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Effect of chair design on ratings of discomfort

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EFFECT OF CHAIR DESIGN ON RATINGS OF DISCOMFORT

A Thesis

Presented to

The Faculty of the Department of Human Factors/Ergonomics

San Jose State University

In Partial Fulfillment

of the Requirement for the Degree

Master of Science

by

Musaed Alnaser

May 2003

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ABSTRACT

EFFECT OF CHAIR DESIGN ON RATINGS OF DISCOMFORT

By Musaed Alnaser

The purpose of this study was to determine if ratings of discomfort differ over time between two ergonomic chairs of the same approximate cost. Twenty participants from a metropolitan university sat on two types of ergonomic chairs for 1 hour and 30 minutes while performing typing, reading, and writing activities. Repeated measure three-way and two-way analyses of variance were used to uncover the effects of the ergonomic chair design on discomfort. The data were collected using the General Comfort Rating Scale and the Body Part Discomfort Rating Scale, which were administered at 0, 30, 60, and 90 minute marks of each session. The results revealed: 1) discomfort increased over time, 2) no significant difference was uncovered between the two chairs, 3) most discomfort was reported in the lower back, 4) number of body parts with discomfort was reduced when chairs were varied, and 5) discomfort was influenced by the activities performed.

DEDICATION

I would like to dedicate my thesis to my late father, 1929-1988, whose encouragements, teachings, and principles about education still echo in my mind for the past 15 years. I would like to thank him for the discipline and ethics that he instilled in me. I believe that he is smiling and proud of me right now.

I also would like to dedicate my thesis to my mother, whose everyday prayers helped me with every achievement and protected me from evil. I know there are thousands and thousands of miles between us. I ask Allah to comfort you because I know you will never stop worrying until I am home.

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Table of Contents

	Page
LIST OF TABLES	xi
LIST OF FIGURES	xiii
CHAPTER 1	
Introduction	1
Hypotheses	3
Delimitations	4
Definition of Terms	4
Importance of the Study	5
CHAPTER 2	
Review of Literature	7
Features and Cost of Ergonomic Chairs	7
Sitting and Chair Positioning	8
Independence of Comfort and Discomfort	10
Effect of Musculoskeletal and Posture on Discomfort	11
Effect of Sitting Tasks on Discomfort	15
Outcomes of Discomfort	16
Summary	17
CHAPTER 3	
Methods	18
Participants	18

Instrumentation	20
Procedures	25
Design	28
Analysis of Data	29
CHAPTER 4	
Results	31
Main Effects	32
Interaction Effects	34
Body Part Discomfort	35
Summary	43
CHAPTER 5	
Discussion	45
Chair	45
Time	46
Session	47
Effect of Switching Chairs	48
Body Part Discomfort	51
Effect of Activities on Discomfort	53
Limitation of the Study	55
Recommendation for Future Research	56
CHAPTER 6	
Conclusion	58

REFERENCES	61
APPENDIXES	
A. Screening Questionnaire	64
B. General Comfort Rating Scale	65
C. Body Part Discomfort Rating Scale	66
D. Human Subjects-Institutional Review Board	67
E. Consent Form	68
F. Flier	70
G. Adjustment Check Off Form	71
H. Ergonomic Chair Principles	72

LIST OF TABLES

Table	Page
1. Demographic of Participants	18
2. Frequency Distribution Table of Participants' Daily Sitting Hours	19
3. Description of Features in the Ergonomic Chairs	23
4. Independent Variable of Chair	29
5. Three-Way Analysis of Variance (ANOVA), 2 x 2 x 4, with Repeated Measure on the last two factors	30
6. Two-Way Analysis of Variance (ANOVA), 2 x 4, with Repeated Measures on the Last Factor	30
7. ANOVA Source Table 2 (Switch) x 2 (Session) x 4 (Time)	31
8. Table of Means for the Three-Way Analysis of Variance (ANOVA), 2 (Switching) x 2 (Session) x 4 (Time), with Repeated Measure on the Last Two Factors	32
9. ANOVA Source Table 2 (Chair) x 4(Time)	32
10. Discomfort Level Every 30 Minutes	34
11. Effect of Chair Type on Body Parts with Discomfort	36
12. Descriptive Statistics of the Body Part Discomfort Rating Scale Collapsed Across Groups	37
13. Descriptive Statistics of the Body Part Discomfort Rating Scale for Chair A/Chair B	38
14. Descriptive Statistics of the Body Part Discomfort Rating Scale for Chair B/Chair A	39
15. Descriptive Statistics of the Body Part Discomfort Rating Scale for Chair A/Chair A	40

16.	Descriptive Statistics of the Body Part Discomfort Rating Scale for Chair B/Chair B	41
17.	Lower Back Discomfort	42
18.	Lower Arm Discomfort	42
19.	Neck Discomfort	43
20.	Interaction of Switch and Session on Body Parts with Discomfort	50

LIST OF FIGURES

Figure	Page
1. The Aeron Work Chair	21
2. The Wharton WH88 Deluxe Chair	22
3. Discomfort as a Function of Time	33
4. Discomfort as a Function of Session and Time	35

CHAPTER 1

Introduction

The purpose of this study was to determine if ratings of discomfort would change over time between two ergonomic chairs of the same approximate cost. Today, people sit in chairs for long hours to execute their work tasks, study, perform leisure activities, and relax. Long hours of sitting could cause health problems and occupational diseases and disorders, especially disorders of the musculoskeletal system (Landrigan & Backer, 1991). Chair design has been revolutionized, and ergonomic chairs have been developed to prevent injuries and disorders. Ergonomic chairs are designed in different sizes and shapes with adjustable features and contours such as seat height, seat depth, backrest tilt, sliding seat, lumbar support, and chair tilt to maintain comfort and to reduce stress (Syarto, 2000).

For chairs, including ergonomic chairs, to be effective in maintaining comfort, a user has to maintain an upright and an erect posture while occupying the chair, which would be a typical ergonomists' recommendation for sitting. However, people could not maintain an erect upright posture for long periods (Fenety, Putnam, & Walker, 2000). Fenety et al. (2000), by continuously recording in-chair movement and measuring sitting discomfort by tracking the center of pressure at the buttocks, found that participants maintained firm sitting for the first 15 minutes, a significant increase in in-chair movement developed after 30 minutes, and a significant constant increase in-chair movement occurred at the end of the 2 hours testing. Corlett and Bishop (1976) stated that increasing the level of discomfort would cause workers to stop working and to take

rest breaks to recover from discomfort and pain, which in turn would lead to less work time and productivity.

In a review paper describing the possible causes of musculoskeletal pain in video display terminal users, Carter and Banister (1994) found that fatigue caused sitters to slouch forward on their seats. In addition, the tasks and activities performed when sitting could increase discomfort and alter posture. Type of work was commonly the cause of work-related injuries such as low back pain, neck pain (Grieco, 1986), carpal tunnel syndrome, poor blood circulation to the legs, edema (Carter & Banister, 1994), tendonitis, tenosynovitis, epicondylitis (National Institute for Occupational Safety and Health [NIOSH], 1997), and disorders of the upper extremities (NIOSH, 1995).

To show that a relationship existed between time and discomfort Helander and Zhang (1997) examined 21 office chairs that passed ergonomic features evaluation and sturdiness, durability, and compliance criteria. Helander and Zhang administered the General Comfort Rating Scale, the Body Part Discomfort Rating Scale, and Chair Evaluation Checklist every 90 minutes (8 hours experiment), and discovered that discomfort was related to fatigue accumulated during the workday, but discomfort was not related to the chair design.

In the present study, two ergonomic chairs (Aeron Work Chair and Wharton WH 88 Deluxe Chair) were used to examine the effect of chair design on ratings of discomfort over two 90 minutes sessions and whether or not the participants changed chairs from Session 1 to Session 2. The two ergonomic chairs were selected based upon the

differences in their design philosophies. Designers of the chairs claimed their design philosophy to be best in reducing discomfort level. Herman Miller, Inc. (2002) stated that three design strategies were the basis for the design of the Aeron Work Chair. The first design strategy was to make the Aeron Work Chair to look completely different than any other ergonomic chairs. The second strategy was to use Pellicle suspension material to make the chair transparent to allow the flow of air and moisture to the skin to reduce heat storage and to distribute weight evenly on the chair. The third strategy was to design the chair with curves and cuts to fit the human body, which has no straight lines. Office Master, Inc. (2001) claimed that the Wharton WH88 Deluxe Chair was designed to have the look and the style for managers and executives and to provide the most comfort. The chair was also designed to integrate multifunctional tasks with fewer adjustments with the most flexibility (Office Master, Inc., 2001).

Hypotheses

To examine the effect of the independent variable on the dependent variables, the following null hypotheses tested: (a) chair switch, session, and time would not interact to affect ratings of discomfort, (b) chair switch and time would not interact to affect the ratings of discomfort, (c) session and time would not interact to affect the ratings of discomfort (d) chair switch would not affect ratings of discomfort, (e) session would not affect ratings of discomfort, and (f) time would not affect ratings of discomfort. Also another set of null hypotheses were developed for a repeated measure two-way analysis of variance 2 x 4 as follows: a) type of chair and time would not

interact to affect ratings of discomfort, b) type of chair would not affect ratings of discomfort, and c) time would not affect ratings of discomfort.

Delimitations

Participants were recruited from a large metropolitan university. Participants completed the screening questionnaire (Appendix A), and only participants with no prior history of back, shoulder, pelvic, leg, arm, wrist and/or hand problems and/or surgeries participated in the study. Moreover, prior users of either of the two chairs (Aeron Work Chair or Wharton WH88 Deluxe Chair) or similar to them were excluded from their participation in the study. Participants were 18 years of age or older.

Definition of Terms

The following terms were defined for the purpose of the study.

Comfort. Helander and Zhang (1997) defined comfort as feelings of “well-being.” Comfort is a feeling of relaxation and well-being (Zhang, Helander, & Drury, 1996).

Discomfort. Discomfort is a feeling of pain, irritation, numbness, tiredness, soreness, and tenderness (Helander & Zhang, 1997). Zhang, Helander, and Drury (1996) identified poor biomechanics, fatigue, and restlessness to be the major patterns of discomfort. Zhang et al. also added that poor biomechanical factors could cause feelings of pain, soreness, numbness, and stiffness. Absence of discomfort was not the elimination of all feelings, it was not necessarily a positive effect, and absence of pain did not always lead to feelings of comfort (Branton, 1969).

Level of discomfort was measured using the General Comfort Rating Scale (Appendix B) and the Body Part Discomfort Rating Scale (Appendix C), which were completed once at 0 (baseline), 30, 60, and 90 minute marks for a total of two sessions.

Importance of the Study

Conducting research was important to generate deeper understanding of human biomechanics and to find ways to improve sitting comfort. Technology has changed the behavior of workers and types of jobs. Now, People work and sit for many hours a day (Carter & Banister, 1994). Many jobs are performed with static posture and repetitive motion and require less time standing and moving (Carter & Banister, 1994). Examining chair design on the human body is critical to providing recommendations, preventing injuries, creating safe environments, and justifying advantages and cost (Martocchio, Harrison, & Berkson, 2000).

This study examined the notion that ergonomic chairs produce minimal discomfort and postural complaints. This study was also designed to provide useful information about the effects of factors such as type of chair, duration of sitting, and type of activity that could increase human body discomfort. Four dynamic factors would affect the work environment: safety, health, productivity, and legal issues. Unsafe environments could have a cascading effect by causing injuries. Injuries have an effect on decreasing workers' productivity and increasing workers' compensation issues, which could create economical and social impact on both workers and employers (Martocchio et al., 2000). Therefore, creating a safe environment would be an important element in protecting workers from injuries, increasing workers' productivity, and reducing workers'

compensation lawsuits (Martocchio et al., 2000). Understanding the design philosophy of chairs and the effects of chair design on discomfort is important because chairs are essential part of the work environment (Carter & Banister, 1994). Although, Carter and Banister stated that due to different body dimensions, work habits, and preferences, it is hard to appoint an optimal chair, current and future chair studies might assist in narrowing the selections to good quality chairs.

CHAPTER 2

Review of Literature

Features and Cost of Ergonomic Chairs

Ergonomic chairs could have many adjustable features and moving parts to accommodate different users' heights, shapes, and sizes. Users perform different tasks and chairs should allow movement to support static and dynamic postures (Helander, Zhang, & Michel, 1995). Ergonomic chairs designed with many adjustable features and control mechanisms such as seat height and depth, seat-pan tilt, backrest height and angle, back tension, armrest height, and lumbar height and depth (Helander et al. 1995). Syarto (2000) described ergonomic chairs as coming in different shapes, sizes and costs; the number of options or adjustable features determines cost. For example, Leap designed by Steelcase ranges between \$500 to \$1,400, Waveland designed by Geiger Brickel ranges between \$750 to \$950, and Freedom designed by Humanscale ranges between \$985 to \$1,155 depending on options.

According to Helander et al. (1995) adjustable features and control mechanisms often go unnoticed and unidentified, and users do not read manuals to learn about chair adjustment. Helander et al. conducted three experiments. The purpose of the first experiment was to determine the types of chair control mechanisms that could be identified by 20 naïve users. In the second experiment after training participants in the operation of the chair controls for 20 chairs, participants performed a chair adjustability task on all 20 chairs to determine the ease of use of the controls. The purpose of the third experiment was to investigate the effect of the number of adjustability features on

ratings of comfort and time for adjustment. Helander et al. found that users spend very little time identifying, and learning about adjustable features and control mechanisms, and some features and controls were unused. Helander et al. concluded that users would need education and training to use chairs with adjustable features, and chairs should be designed in a style to make adjustable features and controls easy to locate, understand, and use in order to generate the most benefit and to decrease the level of user discomfort. Helander, Little, and Drury (2000) found that adjustable features were frequently not used, and some users thought that adjustable features were not important.

Sitting and Chair Positioning

For many years, researchers attempted to find a perfect sitting working position, and they discovered that the right angle position (90 degrees at hip, knees, ankle, and elbow) was the best sitting posture (Mandal, 1981, 1987). Mandal found no justifiable scientific base that the right angle position was correct or optimal; in addition, Mandal found that no one could maintain this posture for a long time. From a prospective of human anatomy and by observing sitting behaviors, Mandal proposed that the correct postural sitting would be 60 degrees at the hip and 30 degrees bend at the lumbar region with 20 degrees forward tilt of the seat pan and 10 degrees front tilt of the table. Canadian Center for Occupational Health and Safety (1998) recommended that a good sitting body position is 90 to 120 degrees of hip and elbow angles, 90 to 120 degrees of knee angle, and 0 to 30 degrees of trunk inclination with 30 degrees of front tilt of the table.

Burandt and Grandjean (1963) investigated the sitting habits of 378 clerical employees and conducted an experimental study of seat height with 68 participants.

Participants were seated in a fixed chair and completed a questionnaire on a fixed tabletop. The distance between the seat and the tabletop was set at 28 cm (11.00 in), and the floor panel was raised or lowered by 2 cm (0.80 in) at a time during the test.

Participants were asked to indicate the most comfortable height adjustment on the questionnaire. Burandt and Grandjean concluded that the most comfortable chair height was between 42 and 47 cm (16.50 and 18.50 in) and at distance of 27 and 30 cm (10.60 and 11.80 in) between the seat and the tabletop. They also found that 78 cm (30.70 in) table height provided adequate space for adjustment. Burandt and Grandjean recommended 14 to 24 cm (5.50 to 9.45 in) of vertical backrest adjustability, 33 to 44 cm (13.00 to 17.30 in) of seat pan tilt, and no less than 35 cm (13.75 in) of seat pan depth. Their investigation revealed that seat height and sitting habits were determined by the comfort of the sitter's upper body.

In a seated workstation, the chair is most likely to be the most important component. Chair can affect posture because of static work and limited movement. Recommending an optimal chair would be a difficult task because people come in different body dimensions, habits, and personal preferences (Carter & Banister, 1994). In their review paper describing the possible causes of musculoskeletal pain in video displays terminals, Carter and Banister (1994) also added that due to increase office automation (e.g., electronic mail, personal printers, local area networking), workers were sitting for long periods and performing most tasks while sitting. Therefore, the current study would assist in revealing the consequences of sitting for long periods and the effect of performing repetitive task while sitting, and how time and task induce discomfort.

Independence of Comfort and Discomfort

According to Helander and Zhang (1997), comfort and discomfort are independent factors, i.e., reduction in discomfort does not bring about comfort. To show that comfort and discomfort were two different but complementary factors, Zhang, Helander, and Drury, (1996) collected 104 responses to two questionnaires (A for comfort and B for discomfort) investigating the importance of sitting comfort/discomfort of seated office workers and to gather descriptors of feelings of comfort and discomfort. Zhang et al. found that discomfort was linked to biomechanical factors and fatigue, and it was described in terms of pain (44 responses), soreness and numbness (31 responses), fatigue (16 responses), and environmental (13 responses) factors, whereas comfort was linked to well-being, aesthetics, and impression, and it was described as relaxation (28 responses), natural feeling (19 responses), well-being (12 responses), and energy (8 responses) factors. To determine the effect of pain on level of discomfort, Vergara and Page (2002) administered the General Comfort Rating Scale and the Body Part Discomfort Rating Scale every 25 minutes to 6 participants. Participants sat on 6 different chairs of different sizes, shapes, and features for 100 minutes while performing reading and writing tasks. Vergara and Page found that when the General Comfort Rating Scale showed an increase in discomfort, and the Body Part Discomfort Rating Scale revealed a rise in discomfort in the neck region and followed by the lumbar region. When the scores of the two scales were correlated, they showed a significant increase in discomfort in the lumbar region, followed by the neck and dorsal region, respectively. Vergara and Page concluded that lumbar pain was the primary cause of discomfort.

When assessing chair comfort, the chair aesthetic could affect sitter perception of comfort (Shackel, Chidsey, & Shipley, 1969; Helander & Zhang, 1997). The aesthetic design of the chair was an important factor explaining comfort. Aesthetic had been associated with the sense of well-being, which could lead people to evaluate chairs in term of visual and artistic preference than comfort/discomfort (Helander & Zhang, 1997), and it could increase the sensation of comfort (Helander, Czaja, Drury, Cary, & Burri, 1987).

Effect of Musculoskeletal and Posture on Discomfort

Musculoskeletal discomfort had been associated with poor posture, biomechanical stress and repetitive work, and discomfort manifested in varieties and frequencies as soreness, aching, stiffness, fatigue, cramps, numbness, tingling, and/or tremors (Carter & Banister, 1994). Carter and Banister identified several factors that contributed to discomfort and pain in operators of video display terminals as follows: (a) seated work, (b) awkward positions, (c) static (isometric) work, (d) inactivity, (e) overuse, (f) pressure on blood vessels and nerves, and (g) pain-spasm cycle. Burandt and Grandjean (1963) determined the most comfortable seats height position and found that discomfort from sitting could affect all parts of the body, including back discomfort with the highest reported frequency of physical discomfort (57% of 246 participants), followed by the knees and feet (29%), and then the neck and shoulders (24%). Burandt and Grandjean found that workers with back complaints (the highest frequency of physical discomfort) often used the backrest, which is an ergonomic feature to reduce discomfort. They also determined that the type of work influenced discomfort complaints.

With sitting and chair position recommendations, workers continue to get injured while performing their work. Occupational injuries could be due to musculoskeletal nature or form, faulty biomechanics, and inadequate design of chairs. Grieco (1986) described the development and the causes of a new postural problem as:

The structure of work tasks has changed and the resulting relationship between operators and layout, speed in performing tasks and sometimes the introduction of ergonomic furniture itself, all contribute to the emergence of a new problem, postural fixity, which cannot be solved solely by using ergonomically designed furniture. (p. 350)

Posture has played an important role in equipment design. The human body is well designed to perform a variety of postures, however each separate body part is limited in range of motion and direction (Priel, 1974). Repetitive activities, maintenance of upright posture, and keeping active contraction of back muscles for a long period of time leads to fatigues and discomfort. Erect posture can be maintained for a maximum of two minutes and sustaining the effort to maintain good posture causes fatigue and awkward sitting position (Mandal, 1987). Continual static muscular force contributes to lumbar and dorsal pain, which would increase postural movement and an indication of discomfort (Vergara & Page, 2002).

In a study examining 19 participants, Genaidy and Karwowski (1993) studied the deviation from neutral posture of 24 body movements in sitting position. Participants were asked to move a body part in a specific direction to the extent of their full range of motion and to hold the position for 30 seconds. Immediately after the end of 30 seconds

holding position, participants rated joint discomfort using Rating of Perceive Joint Discomfort. Genaidy and Karwowski found significant discomfort in back flexion and rotation, lateral bending of the neck, and hips movements.

Poor posture increases low back loading and limits workers performance (Corlett, Madeley, & Manenica, 1979). To reduce discomfort, sitters attempt varied postural strategies and approaches (Carpentier, 1969). Michel and Helander (1994) examined 16 young and old participants with healthy and herniated discs sitting on conventional and sit-stand chairs. Michel and Helander administered the General Comfort Rating Scale and the Body Part Discomfort Rating Scale every 30 minutes. The conventional chair recorded body movements through a load cell attached to the backrest. Michel and Helander found that participants tended to shift their weight to reduce load and pressure on their bodies as feelings of discomfort increased. Moreover, using a three dimensional model of the body and a computer aided ergonomics package called SAMMIE to calculate intervertebral disc compression, Kayis and Hoang (1999) found that when the back was completely resting on a reclined backrest (an ergonomic chair feature), the lumbar discs were at the lowest loading level, but loading was not completely eliminated in the lower back.

In the study by Vergara and Page (2002), a rachimeter containing a goniometer and inclinometer to measure posture of the lumbar curvature and pelvic inclination was attached to the spines of participants. Electrodes were used to measure the contact of the back with the backrest of the chairs (six types of chairs). Vergara and Page measured the macro-movements (total movement) and micro-movement (small and within movements)

of posture in the lumbar and pelvic regions of 6 participants performing writing and reading tasks to determine the cause of discomfort. Vergara and Page found that forward rotation of the pelvic and static posture increased lumbar pain, and performing work in a forward bending position increased dorsal pain. They also found that macro-movements were large and quick when lumbar pain was present, and micro-movements were small and slow and preceded lumbar pain and discomfort. Vergara and Page concluded that micro-movement and posture were the cause of discomfort, and macro-movements and lumbar pain were signs and indications of discomfort.

To determine the effect of posture on discomfort and performance, Bhatnager, Drury, and Schiro (1985) examined 12 participants sitting on an adjustable chair for 3 hours while detecting defected slides on a printed circuit board. Participants were randomly assigned to a screen height position (low, medium, and high). Participants' postures were video recorded. The Body Part Discomfort Rating Scale was administered every 25 minutes with 5 minutes break, heart rate was recorded, and three postural angles were measured (head, neck, and trunk). Data from the Body Part Discomfort Rating Scale were divided into body part discomfort severity and frequency. Bhatnager et al. found that the participants maintained four types of postures 95.3% of the time, which were influenced by head and neck discomfort more often than trunk discomfort. Bhatnager et al. concluded that as time increased, so did severity and frequency of body part discomfort, perceive discomfort, forward lean, postural change, and poor performance. To demonstrate the effect of workplace design and work duration on postural shift, which could intensify discomfort, Liao and Drury (2000) examined 6 participants sitting on an

adjustable chair for 120 minutes performing a transcription task on three keyboard heights. Keyboard was placed at sitting elbow height (low), 60 mm above elbow height (medium), and 120 mm above sitting elbow height (high). Liao and Drury recorded postural shift concurrently using a video system for joint angle measurement, and they found that a significant increase in postural shift happened over time and mostly when the keyboard was at the high position. Postural shift was positively correlated with level of discomfort, and Liao and Drury concluded that postural shift could be used as an indication of severity of discomfort.

Effect of Sitting Tasks on Discomfort

When workers perform a lot of work tasks such as writing, reading, typing, and holding items while sitting, these work tasks could alter sitting posture and could lead to loading and pressure on the body. To determine the effect of chairs and work tasks on the trunk kinematics and erector spinae EMG, Van Dieen, De looze, and Hermans (2001) evaluated one fixed chair and two dynamic chairs with 10 participants performing 3 hours of simulated office work such as word processing, reading, and computer-aided design. Markers were attached to the C7 spinous process, the right hip, the knee, and ankle joint of the participant, and to the axis of rotation of the seat to provide data regarding positioning. Also surface-EMG was used to measure activities of the back muscle. Van Dieen et al. (2001) found that positioning and changing in trunk posture was only significantly affected by work tasks but not by fixed or dynamic chairs. They found that back muscle activities and loading were more significantly affected by work tasks than the chairs.

Kayis and Hoang (1999) using a three dimensional model and SAMMIE concluded that leaning and bending forward while performing a task caused the greatest disc loading and increased back muscle activities. Liao and Drury (2000) studied the effect of workplace design and work duration on discomfort. Liao and Drury administered on-screen the Body Part Discomfort Questionnaire (BPDQ), frequency (BPDF), and severity (BPDS) and the fatigue questionnaire every 10 minutes for 120 minutes to 6 participants in three keyboard positions. Liao and Drury found that participants reported the highest level of discomfort and fatigue in the neck, shoulders, right upper arm, buttock, and thighs, which corresponded with the increase frequency of the overall postural shift.

Fenety et al. (2000) identified the task performed by the individual as a factor to increase in-chair movement, which was an indication of increased discomfort. Work tasks place the body in a poor postural position that increases load and pressure on the lower back causing fatigue, discomfort, and pain.

Outcomes of Discomfort

In 1989, the National Institute for Occupational Safety and Health (NIOSH) of the United States reported that musculoskeletal injuries of the hands, wrists, elbows, arms, knees, legs, neck, and back had doubled between 1984 and 1987. Musculoskeletal injuries exceeded 72,900 cases, which reflected 39% of all occupational illnesses reported to the Occupational Safety and Health Administration in 1987 (NIOSH, 1989). Some of the musculoskeletal symptoms are pain, numbness, and tingling sensations (NIOSH, 1997), which increases discomfort and affect performance. Bhatnager, Drury,

and Schiro (1985) demonstrated that discomfort increased after 3 hours of experimentation, participants had an increase in error percentage from 4% to more than 8% in detecting defective slides. Liao and Drury (2000) found that the error rate of the second hour of typing was higher than the first hour. Carter and Banister (1994) recommended reducing musculoskeletal discomfort and pain as follows: (a) exercise, (b) postural training, (c) fatigue awareness, (d) familiarity with adjustments of work station, (e) frequent breaks, (f) regular health examination, (g) education, and (h) vary work tasks.

Summary

In summary, chairs vary by shape, size, materials, features, and cost. Previous research illustrates how discomfort level is affected and influenced by a chair's aesthetics, the tasks being performed, and the posture of the participants. Earlier studies demonstrated how comfort and discomfort were independent and should be treated as separate elements. Discomfort is viewed as a feeling of pain, irritation, numbness, tiredness, soreness, and tenderness and it is linked to biomechanical factors and fatigue. No sitting standards or specifications to reduce discomfort were found, however, seat-positioning standards were established to reduce discomfort level.

In the present study, two ergonomic chairs with the same approximate cost were investigated to determine if ratings of discomfort would change over time. The ergonomic chairs had similarities and differences in features, materials, and design philosophies. Discomfort level of each chair was examined over time using the General Comfort Rating Scale and the Body Part Discomfort Rating Scale.

CHAPTER 3

Methods

The purpose of this study was to determine if ratings of discomfort differ over time between two ergonomic chairs of the same approximate cost. Assessing level of discomfort had been evaluated in few research studies in the past such as Shackel, et al. (1969); Corlett and Bishop (1976); Granaidy and Karwowski (1993); Michel and Helander (1994); Zhang, Helander, and Drury (1996); Helander and Zhang (1997); Liao and Drury (2000), and Fenety et al. (2000). In this study, two structured scales were used to assess discomfort at 0 (baseline), 30, 60, and 90 minute marks over two sessions.

Participants

Twenty participants (11 females and 9 males; Table 1), university students, between the ages of 18 and 32 years ($M = 22.6$ years) participated in this research study. All participants completed the Screening Questionnaire (Appendix A). No participants had been previously engaged in postural sitting training classes. All participants indicated that they routinely sat on conventional/standard chairs, and none indicated sitting on

Table 1

Demographic of Participants

Demographic	Female	Male
Participant	11	9
Percent	55%	45%
Mean Age	23.55	21.44

Table 2

Frequency Distribution Table of the Participants' Daily Sitting Hours

Sitting Hours	Frequency	Percent
1	0	0
2	1	5
3	6	30
4+	13	65

ergonomic chairs. On daily chair sitting, 13 participants documented that they sat for more than four hours a day, six participants indicated that they sat for four hours a day, and one participant reported sitting for two hours a day (Table 2). The rankings from the most to the least performed activities while sitting on a chair were: nine participants (45%) ranked computer tasks first, followed by writing, and then reading tasks. Seven participants (35%) ranked computer tasks as first, reading as second, and writing as third. Three participants (15%) indicated reading as the most tasks performed, writing as second, and computer tasks as third. One participant (5%) ranked writing as the most performed task, followed by reading, and then computer tasks. Therefore, 16 participants (80%) ranked computer tasks to be the most activity performed while sitting on a chair. None of the participants had a history of discomfort, pain, surgery, and/or any other problems at any time in the shoulders, neck, upper back, middle back, lower back, pelvic/hip, legs, arms, wrists, and/or hands.

Approval from the Human Subject Institution Review Board (Appendix D) was obtained. Participants read and signed a consent form (Appendix E) before the start of the study, and a hard copy was given to participants. Participation in the study depended on availability and participants' schedules. Participants were paid \$10.00 per hour for their participation. A \$5.00 break allowance was given to participants to purchase refreshments from the Student Union cafeteria during the break period. Each participant was paid a total of \$35.00.

Instrumentation

The ergonomic Aeron Work Chair (Figure 1) was designed by Herman Miller and was provided for the study by Western Contractors, Inc. The ergonomic Wharton WH88 deluxe (Figure 2) chair was designed and distributed by Office Master, Inc. Both ergonomic chairs have multiple adjustable features and contours (Table 3). Both have lumbar support, tilt backrest and seat-pan, adjustable seat height, backrest, and arms rest, and casters. Although the two chairs have similarities, they also have differences in adjustments, materials, and design philosophies. The Aeron Work Chair has a movable backrest and the lumbar support pad could be adjusted horizontally and vertically to fit the lower back and to provide the support, whereas the Wharton WH88 Deluxe Chair has a movable backrest to fit the lower back and another mechanism to move the lumbar support horizontally to provide a maximum support. The armrest of the Aeron Work Chair could be moved up and down and it pivots inward for keying and outward for mousing. The armrest of the Wharton WH88 Deluxe Chair could be pulled up and

Figure 1. The Aeron Work Chair.

Figure 2. The Wharton WH88 Deluxe Chair.

Table 3

Description of Features in Ergonomic Chairs

Feature	Aeron Work	Wharton WH88
Seat Height	16-20.5	17-21
Seat-Pan Width	20	21
Seat Depth	17	17-20
Sliding Seat	Yes	Yes
Backrest Height	22	23
Backrest Width	19	18
Tilt Backrest	Yes	3-angles
Lumbar Support	Yes	Yes
Adjustable Lumbar	Horizontal/vertical	Horizontal
Armrest range	4" range	4"
Armrest Pivot	Inward 17.5 degrees Outward 15.0 degrees	No No
Pneumatic Lift	Yes	Yes
Casters	Yes	Yes
Pad/Cushion Thickness	1.5	5
Padding Type	Pellicle Suspension	Memory Foam
Seat Cover	Pellicle	Vinyl
Cost	\$600	\$550

Note. Measurements are in inches.

pushed down. Moreover, the Aeron Work Chair made of Pellicle suspension material, which allows air and moisture circulation to reduce heat storage and to distribute weight evenly on the chair. The Wharton WH88 Deluxe Chair is made of memory foam, which conforms to the contours of the body to provide the most comfort, and uses vinyl for seat covering. The cost for the Aeron Work Chair and the Wharton WH88 Deluxe Chair is approximately \$600.00 and \$550.00 respectively.

Corlett and Bishop (1976) identified the subjective judgments of users to be important in exploring and examining discomfort of work situations. In the present study, the General Comfort Rating Scale (Shackle et al., 1969) and the Body Part Discomfort Rating Scale (Corlett & Bishop, 1976) were administered at 0, 30, 60, and 90 minute marks to measure ratings of discomfort over time for two sessions: the order of chairs was counterbalanced across sessions for those participants who switched chairs. The constant groups sat in either the Aeron Work Chair or the Wharton WH88 Deluxe Chair. Because the literature did not indicate any significant gender effects on comfort, discomfort, or outcomes of ratings (Zhang, 1996), the scales were administered to all participants without gender identification.

The subjective judgment of users was the definitive measure of the General Comfort Rating scale. The General Comfort Rating Scale was used to evaluate chair discomfort with an 11-point scale and 10 intervals, and was administered four times: 0 minute, 30 minute, 60 minute, and 90 minute marks over two 90 minutes sessions. Each point scale had a discomfort statement printed along 10 cm vertical line. The first point on the scale describes being most comfortable and the eleventh point on the scale

describes being most uncomfortable. Participants draw a horizontal line anywhere on the vertical scale to indicate the level of comfort or discomfort. The score was rounded to the nearest half interval (i.e., 1.6 to 1.5 and 3.9 to 4). Then as recommended by Shackle et al. the score was multiplied by two for easy handling and calculation and to give a score between 0 to 20.

The Body Part Discomfort Rating Scale measured discomfort for several body parts. First, the overall discomfort was rated on a seven-point scale from “extremely comfortable” on the left end to “extremely uncomfortable” on the right end of the scale. Then a figure of a human body with numbered body parts was presented. Participants identified the most uncomfortable body part by its number and rated discomfort level by using a 7-point scale. Next participants identified the second most uncomfortable body part by its number and rated it, and so forth. Finally, the average score of each discomfort body part described the level of discomfort. The Body Part Discomfort Rating Scale was administered four times for each session at 0 minute and after 30 minutes, 60 minutes, and 90 minutes. The scale provided data regarding discomfort level and areas of most discomfort.

Procedures

Following the approval from the San Jose State University Institution of Review Board to study human participants, fliers (Appendix F) about the study were posted around in several locations in San Jose State University campus. Students who volunteered to participate in the study completed the screening questionnaire. After

reviewing the screening questionnaire, 20 students were contacted to participate in the study and were randomly assigned to one of four groups as follows: Chair A /Chair B, Chair B /Chair A, Chair A /Chair A, or Chair B /Chair B. Each participant was scheduled to come to the engineering laboratory. Fourteen participants were tested in the morning to limit factors such as accumulated fatigue that might possibly affect participants' discomfort level. Six participants were examined in the afternoon due to conflict with classes.

The environment mimicked a real office as much as possible and included a personal computer with a monitor, a keyboard, and a mouse. Pens, pencils, note pads, and a desk were provided. Only, one chair was present at a given time. The ergonomic chair was set up as recommended by the literature and as described earlier. Participants were given the opportunity before the start of the study to adjust the chair to their own comfort level. Adjustments made to either chair were documented on the Adjustment Check Off Form (Appendix G). Participants typed, read, and wrote some documents. The documents were provided for the participants, or participants brought their own materials. A document holder was supplied as a good ergonomic practice. Participants typed for a period of 30 minutes, read for duration of 30 minutes, and wrote during the final 30 minutes while sitting in each chair.

Before starting the study, the participant read and signed the consent form. To prevent biased behavior, the participants were told that the purpose of the study was to evaluate chairs, and no reference to discomfort evaluation was made. Participants were

provided a short training session regarding ergonomic principles (Appendix H) and chair adjustment. Participants were asked to use the restroom if they needed to before the testing started. Participants were reminded of the duration of the examination, and they were instructed to remain sitting throughout the 90 minutes of each session if possible. Participants were given the option to take a break during testing session due to abnormal feelings of discomfort or intolerable level of discomfort. Time of testing was stopped, break time was not included in the testing session, and testing session was resumed when participant decided to continue sitting.

At the beginning of testing in each session (0 minute/baseline), participants completed the General Comfort Rating and the Body Part Discomfort Rating Scales. Participants were asked to indicate their response to chair discomfort. Then, participants were instructed to carry out the typing activity (Task 1) for 30 minutes as normal as possible. After 30 minutes, the General Comfort Rating and Body Part Discomfort Rating Scales were administered again. After completion of the scales, participants were instructed to perform the reading activity (Task 2) for 30 minutes as normal as possible. After 60 minutes since the start of testing, participants completed the General Comfort Rating and Body Part Discomfort Rating Scales. Then, participants were directed to carry out the writing activity (Task 3) for 30 minutes as normal as possible. After 90 minutes, participants executed the General Comfort Rating and the Body Part Discomfort Rating Scales.

Participants took a 30 minute break between the two sessions, regardless of whether they took a break during Session 1. During the 30 minute break, participants

were paid \$5.00 break allowance to purchase refreshments. The researcher went with participant to the Student Union cafeteria to insure that the participant would be back on time for Session 2. The exact procedure in Session 1 was carried out in Session 2 after the 30 minute break between the two sessions.

No changes to the General Comfort Rating Scale were made, however, minor modifications of the Body Part Discomfort Rating Scale procedures were completed to fit the study and to provide appropriate data. The procedure of the Body Part Discomfort Rating Scale was as follows: (a) the test was implemented at 0 (baseline), 30, 60, and 90 minute marks of each session, (b) participants were presented with a form containing a figure of a human body and four scales with seven points ranging from “extreme comfort” on the left end to “extreme discomfort” on the right end, (c) the participant rated the first scale, which was the over all discomfort level, and (d) finally, the participant rated the first most uncomfortable body part, then the second body part, and finally, the third body part. No adjustment to the chair was made due to the outcome of each measurement.

Design

In this study, a repeated measures counterbalanced (Latin square) design ($2 \times 2 \times 4$) was used to determine the interaction and main effects of three independent variables: (a) switch (b) time, and (c) session. Switching had two levels: (a) WITH and (b) WITHOUT; session had two levels (1 and 2); and time had four levels: (a) 0 minute (baseline), (b) 30 minute, (c) 60 minute, and (d) 90 minute (Table 4). Also a repeated measures counterbalanced design (2×4) was used to determine the effect of chair design

Table 4

Independent Variable of Chair

<u>Group</u>	<u>Session 1</u>	<u>Session 2</u>	<u>Outcome</u>
R ₁	A	B	O ₁
R ₂	B	A	O ₂
R ₃	A	A	O ₃
R ₄	B	B	O ₄

Note. A stands for the Aeron Work Chair. B stands for the Wharton WH88 Deluxe Chair.

on discomfort level with two independent variables: chair and time. Chair had two levels: Aeron Work Chair and Wharton WH88 Deluxe Chair. The dependent variable was discomfort. Discomfort was measured four times at 0 minute (baseline) and after each 30 minutes using the General Comfort Rating Scale and the Body Part Discomfort Rating Scale while sitting in each chair.

Analysis of Data

To analyze the results of this study two ANOVAs were conducted, a three-way analysis of variance (ANOVA) 2 (Switching) x 2 (Session) x 4 (Time) with repeated measures on the last two factors (Table 5) and a two-way analysis of variance (ANOVA) 2 (Chair) x 4 (Time) (Table 6) were used to determine significant interactions and main effects on participants' General Comfort Rating Scale. The critical alpha was set at 0.05 to determine significant differences. Descriptive statistics were used to analyze data from

the Body Part Discomfort Rating Scale including frequencies, means, and standard deviations.

Table 5

Three-Way Analysis of Variance (ANOVA), 2 x 2 x 4, with Repeated Measure on the Last Two Factors

Switching	Time							
	Session 1				Session 2			
	0	30	60	90	0	30	60	90

WITH

WITHOUT

Note. The higher the score, the greater the level of discomfort. Actual scores have been multiplied by 2.

Time is in minutes.

Table 6

Two-Way Analysis of Variance (ANOVA), 2 x 4, with Repeated Measures on the Last Factor

Chair	Time			
	0 min	30 min	60 min	90 min

Aeron Work Chair

Wharton WH88 Deluxe Chair

Note. Same as table 5

CHAPTER 4

Results

While sitting on the ergonomic chairs, discomfort level was measured using the General Comfort Rating Scale and the Body Part Discomfort Rating Scale. A three-way analysis of variance (ANOVA, Table 7; 2 [Switching] x 2 [Session] x 4 [Time], Table 8) with repeated measures on the last two factors and a two-way analysis of variance (ANOVA, 2 [Chair] x 4 [Time], Table 9) with repeated measures on the last factor were used to determine interactions and main effects of participants' General Comfort Rating Scale. SPSS software (version 11.0 for PC) was used to conduct the statistical analysis, Table 7

ANOVA Source Table 2 (Switch) x 2 (Session) x 4 (Time)

Source	df	SS	MS	F	P
Switch	1	44.10	44.10	3.07	0.097**
Session	1	2.50	2.50	0.225	0.641
Time	1	208.08	208.08	37.33	0.00*
Time x Switch	1	3.38	3.38	0.606	0.446
Time x Session	1	10.58	10.58	3.096	0.095**
Switch x Session	1	1.60	1.60	0.144	0.709
Time x Switch x Session	1	4.50	4.50	1.317	0.266

* $p < 0.05$, ** $p < 0.1$

Table 8

Table of Means for the Three-Way Analysis of Variance (ANOVA), 2 (Switching) x 2 (Session) x 4 (Time), with Repeated Measures on the Last Two Factors

Switching	Time							
	Session 1				Session 2			
	0	30	60	90	0	30	60	90
WITH	1.90	3.60	3.90	4.50	1.80	3.30	4.30	4.70
WITHOUT	2.90	4.30	4.80	5.30	2.50	4.20	5.10	7.30

Note. The higher the score, the greater the level of discomfort. Actual scores have been multiplied by 2.

Table 9

ANOVA Source Table 2 (Chair) x 4 (Time)

Source	df	SS	MS	F	P
Chair	1	7.20	7.20	0.398	0.536
Time	3	157.70	52.56	18.614	0.000*
Chair X Time	3	13.30	4.43	1.570	0.207

* $p < 0.05$

and alpha level was set at 0.05. A higher score on the General Comfort Rating Scale indicated greater discomfort level. Descriptive statistics were used to analyze the Body Parts Discomfort Rating Scale.

Main Effects

The analysis of the General Comfort Rating Scale revealed no significant difference ($p > 0.05$) between the Aeron Work Chair ($\bar{M} = 4.45$) and the Wharton WH88 Deluxe Chair ($\bar{M} = 3.85$) on discomfort level. The analysis failed to reveal a significant main

effect ($p > 0.05$) of session on discomfort level. However, a significant main effect of time on discomfort level (Figure 3) was found ($F = 25.30$; $p < 0.05$). Although, the analysis reflected a low to moderate level of discomfort, participants reported a gradual increase in discomfort level every 30 minutes at the beginning and end for both Session 1 and Session 2 (Table 10). Moreover, the analysis of the General Comfort Rating Scale revealed marginal main effect ($p = 0.097$) of WITH and WITHOUT switching of the chairs on discomfort was found. Due to the limitation of a small sample size, increasing the standard error and reducing power, significant effects are more difficult to reveal.

Figure 3. Discomfort as a Function of Time. There was a rapid increase in discomfort level over time in Session 1 and Session 2 and a sizable increase at the end of Session

Table 10

Discomfort Level Every 30 Minutes

Time	<u>Discomfort Level</u>			
	Session 1		Session 2	
	M	SD	M	SD
0 Min	2.40	1.875	2.15	1.872
30 Min	3.95	2.089	3.75	2.314
60 Min	4.35	1.694	4.70	2.319
90 Min	4.90	1.832	6.00	3.464

Note. Discomfort level was measured using the General Rating Scale with 11-point scale (0 = I feel completely relaxed, 10 = I feel unbearable pain). Scores were multiplied by two. There was a noticeable increase in discomfort every 30 minutes during Session 1 and Session 2.

Interaction Effects

The analysis of the General Comfort Rating Scale failed to reveal a significant interaction between Time x Switch, Switch x Session, Chair x Time, and Time x Switch x Session. Although the interaction of Time x Session was not statistically significant, which may be due to the limitation of a small sample size, the interaction was marginally significant with $p = 0.095$. Close inspection of the data revealed a higher discomfort level at the end of Session 2 ($\underline{M} = 6.00$) than at the end of Session 1 ($\underline{M} = 4.90$; Figure 4). The data from Session 2 (Table 10) also revealed a continuous rise in discomfort from baseline to the 30 minute mark and then to the 60 minute mark, and finally to the 90 minute mark ($\underline{M} = 2.15, 3.75, 4.70, 6.00$, respectively).

Figure 4. Discomfort as a Function of Session and Time.

Body Part Discomfort

The analysis of the Body Part Discomfort Rating Scale showed that discomfort was not due to the Aeron Work Chair and the Wharton Wh88 Deluxe Chair. Participants reported about the same number of body parts with discomfort for each chairs in Session 1 and Session 2 (Table 11). After collapsing all scores from the Body Part Discomfort Rating Scale of all four groups (Table 12), 25.15%, 16.17%, 11.98% and 10.18% of the participants reported discomfort in the lower back, the lower arms, the neck, and the thighs, respectively. The descriptive statistics revealed that participants reported the greatest discomfort level in the lower arm ($\bar{M} = 2.92$) followed by the lower back ($\bar{M} = 2.69$). There was also an increase in the total number of responses of the body part discomfort from Session 1 (80 responses) to Session 2 (87 responses).

Table 11

Effect of Chair Type on Body Parts with Discomfort

Chair	Body Parts with Discomfort	
	Session 1	Session 2
Aeron Work Chair	36	35
Wharton WH88 Deluxe Chair	44	42

When examining Tables 13 and 14 for Chair A/Chair B and Chair B/Chair A, respectively, that did switch chairs, the total number of responses indicating discomfort in a specific body part decreased from Session 1 (21 responses, and 19 responses, respectively) to Session 2 (17 responses, and 12 responses, respectively). The overall mean discomfort for Chair A/ Chair B and Chair B/Chair A in Session 1 ($\bar{M} = 1.27$, $M = 1.39$, respectively) was decreased in Session 2 ($\bar{M} = 1.2$, $M = 0.82$, respectively). Also when examining each body part reported by participants sitting in Chair A/Chair B and Chair B/Chair A, for example lower arms and lower back, the level of discomfort decreased from Session 1 to Session 2 (Table 13 and 14).

Table 12

Descriptive Statistics of the Body Part Discomfort Rating Scale Collapsed Across Groups

Body Part	<u>Session 1</u>		<u>Session 2</u>		Responses Percentage	Overall Discomfort
	Response	Mean Discomfort	Response	Mean Discomfort		
Neck	10	1.31	10	1.83	11.98	1.57
Shoulders	4	1.46	8	2.56	7.19	2.01
Upper Arms	0	0	3	1.56	1.80	0.78
Lower Arms	13	3.46	14	2.38	16.17	2.92
Upper Back	8	1.33	4	1.13	7.19	1.23
Middle Back	6	1.42	7	1.66	7.79	1.54
Low Back	20	3.09	22	2.29	25.15	2.69
Buttocks	5	1.33	8	2.06	7.79	1.70
Thighs	10	1.81	7	1.43	10.18	1.62
Legs	4	0.94	4	1.38	4.97	1.16
Total	80	1.47	87	1.66	100%	1.57

Note. The Body Part Discomfort Rating Scale measures along a 7-point scale (1 = extreme comfort, 7 = extreme discomfort).

Table 13

Descriptive Statistics of the Body Part Discomfort Rating Scale for Chair A/ Chair B

Body Part	Session 1		Session 2		Responses Percentage	Overall Discomfort
	Response	Mean Discomfort	Response	Mean Discomfort		
Neck	4	0.88	2	1.25	15.79	1.07
Shoulders	0	0	0	0	0	0
Upper Arms	0	0	0	0	0	0
Lower Arms	2	3.75	4	2.88	15.79	3.32
Upper Back	5	1.80	1	0.50	15.79	1.15
Middle Back	0	0	0	0	0	0
Low Back	6	3.83	6	2.08	31.58	2.96
Buttocks	0	0	2	3.00	5.26	1.50
Thighs	0	0	0	0	0	0
Legs	4	3.75	2	3.50	15.79	3.63
Total	21	1.27	17	1.20	100%	1.24

Note. Body Part Discomfort Rating Scale was a 7-point scales (1 = extreme comfort, 7 = extreme Discomfort).

Table 14

Descriptive Statistics of the Body Part Discomfort Rating Scale for Chair B/ Chair A

Body Part	Session 1		Session 2		Responses Percentage	Overall Discomfort
	Response	Mean Discomfort	Response	Mean Discomfort		
Neck	3	2.67	2	1.75	16.13	2.21
Shoulders	0	0	2	2.5	6.45	1.25
Upper Arms	0	0	0	0	0	0
Lower Arms	2	3.25	0	0	6.45	1.62
Upper Back	2	1.00	2	1.00	13.00	1.00
Middle Back	0	0	0	0	0	0
Low Back	4	3.13	4	2.75	25.81	2.94
Buttocks	0	0	2	1.00	6.45	0.50
Thighs	8	5.25	0	0	25.81	2.63
Legs	0	0	0	0	0	0
Total	19	1.39	12	0.82	100%	1.10

Note. Same as Table 13.

Participants who sat in Chair A/Chair A and Chair B/Chair B that did not switch chairs reported an increase in the total number of responses indicating discomfort in a body part from Session 1 (15 responses, 25 responses, respectively) to Session 2 (23 responses, 35 responses, respectively). Also the overall mean discomfort level of Session 2 ($\bar{M} = 2.08$, $\bar{M} = 2.54$) was greater than the overall discomfort level of Session 1 ($\bar{M} = 1.5$, $\bar{M} = 1.7$, respectively; Table 15 and 16). When examining each body part reported by participants who were sitting in Chair A/Chair A and Chair B/Chair B, one could notice

Table 15

Descriptive Statistics of the Body Part Discomfort Rating Scale for Chair A/ Chair A

Body Part	Session 1		Session 2		Responses Percentage	Overall Discomfort
	Response	Mean Discomfort	Response	Mean Discomfort		
Neck	3	1.67	3	2.83	15.80	2.25
Shoulders	1	2.50	4	3.75	13.20	3.13
Upper Arms	0	0	2	2.75	5.30	1.38
Lower Arms	2	3.25	3	2.83	13.20	3.04
Upper Back	1	2.50	1	3.00	5.30	2.75
Middle Back	3	2.00	3	2.50	15.80	2.25
Low Back	2	2.25	4	1.25	15.80	1.75
Buttocks	3	2.33	2	1.50	13.20	1.92
Thighs	0	0	1	2.5	2.60	1.25
Legs	0	0	0	0	0	0
Total	15	1.50	23	2.08	100%	1.79

Note. Same as Table 13.

higher discomfort level in Session 2 than in Session 1 for most body parts such as the neck, shoulders, and lower back. Finally, the Body Part Discomfort Rating Scale included 10 body parts to be tested. Participants reported more discomfort in individual body parts while sitting in Chair A/Chair A (9 out of 10) and Chair B/Chair B (9 out of 10) that did not switch chairs than while sitting in Chair A/Chair B (6 out of 10) and Chair B/Chair A (5 out of 10) that did switch chairs, which indicated more body parts effected by

Table 16

Descriptive Statistics of the Body Part Discomfort Rating Scale for Chair B/ Chair B

Body Part	Session 1		Session 2		Responses Percentage	Overall Discomfort
	Response	Mean Discomfort	Response	Mean Discomfort		
Neck	0	0	3	1.50	5.00	0.75
Shoulders	3	3.33	2	4.00	8.33	3.67
Upper Arms	0	0	1	3.50	1.67	1.75
Low Arms	7	3.57	7	3.79	23.33	3.68
Upper Back	0	0	0	0	0	0
Middle Back	3	3.67	4	4.13	11.67	3.90
Low Back	8	3.13	8	3.06	26.67	3.10
Buttocks	2	3.00	2	2.75	6.66	2.88
Thighs	2	2	6	3.25	13.33	2.63
Legs	0	0	2	2	3.33	1.00
Total	25	1.70	35	2.54	100%	2.12

Note. Same as Table 13.

maintaining sitting in the same chair throughout the testing.

Examining the lower back, lower arm, and neck, which were the most reported body parts with discomfort (see Table 12, p. 38), they were influenced by the activity performed. The lower back was affected by all activities and gained a total of 14 responses of body part with discomfort during the writing activity, 13 responses during the reading activity, and 12 responses of body part with discomfort during the typing

activity (Table 17). The lower arm was mostly affected by the typing activity and received 14 responses of body part with discomfort and followed by the writing activity and received 10 responses of body part with discomfort (Table 18). The neck was mostly affected by the writing task and got 12 responses of body part with discomfort (Table 19).

Table 17

Lower Back Discomfort

Time	Session 1	Response	Session 2	Response	Activity
0 min.	3.5	1	2.5	2	None
30 min.	3.3	5	1.9	7	Typing
60 min.	3.14	7	3.2	6	Reading
90 min.	3.3	7	2.3	7	Writing

Table 18

Lower Arm Discomfort

Time	Session 1	Response	Session 2	Response	Activity
0 min.	0	0	0	0	None
30 min.	3.3	7	3.3	7	Typing
60 min.	3.5	1	2.8	2	Reading
90 min.	3.8	5	3.6	5	Writing

Table 19

Neck Discomfort

Time	Session 1	Response	Session 2	Response	Activity
0 min.	0	0	0	0	None
30 min.	2.0	1	2.5	1	Typing
60 min.	1.0	3	1.7	3	Reading
90 min.	1.9	6	1.9	6	Writing

The data revealed that the writing activity was accountable for the greatest discomfort in the three most affected body parts with discomfort. During the writing activity, participants reported 14 times discomfort in the lower back, 10 times in the lower arm, and 12 times in the neck.

Summary

Analysis of the General Comfort Rating Scale revealed no significant difference between the two ergonomic chairs. However, the analysis revealed an increase of discomfort level over time. There was a marginally significant interaction between time and session. The results indicated an increase of discomfort at the end of Session 2. Also there was a marginally significant main effect of switching chairs. Discomfort level and number of body parts with discomfort was decreased in the WITH switching groups in Session 2. The descriptive analysis of the Body Part Discomfort Rating Scale showed that the lower back was the body part most effected by discomfort and followed by the lower

arms, neck, and thighs. In addition, the writing task was identified to most likely task to increase discomfort in the body parts.

CHAPTER 5

Discussion

The purpose of this study was to determine if ratings of discomfort differed over time between two ergonomic chairs of the same approximate cost. The analysis of the General Comfort Rating Scale was conducted to determine significant main effects and interactions of chairs, switching of chairs, session, and time on discomfort level. The Body Part Discomfort Rating Scale was administered to examine discomfort in different body areas.

Chair

The Aeron Work Chair and the Wharton WH 88 Deluxe Chair have different design philosophies, use diverse materials, utilize different operating features, and exploit different aesthetics (see Table 3, p.24). Analysis of the General Comfort Rating Scale revealed no significant difference between the two ergonomic chairs. Discomfort level increased over time with increase duration of sitting, but the rise in discomfort was not due to chair type. Increase in discomfort level over time was also reported by Vergara and Page (2002), Fenety et al. (2000), Helander and Zhang (1997), and Bhatnager et al. (1985). Although, participants reported a low to moderate level of discomfort, there was a constant increase in discomfort through out the 3 hours and 30 minutes testing.

This result supports by the finding of Helander and Zhang (1997). They examined 21 ergonomic office chairs and found discomfort level increased over time but was not related to the chair design. Also Van Dieen et al. (2001) tested one fixed chair and two dynamic chairs. They found that loading and increasing back muscle activities were not

provoked by different chair design. Sitting on the Aeron Work Chair or the Wharton WH88 Deluxe Chair did not impact ratings of discomfort, and it could not be concluded that one chair is better than the other in reducing discomfort ratings.

Time

Time had a significant effect on the General Comfort Rating Scale. Discomfort was measured four times for each of two sessions: 0 minute (baseline), 30 minute, 60 minute, and 90 minute marks. Discomfort increased from baseline throughout the sessions. Similarly, Vergara and Page (2002) found a continuous rise in discomfort in their research. They administered the General Comfort Rating Scale every 25 minutes to six participants who sat on six different chairs. Vergara and Page showed an increase in discomfort level from the first 25 minutes measure through the end of testing.

In the present study, participants engaged in typing, reading, and writing activities during testing. The build up of fatigue and loss of energy increased discomfort at the end of Session 1 and Session 2 (see Figure 3, p. 34). Although, participants reported a low to moderate level of discomfort, their reports were developed over 3 hours and 30 minutes of testing. However, review of literature revealed that office workers sit for about 8 hours a day, and 65% of the participants in the current study reported sitting for more than 4 hours a day. Moreover, the findings of previous research and the current study showed a steady increase in discomfort over time. Therefore, the current findings suggest that participants were more likely to report higher level of discomfort if time of testing increased and discomfort might reach moderate to high levels. Increasing the duration of sitting could be the subject of future study. It is also evident that at the end of Session 2

discomfort level increased noticeable and could continue to increase if time of testing extended. Likewise, Helander and Zhang (1997) examining 21 ergonomic chairs found a correlation between time and discomfort level. They revealed that discomfort level was related to the accumulation of fatigue during the workday. Also engaging in repetitive activities such as typing and writing could overtime intensify discomfort, which was also suggested by Carter and Banister (1994) and Mandal (1987). Mandal stated that repetitive activities lead to fatigue and discomfort. Zhang et al. (1996) found responses to discomfort questionnaire were linked to fatigue and biomechanical factors such as joint angles, muscle contractions, and pressure distribution. Posture, body alignment, muscle strength, and endurance to maintain upright posture impacted discomfort level in addition to the activities performed over long periods of sitting. Bhatnager et al. (1985) concluded that as the duration of sitting increased, so did severity and frequency of body part discomfort, perceived discomfort, forward lean, postural change, and poor performance.

There was no significant Chair x Time interaction, which indicated that the chair did not influence the outcome of testing. Discomfort increased as a function of time, not as a function of chair design.

Session

The research was conducted to study ratings of discomfort across two 90 minutes sessions. The interaction of time and session on discomfort level failed to be statistically significant, which was due to the limitation of having a small sample size. However, the interaction was marginally significant with $p = 0.095$, therefore, the finding was worth discussing. Close inspection of Figure 4 (p. 36) reveals an increase in discomfort at the

90 minute mark in Session 2. At this point, participants had been involved in the experiment for 3 hours and 30 minutes. The escalation of discomfort at the end of Session 2 was due to time spent sitting causing fatigue accumulation, intensifying biomechanical factors, and exaggerating repetitive activities. Mandal (1987) recognized that repetitive tasks, trying to maintain upright posture, and keeping constant contraction of back muscles could lead to discomfort, and as in the current study, these factors were growing in Session 2. Mandal also added that the inability of people to maintain upright posture for long periods and the effort and energy to maintain a good posture receded discomfort. In addition, Grieco (1986) noted that biomechanical factors such as postural fixity could increase discomfort.

A close look at Figure 3 (p. 34), the mean of over all discomfort at the 90 minute mark in Session 1 was 4.90 whereas the mean of the over all discomfort at the 0 minute mark of Session 2 was 2.15 after the 30 minute break. There was a decrease in discomfort level from the end of Session 1 to the beginning of Session 2 after the 30 minute break. Therefore, taking breaks helped to alleviate discomfort, which also found and recommended by Carter and Banister (1994). The current findings of this study supported the idea of taking breaks when sitting for a long periods.

Effect of Switching Chairs

In the present study, participants sat in either the same chair or they switched chairs across experimental sessions. The main effect of switching on discomfort failed to reach statistical significance, which was more likely due to having small sample size. However, marginal significance was obtained with $p = 0.097$, therefore the finding was

important to be mentioned. The finding indicated that switching or not switching of chairs had an effect on the level of discomfort. Switching chairs with varying designs and shapes might help to reduce reported discomfort. Sitting in the same chair during the two sessions could have facilitated the increase in discomfort level in the same body parts due to maintaining contraction of the same muscles. Examining the design of both chairs (see Table 3, p. 24), some important features were noticed. The thickness of the cushion and backrest of the Aeron Work Chair was only 1.5” whereas the Wharton WH88 Deluxe Chair was 5.0”. Also the padding material that was used to design the Aeron Work Chair was pellicle suspension whereas the Wharton WH88 Deluxe Chair was memory foam. Pellicle suspension material was used to allow for air and moisture circulation to reduce heat storage and to distribute weight evenly on the chair. Memory foam material was used to conform to the contours of the human body. These factors were more likely to manipulate muscle activities and body pressure points.

The descriptive statistics of the Body Part Discomfort Rating Scale supported the notion that different muscle were engaged in the WITH switching chair groups and the same muscles were contracting continuously in the WITHOUT switching chair groups in Session 1 and Session 2. The results from Table 13 and 14 for Chair A/Chair B and Chair B/Chair A (p. 39 and 40, respectively) revealed an interaction of Switch and Session. The analysis showed that participants’ total number of responses decreased in Session 2 after switching chairs (Table 20). Also, the overall discomfort of all body parts decreased in Session 2 after switching chairs. Moreover, discomfort in specific body parts such as lower arms, upper back, low back, and legs decreased in Session 2 after switching chairs.

Table 20

Interaction of Switching and Session on Body Parts with Discomfort

	WITH Switching		WITHOUT Switching	
	A/B	B/A	A/A	B/B
Session 1	21	19	15	25
Session 2	17	12	23	35

Note. Data is taken from Table 13, 14, 15, and 16.

These findings suggested that some type of muscular activities changed or engaged when switching chairs that helped to reduced discomfort. However, the results from Table 15 and 16 for Chair A/Chair A and Chair B/Chair B (p.41 and 42, respectively) revealed that participants' total number of responses increased in Session 2 after maintained sitting on the same chairs (Table 20). Also, the overall discomfort of both groups increased in Session 2. Moreover, discomfort in specific body parts such as the neck, shoulders, middle back, and thighs increased in Session 2 after sustaining sitting in the same chairs. These findings indicate that the same musculoskeletal activities continually engaged through out the sessions that intensified participants' feelings of discomfort.

Although, Helander and Zhang (1997) and Vergara and Page (2002) switched participants to different chairs, the switching occurred on different days. The literature did not reveal any close examination of switching chairs in the same day. Mandal (1987) found that a person could not keep an active contraction of back muscles for long periods, and using bilateral EMG, Van Dieen et al. (2001) reported strong muscular activities in

the back while sitting. In the present study, performed activities were similar and maintained constant during Session 1 and Session 2. Therefore, slowness in the rise of discomfort was possible because switching to a different chair with different design contours and shapes activated different muscles. When the chairs were switched, different muscles were contracted, which took the load of the already exhausted muscles in the back. It was also possible that pressure points on the body that were creating discomfort and originated by the first chair in Session 1 were not the pressure points that were caused by the second chair in Session 2. Pressure points were more likely to be induced by the padding material and thickness of cushions and backrests. Switching chairs led participants to perform new upright sitting postures that were different than the upright sitting postures performed while sitting on the preceding chair.

As Mandal (1987) stated no one could maintain upright posture for a long periods. Using more than one upright posture could lead to slowing the increase in discomfort level. Therefore, participants reported feeling relief of pressure and less discomfort in Session 2. This idea of switching chairs should be further examined in future studies where bilateral EMG analysis would be conducted and the biomechanical features of posture would be measured.

Body Part Discomfort

The analysis of the Body Part Discomfort Rating Scale showed that participants reported about the same number of body parts with discomfort for the Aeron Work Chair and the Wharton WH88 Deluxe Chair in Session 1 and Session 2. Therefore, discomfort in body parts was not due to chair type. This finding supported what was already found in the

current study when the General Comfort Rating Scale was analyzed and found no significant difference between the two ergonomic chairs. The finding of no difference between chairs was also concluded by Helander and Zhang (1997) and Van Dieen et al. (2001).

The descriptive analysis of the Body Part Discomfort Rating scale revealed that the greatest number of participants (25.15% out of 20 participants) reported the most discomfort in the lower back, followed by the lower arms (16.17%), neck (11.98%), and thighs (10.18%; see Table 12, p. 38). These findings were explained by previous research. Burnadt and Grandjean (1994) found that discomfort extended to all body parts in the following order of frequency: back, followed by the knees and feet, and then by neck and shoulders. Vergara and Page (2002) concluded that most discomfort occurs in the lumbar region. Moreover, Bhatnager et al. (1985) and Liao and Drury (2000) reported that the neck led the most discomfort of body parts. In the present study, most participants reported discomfort in the lower back because the lower back supported most the weight of the body, rotated the trunk, bent the body to perform activities, and activated its muscles at all time to support, stabilize, and move the body. Then the lower arms was reported by participants as second most discomfort of body parts because the lower arms performed two repetitive activities, typing and writing, for an hour in each session, which stressed and intensified their use. The neck ranked third in discomfort body areas because, while writing and reading, participants were likely to bend their necks to look down on materials, which increased tension of the neck muscle. The thighs were reported fourth as most discomfort body part because the thighs (and buttocks) were

the pressure points of sitting. Long time of sitting could intensify the feeling of discomfort on these pressure points. Also heat could be stored in the thighs and could increase discomfort level.

Effect of activities on Discomfort

The descriptive analysis of the Body Part Discomfort Rating Scale revealed that different parts of the body were influenced differently by different activities. Grieco (1986) stated that the type of work was the cause of work related injuries, and Burandt and Grandjean (1963) determined that the type of work was the source for discomfort complaints. Presented in Table 17 (see p. 43) are the lower back discomfort scores developed from the analysis of the Body Part Discomfort Rating Scale. It appeared that discomfort was influenced by all activities in the study (typing, reading, and writing). There were a constant number of responses regarding discomfort in the lower back indicating a constant stress on the lower back during performing the three activities. Liao and Drury (2000), Vergara and Page (2002), Burnadt and Grandjean (1994), and Bhatnager et al. (1985) concluded great level of discomfort in the back while sitting. Also using bilateral EMG, Van Dieen et al. (2001) found the greatest muscle activities in the back muscles.

Displayed in Table 18 (see p. 44) are the lower arm discomfort scores that were extracted from the analysis of the Body Part Discomfort Rating Scale. The lower arm discomfort was likely to be induced by typing and writing activities, but it was not impacted by the reading activities. The number of responses descriptively indicating lower arm discomfort decreased from the typing activity (14 responses) to the reading

activity (3 responses), then the number of responses increased when participants engaged in the writing activity (10 responses) of Session 1 and Session 2. The increase in the number of responses was due to the repetitive nature of the typing and writing activities, which intensified the use of the lower arms joints, muscles, tendons, ligaments and nerves. The rise in discomfort responses in the lower arms was possibly due to not placing the wrist joints in a neutral position when typing and writing, which could cause a median nerve compression. Appenrodt (1999) found fatigue and discomfort in the low arm when extensively using the computer mouse. Other studies in the literature, although included repetitive activities, did not look into the effect of activities on the lower arm.

Demonstrated in Table 19 (see p. 44) are the neck discomfort scores that were established from the analysis of the Body Part Discomfort Rating Scale. The type of activity increased neck discomfort. During the typing activity, only one participant of Session 1 and Session 2 reported discomfort in the neck because the neck more likely was kept in neutral position while typing. However, during the reading and writing activities, participants had the reading and writing materials on the table and they were looking down on the materials, which led to bending of the neck, increased discomfort, and increased the number of responses to 6 and 12 for reading and writing, respectively.

Further examination of Tables 17, 18, and 19, it was noticed that the writing activity was greatly involved in the discomfort of the body parts. Participants reported more responses of discomfort in the lower back, lower arm, and neck when engaged in the writing activity. Based on this conclusion, the writing activity was identified to cause the greatest discomfort when compared to the typing and reading activities.

Vergara and Page (2002) made similar conclusions. They determined that forward rotation and bending of the trunk when performing a writing task increased dorsal discomfort. Fenety et al. (2000) indicated that the task performed while sitting was one of the factors leading to increase in discomfort. Van Dieen et al. (2001) and Kayis and Hoang (1999) found that the work task and activities, but not the chair design, significantly changed sitting posture and increased back muscle activities and loading. Liao and Drury (2000) examined 6 participants sitting on adjustable chairs and performing transcription tasks. They found that there was a significant increase in postural shift over time and concluded that postural shift was a sign of discomfort caused by performed tasks.

Limitations of the Study

This research study had some limitations that could be improved or avoided in future studies.

1. The research study was conducted in a laboratory. Although the workstation was designed to mimic a real work environment, there were more elements missing such as filing cabinets, shelves, phone, and printers that provide more activities and movements.
2. Although, three hours of testing provided useful information, a typical eight hour workday testing would provide results closer to a real working situation.
3. The research study contained a small number of participants. Although, 20 participants provided enough data to reveal trends, a larger number in each group would supply more robust and convincing results.

4. A 30 minute break between the two sessions might be not enough to bring participants to a normal level of comfort, and possibly fatigue might carry over to the next session. However, taking a break then resuming testing would more likely to imitate a real workday than testing on different days and to reflect on the advantage or disadvantage of taking breaks.
5. Some factors beyond control such as life and emotional stressors and intense activities within few days of examination could affect the results of the study.
6. By changing their usual chair, participants might perceive greater or lesser discomfort due to sitting in a new and unfamiliar chair design.
7. Video and bilateral EMG analysis of the sessions were not used that could provide more specific biomechanical and postural measures.
8. The effect of age on discomfort of participants could be studied. This study was limited to a young adult group of participants.
9. The generalization of the findings from this study should not be generalized beyond the two types of chairs examined.

Recommendations for Future Research

Further research studies are essential to better understand the effect of chair design on discomfort level. More elements and variations of this study could be added and conducted to reflect on and explain the relation between chair design, activities, and human body on discomfort. Some of these element and variations would include:

1. Conducting the study in a real office-working environment to extract more representative data of the workplace.

2. Increasing the testing time to eight hours to correspond to the typical length of a workday.
3. Incorporating measures such as video recording of participants while sitting on the chairs to provide biomechanical measures on posture and sitting position, which could be useful to correlate it with discomfort.
4. Testing a greater variety of ergonomic chairs would help to provide more information about switching chairs and the activation of muscle groups and changing pressure points.
5. Measuring and locating lower body pressure points and conducting bilateral EMG analysis examining upper body muscular activities would contribute important data regarding the effect of switching chairs on pressure points and muscular activities.
6. Examine assumption about discomfort made in this study.
7. In the current study, the ergonomic guidelines for typing, reading, and, writing activities were not clearly defined. However, variations in postural behaviors were observed during testing. Therefore, future studies should account for these factors by specifying the ergonomic guidelines to be followed during testing.
8. Comparing a conventional chair to an ergonomic chair would provide more resources about discomfort and advantages and disadvantages of ergonomic chairs.

CHAPTER 6

Conclusion

Because of technology and increasing office automation, office workers are sitting longer and performing more repetitive activities, which leads to complaints of work discomfort as well as work related injuries. Industry has been concerned with designing chairs and adding features rather than investigating other causes of discomfort.

The purpose of this research was to determine if ratings of discomfort would change over time between two ergonomic chairs of the same approximate cost. Results from the General Comfort Rating Scale showed that discomfort level increased over time. Although, participants reported low to moderate level of discomfort, their reports developed over 3 hours and 30 minutes. The results of the current and previous studies suggest that discomfort would continue to rise if time of testing increased. Discomfort level gradually increased during the first phase of testing, however at the end of Session 2, the level of discomfort rose rapidly and significantly due to inability to maintain upright posture and accumulation of discomfort overtime that was caused by typing, reading, and writing activities. The results revealed that by switching chairs there was a lower tendency in discomfort, which was possibly due to activating different muscles, changing to a different body pressure points, and creating a new sitting posture. No significant difference between the two ergonomic chairs was found, and increase in discomfort level was not due to the type of chair. Neither chair was determined to be better than the other.

Findings from the Body Part Discomfort Rating Scale revealed that discomfort in lower back was the most frequently reported and followed by the lower arm and the neck. Activities performed while sitting seemed to seriously impact bearing and discomfort more than the chair design. Different types of activities would result in discomfort in different parts of the body and changing sitting positions, and the writing activity was identified as causing discomfort in most body parts. People tended to alter their posture by bending forward, having no contact with the chair backrest, leaning on one body side, and activating certain muscles repetitively to execute work activities. Although, the literature provided recommendations regarding sitting positions that might help to maintain upright posture and comfort, however discomfort level seemed to be greater than the ability of human to maintain the recommended sitting positions for long periods.

In conclusion, the findings of the current study were important because of their implication for chair manufacturers, purchasers, and users. Price, aesthetic, material, design philosophy, or advertisement should not influence the selection of an ergonomic chair. Selecting an ergonomic chair should depend on the feeling of the person occupying the chair. Other recommendations established by this study were as follow:

1. Switch chairs to maintain activation of different muscles and changing pressure points.
2. Test a chair before purchase to determine if it fits the person occupying the chair.
3. Examine padding material and thickness of cushion and backrest.
4. Take frequent breaks to relief pressure and load on the body.
5. Do not maintain one activity over a long period of time.

6. Vary work tasks to eliminate repetitive activities.

General recommendations to reduce discomfort and maintain upright posture.

1. Exercise to strengthen back and abdominal muscle.
2. Become sensitive and aware of discomfort; avoid letting the body becoming accustomed to discomfort.
3. Participate in postural training classes semiannually to keep active awareness of the importance of upright posture.
4. Engage in activities such as communicating with co-workers, filing documents, and taking lunch break out side the workstation to allow movement, blood circulation, and pressure relief.

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Appendix A Screening Questionnaire

Name: _____ Age: _____ Sex: M F
 Occupation: _____
 Contact #: _____ E-mail: _____

1. Did you ever participate in any postural sitting training class?

Yes _____ No _____

2. What type of chair do you usually use?

Ergonomic _____ Conventional/Standard _____

If ergonomic chair, please indicate the name: _____

3. Number of hours sitting on a chair per day:

1 Hour _____ 2 Hours _____ 3 Hours _____ 4 Hours _____ More _____

4. What type of activities do you do while sitting on a chair?

(Rank activities from 4 as the most to 1 as the least)

a. Computer tasks _____ b. Reading _____ c. Writing _____ d. Others _____

5. Do you have a **history** of discomfort, pain, surgery, and/or any other problems **at all time** in the following areas?

Area	Explanation
Shoulder	
Neck	
Upper Back	
Middle Back	
Lower Back	
Pelvic/Hip	
Leg	
Arm	
Wrist	
Hand	

Signature

Date

Appendix B
General Comfort Rating Scale

Participant: _____ Group: 1 _____ 2 _____ 3 _____ 4 _____
Type of Chair: Ergonomic A _____ Ergonomic B _____
Session: One _____ Two _____
Condition: 0 minute _____ 30 minutes _____ 60 minutes _____ 90 minutes _____

Make one horizontal line that describes the level of comfort/discomfort that you experienced.

Appendix C: Body Part Discomfort Rating Scale

Participant: _____ Group: 1 _____ 2 _____ 3 _____ 4 _____

Type of Chair: Ergonomic A _____ Ergonomic B _____

Session: One _____ Two _____

Condition: 0 minute _____ 30 minutes _____ 60 minutes _____ 90 minutes _____

Rate Over All Discomfort

Extreme Comfort

Extreme Discomfort

Rate First Most Body Part Discomfort

List Number:

Extreme Comfort

Extreme Discomfort

Rate Second Most Body Part Discomfort

List Number:

Extreme Comfort

Extreme Discomfort

Rate Third Most Body Part Discomfort

List Number:

Extreme Comfort

Extreme Discomfort

Appendix D

San José State
UNIVERSITY

Office of the Academic
Vice President
Associate Vice President
Graduate Studies and Research One
Washington Square

To: Musaed Alnaser
1394 Teakwood Drive
San Jose, CA 95128

From: Nabil Ibrahim,
AVP, Graduate Studies & Research

Date: August 12, 2002

The Human Subjects-Institutional Review Board has approved your request to use human subjects in the study entitled:

"Effect of chair design on ratings of discomfort."

This approval is contingent upon the subjects participating in your research project being appropriately protected from risk. This includes the protection of the anonymity of the subjects' identity when they participate in your research project, and with regard to all data that may be collected from the subjects. The approval includes continued monitoring of your research by the Board to assure that the subjects are being adequately and properly protected from such risks. If at any time a subject becomes injured or complains of injury, you must notify Nabil Ibrahim, Ph.D. immediately. Injury includes but is not limited to bodily harm, psychological trauma, and release of potentially damaging personal information. This approval for the human subjects portion of your project is in effect for one year, and data collection beyond August 12, 2003 requires an extension request.

Please also be advised that all subjects need to be fully informed and aware that their participation in your research project is voluntary, and that he or she may withdraw from the project at any time. Further, a subject's participation, refusal to participate, or withdrawal will not affect any services that the subject is receiving or will receive at the institution in which the research is being conducted.

If you have any questions, please contact me at (408) 924-2480.

Appendix E

Consent Form

Agreement to Participate in Research**Responsible Investigator:** Musaed Alnaser, OTR**Title of Protocol:** Effect of Chair Design on Ratings of Discomfort.

I understand that:

- I have been asked to participate in a research study that will evaluate two types of chairs.
- I will be asked to come once to the testing room in the Engineering Department at San Jose State University at a scheduled time to conduct the study.
- I will be asked to perform typing, reading, and writing tasks while sitting for a total of three hours. I will be asked to complete written evaluation tools for a total of 15 minutes.
- The criteria for this study is that participants will have no history of shoulder, back, or hip surgeries or problems. Participants must be 18 year old or older. Participants must be student at San Jose State University.
- I may experience some discomfort during the study. Discomfort may result because of a constant sitting position, similar to what one may encounter with daily sitting position. The procedures of the study are not expected in any way to overstress the body.
- I understand that I have the option to take a break or rest at any time during the study.
- I will take 30 minutes break between session 1 and 2, regardless of taking breaks or rests during the sessions.
- There are no physical or psychological benefits from participating in this study.
- The data and results produced from the study will be subject to the confidentiality and the privacy regulation of San Jose State University. If data are used for publication, your name will not be used.
- I will be paid \$10.00 per hour for participating in the study. I will also be paid \$5.00 break allowance. Therefore, I will be paid a maximum of \$35.00.
- If I have any questions regarding this research may be addressed to the investigator, Musaed Alnaser (408) 866-8868, and the questions will be answered to my satisfaction. Complaints about the research may be directed to the chairperson of the researcher committee, Dr. Emily Wughalter (408) 924-3043. Questions or complaints about my rights or research-related injury may be presented to Nabil Ibrahim, Ph.D., Associate Vice President for Graduate Studies and research, at (408) 924-2427.

Initial after reading page 1 _____

- No services of any kind, to which I am otherwise entitled, will be lost or jeopardize, if I chooses not to participate in the study.
- My consent is given voluntarily. I may refuse to participate in the study or any part of the study. If I decide to participate in the study, I will be free to withdraw at any time without prejudice to my relation with San Jose State University or any other participating institution.
- I will receive a signed and dated copy of the consent form.
- My signature on this document indicates agreement to participate in this study.
- The signature of the investigator on this document indicates agreement to include me, the above named participant, in the research and attests that the participant has been fully informed of own rights.

Participant's Signature

Date

Investigator's Signature

Date

Appendix F
Flier

GET PAID \$10 AN HOUR FOR JUST SITTING ON A CHAIR

ALL WE NEED TO KNOW WHAT YOU THINK OF OUR CHAIRS

This ergonomic study needs participants to sit on two different types of chairs and to provide evaluation. The study will be conducted at San Jose University department of engineering.

This study requires you to:

- Sit for 1 ½ hour on each chair.
- Type, read, and write some materials.
- Complete 4 short evaluations.
- Be an 18 years old or older.
- Be a student at SJSU.

Participant must complete a screening questionnaire before being selected to participate in this study. If interested, please E-mail or call the number below to receive the screening questionnaire.

Musaed Alnaser
musaeda@hotmail.com
(408) 866-8688

Musaed Alnaser
musaeda@hotmail.com
(408) 866-8688

Musaed Alnaser
musaeda@hotmail.com
(408) 866-8688

Musaed Alnaser
musaeda@hotmail.com
(408) 866-8688

Musaed Alnaser
musaeda@hotmail.com
(408) 866-8688

Appendix G

Adjustment Check Off Form

Feature	Set Up	Adjustment
Seat Height	17.5"	
Backrest Height	25.0"	
Backrest Tilt	90 degrees	
Armrest	2.0"	
Lumbar Support	Medium	

Appendix H
Ergonomic Chair Principles

Principle	Benefit
Seat Height Adjustable	To adjust seat height from low to high to adapt comfortable lower body joint degrees
Backrest Adjustment	To fit the shape of the back.
Lumbar Support	To provide lower back support
Backrest Tension and tilt	To provide back support
Armrest	To provide arm support and to relief shoulder pressure.
Sliding Seat	To relief back of the leg pressure
Casters	To allow maneuvering