

An Experimental Study on Seat Depth

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Abstract

A methodology has been developed to evaluate the useful seat depth for a target population. The methodology is found to be reliable and valid based on both objective and subjective measurements. A chair with an “adjustable” seat depth was designed and developed for this purpose. A total of 30 Chinese students were tested. The objective measure was the seat edge protrusion when seated. Eight seat features were rated using a 5-point scale. The results indicate no statistical difference between the seat depths of 30.4 cm and 38 cm for the Acceptability and the Overall Discomfort seat ratings. In addition, the objective measure indicated that a seat depth of 31 to 33 cm is adequate for the Hong Kong Chinese. Thus, it may be concluded that a seat depth of 30 to 33 cm is ideal for the same population.

Index words: seat depth, sitting, anthropometry.

1. Introduction

Sitting is a very primitive form of body support. Even though 65% of the weight (Branton, 1969) is carried by the seat pan, investigations on the seat pan have been very few. Most seat studies have been limited to backrests, cushioning or contouring of the surface. Hence recommendations for seat pan depth have been based on empirical reasoning and the so called common industry practice (ANSI/HFS 100-1988; Floyd and Roberts, 1959; Grandjean, et al 1973; JIS S 1011, 1978; Sanders and McCormick, 1992; Shao et al, 1990). A recent survey done by Renae (1995) has shown that the seat pan ranked as the number one aspect needing improvement.

Seat pan dimensions have been primary candidates for anthropometry based recommendations. Hence it is natural for dimensions such as seat depth to vary among standards and countries (Table 1). For example, the ANSI/HFS 100-1988 specifies a seat depth between 38 and 43 cm, “based on common industry practice”. The standard further states that the establishment of a strict criterion for maximum seat depth is difficult due to the large variation in buttock-popliteal length of the large male and the small female. However, the minimum seat depth appears to be around 38 cm. The study reported here is an experimental investigation of the seat depth for the Hong Kong Chinese population.

2. Methodology

A special seat having a sitting surface made of cane, but no backrest, was fabricated. The seat was designed to accommodate 5 cane units. Each cane unit was 45.8 cm wide and 7.6 cm deep giving an “adjustable” depth from 7.6 cm to 38 cm. The seat was height and tilt adjustable. A total of 30 subjects (22 male and 8 female) participated in the experiment. All subjects were university students and the participants were paid HK\$ 40 for their time. None of the subjects had any musculoskeletal injury. Prior to experimentation, the height, weight, age, popliteal height (PH), and buttock-popliteal length (BPL) were recorded. The seat, height adjustable foot-rest, and a table comprised a computer “workstation” (Figure 1). The height of the seat was adjusted so that the top of the computer monitor set to eye level. A foot rest was placed under the feet so that the knee angle was 90 degrees. The subject was asked to sit in the most comfortable posture on one of five possible

seat depths, and the experimenter recorded the distance from the buttock to the seat edge distance (dimension “a” in Figure 1). The order of presentation was counterbalanced between subjects with an ordering similar to a Latin square design. After the measurement, the subject rated the chair characteristics of Seat Height, Seat Width, Seat Depth, Seat Cushioning, Seat Stability, Seat Surface, Personal Acceptability of the seat, and Overall Discomfort on a 5 point scale (Figure 3). At the end of all ratings, the subject was asked to stand and relax until the chair was set to perform the second trial. When the chair was repositioned, the subject sat down again and the above procedure was repeated. The total experimental time for each subject varied between 1 to 1.5 hours.

Table 1. Seat depth recommendations

<i>Source</i>	<i>Criterion</i>	<i>Recommended seat depth</i>
ANSI/HFS 100-1988	standard industry practice	38 cm - 43 cm
BS 5940 Part 1 (1980)/ BS 3044 (1990)	smallest person in design range (38-43 cm with fixed back)	40.5 cm*
BellCore (1985)		40.6 cm - 43.2 cm
CEN ¹		38 cm - 47 cm
DIN ¹		38 cm - 42 cm
Swedish Standard ¹		38 cm - 43 cm
Bennett (1928)	less than 6-8 inches between popliteal part and the front edge of seat	more than 20 cm - 25 cm*
Diffrient, et al. (1974)		33 cm - 41 cm
Kroemer et al (1994)	do not press into sensitive tissues near knee	38 cm - 42 cm
Ayoub, et al (1987)	10 cm clearance between popliteal part and the front edge of seat	30.5 cm*
Grandjean (1986)		38-42 cm
Shao, et al (1990)	three-quarters of the thigh length	30.4 cm*

3. Results and Analysis

The descriptive statistics of the subjects are shown in Table 2.

Table 2. Descriptive Statistics of Subjects

Variable	N	Mean	Median	Std. Dev.	Minimum	Maximum
Age (Years)	30	28.9	28	4.38	21.0	38
Height (cm)	30	169.09	168.25	6.64	154.0	181.70
Weight (kg)	30	64.4	64.82	10.85	45.75	81.05
Popliteal height (PH), cm	30	39.999	39.755	1.917	36.1	45.20
BPL (cm)	30	44.47	44.2	2.21	41.5	49

The projection “a” (Figure 1) was used to determine the optimum seat depth. Since the subjects had varying buttock-popliteal lengths (BPL), “a” was normalized with respect to the BPL of each subject. The plot of these normalized values expressed as a percentage against seat depth (cane depth or number of canes) is shown in Figure 2. The figure shows that the cross-over point (that is where the graph crosses the x-axis) occurs at a seat depth of approximately 31 cm. At the higher seat

* Based on 5th %ile BPL of 40.5 cm as given in Pheasant (1994)

¹ Adapted from Chaffin and Andersson (1991)

depth of 38 cm, the mean (a/BPL)% value is -11.69 . The mean observed BPL in this experiment was 44.47 cm even though Pheasant (1988) reported a mean value of 45 cm. Using a BPL of 44.47 cm at a seat depth of 38 cm, dimension “a” would equal $(-11.69)(44.47)/100 = -5.20$ cm. In other words, the support depth would equal $(38 - 5.2) = 32.8$ cm². Both the above results suggest that a seat depth of approximately 31–33 cm is adequate for the Hong Kong Chinese population.

The ANOVA on the subjective ratings (Figure 4) showed no significant ($p < 0.05$) effects for the dependent variables of seat width (Table 3). Note that the seat width was kept constant through the complete experiment. However, significant effects do exist for the number of cane units with the dependent variables of Seat Depth, Cushioning, Seat Surface, Stability, Personal Acceptability, and Overall Discomfort ratings. A *post-hoc* Student Newman Keuls test showed no significant difference between 4 canes (30.4 cm seat depth) and 5 canes (38 cm seat depth) for the two ratings of Personal Acceptability and Overall Discomfort. The SNK for seat depth showed obvious differences among all seat depths. However, Figure 4 shows that a mean value of 3 (or “correct”) is achieved with a total of four canes (i.e., seat depth of 30.4 cm).

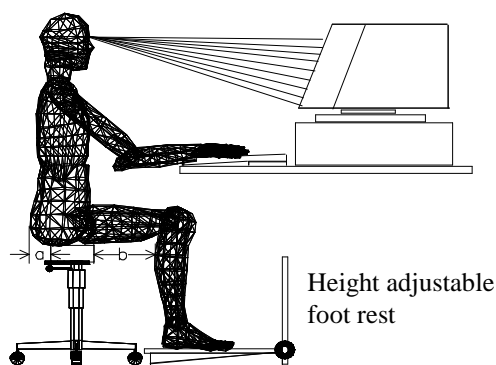


Figure 1. *Experimental set-up and dimensions “a” and “b” measured during sitting. ($a + b + \text{seat depth} = \text{BPL}$)*

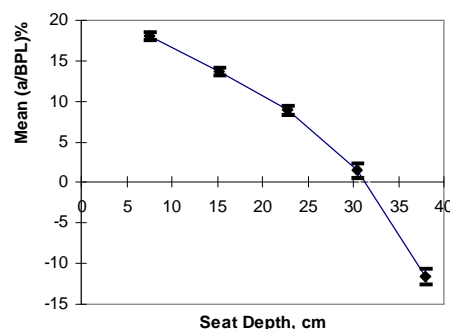


Figure 2. *Dimension “a” as a percentage of buttock-popliteal length for all subjects. The vertical lines correspond to the standard error.*

Table 3. ANOVA results of subjective ratings. The F-value and the corresponding probability (in parenthesis) for $p < 0.05$ are shown below.

Source(df)	S. Height	S. Width	S. Depth	Cushion.	S. Surface	Stability	Acceptab.	Overall
gender (1)								
trial (1)								
gender * trial				5.23 (0.03)				
cane (4)			80 (.0001)	16.2 (.0001)	28.6 (.0001)	50.8 (.0001)	74.96 (.0001)	99.2 (.0001)
gender*cane	2.58 (0.04)					3.11 (.0182)		
trial*cane					3.11 (.018)			
gender*trial* cane								

² A BPL of 45 cm would give a support depth 32.7 cm.

4. Discussion and Conclusions

Both subjective and objective measures indicate that a seat depth of approximately 30-33 cm is suitable for the Hong Kong Chinese population in contrast to the ANSI standard of 38-43 cm for the US population. The results are consistent and are statistically reliable. Hence the methodology that has been developed and used is suitable to determine the optimum seat depth for a target population.

Seat depth has been governed by anthropometry in the past. Even though seat usability studies have been performed by many, no study has systematically explored the subjective and objective effects of increasing/decreasing seat depth. The special seat designed and developed has been the key to this study. The use of the seat is not restricted to a particular population since the seat depth can be varied between 7.6 cm and any desired upper limit even though a maximum of only 38 cm was used in this study.

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Seat Height	<div> <div>1</div> <div>2</div> <div>3</div> <div>4</div> <div>5</div> </div> <div> <div>Too High</div> <div>Correct</div> <div>Too Low</div> </div>
Seat Width	<div> <div>1</div> <div>2</div> <div>3</div> <div>4</div> <div>5</div> </div> <div> <div>Too Narrow</div> <div>Correct</div> <div>Too Wide</div> </div>
Seat Depth	<div> <div>1</div> <div>2</div> <div>3</div> <div>4</div> <div>5</div> </div> <div> <div>Too Long</div> <div>Too Short</div> </div>
Seat Cushioning	<div> <div>1</div> <div>2</div> <div>3</div> <div>4</div> <div>5</div> </div> <div> <div>Too Hard</div> <div>Correct</div> <div>Too Soft</div> </div>
Seat Stability	<div> <div>1</div> <div>2</div> <div>3</div> <div>4</div> <div>5</div> </div> <div> <div>Poor</div> <div>Adequate</div> <div>Good</div> </div>
Seat Surface	<div> <div>1</div> <div>2</div> <div>3</div> <div>4</div> <div>5</div> </div> <div> <div>Poor</div> <div>Adequate</div> <div>Good</div> </div>
Personal Acceptability	<div> <div>1</div> <div>2</div> <div>3</div> <div>4</div> <div>5</div> </div> <div> <div>Strongly Dislike</div> <div>Dislike</div> <div>Neutral</div> <div>Like</div> <div>Strongly Like</div> </div>
Overall Discomfort	<div> <div>1</div> <div>2</div> <div>3</div> <div>4</div> <div>5</div> </div> <div> <div>Very Uncomfortable</div> <div>Uncomfortable</div> <div>Some Discomfort</div> <div>Slight</div> <div>No Discomfort</div> </div>

Figure 3. Chair Feature Questionnaire (Adapted from Drury and Coury, 1982)

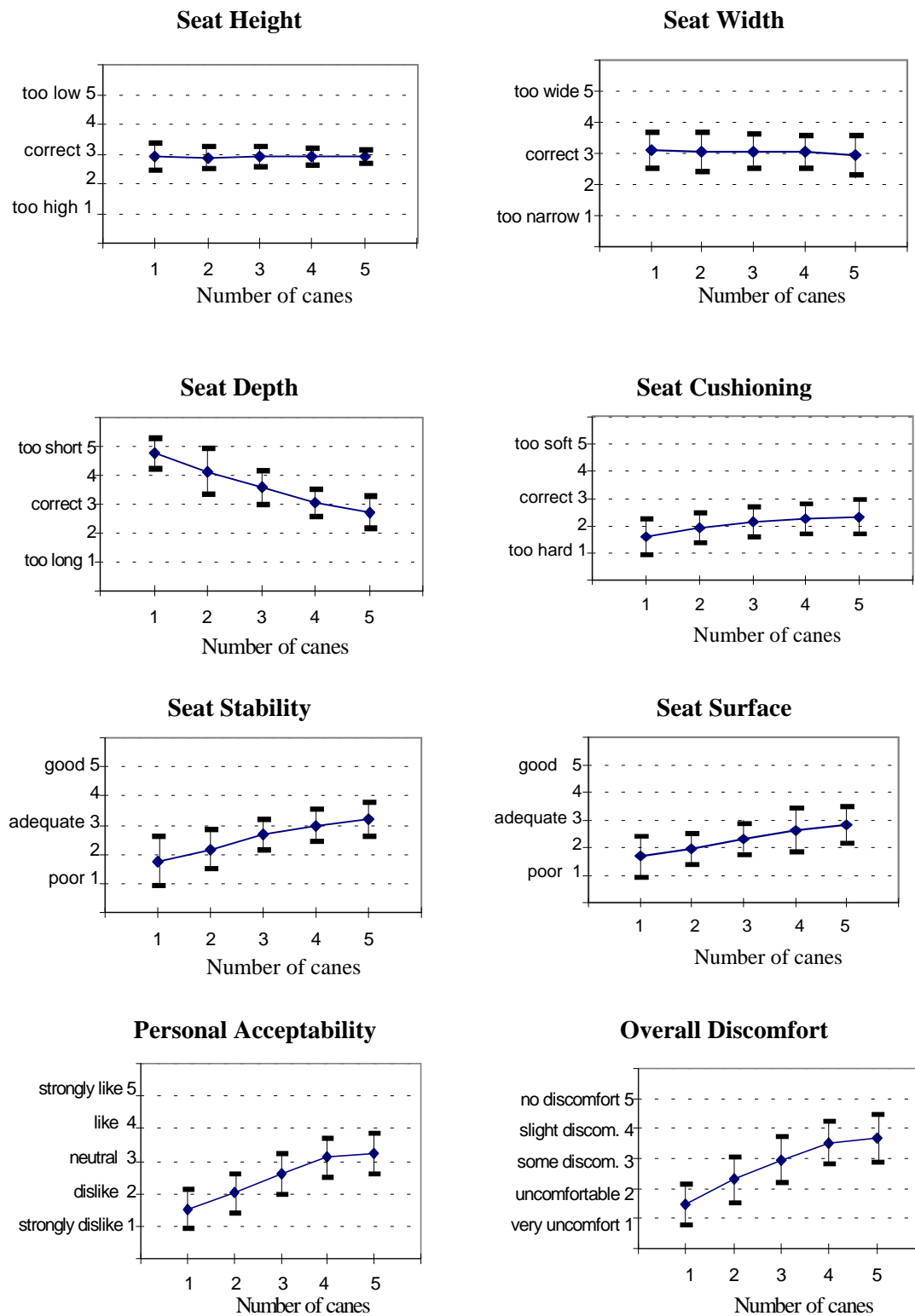


Figure 4. Mean subjective rating and standard deviation for seat features.