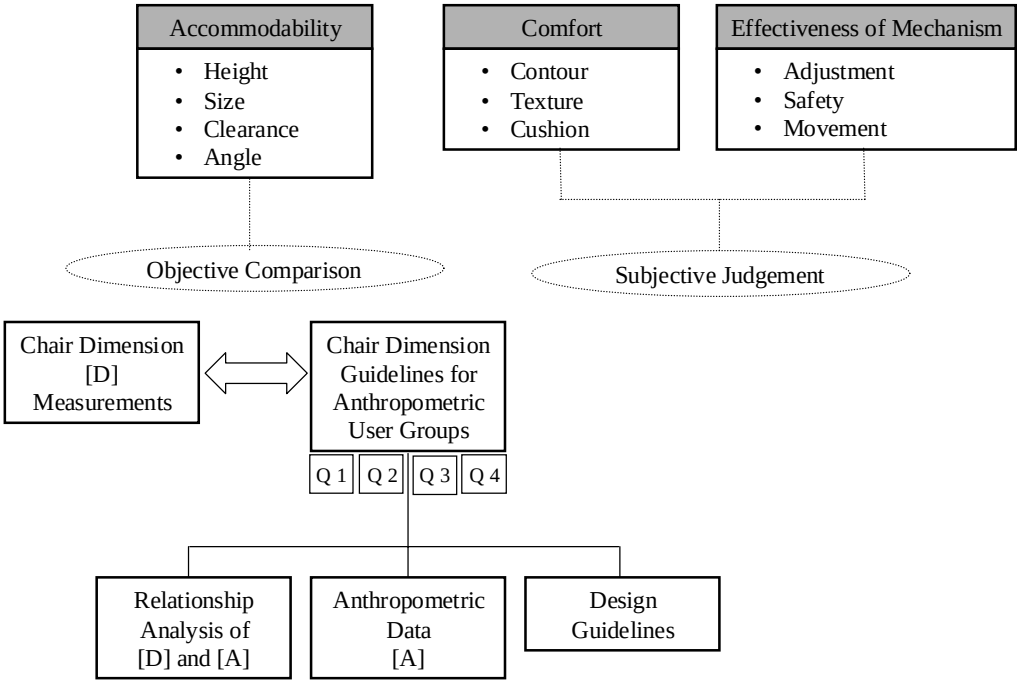

Figure 1 Ergonomic protocol for chair evaluation and selection

2.1. User Groups and Anthropometric Data

Four user groups were defined which equally divide 95% (2.5 to 97.5 percentiles) of the US population based on height. The quadrant groups are Q1 (2.5th %tile to 26.5th %tile), Q2 (26.5th %tile to 50.0th %tile), Q3 (50.0th %tile to 73.75th %tile), and Q4 (73.75th %tile to 97.5th %tile) and their height ranges are 60.3" 64.7", 64.7"to 66.8", 66.8" to 68.9", and 68.9" to 73.3", respectively.

Anthropometric variables associated with chair evaluation were identified and then their values for the quadrant groups were estimated by using averages and standard deviations of anthropometric data of the US population (Table 1). Eight anthropometric variables were selected for the shoulder, elbow, trunk, hip, and knee as major variables for chair dimensions. The anthropometric dimensions for each user group were estimated by means of the z-transformation technique [3].

Table 1 Estimates of anthropometric data for quadrant user groups (unit: inches) [1, 2]

Anthropometric Variables		Average	Standard Deviation)	Q1 (2.5%tile - 26.25%tile)		Q2 (26.25%tile - 50%tile)		Q3 (50%tile - 73.75tile)		Q4 (73.75%tile - 97.5%tile)	
				Min	Max	Min	Max	Min	Max	Min	Max
Shoulder (S)	Height (sitting)	22.7	2.90	17.0	20.9	20.9	22.7	22.7	24.5	24.5	28.4
	Breadth	14.1	1.90	10.4	12.9	12.9	14.1	14.1	15.3	15.3	17.8
Elbow (L)	Elbow-elbow breadth (sitting)	20.4	1.57	17.3	19.4	19.4	20.4	20.4	21.4	21.4	23.5
	Elbow Height (sitting)	8.8	1.05	6.7	8.1	8.1	8.8	8.8	9.5	9.5	10.9
Trunk (T)	L5/S1 Height (sitting)	8.0	1.00	6.0	7.4	7.4	8.0	8.0	8.6	8.6	10.0
Hip (H)	Breadth (sitting)	14.9	1.38	12.2	14.0	14.0	14.9	14.9	15.8	15.8	17.6
Knee (K)	Buttock-Popliteal Length (sitting)	19.0	0.90	17.2	18.4	18.4	19.0	19.0	19.6	19.6	20.8
	Popliteal Height	16.6	1.35	14.0	15.7	15.7	16.6	16.6	17.5	17.5	19.2

2.2. Categories of Use of Chairs

This study considered three categories of use of chairs: office, executive, and guest chairs. Office and executive chairs are those equipped with mechanisms for adjustment to provide better fit and functional support to the users, whereas guest chairs are those having no adjustment mechanisms due to design for the public. Office and executive chairs are differentiated depending on presence of support for the head and neck—executive chairs have supporting components for the head and neck, while office chairs do not have.

2.3. Ergonomic Guidelines for Chair Dimensions

Ergonomic guidelines of chair dimensions were determined for each user group by considering relationships between chair dimensions and anthropometric variables, anthropometric data of the US population, and relevant ergonomic guidelines. Twenty-two dimensions (Table 2) were defined for the seat pan, backrest, armrest, and accessories (legs and wheels) of chair. Of the chair dimensions, seven dimensions such as seat-height and lumbar-support height were identified as those related to the anthropometric variables selected (Table 3). The check mark in a cell indicates that the anthropometric variable should be considered in designing the chair dimension. For example, the height of seat-pan should be determined by considering information of popliteal height of the user population of interest. The chair

Table 2 Glossary of chair dimensions (selected)

Dimensions		No	Descriptions
Seat-Pan	Height	1	Distance of the foremost point of the seat-pan from the floor.
	Depth	2	Maximum vertical length of the seat-pan.
	Width	3	Maximum horizontal length of the seat-pan.
	Angle	4	Degree of inclination of the seat-pan (minus sign to indicate forward tilt and plus sign backward tilt, respectively).
	Curvature	5	Contour of the seat-pan.
	Texture	6	Degree of softness of the seat-pan cover.
	Cushion	7	Degree of comfort of the seat-pan cushion material.
Backrest	Top-Height	8	Distance of the highest point of the backrest from the point on the seat-pan projected from the lumbar support.
	Bottom-Height	9	Distance of the lowest point of the backrest from the point on the seat-pan projected from the lumbar support.
	Length	10	Distance between the top-height and the bottom-height of the backrest.
	Lumbar-support Height	11	Distance of the lumbar-support (most protruded point on the backrest) from the seat-pan.
	Width	12	Maximum horizontal length of the backrest.
	Angle	13	Degree of reclining of the backrest, measured at a point above about 5 inches from the lumbar support.
	Curvature	14	Contour of the backrest.

Table 3 Analysis of relationship between chair dimensions and anthropometric variables (illustrated)

			Seat-Pan (P)			
			Height	Depth	Width	Angle
Anthropometric Variables		**Codes**	PH	PD	PW	PA
Shoulder (S)	Height (sitting)	SH				
	Breadth	SB				
Elbow (L)	Elbow-elbow width (sitting)	EEL				
	Elbow Height (sitting)	EH				
Trunk (T)	L5/S1 Height (sitting)	TH				
Hip (H)	Breadth (sitting)	HB			✓	
Knee (K)	Buttock-Popliteal Length (sitting)	BPL		✓		
	Popliteal Height	PH	✓			

dimensions were classified into two groups in terms of importance: (1) primary dimension group including seat-pan height, lumbar-support height, and armrest-to-armrest width and (2) secondary dimension group including seat-pan depth, seat-pan width, backrest width, and armrest height.

The relationship analysis results and associated ergonomic guidelines such as clearance for postural changes were combined into formulas (Table 4). Then, the anthropometric data of each user group were substituted into the formulas to identify lower and upper limits of the chair dimensions to accommodate each user group.

Table 4 Ergonomic guidelines for chair dimensions for quadrant user groups (illustrated) (unit: inch)

Chair Dimensions		Lower Limit (LL)/ Upper Limit (UL)	Ergonomic Guide Formulas	Ergonomic Guides for Quadrant Groups			
				Q 1 [2.5%tile - 26.25%tile]	Q 2 [26.25%tile - 50%tile]	Q 3 [50%tile - 73.75%tile]	Q 4 [73.75%tile - 97.5%tile]
Seat-Pan	Height	LL	Popliteal height (KPH) + 1 (shoe effect) - 1 (preference)	14.0	15.7	16.6	17.5
		UL	Popliteal height (KPH) + 1 (shoe effect) + 1 (preference)	17.7	18.6	19.5	21.2
	Depth	LL	Buttock-popliteal length (KBP) - 2 (knee clearance) + 1 (preference)	14.2	15.4	16.0	16.6
		UL	Buttock-popliteal length (KBP) + 1 (preference)	19.4	20.0	20.6	21.8
	Width	LL	Hip breadth (HB) + 2 (clearance)	16.0	16.9	17.8	19.6

2.4. Evaluation and Synthesis

Three ergonomic criteria were used for chair evaluation: (1) accommodability, (2) comfort, and (3) effectiveness of chair mechanism. While evaluations of both chair comfort and effectiveness of mechanism use subjective judgement by evaluators using a scale of 1 (very poor) to 5 (very good), those of chair accommodability is based on the objective comparison of chair dimensions measured with the ergonomic guidelines for each user group identified.

The evaluations of accommodability, comfort, and mechanism effectiveness were summarized into one of three recommendation categories: *recommended*, *acceptable*, and *unacceptable*. For comfort and mechanism effectiveness, the minimum values of *recommended* and *acceptable* were 3.5 and 2.5 of average score, respectively; for accommodability, a scale shown in Table 5 was used having different cut-offs depending on type of use of chair.

Table 5 Accommodability scale for overall assessment *

Assessment Category	**Usage of Chair**		
	Office	**Executive**	**Guest**
Recommended	All the primary and the secondary dimensions fit the user group of interest	At least two thirds (2/3) of the primary dimensions and three quarters (3/4) of the secondary dimensions fit the user group interest.	At least one third (1/3) of the primary dimensions and half (1/2) of the secondary dimensions fit the user group of interest.
Acceptable	At least two thirds (2/3) of the primary dimensions and three quarters (3/4) of the secondary dimensions fit the user group of interest.	At least one third (1/3) of the primary dimensions and half (1/2) of the secondary dimensions fit the user group of interest.	At least one third (1/3) of the primary dimensions and one third (1/3) of the secondary dimensions fit the user group of interest.
Unacceptable	Otherwise		

* The primary and secondary dimensions are defined in section 2.3.

3. Ergonomic Chair Evaluation - Case Study

The proposed protocol for chair evaluation was used to help a county in Kansas purchase ergonomic chairs suitable to the county's employees. This section presents evaluation of chairs step by step based on the protocol.

3.1. Classification of Use of Chair

Twenty-eight chairs were available for ergonomic evaluation, which were delivered to the county by several chair companies. It was identified that, of the 28 chairs, 15 chairs are for office workers, 7 chairs for executives, and 6 chairs for guests, respectively.

3.2. Chair Dimension Measurements

Of the 22 chair dimensions defined, 16 linear and angular dimensions such as height, size, and inclination were surveyed for each chair by using a tape measure, protractor, and bubble scale (Table 6). In case that a dimension varies due to adjustment mechanism, the maximum and minimum of the dimension were measured when its corresponding chair component is fully adjusted to the extremes and then its range was computed.

Table 6 Dimensions of a chair measured (illustrated)

(unit: inches for linear dimensions and degrees for angular dimensions)

Dimensions		Code	Min.	Max.	Range
Seat-Pan (P)	Height	PH	16.5	21.75	5.25
	Depth	PD	16.25		-
	Width	PW	19.75		-
	Angle	PA	5		-
Backrest (B)	Top Height	BTH	23		-
	Bottom Height	BBH	1.25		-
	Bottom-to-Top Length	BBTR	21.75		-
	Lumbar-Support Height	BLSH	7.25		-
	Width	BW	20.5		-
	Angle	BA	14	30	16
Armrest (A)	Height	AH	6.5	10.5	4
	Length	AL	14		-
	Width	AW	3.25		-
	Armrest-to-Armrest Width	AAW	19.25		-
Accessories (C)	Number of Legs	CL	5		-
	Number of Wheels	CW	5		-

3.3. Accommodability Evaluation

The dimensions of a chair measured were compared with the ergonomic guidelines determined to identify what quadrant groups the chair can accommodate (Table 7). If a chair dimension belongs to the upper and lower bounds of corresponding ergonomic guideline for a particular user group, the chair dimension was judged fit to the user group; if not, the reverse was concluded. For example, in the table, the seat-pan height is adjustable between 17.75" and 22.75", but, this adjustment range does not cover the corresponding guideline for Q1, 14.0" to 17.7"; thus, it was evaluated that the seat-pan height of the chair is not suitable to the user group Q1.

Table 7 Accommodability evaluation (illustrated)

Dimensions		Code	Min.	Max.	Q1	Q2	Q3	Q4
Seat-Pan (P)	Height	PH	17.75	22.75		✓	✓	✓
	Depth	PD	18.5		✓	✓	✓	✓
	Width	PW	23.25		✓	✓	✓	✓
	Angle	PA	0	4	N/A	N/A	N/A	N/A

3.4. Comfort Evaluation

Of the 22 chair dimensions defined in the present study, six chair dimensions which are complex to measure such as curvature or related to subjective comfort such as cushion were assessed by two evaluators using a scale of 1 (very poor) to 5 (very good) (Table 8). Averaging was used for each dimension and then comfort scores of the six dimensions were averaged, assuming equality of their importance, to determine the overall level of comfort of a chair of interest.

Table 8 Comfort evaluation (illustrated)

Dimensions		Evaluator 1	Evaluator 2	Average
Seat-Pan (P)	Curvature	3	3	3
	Texture	4	4	4
	Cushion	3	4	3.5
Backrest (B)	Curvature	3	3	3
Armrest (A)	Curvature	4	3	3.5
	Texture	4	4	4
			Overall Average	3.50

3.5. Mechanism Effectiveness Evaluation

Eight mechanisms for adjustment of chair, safety, and movement were assessed in terms of effectiveness by two evaluators with a scale of 1 (very poor) to 5 (very good) (Table 9). A score of 2.5 was assigned to the effectiveness of a mechanism in case the mechanism is not present in the chair. Averaging was utilized to summarize the mechanism evaluations of each chair the same as described in the comfort evaluation.

Table 9 Mechanism effectiveness evaluation (illustrated)

Dimensions		Evaluator 1	Evaluator 2	Average
Seat-Pan (P)	Depth Adjustment Mechanism	2.5	2.5	2.5
Backrest (B)	Height Adjustment Mechanism	4	3	3.5
	Angle Adjustment Mechanism	4	4	4
Armrest (A)	Height Adjustment Mechanism	2.5	2.5	2.5
	Width Adjustment Mechanism	2.5	2.5	2.5
Accessories (C)	Reclining Lock Mechanism	4	5	4.5
	Reclining Support Mechanism	4	4	4
	Movement Mechanism	4	5	4.5
			Overall Average	3.50

3.6. Synthesis

The analysis results for the 28 chairs with respect to use of chair, accommodability, comfort, and effectiveness of mechanism were integrated in Table 10 based on the proposed scheme for synthesis (described in section 2.4). The table presents recommended and acceptable chairs for each user group based on ergonomic evaluation.

Table 10 Synthesis of chair evaluation

● : Recommended; ❍ : Acceptable; blank: Not acceptable

Chair No	Usage			Accommodability				Comfort	Usability
	Office	Executive	Guest	Q1	Q2	Q3	Q4		
1	●			●	●	❍	❍	❍	❍
2	●			●	●	❍	❍	●	●
3	●			❍	●	❍	❍	●	●
4	●			❍	●	●	●	●	❍
5	●			❍	❍	❍		●	❍

4. Summary

This study proposed an ergonomic protocol for chair evaluation and provided ergonomic evaluations of chairs provided by vendors for a county. The chair evaluation protocol incorporated anthropometric characteristics of four user groups (Q1 to Q4) defined, three uses of chair (office, executive, and guest chairs), relationships between chair dimensions and anthropometric variables, and assessments of comfort and mechanism effectiveness. It is expected that the information of ergonomic chair evaluation would facilitate acquisition of chairs fit to the county's employees. A further study is needed to validate the chair evaluation protocol in providing an ergonomic chair for the user, which will contribute to job satisfaction, quality of health, and productivity in the workplace.

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