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The Development of a Computer Operator Risk Index to Assist Computer Operators

Sandra Louise Rudd
University of Tennessee - Knoxville

To the Graduate Council:

I am submitting herewith a dissertation written by Sandra Louise Rudd entitled "The Development of a Computer Operator Risk Index to Assist Computer Operators." I have examined the final electronic copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Industrial Engineering.

Dongjoon Kong, Major Professor

We have read this dissertation and recommend its acceptance:

John Hungerford, Robert Ford, Susan Smith

Accepted for the Council:

Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

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Anne Mayhew
Vice Chancellor and
Dean of Graduate Studies

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THE DEVELOPMENT OF A COMPUTER OPERATOR RISK INDEX TO ASSIST COMPUTER OPERATORS

A Dissertation
Presented for the
Doctor of Philosophy
Degree
The University of Tennessee, Knoxville

Sandra Louise Rudd
May 2006

DEDICATION

This dissertation is dedicated to my family for their continued belief and support in me, to my future husband for his long and countless hours of help, support, and understanding, to my professors for their experience and guidance throughout this entire process, and to my co-workers for their encouragement and patience.

ACKNOWLEDEMENTS

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- Carolyn Lundberg – President - ACE Ergonomics
- Les Albor – EZ INPUT – Healthy Computing
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- Nicholas Warren, ScD, MAT - Ergonomic Technology Center - University of Connecticut Health Center
- Jeannette Murphy, OTR/L, CEA - Injury Prevention Specialist – Ergonomist - St. Luke's Rehabilitation Institute
- Isabel Lopex Nunes – Professor of Industrial Engineering – Ergonomics and Safety and Health at Work – New University of Lisbon – Portugal
- Donald W. Patterson, Jr.

Lastly, I would like to thank the members of my family, who stood behind me and pushed when necessary and otherwise helped me stand strong in continuance of my journey. They are the very core of my being.

Abstract

Computer workstation ergonomics is well into its third decade of computer related injuries and disease. Numerous studies have been completed to inform the scientific and private communities of the threats that are posed when working at a computer. There are also multiple variables involved with attaining a computer related injury or disease, and any one of those variables, or a combination of those variables, may put a computer operator at risk. The purpose of this study was to develop a computer operator risk index (CORI), based on previous literature and containing risk variables approved by an expert panel, which is designed for relatively simple calculations. The four main risk variables were time, posture, stress, and environment.

This study used 100 participants (58 females and 42 males), with a mean age of 45.8 years from an age range of 20 to 64 years, who had worked at a computer for at least 1 year and worked at least three hours per day at the computer. Not only were females and males incorporated into this study, but four ethnic backgrounds as well.

Participants were asked to complete a demographic survey developed for this study, as well as a combined pain/discomfort rating chart adapted from Corlett and Bishops (1976) body chart and Borg's (1970) CR-10 pain rating scale, a self-evaluating stress test, adapted from Yang' (2003) self-evaluation stress test, and a Likert-type survey, which was part of the CORI form, concerning the computer operator's work environment. The remaining sections of the CORI form were completed from observations of an expert analyst. Information contained in the demographic survey and the pain/discomfort chart was used to verify previous research that stated gender was

considered a risk factor in computer operators for related illnesses or injuries. In this study Chi-Square tests showed no association ($X^2 = 0.036, p = 0.85$) in gender to show this to be true.

Data from the pain/discomfort chart was combined with data taken from the CORI form and found to show a significant difference with all four major risk variables. Time, posture, stress, and environmental measures at $\alpha = .05$, showed correlation ($\rho < .05$) with the pain measures.

Furthermore, the demographic survey contained data stating that some participants had been previously medically diagnosed with a computer related injury or disease and those participants, using Chi-Square testing, were compared to the results produced from the CORI equation and found to have a significant difference and high correlation ($X^2 = 6.683, p = .01$) .

From the data retrieved and calculated in this study a logistic regression model was developed that provided the expert analyst with a means with which to measure risk to computer operators. This model included the four independent variables: time, posture, stress, and environment, which are also the four main sections of the CORI form. The CORI form is recommended for initial risk screening, but is not meant to be solely dependent upon in determining the risk of a computer operator...

There are several parts of this study that in themselves may be useful. The Pain/Discomfort Rating Scale may be used to discern between severity levels of pain for computer operators, the Self-Evaluation Stress test may be used to test stress levels of computer operators, and the Computer Operator Survey may be used to collect pertinent demographic information for employers.

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INTRODUCTION

Chapter 1

1.1. Problem Statement

The computer workstation has long been discussed in scientific and non-scientific circles. Scientific or not, most scientists and ergonomists agree that computer operators have a significant chance of being injured while working at a computer if they are not using correct methods and/or equipment with which to work. Not only do the methods and equipment need to be correct, but other factors play into the equation as well. Such factors as the overall lighting of the room in which the computer operator will be working; the type and/or colors of the desk, keyboard, and walls; the chair and the position the operator maintains while working; the temperature and noise factors (Paoli and Merllié 2003); and even the general psychological and psychosocial factors (Kong 2002) of the job may accrue into musculoskeletal disorders in some shape or fashion. But are there enough computer operators in this field with enough damage being done to necessitate more investigation, more research, and more ways of helping the computer operator to work virtually risk free?

The National Institute of Occupational Health and Safety (NIOSH) estimated that in 2004, there were more than 90 million computer operators in the United States alone (CWA 2004). That is too many people doing the same thing for something not to go wrong. In fact, a little over two decades ago NIOSH stated Computer Vision Syndrome (CVS) as being the number one cause of eyestrain for workers (NIOSH 1981). At that time the symptoms were causing productivity problems, increased error rates, and absenteeism on the job. In general, 90% of computer operators indicated visual problems from computer work, with more than ten million eye exams being performed. Of those ten million eye exams, 14% are due to CVS, and another 40% of vision patients began wearing glasses specifically for computer use. Crews estimated that there will be 9 million persons with severe visual impairment by 2030 (Crews 1994). And an overall twenty-two percent complaining of general fatigue (Sheedy 1996).

By 1996, already more than $8 billion in medical costs was being spent on disability and lost work days, per year (CTD-News 1996; OfficeFurniture 2005), with typing being one of the leading events causing the longest absences (BLS 1999). And by 1998, Cumulative Trauma Disorders (CTD), were cited as 'the fasted growing workplace injuries in the United States.' The Bureau of Labor Statistics (BLS 1999) showed that incidence of these injuries has exponentially grown 770% in the past decade (Tyler 1998), not to mention that approximately 50% of all U.S. households have a least one computer, up 27% from 1995 (Nelson, Treaster *et al.* 2000), thus even more time is spent at the computer since many computer operators go home and use the computer. The United States Department of Labor states that Americans spend 33% of their time at work and eight million of those Americans are affected by Carpal Tunnel Syndrome (CTS) (Hedge and Powers 1995; Kumar, Narayan *et al.* 1997; Fagarasanu and Kumar 2003). Twenty-one percent of those affected by CTS were affected by repetitive typing or keying in data (Szabo 1998). And nearly 36% of CTS affected operators require medical treatment for several years to life (Fagarasanu and Kumar 2003).

Research indicates that the majority of computer operators are female, although most programming jobs are filled by males. Evans *et al*. (1987) stated that the majority of computer jobs being held by females may be due to the fact that more females are in secretarial positions. Of those computer operators that were non secretarial, 65% indicated pain and/or discomfort in the neck and shoulder areas and further testing still showed with statistical significance that gender was considered a risk factor (Evans and Patterson 2000). For these reasons, gender will be a factor in this study.

The age of computer operators, from several studies, ranges from 30 to 45 years of age, with the operators working an average of 6 to 8 hours per day, and having at least one year of experience (Saltzman 1998; Evans and Patterson 2000; Galinsky, Swanson *et al.* 2000).

1.2. Objectives

There are four objectives of this study that will be discussed in this section.

First, this study was used to develop a computer operator risk index model that contained statistically significant, work-related risk factors for the purpose of predicting the probability of developing computer related illnesses or injuries. The model describes the majority of risk factors that are instrumental in the development of a computer operator illness or injury. It also provides numerical values to present a method for the prediction of the probability of risk.

Two groups out of the sample population were used for the model. One group was those participants at high pain levels and the other group was those participants at low pain levels. The two groups were distinguished between by using the pain/discomfort rating scale, which was developed for use in this study. The hypotheses were tested from collected data and run through statistical analysis, which included correlation and logistic regression.

Second, in keeping with validated research in the field of computer workstation ergonomics and having each factor reviewed by an expert panel in the field of computer workstation ergonomics, the risk variable validity of the model would be maintained.

Third, a modified stress test is used to determine stress levels of computer operators. The stress test was tested for reliability using Cronbach's alpha and found to have excellent reliability. The score calculated from the stress test was used a one of the risk factors of the computer operator risk index model.

Last, this study determines that a correlation exists between those participants indicated to be at risk by the computer operator risk index score and those participants that were determined to actually be at risk through previous, medical diagnosis.

1.3. Research Questions

There are four questions that must be answered from this research:

1. Is there a relationship between the Computer Operator Risk factors and the Pain/Discomfort rating? The answer to this research question will indicate whether there a difference in pain/discomfort involved in at risk participants and those participants not at risk.
2. Can pain groups be predicted using the factors in the Computer Operator Risk Index?

3. Is there a relationship between gender and those participants found to be at risk?

4. Does the Computer Operator Risk Index (CORI) accurately predict those participants medically diagnosed at risk to actually be at risk?

1.4. Significance

The significance of this study was contains three sections:

First, this study is used in the development of a valid risk index model for assessing the probability of a computer operator to develop a computer related injury or disease. The model consists of four sections with questions in each section having been validated through previous research studies and an expert panel in the field of computer workstation ergonomics. The design is to combine these risk factors and evaluate reach one's contribution to the overall risk associated with working at a computer workstation for an extended time period. The importance of specializing a risk index specifically for computer operators lies in the fact that each individual operator can be affected differently by a variety of risk factors. The questions contained in the assessment of risk will indicate which risk factors are contributing to the computer operator's present or possible future computer related injury or disease.

Second, this study also offers revisions of current assessment questionnaires and tools used as part of the risk index assessment, which in turn offers increased reliability and credibility to the work of others. Recommendations are proposed for future research using the questionnaires and tools of this study.

And third, this study uses four major factors in determining risk for computer operators: time, posture, stress and environment. Previous studies have used only one or at most two of these risk factors together in determining risk for a computer operator. By using all four risk factors, the analyst can predict the risk of a computer operator with confidence, as well as being able to point out the specific areas of concern and orchestrate an immediate change in all risk factors that were indicating risk for the computer operator.

1.5. Assumptions

The following basic assumptions were used for this study:

1. All self reported information was true and accurate.
2. The participants were working in their usual manner.
3. The participants understood the confidentiality used in this study.
4. The participants knew enough about their own pain/discomfort to distinguish between the levels of each.
5. All computer operators were familiar with their job functions.
6. The participants of this study were representative of the field of computer operators, regardless of job title.
7. Participants were assumed to have high pain when the pain level reached a level of 2 in the Pain/Discomfort Severity Scale.

1.6. Delimitations

The following delimitations were made for the purpose of this study:

1. The time period for data collection was within the years 2005 and 2006.
2. The working time period was considered to be 5, 24-hour days.
3. Data was gathered from the Knoxville, Tennessee area and its surrounding counties.
4. Data was collected from: Farragut High School; The University of Tennessee, Departments of Industrial and Information Engineering and the Office of Information Technology; and Sparks' Resources, LLC.

1.7. Limitations

The study was limited as follows:

1. The participants were self reporting of stress evaluations
2. The participants were self reporting of their own pain/discomfort
3. The participants were self reporting of environmental risk factors in the COTI form.
4. The participants were given only one opportunity to complete all self evaluations forms.
5. The participants were using desktop computers.
6. The instrument used to determine a risk index was experimental and validity was determined upon completion of this study.
7. All participants in this study were between the ages of 20 and 70 years.

1.8. Definitions of Terms

Carpal Tunnel: A narrow, rigid passageway (like a tunnel) of ligament and bones at the base of the hand which houses tendons and the median nerve.

Carpal Tunnel Syndrome: Pain, discomfort, weakness, or numbness of the hand caused by the median nerve being pressed or squeezed at the wrist, usually due to inflamed or irritated tendons.

Central Processing Unit: CPU, the brains of the computer.

Computer Case: The unit that houses the electrical hardware of a computer.

Computer Operator: Any person whose job function includes working at a computer workstation.

Computer Workstation: Any desk, table, or other desirable location to place a monitor, keyboard, mouse, and working computer case with varying CPU speeds.

CORI: Computer Operator Risk Index, an experimental instrument in this study.

CTD Risk Index: Carpal Tunnel Disorder Risk Index; a form used to predict risk of carpal tunnel syndrome in industrial type job settings.

CVS: Computer Vision Syndrome: Characterized by assorted eye irritations, such as dry eyes, red, itchy, watery eyes, fatigue, difficulty focusing, and eyestrain in general.

Desktop Computer: A computer using any operating system that is not mobile.

Discomfort: Bothersome mental or bodily feeling, but not quite to a level of pain; an annoyance.

Ergonomics: The science of fitting the job to the worker.

Keyboard: A tool used to input data into the computer by typing.

Monitor: The viewing screen used by a computer operator; also termed VDT (Visual Display Terminal and VDU (Visual Display Unit).

Mouse: A tool used to input data into the computer that has maneuverability actions, such as dragging, pushing, and clicking.

Pain: An unpleasant sensation occurring in varying degrees of severity as a consequence of injury, disease, or emotional distress.

Risk: The probability or chance that an activity will lead to injury or disease.

Stress: A condition or feeling experienced when a person perceives his/her demands exceed the personal and social resources that the individual is able to assemble. The person is said to be in a state of mental or emotional strain or suspense.

Time at Computer: Includes reading, keying, and mousing.

1.9. Scope

There are six major sections to this thesis:

Chapter 1: Introduction to the study, including the problem statement, objectives, research questions, need for the study, assumptions, delimitations, limitations, and definitions.

Chapter 2: Review of literature on what experts and research are informing the computer workstation user to be the best possible ways to work at a computer workstation with minimal injuries. This includes detailed research information on specific parts of the human body in which injuries are most likely to occur for the computer operator.

Chapter 3: Presentation and discussion of the Demographic Survey, Corlett and Bishop's Pain Discomfort Chart (Corlett and Bishop 1976), Borg's CR-10 Rating Scale (Borg 2001), the Self-Evaluating Stress Test, and the Computer Operator Risk Index (CORI).

Chapter 4: Discussion of the verification and analysis methods used in this study. Discussion of various ways to put these models to use in the ergonomic workplace, and of further opportunities associated with research and improvements that can be done to better enhance the working situation of the computer workstation user and to have the computer workstation user become more involved in said improvements.

Chapter 5: Summary, Discussion, Conclusions, and Future Study Recommendations

Chapter 6: The Study in Retrospect

1.10. Statement of Non-Disclosure

This study has been restricted by certain conditions that were beyond the researcher's control. The voluntary nature of the sampling has potentially limited the results of the study. It is possible that the attitudes of individuals not choosing to participate in the study differ significantly from those of subjects volunteering to participate. The sample might more appropriately be termed an incidental sample, in which subjects participate on the basis of availability and willingness to cooperate. This factor may restrict the generalizability of the findings regarding subjects' attitudes.

LITERATURE REVIEW

Chapter 2

This chapter was used as a basis for determining the factors that were used in determining the risk of a computer workstation operator. Nearly all parts of the body are used when operating a computer, therefore a careful study of previous research is discussed.

2.1. Primary Musculoskeletal Systems of Computer Operators

Computer operators use several parts of their musculoskeletal system while operating a computer. Persons that perform this operation involuntarily overwork various parts of this system. Research at the University of California at San Diego indicates that a person using a computer at least 8 hours per day will make approximately 80,000 finger and/or hand movements. The human body was not made for this type of repetition (UCSD 2005). This section covers various aspects of the arms and their extremities, the upper part of the body, specifically the neck and the shoulders, and the lower part of the body, specifically the back and legs.

2.1.1. The Hands, Arms, and Wrist

Positions of the hands/arms/wrists are of vital importance for computer operators. Since computer use is highly repetitive, the possibility for injuries exists in high numbers. Examples of some basic positions to keep in mind for the hand and arm would be ulnar/radial deviation Figure 2-1, greater than 24/15 degrees respectively;

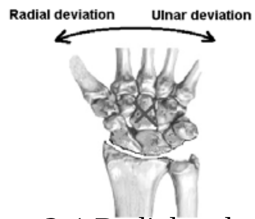


Figure 2-1 Radial and ulnar deviation of the wrist (Thompson 2002)

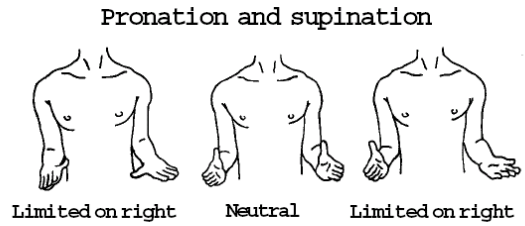


Figure 2-2 Pronation and supination (Huckstep 1994)

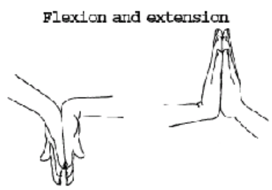


Figure 2-3 Flexion and extention the wrists (Huckstep 1994)

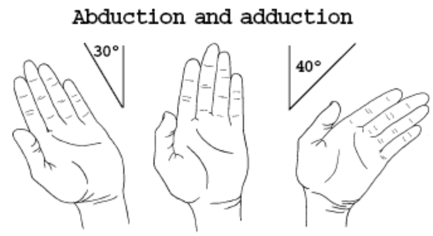


Figure 2-4 Abduction and adduction of the wrists (Huckstep 1994)

pronation/supination (Figure 2-2), greater than 40/57 degrees respectively; and abduction/extension/flexion (Figure 2-3,2-4), greater than 67/50/45 degrees respectively (Bergamasco, Girola *et al.* 1998). It has even been proven with statistical significance that a relationship exists between wrist extension and pronation (Serina, Tal *et al.* 1999). Furthermore, the ANSI/HFS 100-1988 and BSR/HFES 100 states that wrist extension further than 15 and 10 degrees respectively, may be a risk factor for carpel tunnel problems (ANSI/HFS 1988; BSR/HFES 2002), with the highest risks being found in the arms, wrists, and hands (Rempel, Tittiranonda *et al.* 1999). These risks have produced ailments of disabling proportions from improper or prolonged computer use. The expected prevalence of wrist and hand problems is expected to reach 40% (Bammer 1990).

Naturally, the best position for the wrist would be in the neutral position. The neutral position, where the wrist is concerned, is defined as being on the line that continues out of the middle finger and stays parallel with the forearm. However, the wrist, in its natural position, already has an ulnar deviation of 4-6 degrees. This is seen through studies showing that pressure inside the carpel tunnel is lowest when the hand is in slight pronation (Hedge and Powers 1995). When computer operators type on a keyboard for prolonged periods of time, ulnar deviation may play an important role in disorders of the carpel tunnel (Simoneau, Marklin *et al.* 1999). This may not appear to be such a threat alone, but computer operators do not work solely with their hands and body in one position throughout the day. When two or more factors, such as wrist ulnar deviation and finger position while typing on a keyboard are synergistic, then even more complications occur in maintaining a healthy operator (Nelson, Treaster *et al.* 2000).

Previous studies have been conducted to assess discomfort in the wrists, arms, and hands. One such study had complaints of arm/wrist discomfort from 12-13% of the 932 computer operators studied. Another interesting fact was that the participants of the study listed keyboard height as their main complaint with respect to arm discomfort(Sauter, Schleifer *et al.* 1991). These items may indirectly affect the wrist by the affect that arm abduction has on the arm pronation and ulnar deviation of the wrist (Simoneau, Marklin *et al.* 1999; Marklin and Simoneau 2001)

Prolonged use of different variations in wrist/hand/arm positions may cumulate into problems for the computer operator. Pressure that builds up within the carpal tunnel is one result of this prolonged use (Phalen and Kendrick 1957; Szabo 1989a; Seradge, Jia *et al.* 1995; Keir, Bach *et al.* 1998; Szabo 1998; Fagarasanu and Kumar 2003). Optimum hand and wrist positions, in which the wrists are in a neutral position and the hands are relaxed with fingers slightly flexed at approximately 30 degrees, and the forearm in a position of semipronation, are seldom reached in computer operator tasks (Werner, Peterzell *et al.* 1990). With respect to pressure on the carpal tunnel, wrist extension has a more lasting effect than ulnar deviation (Marklin, Simoneau *et al.* 1999). This is easily seen when computer operators use a mouse in such tasks as double clicking and dragging, with time increasing in wrist extension (Amell and Kumar 1999). When using a keyboard, carpel tunnel pressure is also a concern. Finger flexion comes into play since typing force may be 4 to 5 times greater than the force required for a finger to actually press the key (Feuerstein, Armstrong *et al.* 1997). For instance, the pressure required at 90 degrees flexion is greater than the pressure required at 45 degrees flexion (Keir, Bach *et al.* 1998). The only muscles that are used in the flexion of all four fingers are the flexor digitorum profundus and the flexor digitorum superficialis (Nelson, Treaster *et al.* 2000). These muscles are used continuously while performing keyboarding tasks and to overuse them could lead to inflammation of the tendon sheaths (Marklin and Simoneau 2001). High pressure is produced in the carpel tunnel when full wrist flexion or extension is coupled with extended fingers (Armstrong, Werner *et al.* 1991). This pressure will invariably produce inflammation, swelling, and a reduced blood flow, resulting in injury to the median nerve (Rempel, Harrison *et al.* 1992). Furthermore, a keyboard that is too high or low for an operator will produce either excessive wrist flexion or extension. A good elbow-to-keyboard position would be when the elbow flexion is at an angle of approximately 80 degrees, with the arms close to the trunk, shoulders relaxed, and the forearms slightly parallel to the floor (Stammerjohn, Smith *et* *al.* 1981; AFSCME 2005). Not only is keyboard height a factor in comfort of the computer operator but the speed at which an operator types is also a factor. For instance, an operator should not exceed a frequency of 30 repetitive finger actions per minute, per finger. Studies show, however, that most experienced operators exceed this frequency by 8-10 repetitive actions per minute, per finger (Bergamasco, Girola *et al.* 1998).

A very common ailment of the computer operator is carpel tunnel syndrome (CTS), also known as median neuritis. CTS develops in the area where the median nerve is compressed inside the carpel tunnel of the wrist. The median nerve is not solely located within the carpel tunnel, but also extends along the elbow, shoulder and neck. Because of this, compression may also occur in these areas. CTS is also blamed on other ailments that actually occur within specific muscles but since they have the same type of symptoms as CTS, it is sometimes mistakenly diagnosed (Jensen, Finsen *et al.* 2002). CTS can be a very painful condition, especially in its latter stages. Before getting into the latter stages, CTS may have symptoms such as numbness and/or tingling in the hands. This is usually felt in the first 3 fingers of the hand as well as the base of the thumb. Figure 2-5 indicates the part of the hand and wrist that are associated with CTS (AFSCME 2005).

One thing for employers to notice is if their employees start coming to work wearing orthopedic or support devices on their wrists or arms. This is indicative of already painful problems in support of CTS (Shihadeh-Gomaa, Allen *et al.* 1998). It would be a good idea for companies that use computer operators to frequently survey their personnel with routine questions about what type of activities are they involved in before/after working hours, about how many hours they work continuously at their

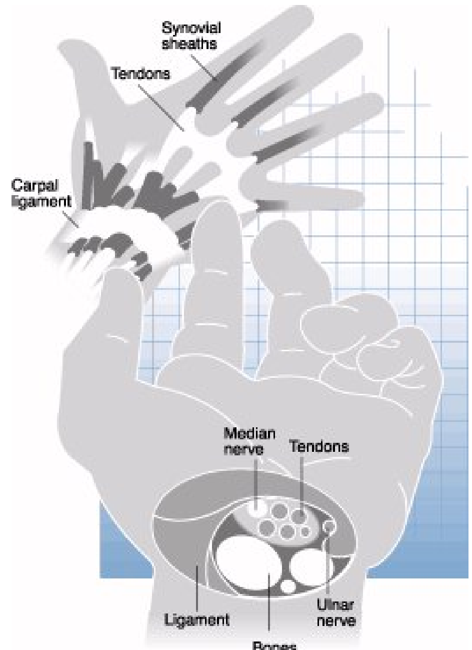


Figure 2-5 Parts of the hand and wrist involved in CTS. (AFSCME 2005)

computer, and whether any other medical conditions exist that may aggravate symptoms of musculoskeletal disorders. Some people just tend to be over achievers and work long hours, giving well over 100% while working. While this may seem good for the company, it will ultimately hurt both the employee and the employer (Quitter 2001).

2.1.2. The Neck and Shoulders

The neck and shoulders are two of the most common parts of the human body that computer operators complain about (Starr 1983; Sauter, Schleifer *et al.* 1991). Computer operators generally spend long hours at their computer, and often times with few or no breaks (Kamwendo, Linton *et al.* 1991; UCSD 2005). And while most people think of the hands, wrists, arms and fingers being used most, the muscles in the neck and shoulders maintain static contractions. This is one condition that may produce discomfort, as well as fatigue (Waris 1980; Hunting, Laubli *et al.* 1981; Smith, Cohen *et al.* 1981; Hagberg 1983; Grandjean, Hunting *et al.* 1983a; Murata, Araki *et al.* 1991; Sauter, Schleifer *et al.* 1991; Carter and Banister 1994; Schleifer, Galinsky *et al.* 1995; Bergqvist, Wolgast *et al.* 1995a). It is even more noticeable in right hand operators (Ong 1984). It has often been suggested to computer operators to change working positions by task rotation or task reorganization This would help relieve some of the discomfort to the neck and shoulders (Oxenburgh 1984; Winkel and Oxenburgh 1990). Some studies suggest lowering the monitor to decrease discomfort in the neck and even though flexor moments were increased, the amplitude electromyography were decreased as shown in Figure 2-6 (Kumar 1994). Other studies have suggested using upper extremity support, such as being able to support their whole forearm and hand on a concaved shaped workstation (Aaras, Horgen *et al.* 2001).

Most people do not have the opportunity to use specially designed workstations and instead tend to either lean forward or backward to accommodate their ability to view

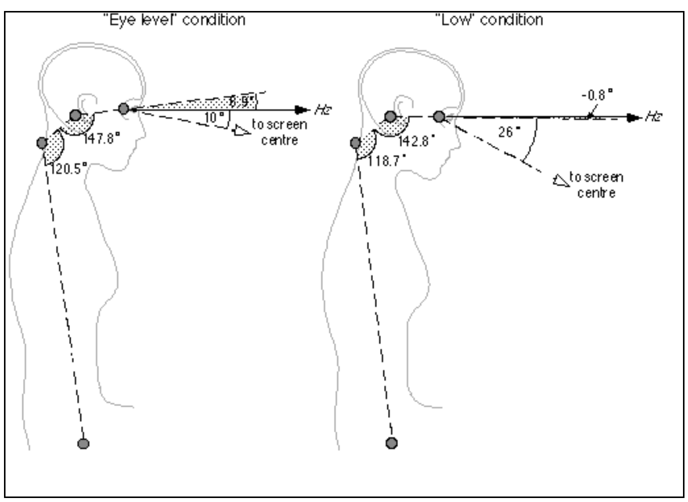


Figure 2-6. Average postures adopted in "eye level" and "low" monitor conditions.(Burgess-Limerick 1996)

the monitor. In doing this their neck muscles have to work harder to increase the force that is required to hold up their head, which generally weighs 8-14 pounds (4-6 kg), and since working at a computer is generally static as far as muscles are concerned, the muscles will contract and hold (Sweere and Sweere 2002; UCSD 2005). This non-action reduces blood flow which is necessary for the muscles to pump in nutrients and remove waste. If this action is reduced or stopped then acids will build up around the fibers of muscle, leading to pain and discomfort (Roberts 1999). The neck, also called the cervical spine, is flexible, thus allowing flexion and extension at the atlanto-occipital and cervical joints (Goel, Clark *et al.* 1988). These flexible vertebrae, although part of the spine, end at the base of the skill (Figure 2-7). The muscles surrounding this support the neck and allow it to move. However, even though the neck is part of the spine, it is less protected and therefore more susceptible to injury and disorders (AAOS 2005). The neck causes the least discomfort when in its neutral position (Figure 2-8).

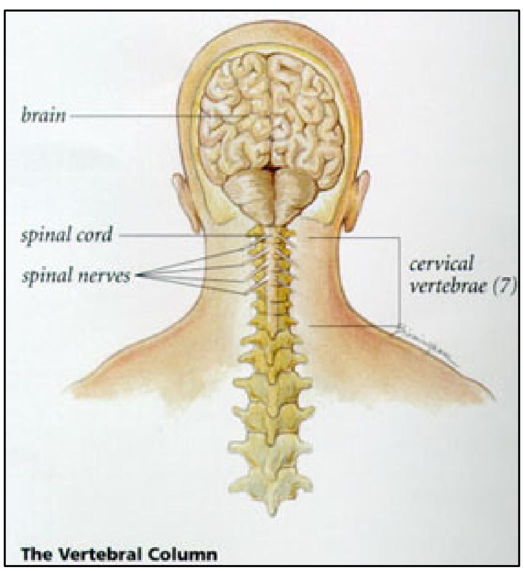


Figure 2-7 The vertebral column (AAOS 2005)

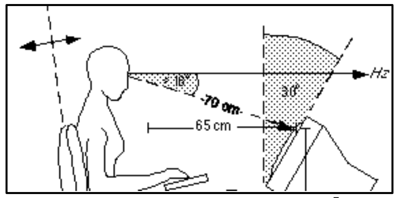


Figure 2-8 Viewing a monitor in a neutral position (Burgess-Limerick 1996)

This position also helps to maintain the natural antero-postero arc of the spine where the neck is involved. In this position, the eyes are still able to move vertically and horizontally up to 35 degrees. Variations from the neutral position, over time, may cause degenerative disc and joint disease, resulting in irritation and inflammation of the nerves that leave from either side of the vertebrae (Burgess-Limerick, Plooy *et al.* 1999; Sweere and Sweere 2002).

Good posture can alleviate neck and shoulder problems. Leaning forward or tilting the head backwards requires the muscles to work harder, generating high forces to keep the head erect. This is not to say that a person cannot lean forward/backward occasionally, it is the continued repetitiveness of a position that ultimately leads to static loading injuries (Roberts 1999).

Computer operators, such as secretaries, may receive training on the proper positions in which to work, but most other types of computer operators do not. This lack of knowledge allows people to work for long periods of time in oftentimes extreme position (forward tilt at 30-45 degrees) with little relief (Chaffin 1973; Patterson and Evans 1996). Operators trying to achieve viewing a computer monitor while flexing the neck can pay a high price in visual comfort. As little as one degree of flexion is required to achieve one degree of elevation in the line of sight (Menozzi, Buol *et al.* 1992).

Ankrum and Nemeth found that placing the monitor lower so the operator has a slight downward gaze increases comfort and decreases neck and shoulder injuries (Ankrum and Nemeth 1995).

Carpel tunnel syndrome is very well known for injuries and illnesses to the arms and wrists, but Tension Neck Syndrome (TNS) is not as well known. This term refers to disorders of the neck and shoulders which can be coupled with a computer operator's occupation. TNS is also referred to as tension myalgia or myofascial syndrome (Waris 1980). Symptoms of TNS are characterized as stiffness in the neck/shoulder area – a constant muscle fatigue. This is usually accompanied by headaches and/or neck pain. TNS has also been found to occur more often in computer operators who had mental and physical stress (Hagberg and Wegman 1987; Arnetz and Arnetz 1992; Smith and Carayon 1996), and mostly in women (Bergqvist, Wolgast *et al.* 1995b).

One way to prevent neck and shoulder pain and injury is to pay attention to warning signs/symptoms. Some common early warnings of TNS would be aching in the neck or shoulders during or after computer use, tingling sensation in the fingers and soreness in the forearms. It is sometimes tempting to self medicate to relieve some of these symptoms, but it is better to give your body time to heal. This may often take up to 6 weeks (Roberts 1999).

2.1.3. The Back and Legs - Posture

Just as the arms, wrists, hands, neck and shoulders are affected by working at a computer workstation, so are the back and legs. NIOSH has linked poor posture to CTS in studies of workplace factors (NIOSH 1997). Posture is important in all aspects of computer work, but especially so where the back is concerned. Poor posture causes the muscles to become tired (Roberts 1999), specifically when working long hours (Quitter 2001). People with poor posture who spend long hours working at a computer will experience fatigue quicker since this increases the compressive load on the spine (Braganza 1994). Adjustable chairs with proper lumbar support could help to alleviate this problem (Occhipinti, Colombini *et al.* 1986; Coleman, Hull *et al.* 1998; Kayis and Hoang 1999). Once the chair is fitted to the worker, it is still important to note the position of the feet from the floor as well. The feet should be flat on the floor with the knees slightly higher than the hip, not touching the workstation surface (Hochanadel 1995; DHHSCDCP 2000).

People did not always work in a seated position. It was not until the middle of the 19th century that the thought of better productivity may occur if workers were seated. Generally speaking, an office worker will spend approximately 70% of their time at work in a seated position, but a computer operator will spend nearly 100% of their time seated. Sitting actually involves 5 major body elements: vertebrae, discs between the vertebrae, pelvis, muscles, and skin (Mandal 1987; Shihadeh-Gomaa, Allen *et al.* 1998; Dowell, Sheidle *et al.* 2003).

There are 24 bones in the vertebrae, which are collectively called the spinal column, and these bones are separated into 3 natural curvatures: the cervical region, which has the curvature known as a lordosis; the thoracic region, that has the curvature known as kyphosis; and the lumbar region, which also has a curvature known as a lordosis (Figure 2-9). And finally at the base of the spinal column is the sacrum.

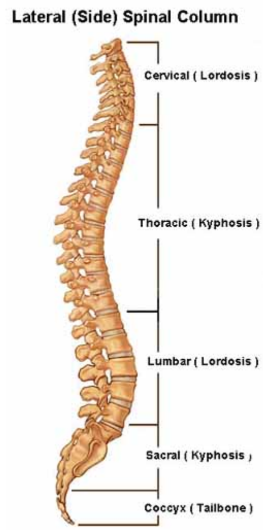


Figure 2-9 Lateral side of the spinal column

The sacrum is a collection of 5 vertebrae in a triangular shape that is lodged between two pelvic bones which in turn can rotate either forward or backward (Dowell, Sheidle *et al.* 2003). When a person sits down, the spine is not in its natural state and to keep the upper torso from leaning forward the lower back muscles contract strongly (Klausen 1965), compressing the discs. As this happens, a fluid will escape from the discs causing them to flatten throughout the workday. Sitting in this manner, without good lumbar support will put more pressure on the nerves coming from the vertebrae (Dowell, Sheidle *et al.* 2003). And, since 70% of body mass is supported by the ischial tuberosities (Figure 2-10), (Kayis and Hoang 1999) continued sitting in this manner will fatigue the muscles in the lower back and the operator will tend to slump in an effort to relax (Milner-Brown and Stein 1975). The head will also come forward putting added tension on the neck. Adding lumbar support and an increased angle between the back and seat of a chair will allow the operator more comfort in the back and pelvic areas

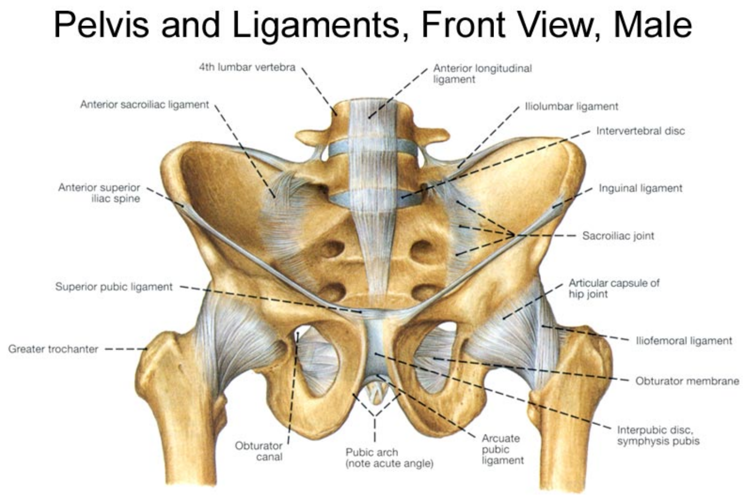


Figure 2-10 Pelvis and ligaments, front view, male (Robert 2004)

(Nachemson 1980; Kayis and Hoang 1999; Dowell, Yuan *et al.* 2001). Insufficient support for the pelvis and lower back and the computer operator will tend to slump in an effort to relax (Milner-Brown and Stein 1975). The head will also come forward putting added tension on the neck. Adding good lumbar support and an increased angle between the back and seat of a chair will allow the operator more comfort in the back and pelvic areas (Nachemson 1980; Kayis and Hoang 1999; Dowell, Yuan *et al.* 2001). Support for the pelvis for computer operators is another way to improve comfort for computer operators as long as the support was set less than 20 degrees inclination. If the support is set above 20 degrees then discomfort is present since the chair will be over inclined. A pelvic support will decrease the load on the hips and increase stability of the pelvis (Wu, Miyamoto *et al.* 1998). Villanueva's research discovered that a person should lean backwards with a 105 degree angle between the trunk and thighs. This position will decrease the activity in the trapezius muscle, allowing the operator more comfort (Hochanadel 1995; Villanueva, Jonai *et al.* 1997). All this is not to say that the computer operator should maintain one position throughout the workday, but instead studies have shown that changing positions throughout the day actually benefit the operator (Andersson and Ortengren 1974; Harms-Ringdahl, Ekholm *et al.* 1986; Mekhora, Liston *et al.* 2000). By changing positions, muscle movements aid in blood circulation, spinal movement keeps the intervertebral discs nourished, and the continuous movement of the joints is therapeutic for the joints (Wijaya 2000; Schmitz, Plikat *et al.* 2003).

It should be noted that not all bad posture is caused solely due to the way an operator is seated. The operator may be seated in such a position due to a non adjustable monitor. Not only will this result in poor posture, but it may also develop into musculoskeletal and/or visual problems (Saito, Miyao *et al.* 1997). The task of having an operator change their position is sometimes harder than it appears. Not only are there physical factors to consider, but also psychophysical and psychosocial factors (Bernard 1997; Kerr, Frank *et al.* 2001)

The computer operator's comfort is the main goal. The tricky thing about posture however, is it is not best in any position for an entire workday. An operator that can achieve several different positions throughout the day will achieve an overall comfort posture. Studies show that it is not the norm to sit at the 90-90-90 position any longer (Kroemer 1985; Green and Briggs 1989; Welch 1991). In fact, studies of posture behavior by Hsiao and Keyserling show that most people are comfortable with their head and neck tilted forward an average of 13 degrees (Hsiao and Keyserling 1991). Kumar also discovered that more discomfort occurred when neck extension increased (Kumar 1994), however, Watson, Trott, and other sources found that cervical headaches occur when the head is tilted forward (Watson and Trott 1993; CUErgo 2005).

2.1.4. Demographic Characteristics

With all the information about equal employment for both genders, studies will still show that males and females are affected differently in certain jobs; computer operator is one of those jobs (Armstrong and Chaffin 1979). For instance, one study, using a relative space concept and defining relative space as [(Cc-Ct)/Cc]100%, where Cc is the cross-sectional area of the canal and Ct is the cross-sectional area of the tendons, finds that the median nerve is significantly smaller in females (Jessurun, Hillen *et al.* 1987).

Anatomical differences in males and females, with respect to wrist circumference and radial bone size, may be the key to discovering how females are able to manipulate more extreme postures, which in turn permits them to be more at risk for CTS (Armstrong and Chaffin 1979; Matias, Salvendy *et al.* 1998). People with large hands, usually males, may be forced to increase flexion of the fingers and extension of the wrists. This action has consequences on tendons (Treaster and Marras 2000), such as increased friction that is a trigger for health problems concerning the tendons and their sheaths (Moore 1992). The difference in wrists and/or muscle dimensions will indicate a higher percentage of CTS cases in females (Armstrong and Chaffin 1979).

Age is another factor that haunts computer workers. As in any occupation, the older a person becomes, the weaker the muscles become. A person in their sixties will find their muscle strength to have decreased 15-25% from their peak strength at age 35. The hands, which are used so often anyway in everyday activities, will be particularly affected (Grandjean 1988). Neck pain, stiffness, headaches, and upper extremity disorders are particularly more prominent in computer operators as they enter middle age and find the need to wear bifocal or trifocal glasses. Persons involuntarily lean their heads back or forward to be able to see through their bifocal/trifocal glasses. This will cause pain and discomfort if not corrected (Sweere and Sweere 2002). This happens around the age of 40 when the lens of the eye becomes thicker and flatter. The pupil also loses enough ability to change diameter which in turn reduces the amount of light that is able to reach the retina. The lenses harden causing the eye to lose some of its capacity to change focus. The eyes also become sensitive to light at around middle-age as well. It may become harder for operators to distinguish between colors therefore allowing contrast to become reduced (Werner, Peterzell *et al.* 1990; Spenkelink and Besuijen 1995). Along with age, females were found in various studies to be younger than males, work fewer hours, type faster, and still have more pain associated with the neck. For this reason, gender is considered a predictor of neck and/or shoulder pain/discomfort (Evans 1987; Bernard, Sauter *et al.* 1994; Bergqvist, Wolgast *et al.* 1995b).

Studies of computer operators have found that comfort lessons as the workday proceeds and should therefore not only be taken notice of at the beginning of the day, but also as the day progresses (Hagberg 1997). Still more research shows that an analysis of the standard anthropometric data that most furniture designers use is data that was published by the U.S. military, which in reality fits less than 68 percent of the U.S. population sample(Gordon, Bradtmiller *et al.* 1989; Dowell 1995; Stumpf, Chadwick *et al.* 2002). So with the different variations in stature, chair designers try to integrate adjustments so that computer operators can adjust the chair to fit their individual needs, but chair height adjustments, for example, usually do not adjust more than 4.5 inches and the variation in lower leg lengths of the U.S. population spans more than half a foot (Stumpf, Chadwick *et al.* 2002)

2.2 Vision Factors of Computer Operators

The human eye plays a vital part in the computer operator's job and good vision education is a must. Many people take their vision for granted never realizing what a complex organ the eye is even though research has found that the majority of computer operators, 70-75%, have or will experience some type of visual disorder (Dainoff, Happ *et al.* 1981; NIOSH 1981; Smith, Cohen *et al.* 1981; Dain, McCarthy *et al.* 1988; Collins, Brown *et al.* 1990). Many of these disorders have been collectively termed "Computer Vision Syndrome" (AOA 1995; AOA 1997). Studies by the American Optometric Association (AOA 1997), have stated that computer vision syndrome (CVS) is a growing concern for many computer operators and standards regarding this concern have been issued both by the American National Standards Institute (ANSI) and the Illuminating Engineering Society of North America (IESNA) (ANSI/IESNA 1995). This section will discuss some aspects of how the human eye works with respect to computer operators and the different types of injuries and/or disorders that may occur.

2.2.1 The Human Visual System

Just as all computer operators have individual body dimensions, they also have different eyes and visual acuity. Some operators are more prone to eye disorders than others due to their ocular surface area (Sotoyama, Jonai *et al.* 1996). Another factor of good acuity is accommodation. This is the distance the eye focuses on when there is nothing to look at which generally averages to be about 31.5 inches. Viewing objects closer than this distance for an extended amount of time may cause the eyes to strain. For example, if a monitor is only 12 inches away from the operator, the ciliary muscle must work 2.5 times harder to focus (Jaschinski-Kruza 1988). The ciliary muscle, a relatively smooth muscle, is able to contract and relax like skeletal muscles. And like the skeletal muscles the ciliary muscle can fatigue causing eye discomfort in computer operators (Ehrlich 1987; Jaschinski-Kruza 1988; Sheedy 1990). The ciliary muscle (Figure 2-11) is what gives the eyes the ability to change focus. There are actually six extraocular muscles that control the eye. These muscles have the responsibility to align the eyes correctly when looking at a computer monitor (Davison 1990; Sheedy 1994).

The converging of the eyes is another factor in computer operators experiencing eyestrain and actually plays a larger part in eyestrain than accommodation (AOA 1997). The eyes converge when viewing objects at close distances; however, as an object becomes closer, the muscles in the eyes will have to strain more to bring it into focus. If

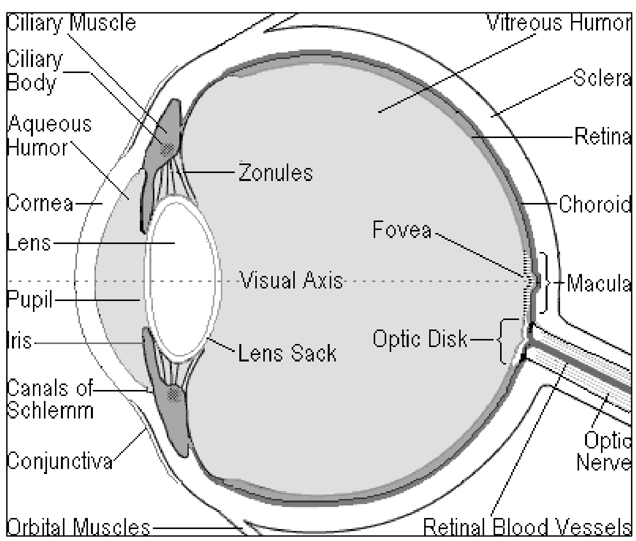


Figure 2-11 Cross section drawing of the eye (Web 2002)

the eyes did not converge correctly, double vision would occur (Collins, O'Meara *et al.* 1975; Tsubota and Nakamori 1993). Other symptoms of stress on the convergence system would be headaches and general fatigue. The resting point of convergence is not the same when looking in various directions. For example, when looking at an object horizontally, the resting point is about 45 inches and when looking upward at an angle of about 30 degrees, the resting point is further – about 52 inches, but when looking downward at the same angle, the resting point is now only 35 inches (Kroemer and Hill 1986; Heuer and Owens 1989). Most computer operators tend to either look straight ahead or at a slightly downward angle. Research has found that tears evaporate at a quicker rate (Figure 2-12) and blinking occurs less when the operator is looking straight ahead at a monitor compared to looking down as in reading a book (Meyer, Bousquet *et al.* 1990; Patel, Henderson *et al.* 1991; Tsubota and Nakamori 1993). Computer operators

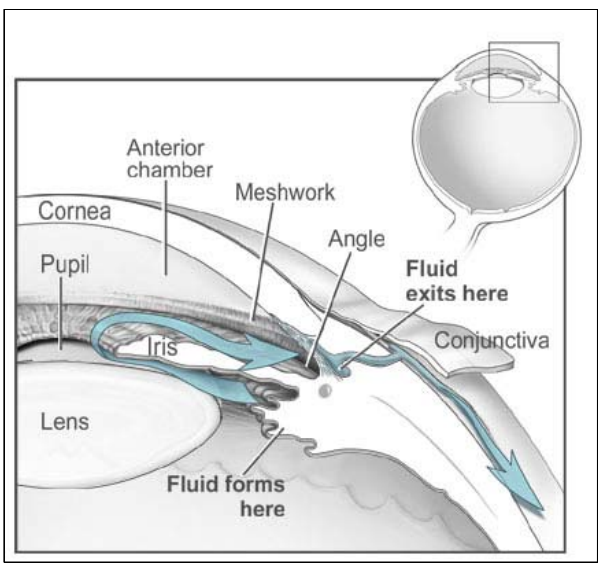


Figure 2-12 A clear fluid flows continuously in and out of the anterior chamber and nourishes nearby tissues (NEI 2004)

that look downward to view their monitor have easier accommodation and convergence and report less occurrences of headaches, eyestrain, and general discomfort (Tyrell and Leibowitz 1990; Salibello and Nilsen 1995). Those that view their monitors at a downward gaze should be doing so at 20-50 degrees angles as suggested by the International Organization of Standardization (ISO) (ISO 1998), although others suggest an approximately 15 degrees distance (Sheedy 1995), and have a horizontal viewing distance from 20-30 inches away (Ripple 1952). At any rate, a good rule of thumb is the 20/20/20 rule. Generally speaking, this states that to keep the eyes rested a computer operator should look at a distance 20 feet away, for 20 seconds, every 20 minutes. This simple exercise will allow the eye muscles to relax allowing them to receive fresh oxygenated blood, thereby removing lactic acid, and in turn help to eliminate vision injuries/disorders (UCSD 2005).

2.2.2 Vision Related Disorders

Many computer operators simply refuse to rest their body while working, especially their eyes. There are several common disorders that will cultivate if proper precautions are not met. Some of the more common disorders include: eyestrain, burning, itching, and even headaches. These disorders may not go away if attention to them is not met. It is possible that they can linger on after working hours and into the following day (Kahn, Fitz *et al.* 1984; Gur and Ron 1992). However, rest breaks throughout the day can help to alleviate these symptoms (NIOSH 2000). Some of the less common disorders are: blurred vision, double vision, deterioration of visual acuity, as well as color fringes. The eye is usually able to recover from these less common disorders within 15-20 minutes, which is probably why they are not reported as often (Yeow and Taylor 1991; CWA 2004).

Research has suggested that the position of the monitor can influence whether or not there is any visual strain. Jaschinski *et al.* (1999) found that the height of the monitor relative to the eyes (gaze inclination) and the distance from the monitor to the eyes played key roles in reducing eyestrain. He found that the preferred viewing distance ranges from 60-100cm (24-39 in.) at a slightly downward angle of approximately 16 degrees (Grandjean 1983b; Jaschinski-Kruza, Heuer *et al.* 1999). Other research has also indicated that the lower gaze angle is easier on the eyes (Grandjean 1983b; Tyrell and Leibowitz 1990).

Taking precautionary measures is an excellent way to reduce the chance of computer related vision problems. The ability to view the monitor legibly is very important (Gould, Alfaro *et al.* 1987; Sheedy 1992). Research has shown that it is much better on the eyes to read from hardcopy than from a computer screen (Ziefle 1998). The color of characters can also make a difference. For example, black characters on a white background (best for persons over 40) or vice-versa would be the best choice (Murch 1982). And one thing that people do not do very often is keep their computer screen clean. Dust and dirt can make viewing the screen harder on the eyes (AOA 1997). Stressful working conditions, bright light, too close or too far from the screen, reflections, glare, an screen flickering are other items of interest that can easily be corrected (AFSCME 2005).

Working at a computer is not the only way that vision problems occur. Some operators may already have vision related disorders and if not properly handled will find that working at a computer for extended hours could compound those disorders. Most of these things are common vision disorders, such as near or farsightedness, astigmatism, and presbyopia. These vision problems are not in themselves a reason to cause computer related vision problems, but precautions need to be made to adjust the computer vision parameters so as not to make them factors to eye stress (Daum, Good *et al.* 1988; Wiggins, Daum *et al.* 1992).

2.3. The Computer Workstation

The computer workstation is a general term implying several items. The core factors of the workstation would include a computer and its accompanying viewing screen (monitor), as well as any peripheral attachments, a keyboard and/or mouse, a desk or some other type of work table, a chair, footrest, and some type of lighting (Sweere 2002). All of these factors put a computer operator at risk if not designed and then used properly (Grandjean, Hunting *et al.* 1984; Aaras 1997) This section will concentrate on the monitor, keyboard/mouse, and the desk/table.

2.3.1. The Workstation in General

More often than not a computer workstation is still setup in a traditional office setting manner not considering the differences that will occur in lighting, seating, and work mannerisms (CWA 2004; AFSCME 2005). Some places will try to incorporate “ergonomically designed” workstations, but may miss the target completely leaving discomfort in its trail (Galinsky, Swanson *et al.* 2000) and cumulative trauma disorders on the rise (Bammer 1987; Faucett and Rempel 1994; Bergqvist 1995; Fine 1996;

McLean, M. *et al.* 2001). Some may also try to "fix" only part of the workstation, but this too will fail. The workstation should be setup with each factor designed specifically for the individual working in it (Hunting, Laubli *et al.* 1981; Sauter, Schleifer *et al.* 1991; Mekhora, Liston *et al.* 2000). The concept is simple – increase the functional ability of the operator while decreasing the functional workload (Bergqvist, Wolgast *et al.* 1995a).

Some research has included methods to try and alleviate discomfort at workstations by completely redesigning the workstation table. One such recent design is called the Up-Line. This Up-Line table enables total forearm support, keeps wrists in the neutral position, and requires slight neck flexion (Tepper, Vollenbroek-Hutten *et al.* 2003). This is only one such design, there are many others. In general, well designed ergonomic workstations have specific dimensions as recommended by ANSI/HFS 100-1988 and/or OSHA. Several of these dimensions include a viewing distance between 18 and 30 inches, adjustable monitor, contrast and brightness controls, adjustable keyboard, padded wrist rests, seat height between 16 and 20.5 inches, seat depth between 15 and 17 inches, adjustable chair arms, and footrests (ANSI/HFS 1988; OSHA 2005).

Other factors in workstation design, but not included in this study, are cost, productivity, and the reliability of the ergonomic product (Sengupta and Das 1997). It is often the case that the idea of purchasing ergonomic workstations for computer users would be costly, whereas in the long run, the cost of compensation claims would be much higher (Green and Briggs 1989; Fagarasanu and Kumar 2003). However, whatever the factors may be, ergonomically speaking, a computer workstation would be one that has available to its operator the ideals of comfort and safety (UCSD 2005). To keep the computer and monitor in optimal condition, regular maintenance should be performed on the monitor, the workstation and the environment in which the operator will work. Any electrical cords should be long enough to allow freedom of movement (CWA 2004).

2.3.2. The Monitor

The monitor, the device from which all computer operators view their work, has increased productivity, as well as the development of safety and health issues when not used correctly (CWA 2004). And how is it to be used correctly…that can only be answered by each individual computer operator and an expert to guide them. There are several key ingredients to keep in mind when setting up the monitor: size of the viewing screen, adjustability, position relative to the operator, including distance, contrast/brightness control, and glare.

The size of computer screens are measured by their diagonal, therefore a monitor screen size of 17 inches would mean the diagonal of the viewing screen is 17 inches. That being said, experts agree that the smallest viewing screen should be no smaller than 14 inches for computer work, with the ideal size at 17 inches (CWA 2004). Operators that use a monitor of size 20 inches or greater should sit slightly further back and position the monitor so that the viewing area is 3 inches above the line of sight (HC 2001).

Most computer monitors are adjustable, as in being able to maneuver them up, down, forward, and backward. The best way to view the monitor, with the least discomfort, is with the monitor tilted slightly backwards (Ankrum and Nemeth 1995). Miller suggests an adjustability range between 5 degrees toward the operator and 20 degrees away from the operator to avoid the possibility of glare (Miller and Suther 1983), while Sweere suggests a tilt range between 12 and 20 degrees (Sweere 2002).

The position of the computer viewing screen is usually suggested to be at a viewing distance of 20 to 40 inches and directly in front of the operator. The top of the monitor should be slightly below eye level (OSHA 2005). But, for computer-aided designers (CAD), it is recommended that the middle of the monitor be at eye level (Wall, Riel *et al.* 1992). Straight ahead viewing is recommended for all computer operators, but in smaller than 20 inch monitors, researchers finding a 10% productivity improvement, have recommended that the monitor be tilted between 17 and 35 degrees, depending on the individual (Sommerich, Joines *et al.* 1998). Either way, the monitor should not be to one side or the other due to the fact that this may cause neck and shoulder discomfort and/or pain because at this position the body tends to shift away from its natural posture (DHHSCDCP 2000; HC 2001). OSHA recommends that the monitor not be positioned further in either direction, more than 35 degrees (OSHA 2005). With respect to any windows that might be in the room, the monitor screen should be perpendicular to the window with the computer operator's line of sight parallel to the window.

Monitors usually have contrast/brightness controls on them (CWA 2004; UCSD 2005). The knowledge and ability to adjust contrast and/or brightness will give the computer operator a way to reduce screen glare (Miller and Suther 1983). The refresh rate of the monitor, which means the frequency of the image being redrawn, should not be less than 60 Hz and is usually up to 75 Hz on newer machines with an optimal setting being between 85 to 90 Hz (Meyer, Bousquet *et al.* 1990). Refresh rates lower than 60 Hz will cause the screen to give off a flicker effect, in turn causing eye discomfort (Bergqvist, Wolgast *et al.* 1995c).

Glare is possible in any computer environment and can cause visual discomfort and pain if not corrected. Glare can be caused by certain types of lighting, by having the monitor positioned incorrectly in relation to a window, by shiny objects on the workstation desk, or by the color of the surroundings (Lutron 1998). Glare should be avoided whenever possible.

2.3.3. The Keyboard and Mouse

The keyboard, which has actually been in existence for over 100 years, although not always for computers (Fagarasanu and Kumar 2003), is a vital tool for any computer operator. With the exception of the mouse and some auditory programs, the keyboard is the only way to send and view information from the computer operator to the computer. A skilled computer operator can easily achieve over 500 keystrokes per minute, which equals to over 30,000 keystrokes per hour of typing continuously. And, as age increased, keystroke per hour decreased(Knave, Wibom *et al.* 1985) It is also interesting to note that 58% of English letters are typed with the left hand (Fagarasanu and Kumar 2003). Most computer operators use a QWERTY keyboard (lateral slope with separate numeric keypad (Zecevic, Miller *et al.* 2000)), which implies that both wrists are in ulnar deviation and extension, and both forearms are pronated (Smith, Karsh *et al.* 1998; Visser, de Korte *et al.* 2000; Marklin and Simoneau 2001) as seen in Figure 2-13, 2-14. There is a 60% increase in time that the wrists spend in the neutral position when using a downward tilt keyboard, therefore scientists recommend that a downward tilt keyboard

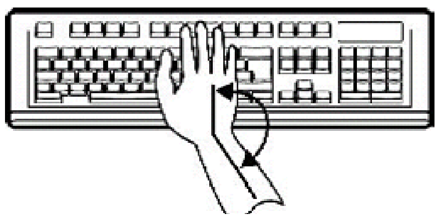


Figure 2-13 QWERTY keyboard (NIOSH 1997)

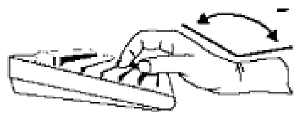


Figure 2-14 Wrist in extension (NIOSH 1997)

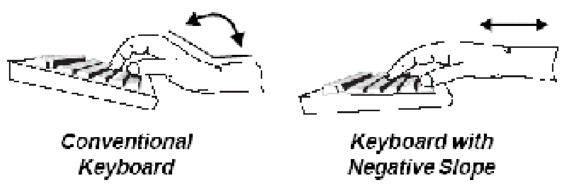


Figure 2-15 Conventional and negative tilt keyboard (NIOSH 1997)

(Figure 2-15) be used (Sweere 2002), but not for the inexperienced operator since it is harder to view the keys in this manner (Fagarasanu and Kumar 2003). Numerous studies have been conducted on what type of keyboard is the best to use and most ergonomic for the computer operator. One such study states that the keyboard should be thin with an adjustable angle; the keys should be concave for better finger comfort; and the keyboard itself should have a matte type finish to reduce reflection (CWA 2004). In another study of split and conventional keyboards it was found that the hands, wrists, and arms stay in a more neutral position with a split keyboard, reducing ulnar deviation and pronation in both hands (Lincoln, Vernick *et al.* 2000). Typing for long periods with the hands, wrists, and arms in this position will allow the carpal bones and ligaments to have less force applied (Smith, Karsh *et al.* 1998; Marklin, Simoneau *et al.* 1999).

The best way to type on a keyboard is with a fairly straight wrist. In fact, a wrist that has a slight degree of wrist extension combined with a small degree of ulnar deviation and flexed fingers will apply the least discomfort to the operator (Nelson, Treaster *et al.* 2000). However, keep in mind that with respect to CTS, flexion and extension put an operator more at risk than radial and ulnar movements due to increased tendon travel (Hedge and Powers 1995). Some operators are tempted to use a wrist rest while typing. This can actually hurt more than help by increasing pressure inside the carpal tunnel as the undersurface of the wrist is compressed (Hedge 2004).

An improperly used keyboard or incorrect type of keyboard has the potential to cause pain and discomfort for the operator (Evans 1985; Lueder 1986; Ignatius, Yee *et al.* 1993). This is mainly due to the fact that while using a keyboard many muscles are forced to remain still against what would normally be moving (Saltzman 1998; Roberts 1999). Specifically, surveys show the proximal and distal upper extremities discomforts and pain as being associated with keyboards (Erdelyi, Sihvonen *et al.* 1988; Bergqvist, Wolgast *et al.* 1995b; Cook 2000).

The placement of the keyboard can be a factor of discomfort and pain as well as the way it is used. It was reported in an epidemiological study that a keyboard positioned more than 5 inches(12 cm) away from the edge of the work area is better for the computer operator in the sense that there is a lower risk of attaining work related injuries to the arm and hand (Cook and Burgess-Limerick 2001; Marcus, Gerr *et al.* 2002). It is suggested by Marklin et al. that the keyboard should be positioned about one inch above the knees to allow the operator to type with their forearms parallel to the floor (Marklin, Simoneau *et al.* 1999).

The mouse, which has been a tool of computer operators since the 1980's (Roberts 1999), is another way of interacting with the computer screen and has been reported to be the most used device in computer work (Jensen, Finsen *et al.* 2002). Most computer operators will use both the keyboard and the mouse so it is important to know the about both (Fogelman and Brogmus 1995). Computer users that work with graphics will use the mouse approximately 65-70% of their working time (Keir, Bach *et al.* 1999), while regular computer operators are estimated to use their mouse approximately 60% of the time (Chaparro, Rogers *et al.* 2000; Phillips and Triggs 2001).

The mouse should be a comfortable fit with the hand; it should have the buttons that the operator will click on level and at the same angle as the keyboard (CWA 2004; UCSD 2005). This will prevent possible CTS by removing awkward postures (Jensen 1998; Liao and Drury 2000). However, most operators do not use the mouse as they should. Most operators will use the mouse by pushing it in some way or fashion away from their body. This not only involves the wrist, but also fatigues the shoulder, especially in cases where the mouse is at a different level than the keyboard. Keeping the shoulder relaxed and the mouse close to the body will help alleviate probable discomfort (Roberts 1999).

The mouse does not need to be held tightly and the buttons do not require much force for it to work properly. Many operators, while using the mouse, continue to keep a tight grip on it instead of relaxing the grip when they are finished with their respective functions (Roberts 1999). In fact, research shows that dragging the mouse caused the most intratunnel pressure, followed by pointing procedures as risk factors for CTS (Keir, Bach *et al.* 1999). This worsens with age, especially for computer operators over the age of 40, due to a loss of ability to attempt fine movements (Hsu, Huang *et al.* 1997; Phillips and Triggs 2001). Fagarasanu and Kumar (2003) suggests redesigning the mouse to be thinner with more distance between the buttons. This is suggested for the reason of reducing wrist and finger extensions (Fagarasanu and Kumar 2003).

Another reason that operators might hold their mouse tightly is that it has become hard to maneuver. This is usually due to the ball inside the mouse becoming clogged from extended use. Each time the mouse is moved; the trackball on the underside of the mouse gathers tiny fibers of dust and will eventually not be as controllable. The easy remedy to this is to remove the ball mechanism, clean it and the inside of the compartment, and then replace it. Periodically, a new mouse pad may be needed as well (Roberts 1999).

2.4. The Environment

The environment of the computer workstation operator can be just as important as any of the machinery involved. Lighting especially, with regard to vision related issues, is the most important factor of the workplace (Anshel 1998b). Several factors are in the environment calculation. These factors include lighting in the computer workroom, along with the color and type of surroundings; temperatures in the computer workroom with respect to the operator and the computer unit; frequency of breaks required for the operator to work uninjured; and job, as well as job-related and personal stressors that can inflict unknowing amounts of harm on the computer operator.

2.4.1 Lighting and Color of Surroundings

Before computers were common in office settings it was normal to have bright lighting (approximately 1000 lux) and white or near white walls. Lighting in these offices were designed with the idea that the workers would be reading at downward angles between 20 and 40 degrees (NAP 1983). Many computer operators still work in this type of environment, which can be more harmful than they realize (Lutron 1998; DHHSCDCP 2000). Most experts recommend illumination levels to be between 300-700 lux and to use task lighting as needed (NIOSH 1981; ANSI/HFS 1988). The higher illumination levels are for computer operators of middle age, due to the fact that as people age more light is required to have better visual acuity (Werner, Peterzell *et al.* 1990). Some offices have a combination of computer operators and regular office workers. In such cases as these it is recommended to have fluorescent dimmers, luminaire covers, or some type of indirect lighting where appropriate for computer operators. Another option for fluorescent lighting would be to use only half the bulbs as well as white, warm-tone bulbs (CWA 2004). In any case, high levels of luminance cause operators to blink less causing eyestrain and dry eyes (Akaski 1990).

Window light is another matter altogether, but easily remedied (CWA 2004). Light from a window can cause an abundant amount of glare for the computer operator to cope with (AOA 1997; Anshel 1998b). This usually results in eyestrain and/or headaches. Putting up curtains or window blinds is an easy, inexpensive way to eliminate window lighting. If for some reason it is not feasible to put up blinds or curtains, then the very minimal requirement would be for the monitor to be positioned perpendicular to the window to avoid glare.

Another problem with respect to lighting in a computer workroom is veiling reflections, which should be avoided as much as possible (HC 2001). These are reflections of some light source on the computer screen that cause a reduction in contrast, thereby making the eyes strain more to see the image (Sheedy 1992; Anshel 1998a). These can be reduced by using a hood over the monitor (UCSD 2005), painting ceilings white, using a neutral floor covering with low reflectance, and by using office furniture and technology with low reflectance range (HC 2001; ANSI/IESNA 2004). Examples of items causing veiling reflections could be the operator's clothing or furniture in the room (Anshel 1998a).

Glare, which causes the eyes to strain harder to focus, is a problem in any working environment where computers are operated. Even the use of ambient lighting can affect the contrast of the computer screen. For instance, a uniform, ambient light can cause the screen to appear lighter than it really is, thereby various colors to become closer in value. For instance, black letters may appear gray therefore losing contrast with lighter objects on the screen. (Sheedy 1995).

White and brightly painted walls or equipment are other problems in a computer operator's work environment, especially if the paint is glossy (CWA 2004). This will also cause a glare. To reduce this source of glare, walls and/or equipment in the work area should be painted so as not to be reflective and/or use pastel colors. Carpeted floors will also help reduce reflections.

2.4.2. Temperatures

Most people do not give a second thought to the temperature in the place they work unless it becomes uncomfortable to them. Rooms that computers are in have comfort temperatures as well. Generally, the room in which a computer operator works should be between 68 and 75 degrees (SunMicrosystems 2002; CWA 2004). In fact, if the temperature reaches above a certain threshold, the life of the computer will decrease by half for each increase of 10 degrees Fahrenheit (ProTech 2005). Not only is the wrong temperatures dangerous for the computer, but temperatures that are too hot or cold for the computer operator can bring on stress (AFSCME 2005).

Humidity is another issue not commonly thought of in a computer environment. However, if the ambient, relative humidity levels are not correct (they should be between 45% and 50%) (SunMicrosystems 2002), and the air becomes too dry, the eyes do not stay as moist and become irritated. This is especially true for operators wearing contact lenses. Other than that, electrostatic charges can build up in the air between the operator's body and the monitor screen. This in turn can attract germs in the air to the skin. Upper respiratory problems can also be a result of the humidity levels being incorrect (SunMicrosystems 2002). Suggested temperature and relative humidity levels may be seen in Table 2-1.

2.4.3. Breaks

Rest breaks are vital for any type of operation, but even more so for computer operators (Sauter and Swanson 1992; CWA 2004). More specifically, rest breaks are not

Table 2-1 Environmental requirements chart (SunMicrosystems 2002)

Environmental Requirements			
Environmental Factor	**Optimal**	**Operating**	**Non-operating**
Temperature	70° to 74° F (21° to 23° C)	50° to 90° F (10° to 32° C)	-4° to 140° F (-20° to 60° C)
Relative Humidity	45% to 50% RH	20% to 80% RH1	up to 93% RH
		(noncondensing)	
Altitude	up to 10,000 ft (3,048 m)	up to 10,000 ft (3,048 m)	up to 40,000 ft (12,192 m)

just to stop working at the computer, but to actually get up and stand or walk can help prevent intervertebral disc pressure, static muscle fatigue, dynamic muscle fatigue, tendon, nerve, and muscle inflammation, and reduced blood circulation (Sundelin and Hagberg 1989; Carter and Banister 1994; Bergqvist, Wolgast *et al.* 1995a) .

So, how long and frequent should these rest breaks be? NIOSH has recommended that for jobs that spend at least 60% of their time viewing a computer screen, require constant, rapid motions, maintain fixed postures over an extended period of time, and/or are highly repetitive or mundane should spend about 15 minutes per hour resting away from the computer workstation (NIOSH 2000). Galinsky *et al.* found that for more demanding computer jobs, such as data entry, the operator should take a 15-minute break for every half hour of work (Galinsky, Swanson *et al.* 2000), although Geo *et al*., and others suggested rest breaks after 40-50 minutes of work for the same type of operation due to observed decrements in performance (Floru and Cail 1987; Gao, Lu *et al.* 1990).

Research has found that computer operators, from age 23 to 50 years old, taking mini and micro breaks, lasting 3 minutes and 30 seconds respectively, showed significant improvement in performance (Sauter and Swanson 1992; McLean, M. *et al.* 2001). And still other research found performance to be improved even though the added breaks reduced the actual working time in an eight hour shift (Ong 1990; Galinsky, Swanson *et al.* 2000). In a study conducted by Henning et al., he asked computer operators to take breaks and resume their work when they felt ready. On average, the operators took breaks of 27.4 seconds (Henning 1989).

Whatever amount of time that research has shown to be sufficient for rest breaks, the importance of breaks cannot be underestimated. Injuries and disorders that cumulate over time for a computer operator may appear to be modest at first, even disappear at times, but over an extended period of time all these small traumas develop into chronic disorders (Putz-Anderson 1988; Carter and Banister 1994), especially in instances where the eyes are concerned (Galinsky, Swanson *et al.* 2000).

2.4.4. Job Stress

Occupational stress comes in many forms in many different job settings. For computer operators it comes in the form of physical and psychological strains, such as anxiety, anger, depression, frustration, muscle and psychological tension, and gastro-intestinal disorders (Smith and Carayon 1996; CWA 2004).

Stress is not just a term that people use to describe being in duress; it actually may cause physiological changes such an increased breathing rate, rapid pulse, hormonal release, and the productions of more acids in the stomach (AFSCME 2005).

Some of the symptoms that have been discussed previously for other computer related disorders may actually be symptoms of stress. Such symptoms as headaches and backaches are indicators of operators that have repeated or prolonged job stress (AFSCME 2005). Not only are these some symptoms of stress but occupational stress can increase the risk of being injured on the job, make the human body susceptible to disease, as well as causing additional problems at home.

Noise is another stress factor. A study carried out in Austria found that 16%-19% of all women complain of office noise (Paoli and Merllié 2003). One item that may cause office noise in the computer environment is the fan of the computer. These can easily be remedied by replacing the fan with a newer model, but quite often is not.

Floors should be carpeted to reduce noise. Chairs moving around on the floor, people walking around in an office, vibrating machinery can all contribute to a noisy office environment. Replacing tile or linoleum floors with carpeting can greatly improve noise issues.

METHODOLOGY

Chapter 3

This chapter discusses the various methods (in order of use) used in this study to arrive at a conclusive outcome. Computer operators were recruited and asked to fill out a survey (demographic information sheet), as well as being asked to fill out a form relaying information about areas of pain/discomfort on their body. They were then asked to participate in a risk analysis designed especially for the computer operator field. Part of this analysis included a self-evaluation stress test and a self-evaluation of their working environment.   The last section of this chapter discusses how and why the population for this study was chosen and when, how, and why the study will terminate.

3.1 Computer Operator Survey Form

The computer operator began the study by filling out a survey or, demographic information sheet (Appendix A). This sheet divulged information relating to gender, age, ethnicity, preference of handedness, hours spent at the computer at the workplace, as well as hours spent at the computer when away from the workplace. Other questions included an inquiry relating to the specific type of computer function that is performed, and inquiries into any previous medical diagnosis related to computer injury or disease.

Gender plays an important role in computer work, especially for those operators that spend several hours per day at the computer. It has been shown that females are more at risk than males (Armstrong and Chaffin 1979; Evans 1987; Jessurun, Hillen *et al.* 1987; Mathiassen, Winkel *et al.* 1995; Evans and Patterson 2000).

Age is relevant also, but in a different manner than gender. The risk that computer operators are in due to age affects all persons, not just one gender or another. It is a biological fact that as humans age, the muscles of the body become weaker and harder to keep in shape. (Werner, Peterzell *et al.* 1990; Saltzman 1998; Evans and Patterson 2000; Galinsky, Swanson *et al.* 2000). Not only do the muscles of the body become weaker with age, but the eyes become more sensitive to light and may cause the computer operator to develop headaches and eyestrain due to difficulty determining contrast (Spenkelink and Besuijen 1995).

Ethnicity and right or left-handedness is questioned as basic demographic questions. Most computer operators in the United States are Caucasian and right-handed. The responses to these questions verified that this study has participants of like origin and handedness to similar studies of computer operators (Rudd 2001).

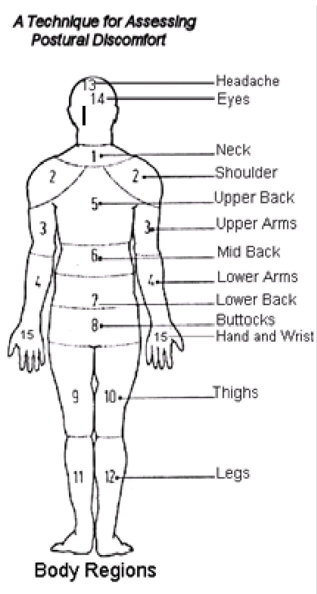
Hours spent per day on a computer play a significant role in determining how much a computer operator may be at risk to injury or disease. Most research indicated that several breaks per day be taken and to be taken at regular intervals if possible (Floru and Cail 1987; Gao, Lu *et al.* 1990). It was suggested that a computer operator take a 5-15 minute break each hour that they are working at the computer to give various parts of the body time to refresh (Sundelin and Hagberg 1989; Carter and Banister 1994; Bergqvist, Wolgast *et al.* 1995a, Putz-Anderson 1988; Carter and Banister 1994). And, not only do persons operate a computer at work, but more often than not these same operators operate a computer at home or other location for some period of time after working hours. The remaining 4 questions on the demographic form are concerned with previously diagnosed medical conditions relating to computer related injury or disease.

3.2 Computer Operator Pain/Discomfort Chart

The Pain/Discomfort Chart, which is a combination of Corlett and Bishop's body chart (Corlett and Bishop 1976) and Borg's CR-10 scale (Borg 1990) (Figure 3-1/Appendix B) was used to determine, through the level of pain/discomfort severity, if the participant should fit into the at risk category or the not at risk category. The chart consisted of a graphical representation of a human body that has specific sections numbered for the operator to indicate pain/discomfort. This representation was adapted from Corlett and Bishop's body chart (Corlett and Bishop 1976). The human body is sectioned into separate parts with numbers that range from one to fifteen and in no way reflect importance by order of numbering.

PAIN/DISCOMFORT RATING CHART
FOR COMPUTER OPERATORS

Indicate any areas where pain or discomforts are felt before, during, and/or after working at a computer by marking through the *Severity Level* most applicable to the respective area of pain or discomfort.

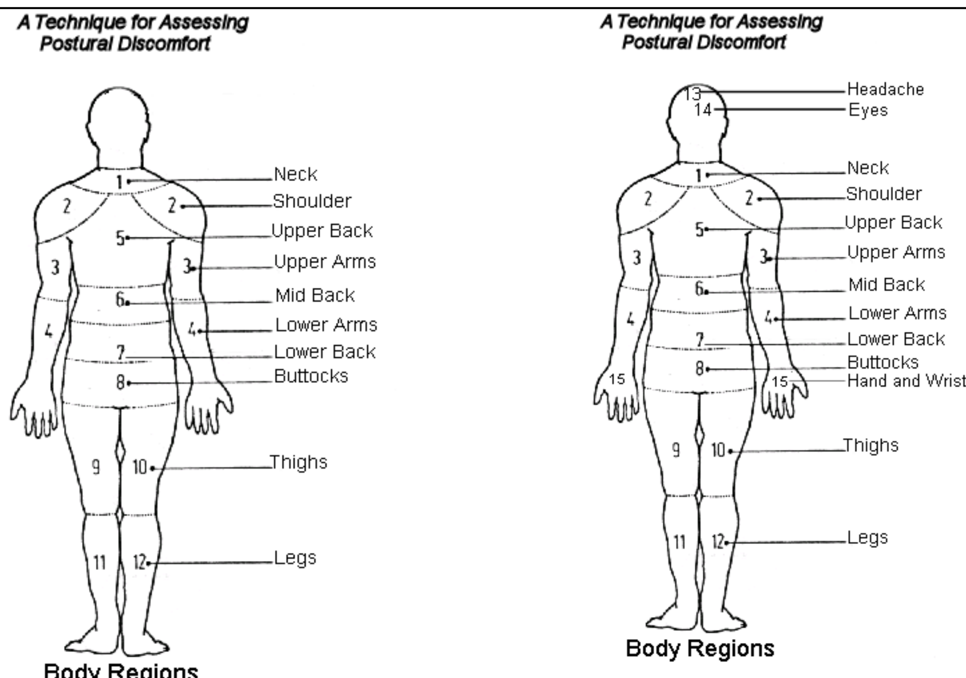


Number On Chart	Severity Level → / Area of Pain Or Discomfort ↓	Nothing at all	Extremely Weak	Very Weak	Weak	Moderate		Strong		Very Strong			Extremely Strong	Maximal
1	Neck	0	.5	1	2	3	4	5	6	7	8	9	10	15
2	Shoulder	0	.5	1	2	3	4	5	6	7	8	9	10	15
3	Upper Arms	0	.5	1	2	3	4	5	6	7	8	9	10	15
4	Lower Arms	0	.5	1	2	3	4	5	6	7	8	9	10	15
5	Upper Back	0	.5	1	2	3	4	5	6	7	8	9	10	15
6	Mid Back	0	.5	1	2	3	4	5	6	7	8	9	10	15
7	Lower Back	0	.5	1	2	3	4	5	6	7	8	9	10	15
8	Buttocks	0	.5	1	2	3	4	5	6	7	8	9	10	15
9	Thigh	0	.5	1	2	3	4	5	6	7	8	9	10	15
10	Thigh	0	.5	1	2	3	4	5	6	7	8	9	10	15
11	Leg	0	.5	1	2	3	4	5	6	7	8	9	10	15
12	Leg	0	.5	1	2	3	4	5	6	7	8	9	10	15
13	Headache	0	.5	1	2	3	4	5	6	7	8	9	10	15
14	Eyes	0	.5	1	2	3	4	5	6	7	8	9	10	15
15	Wrist and Hand	0	.5	1	2	3	4	5	6	7	8	9	10	15

* The graphical model was developed by Corlett and Bishop (1976) and the Severity Scale is likened to Borg's (1990) CR-10 scale

Figure 3-1 Pain/Discomfort Rating Chart for Computer Operators

There were three elements that were added to the Corlett and Bishop body chart (Corlett and Bishop 1976) for the purpose of this study (Figure 3-2). Those elements included headache, eyes, and hand/wrist areas. The purpose for these additional elements was due to the fact that the original body chart, being developed in the mid 1970's, did not consider such things as headaches, eyestrain, and hand/wrist problems relevant to body discomfort. Due to technology increasing at an exponential rate in the past decade, and the popularity and ease of using a computer, the computer operator has become a prime target for studies involving pain and/or discomfort (Hagberg and Sundelin 1986; Sauter, Schleifer *et al.* 1991; Liao and Drury 2000). And since the computer operator continues to have problems with respect to headaches, eyestrain, and hand/wrist issues



(a) Corlett and Bishop's Body Chart (Corlett and Bishop 1976)

(b) Corlett and Bishop's Body Chart (Corlett and Bishop 1976) with 3 added elements

Figure 3-2 Corlett and Bishop's body chart (a) and adaptation (b) (such as carpal tunnel syndrome), as well as the other body parts labeled, this study would not have been complete without those additional elements.

Since it was sectioned into specific areas, such as neck, shoulders, upper back, lower back, and several others, the body chart helped the operator locate which specific sections of his/her body was feeling the pain/discomfort. Once the specific body part was selected, the computer operator circled the correlating number in Borg's CR-10 scale (Borg 1990) to determine severity of pain/discomfort.

The computer operator chose their level of pain/discomfort by using the adapted Borg's CR-10 scale, which ranged from 0, which means there is no pain/discomfort, to 10, which represented extreme pain/discomfort. There was one more severity level called "maximal," in which the participant indicated the worst pain/discomfort imaginable. Borg (1990) states:

> "One very special and important property of the CR-10 scale is that, by anchoring the highest number in a very well-defined perceived effort and exertion with a degree of "sameness" for different individuals, a good point of reference is obtained. One can then use this value or part of it as a "semi-public" unit for many different kinds of interindividual and intermodal comparisons, such as between noise, vibration, pain, taste, and exertion for different groups of people."

Borg's CR-10 Scale (Borg 1990) (Figure 3-3) was chosen for this study primarily since it is widely accepted in many scientific fields in relation to this study, and has such been cited by several previous research scientists (Ahsberg 1998; Ahsberg 2000; Feuerstein, Huang *et al.* 2000; Keyserling 2000; Borg 2001; CDC 2005). This scale

0 nothing at all
0.5 extremely weak (just noticeable)
1 very weak
2 weak (light)
3 moderate
4 somewhat strong
5 strong (heavy)
6
7 very strong
8
9
10 extremely strong (almost maximal)
* maximal

a. Borg's CR-10 Scale

Number On Chart	Severity Level → / Area of Pain Or Discomfort ↓	Nothing at all	Extremely Weak	Very Weak	Weak	Moderate		Strong		Very Strong			Extremely Strong	Maximal
1	Neck	0	.5	1	2	3	4	5	6	7	8	9	10	15
2	Shoulder	0	.5	1	2	3	4	5	6	7	8	9	10	15
3	Upper Arms	0	.5	1	2	3	4	5	6	7	8	9	10	15
4	Lower Arms	0	.5	1	2	3	4	5	6	7	8	9	10	15
5	Upper Back	0	.5	1	2	3	4	5	6	7	8	9	10	15
6	Mid Back	0	.5	1	2	3	4	5	6	7	8	9	10	15
7	Lower Back	0	.5	1	2	3	4	5	6	7	8	9	10	15
8	Buttocks	0	.5	1	2	3	4	5	6	7	8	9	10	15
9	Thigh	0	.5	1	2	3	4	5	6	7	8	9	10	15
10	Thigh	0	.5	1	2	3	4	5	6	7	8	9	10	15
11	Leg	0	.5	1	2	3	4	5	6	7	8	9	10	15
12	Leg	0	.5	1	2	3	4	5	6	7	8	9	10	15
13	Headache	0	.5	1	2	3	4	5	6	7	8	9	10	15
14	Eyes	0	.5	1	2	3	4	5	6	7	8	9	10	15
15	Wrist and Hand	0	.5	1	2	3	4	5	6	7	8	9	10	15

b Borg's CR-10 scale adapted for this study

Figure 3-3 Borg's CR-10 Scale (a) and adaptation (b)

measures nearly all types of perceptions and experiences. Some of those include pain, taste, smell, loudness, and brightness. It is also capable and has been used for the measurement of emotions, such as discomfort and anxiety. The scale's more common usages include measurements for musculoskeletal pain, dyspnea (breathlessness), as well as other types of somatic symptoms. Scientists evaluating items such as risk assessment and strain have used the CR-10 Scale quite often in their research ((Rissén, Melin *et al.* 2000; Reneman, Bults *et al.* 2001; Chen, Fan *et al.* 2002).

3.3 Computer Operator Risk Index

The Computer Operator Risk Index (CORI), which is similar in concept to the CTD Risk Index (Freivalds, Kong *et al.* 2000; Niebel and Freivalds 2003), but has a different set of risk factors, contained four sections that were designed for the analyst to determine if there were risks involved for the computer operator while working at their workstation. CORI takes into account areas including physical, mental, and environmental, of the computer operator while working. This form has been evaluated by a panel of experts in the field of ergonomics for risk variable validity, and can be seen in Appendix C.

The first section provided a time that was determined by total daily hours worked at the computer plus total daily hours worked at a computer other than work, and termed "Total Computer Exposure Time." In earlier trials of CORI it was thought that the quantitative factors would be determined by some threshold. To determine this threshold, this time would be divided by the maximum number of hours that a computer operator may work before strain puts them at risk. This time amount was determined in a study by Blatter and Bongers (2002) indicating that the time for females would be four hours and the time for males would be six hours (Blatter and Bongers 2002). By taking the average of these two elements, an average time to include both genders was determined to be five hours; therefore the total number of hours worked by the computer operator will have a threshold of five. This has been determined to be a risk factor due to increased computer usage, with respect to time, and its high correlation to injury and/or disease (Kahn, Fitz *et al.* 1984; Gur and Ron 1992; Sauter and Swanson 1992; Carter and Banister 1994). However, due to the logistic nature of the final mathematical model this method was no longer useful. The revised "Time" factor, has a coefficient derived from logistic regression that was used as part of the final equation.

Keystrokes per day and mouse use per day were originally planned to be calculated together to formulate the number of wrist motions the computer operator performs per day. The keystrokes and mouse usage was to be counted by either using software created for such activities, or by an average that has been predetermined. These scores were to be further calculated to determine a frequency factor. After researching extensively into the area of keystrokes and mouse use, relevant literature was nearly impossible to locate as to what these two factors would be with respect to risk and the point at which risk is brought on by strain. There were several articles describing mathematical ways to calculate keystrokes per hour based on words typed per minute (Ostrach 1997; Nathan 2000; Miller 2001; Lassen, Mikkelsen *et al.* 2004; TAWPI 2004; Solutions 2005) ,but nothing was found that would correlate keystrokes per hour to the threshold at which strain begins. It was even more difficult to acquire information relevant to an average number of mouse clicks per hour or average mouse usage per hour (Beltran, Ghosh et al. 1998; ErgoType 2005; Esure 2005). However, informative research was completed and published in the area of mouse clicks, but not in relation to time and strain concurrently (Fernstrom and Ericson 1997; Harvey and Peper 1997; Hoffmann, Chang *et al.* 1997; Cook and Kothiyhal 1998; Cooper and Straker 1998; Burgess-Limerick, Shemmell *et al.* 1999; Hedge, Muss *et al.* 1999). Research has been conducted that used wrist motions, which was the original intention of this section, but due to the focused attention on keystrokes and mouse usage that computer operators are concerned with, these calculations were not entirely reliable in this study (Freivalds, Kong *et al.* 2000). However, it is being considered that by using Moore and Garg's Job Strain Index, a way may be possible to measure strain for the hands and wrists (Moore and Garg 1995) and thereby determine a frequency wrist motion factor. If this method is deemed appropriate, it may be useful for future research. Ron Goodman (Goodman 2005), an engineer that developed a software package to count keystrokes and mouse clicks, thereby determining break times due to strain being accumulated, was contacted through email and eventually interviewed by telephone, but was unable to provide pertinent information regarding how he arrived at his calculations due to the proprietary nature of the research. He did state that the calculations were based on an average strain per unit time from ergonomic and other resources, but would/could not describe how he correlated average strain with time.

Due to the difficulty in determining keystrokes per hour and mouse usage per hour, these two items were not used in this study, but will be used in future scientific research to refine specific amounts for relevant material. At the time that this type of research is completed CORI may be revised to reflect these hand motions.

The second section provided information regarding posture of the computer operator while working. The posture section involved individual body positions of the back, wrists, arms, legs, neck, and feet. It further investigated the computer workstation. The monitor position, chair comfort ability, as well as mouse and keyboard positions were questioned with respect to how they affected the computer operator. The responses to this section ranged from zero, which would mean there is no problem, to three, which indicated the worst case scenario. Several of the answers in this section were dichotomous in nature.

The sitting posture scores ranged from 0 to 3. For an operator to score a zero, he/she must have been sitting upright within plus or minus five degrees. If they were leaned back less than 30 degrees, one point was accrued; if they were leaned back greater than 30 degrees, two points were accrued; and if they were leaned forward, which is harder on the spine and causes muscle fatigue quicker, three points were accrued. The ranges for mobility were determined using the Comparison of Mobility Data for Females and Males table (Kroemer, Kroemer et al. 1994) and in the OSHA guidelines (OSHA 2005).

Wrist radial or ulnar deviation (Figure 2.1) was also considered a risk factor. Wrist posture scores for this variable ranged from zero to three. For an operator to score zero, the wrists must have been in a neutral position (straight). A score of one was recorded if the wrists were in the radial (turned inward) position; a score of two was recorded if the wrists were in the ulnar (turned outward) position at least equal to or less than ten degrees; and a score of three was recorded if the wrists were in the ulnar position at an angle greater than ten degrees. The wrists may be in flexion (bent forward) or in extension (bent back) (Figure 2.3). Scores for this variable ranged from zero to three. A score of zero was earned if the operator's wrists were in the neutral position (straight). If the wrists were in flexion, a score of one was recorded; a score of two was recorded if the wrists were in extension, but equal to or less than ten degrees; and a score of three was recorded if the wrists were in extension greater than ten degrees (ANSI/HFS 1988; Hedge and Powers 1995; Marklin, Simoneau *et al.* 1999; Rempel, Tittiranonda *et al.* 1999).

The shoulders are normally in one of two positions – relaxed or not relaxed (tense or hunched upward) (Waris 1980; Stammerjohn, Smith *et al.* 1981; Grandjean, Hunting *et al.* 1983a; Murata, Araki *et al.* 1991). A score of zero or one was assigned respectively to these two variables. The arms, with respect to their position to the body, were another factor. For this factor, the arms were either pulled in close to the body where the forearms were close to parallel to the floor, in which case they rated a score of zero, or the arms were outstretched in front of the operator to reach the keyboard and/or mouse; this rated a score of one. A score of two was rated for an operator whose arms were away from the body less than or equal to 30 degrees and were also outstretched in a forward manner. A score of three was assigned to the operator who worked with his/her arms away from the body (out to the side) manner with an angle greater than 30 degrees whether or not the arms were outstretched or not. (Stammerjohn, Smith *et al.* 1981; Seradge, Jia *et al.* 1995; Keir, Bach *et al.* 1998; Szabo 1998; Fagarasanu and Kumar 2003).

How the legs with respect to the hips are positioned was also a risk factor, this was seen as a knee position on the CORI form. Most operators are not overly concerned with how their legs are positioned while they are working at the computer. Some may sit with their legs at approximately 90 degrees to their hips; this would be the preferred position to use to relieve the danger of injury or strain. If the legs were in this position, the score was zero. Other computer operators preferred to sit with their legs stretched out in front of them at a degree greater than ninety, equated to a score of one. While this was not as beneficial to the operator as the ninety degree angle, it still was not considered as detrimental as the legs being bent underneath the operator at angles less than ninety degrees, equating a maximum score of two (Klausen 1965; Nachemson 1980; Villanueva, Jonai *et al.* 1997; Wu, Miyamoto *et al.* 1998; Dowell, Yuan *et al.* 2001).

The neck was another risk factor included in the posture section. The computer operator will position the neck in basically one of four positions; neutral (straight), leaned forward, and leaned back, or to one side. The scores for these three positions were zero, one, two, and three, respectively. The neutral position maintained a zero score since this position contained the least amount (if any) risk. The forward position of the neck maintained a score of one since this position is not as good as neutral, but better than the leaned back position. The neck leaned backward is the worst position of the three and therefore earned a score of two. Some operators have their monitor positioned so upon viewing they have to turn their head to one side or the other. The head may be turned to either side as well as to be leaned forward or back. This is the worst position of all since it always induces a torque of the muscles in the neck (Chaffin 1973; Kumar 1994; Patterson and Evans 1996; Burgess-Limerick, Plooy *et al.* 1999; Roberts 1999; Sweere and Sweere 2002).

When sitting, the computer operator's feet should be flat on the floor or on an appropriately fitted platform so as to give the impression that the feet are resting flat on a surface while the legs are in the preferred position (Hochanadel 1995). A score of zero was recorded for feet flat on the floor or platform and a score of one was recorded for any other position of the feet.

The viewing angle and visual distance from the monitor can play havoc with a computer operator's comfort and overall well-being if not properly set up. The viewing angle from the computer operator's eyes to the monitor should be between zero of the horizontal and a maximum of thirty degrees. An overall, general recommendation by several ergonomists is between fifteen and 20 degrees (Kroemer and Hill 1986; Heuer and Owens 1989; Meyer, Bousquet *et al.* 1990; Tyrell and Leibowitz 1990; Patel, Henderson *et al.* 1991; Tsubota and Nakamori 1993; Sheedy 1995). For this reason either a score of zero, for a viewing angle of zero to thirty degrees, or a score of one, for a viewing angle of any other measurement, was recorded for the operator.

The distance that a computer operator is positioned from the monitor was also considered a risk factor. Most experts in the field agree that the distance between the operator's eyes and the monitor should be in between a range of eighteen and thirty-six inches. Any further distance than this could cause the eyes to strain. Any distance closer than this could also cause the eyes to strain, just as if a person were reading a book too close (Collins, O'Meara *et al.* 1975; Jaschinski-Kruza 1988; Sheedy 1990; Tsubota and Nakamori 1993). One of the expert panelists used in this study, who is very experienced in dealing with patients with Computer Vision Syndrome (CVS), recommended a range between 24 and 30 inches. Another panelist cited 50-100 centimeters (18-39 inches) as a range for operators to be viewing their monitors. Scores of zero and one were recorded for either a measurement between twenty-four and thirty-nine inches or any other measurement, respectively.

There are many types of chairs produced for computer operator's, but some company employees, as well as some individual operator's still use a wooden chair while working at the computer and usually with no padding or cushioning of sorts. The wooden chair would not be so much a risk factor if it had adequate cushioning. The cushioning is important so that the body has some type of absorber for the strain due for sitting long periods of time. Most modern office type chairs have all the required ergonomic means with which to work comfortably, including arm support, even though some are not cushioned. Those that are not cushioned are usually fitted with some sort of flexible mesh material that allows comfort while working (Nachemson 1980; Occhipinti, Colombini *et al.* 1985; Coleman, Hull *et al.* 1998; Kayis and Hoang 1999; Dowell, Sheidle *et al.* 2003). With respect to this information, a modern office type chair received a score of zero and any other chair received a score of one.

The keyboard and mouse also play vital roles in the computer operator's health; therefore these two variables were also considered as risk factors. The mouse should always be level with the keyboard. This is to prevent any unnecessary stretching of the arm/shoulder and to prevent greater distance in movement (Cook and Kothiyhal 1998; Cooper and Straker 1998). A mouse level with the keyboard scored a zero since this presents the least amount of risk to the operator. A mouse that was level with the keyboard, but not close to the keyboard, although not more than 5 inches away from the keyboard, earned a score of one. A mouse that was level with the keyboard and more than 5 inches away scored a two; while a mouse not level with the keyboard scored a three.

The keyboard and monitor should also be positioned directly in front of the operator. It is still quite easy to find a computer operator to have their monitor to one side and the keyboard directly in front of them. This type of twisting to the truck of the body and turning of the neck may cause serious injury, over time, if not corrected (Marklin, Simoneau *et al.* 1999; Cook and Burgess-Limerick 2001; Marcus, Gerr *et al.* 2002). If the keyboard and monitor were positioned directly in front of the operator, a score of zero was recorded; anything else scored a one. It is important to note that even though the keyboard is positioned directly in front of the operator, it still should be within reach without the arms requiring the need to outstretch forward to perform any typing tasks (Marklin, Simoneau *et al.* 1999; Cook and Burgess-Limerick 2001; Marcus, Gerr *et al.* 2002). A score of zero was recorded if the keyboard was within reach without the arms reaching forward, and a score of one was recorded if the operator was required to reach forward to perform typing tasks.

All of these scores were originally thought to be summed and divided by twelve to formulate a posture factor. The threshold of twelve is used since that is approximately the number that posture would be at maximum risk without danger of injury to the computer operator. This was based on the same principle used by Freivalds, Kong, et al., in the posture factor of the CTD Risk Index (Freivalds, Kong *et al.* 2000). However, due to the logistic nature of the final mathematical model this method was no longer useful. Posture has a coefficient derived from logistic regression that was used as part of the final equation.

The third section involves the computer operator's stress level (Appendix B). Although stress is a very real factor for computer operators, it is not normally considered when dealing with the safety and human factors of computer workstation design and its related functions. However, there are many studies to indicate the need for a stress variable to indicate possible risk to computer operators (Evans 1985; Evans 1987; Henning 1989; Schleifer, Galinsky *et al.* 1995; Smith and Carayon 1996; Paoli and Merllié 2003). To make this study complete, a stress factor was included as part of the risk assessment. The stress level of the computer operator was determined from a self-evaluation stress test adapted from one used by Yang to evaluate the stress of rural farmers (Yang 2003). The test involved the computer operator choosing from one of five responses, ranging from zero to four, with zero being no stress and four being a great deal of stress. Four of the components carry additional weight and were originally marked with an asterisk (*), but the (*) has been removed from the form that the actual operator filled out to refrain from any bias that it may have instigated. The statements scored are concerned with stress factors involved in work and personal levels. Once the scores were calculated, the computer operator fit into one of three ranges. The first level of response ranged from zero to forty and indicated no concern regarding stress; the second level ranged from forty-one to sixty and indicated that there was stress, but it was not too bad and can be improved; and the third level, ranged from sixty-one to ninety-six, and indicated that the stress level of the computer operator was severe and required immediate attention. The stress score was originally calculated to indicate the stress factor by using a threshold of the highest possible score an operator can achieve and still remain within a "no stress" rating, which was forty. However, due to the logistic nature of the final mathematical model this method was no longer useful. Stress has a coefficient derived from logistic regression that was used as part of the final equation.

The last level included environmental risk factors that all computer operators respond to daily. These factors included the lighting in the room; whether it was at an adequate level for working at a computer to reduce the chance of eyestrain (Grandjean, Hunting *et al.* 1984; ANSI/IESNA 1995; Aaras 1998; Lutron 1998; Paoli and Merllié 2003; ANSI/IESNA 2004); the temperature of the working environment with respect to where the operator was comfortable while working (SunMicrosystems 2002; Paoli and Merllié 2003; CWA 2004; AFSCME 2005; ProTech 2005); the amount of breaks per day, which were necessary to avoid injury and discomfort (Sundelin and Hagberg 1989; Kamwendo, Linton *et al.* 1991; Sauter and Swanson 1992; Carter and Banister 1994; Bergqvist, Wolgast *et al.* 1995a; Galinsky, Swanson *et al.* 2000; NIOSH 2000); the quietness of the work area, which can add to stress levels and affect concentration (Paoli and Merllié 2003); and the comfort of the body in general with respect to the computer workstation furniture and work space (ANSI/HFS 1988; Ankrum and Nemeth 1995;

Anshel 1998a; Stumpf, Chadwick *et al.* 2002; OfficeFurniture 2005). The responses for the environmental factors were self-reporting and arranged in a Likert-type fashion. The responses were calculated to form an environmental factor with a threshold of seven. The number seven was used under the same principle that the threshold was chosen for the miscellaneous factor in the CDT Risk Index model (Freivalds, Kong *et al.* 2000). However, due to the logistic nature of the final mathematical model this method was no longer useful. Environment has a coefficient derived from logistic regression that was used as part of the final equation.

Once the four factors were calculated they were used in a formula to find the Computer Operator Risk Index (CORI). This was done by using weighted factors provided through logistic regression

After the calculations were completed the risk index should be less than one for an operator to be considered not at risk. This was based on the same type of risk index number that was used in the Lifting equation for comparing the severity of potentially hazard jobs that deal with low back injury (Waters, Putz-Anderson *et al.* 1993), and the CTD Risk Index equation for comparing different types of jobs that deal with carpal tunnel disorders (Freivalds, Kong *et al.* 2000).

Once the data was collected for the Self-Evaluation Stress Test, Cronbach's alpha (a coefficient of reliability) was found using SPSS statistical software. An outcome close to one will indicate good reliability of the form. The same analysis was performed on the Likert-type scale of the environmental factors to determine reliability. The results of these calculations can be viewed in Chapter 5. Even though Cronbach's alpha was computed using SPSS, for conceptual purposes, the formulation for Cronbach's alpha is:

$$\alpha = \frac{N - \bar{r}}{1 + (N-1)\cdot\bar{r}}$$

Where N is equal to the number of items and r-bar is the average inter-item correlation among the items.

3.4 Study Population

The population for this study was recruited from various jobs that require a minimum three hours computer operation with the exception of short breaks, and had been working at their current job for a minimum of one year. The jobs were such types as computer programmer, data entry clerk, secretary, computerized graphic design, CAD operators, database administrators, web design, and college students/faculty to name a few. The study took place at various computer supported locations throughout the Knoxville and surrounding areas.

The participants in the study included 100 computer operators of four ethnic origins. They ranged in ages from twenty to seventy years. There was no payment associated with this study; and all participation was voluntary.

A sample of convenience was used since the availability of participants was limited. Although every attempt was pursued to recruit participants from multiple related computer fields it was not possible due to time constraints. It is believed by the investigator that the sample used in this study is a fair representation of the field of computer operators.

There is still the possibility of Type I or Type II errors, but due to the design of this study, it was predicted that possible Type I errors would outnumber Type II errors.

For instance, a Type I error would indicate an operator to not be at risk, but found to be at risk through CORI, while a Type II error would indicate an operator is at risk, when in fact they were not determined to be at risk through CORI.

3.5 Study Termination

The study terminated for each participant when they completed all the necessary forms and procedures to acquire the necessary data. The exception to this was for any participant to cease to submit information due to their preference to not continue. The participant was given the opportunity to ask any questions relating to the study. Filling out the forms and being observed took a maximum of one hour.

ANALYSIS AND VALIDATION

Chapter 4

This chapter is dedicated to the analysis and verification of this study. Statistics for this study were calculated using SPSS software, version 14.

4.1 Demographic Information and Analysis

There were 100 participants in this study, 58 females and 42 males (Table 4.1). These 100 participants were of multiple types of computer related occupations. These occupations ranged from secretary to computer programmer and are listed in full in Appendix E.

The ages of the computer operators ranged from a low of 20 years to a high of 64 years, with an average age of 45.8 years (Table 4-1). The range of hours that the participant spent on the computer at work ranged from 2 hours to 9 or more hours, with an average time of 6.26 hours, and the range of hours that the participant spent on the computer other than work ranged from 0 hours to 6 hours, with an average time of 1.54 hours. Total working hours that the participant spent at work ranged from 3 hours to 10 hours, with an average time of 8.34 hours (Table 4-2).

Table 4-1 Gender

		Frequency	Percent	Valid Percent *	Cumulative Percent
Valid	F	58	58.0	58.0	58.0
	M	42	42.0	42.0	100.0
	Total	100	100.0	100.0	

* Valid percent is the % of the sample that the data was extracted from

Table 4-2 Average age and hours worked

	N	Minimum	Maximum	Mean	Std. Deviation
AGE	100	20	64	45.80	11.100
Comp Work Hrs	100	2	9	6.26	2.092
Comp Oth Hrs	100	0	6	1.54	1.176
Total Working Hours	100	5	10	8.34	.867
Valid N (listwise)	100				

Table 4-3 Ethnicity

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	AFRICAN AMERICAN	3	3.0	3.0	3.0
	ASIAN	1	1.0	1.0	4.0
	CAUC	95	95.0	95.0	99.0
	HISPANIC	1	1.0	1.0	100.0
	Total	100	100.0	100.0	

Ethnicity was another demographic variable. It was determined that the majority of computer operators in this study were Caucasian (95%), followed by African-Americans (3%), and Asian, as well as Hispanic, both at 1% each. This data may be viewed in Table 4.3. The majority of computer operators were also right-handed (88%) and this data may be viewed in Table 4.4.

Pain levels were averaged from the neck, shoulder, lower back, headache, eyes, and hand/wrist sections to determine an overall pain score. Scores from other parts of the body chart were not used in the overall pain score since their total combined scores were minimal and added no value to the analysis. Pain scores ranged from 0-12. At this point in the analysis the participants were divided into three groups: 1) Low Pain Group, which scored in the 0-1 range of the pain/discomfort chart; 2) Moderate Pain Group,

Table 4-4 Righ hand/Left hand

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	LEFT	12	12.0	12.0	12.0
	RIGHT	88	88.0	88.0	100.0
	Total	100	100.0	100.0	

Table 4-5 Frequency of break out groups for pain

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Low	37	37.0	37.0	37.0
	Moderate	22	22.0	22.0	59.0
	High	41	41.0	41.0	100.0
	Total	100	100.0	100.0	

which scored in between the 1 and 2 range of the pain/discomfort chart; and 3) High Pain Group, which scored from 2-12 range of the pain/discomfort chart. These groups can be viewed in Table 4-5. The Moderate Pain Group was discarded to better dichotomize the other two groups. This way there was not any participants that almost fit into the Low Pain Group or almost fit into the High Pain Group.

The Low Pain Group was categorized from 0-1 since the severity level on the pain/discomfort chart indicates this to be, at most, a very weak pain/discomfort and therefore would put the computer operator at a low risk to achieve injury or disease. The Moderate Pain Group was categorized for any number falling between 1 and 2 since the severity level on the pain/discomfort chart indicates this to be the period between weak and moderate pain. Once the participant is feeling, at the very least a moderate to high pain/discomfort, then he/she is determined to be at high pain and therefore categorized in the High Pain Group.

4.2 Risk Factors versus Pain/Discomfort Rating

The first research question in this study asks if there is a relationship between the Computer Operator Risk factors and the Pain/Discomfort rating. The answer to this research question indicates whether there is a difference in pain/discomfort involved in at risk participants and those participants not at risk.

Pearson's correlation was used to determine if significant relationships existed between the four main risk factors (time, posture, stress, and environment) and the pain scale average. Pearson's correlation was used to discover if the continuous risk factors were related to continuous pain. The results of this testing are in Table 4-6.

Pain was positively correlated with the posture factor ($p < .01$). Pain was also positively correlated with the time factor ($p < .05$), the stress factor ($p < .05$), and the

Table 4-6 Pearson's Correlation between pain and risk factors

		Pain	Time	Posture	Stress	Environment
Pain	Pearson Correlation	1	.211*	.417**	.241*	.256*
	Sig. (2-tailed)		.035	.000	.016	.010
	N	100	100	100	100	100
Time	Pearson Correlation	.211*	1	.322**	-.136	.074
	Sig. (2-tailed)	.035		.001	.177	.462
	N	100	100	100	100	100
Posture	Pearson Correlation	.417**	.322**	1	-.020	.033
	Sig. (2-tailed)	.000	.001		.845	.744
	N	100	100	100	100	100
Stress	Pearson Correlation	.241*	-.136	-.020	1	.342**
	Sig. (2-tailed)	.016	.177	.845		.000
	N	100	100	100	100	100
Environment	Pearson Correlation	.256*	.074	.033	.342**	1
	Sig. (2-tailed)	.010	.462	.744	.000	
	N	100	100	100	100	100

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

environmental factor ($p < .05$). This significance proves that there is a significant correlation between pain and the risk factors. Simply put, as the risk factors increase, the pain tends to increase. This deduces that the risk variables in the Computer Operator Risk Index are valid with respect to causing pain and/or discomfort to the computer operator thereby allowing an analyst to use these risk factors to determine the probability that a computer operator may be at risk for computer related injury. However, it is interesting to note that Time is more correlated with Posture than with pain (0.322 versus 0.211), and Environment is more correlated with Stress than with pain (0.342 versus 0.256). An explanation for this would be that since the predictors are correlated with one another (multicollinearity), Posture is using up more variability that might be explained by time, and Stress is using up more variability that might be explained by Environment. This would indicate that the Time and Environment variables are not as controllable as the Posture and Stress variables.

The participants that were in the low pain group were also hypothesized to be at low risk. The participants that were in the high pain group were hypothesized to be at high risk. A t-Test was also performed to determine how close, or not so close, the means of factors were between those participants in the low pain category and those participants in the high pain category. A t-Test was used since continuous factors were being used to dichotomize the risk of pain. Table 4-7 shows the differences between the means of each group; and Table 4-8 shows their respective significances.

Using $p < .05$ for significance, Table 4-8 shows that all four factors show significant difference between low and high pain. Participants in the high pain group

Table 4-7 T-test resutls for difference of means of factors

	Pain	N	Mean	Std. Deviation	Std. Error Mean
Time	LOW	37	7.1622	2.21753	.36456
	HIGH	41	8.3902	2.43801	.38075
Posture	LOW	37	5.8108	2.79720	.45986
	HIGH	41	9.0732	3.61518	.56460
Stress	LOW	37	14.2973	11.62102	1.91048
	HIGH	41	22.4146	13.23438	2.06686
Environment	LOW	37	1.1892	1.39120	.22871
	HIGH	41	2.1707	1.61094	.25159

Table 4-8 Significance between means

	t-test for Equality of Means		
	t	df	Sig. (2-tailed)
Time	-2.318	76	.023
Posture	-4.422	76	.000
Stress	-2.865	76	.005
Environment	-2.865	76	.005

show more hours worked (8.39), worse posture (9.07), more stress (22.41), and worse environment (2.17) than the low pain group.

4.3 Prediction of Pain Groups using Risk Factors

The second research question of this study asks if pain groups can be predicted using the risk factors presented in this study. It was decided that logistic regression would be used since membership was being predicted of two groups: those at risk and those not at risk. Logistic regression was performed and shows that the overall model significantly predicts the dependent variable of high pain or low pain, (Chi-Square =26.240, df = 4, $p < .001$). And the classification table (Table 4-9) shows that an overall 72% of participants were predicted correctly, with 73% of low pain correctly identified and 71% of high pain correctly identified.

And finally in answering the question, the table containing the variables in the equation will be observed. Table 4-10 shows the coefficients of the Computer Operator Risk Index equation.

Table 4-9 Classification table for accurate prediction[a]

			Predicted		
			PAIN		Percentage Correct
	Observed		LOW	HIGH	
Step 1	PAIN	LOW	27	10	73.0
		HIGH	12	29	70.7
	Overall Percentage				71.8

a. The cut value is .500

Table 4-10 Variables to be used in the CORI model

		B	S.E.	Wald	df	Sig.
Step 1[a]	Time	.191	.127	2.283	1	.131
	Posture	.175	.064	7.540	1	.006
	Stress	.054	.026	4.432	1	.035
	Environment	.133	.088	2.292	1	.130
	Constant	-4.761	1.291	13.605	1	.000

a. Variable(s) entered on step 1: totalcomputer_hours, postureall, stress, environmentall.

In Table 4-10, Posture and Stress are significant, while Time and Environment are not. Recall the correlation in Table 4-6 that showed Time and Environment to be more significant with Posture and Stress, respectively, than with pain. This variability explains why Time and Environment are not as significant in this logistic regression analysis. To further explain this, the logistic regression used was not a stepwise regression that would have entering and exiting variables, but instead all four factors were grouped together to force them all to be in the regression equation whether they were significant or not. And although Time and Environment are not significant in the regression analysis, they remain as part of the CORI equation for the purpose of this study.

Using the logistic regression formulation:

$$\theta = \frac{e^{(\alpha + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_i x_i)}}{1 + e^{(\alpha + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_i x_i)}}$$

Where α is the constant of the equation and β_i is the coefficient of the predictor variable x_i, the logistic regression equation to be used to determine risk for computer operators in the Computer Operator Risk Index is:

$$Probability\ of\ Risk = \frac{e^{(-4.761+0.191(TimeFactor)+0.175(PostureFactor)+0.054(StressFactor)+0.133(EnvironmentalFactor))}}{1+e^{(-4.761+0.191(TimeFactor)+0.175(PostureFactor)+0.054(StressFactor)+0.133(EnvironmentalFactor))}}$$

This can be written in a simpler fashion such as:

$$Probability\ of\ Risk = \frac{e^{(-4.761+0.191(TF)+0.175(PF)+0.054(SF)+0.133(EF))}}{1+e^{(-4.761+0.191(TF)+0.175(PF)+0.054(SF)+0.133(EF))}}$$

The term "Probability of Risk" will be replaced with "CORI" on the Computer Operator Risk Index form. Probability of risk results in a number between 0 and 1. Probabilities of 0.5 or higher are classified as "at risk." And in keeping with the NIOSH Lifting Equation Index and the CTD Risk Index, both with a threshold of 1, the CORI equation will contain a multiple of 2 to bring the calculation to have a CORI threshold of 1, indicating that the computer operator to be at risk if the score calculated is one or greater. The final CORI equation is as follows:

$$CORI = 2 \times \left(\frac{e^{(-4.761+0.191(TF)+0.175(PF)+0.054(SF)+0.133(EF))}}{1+e^{(-4.761+0.191(TF)+0.175(PF)+0.054(SF)+0.133(EF))}} \right)$$

4.4 Gender and Risk Relationship

The third research question of this study asks if there is a relationship between gender and those participants found to be at risk. This question will be tested using Chi-

Square to test gender differences in predicted risk and actual risk. The new CORI formula was used to calculate predicted risk for the entire sample.

There were 100 participants in this study, 58 females and 42 males. In a cross tabulation comparing gender to predicted risk (Table 4-11) it is easily seen that there is 55.2% of females at risk and 57.1% of males. The Chi-Square test results show no association between the genders. The hypothesis states that females will be more at risk, as does previous research, but testing in this study using Chi-Square proves otherwise.

The crosstabulation table and Chi-Square tests for comparing actual risk to gender are seen in Table 4-12. Actual risk was tested using only those in the low and high risk groups. This table shows that 59.6% of females are at risk and 41.9% of males are at risk, with Chi-Square results showing no association between the two.

4. 5 Computer Operator Risk Index Accuracy

The fourth research question asks if the Computer Operator Risk Index accurately predicts those participants medically diagnosed to be at risk, actually at risk.

Table 4-11 Crosstabulation between gender and predicted risk

			GENDER		
			F	M	Total
Predicted group	LOW	Count	26	18	44
		% within Predicted group	59.1%	40.9%	100.0%
		% within GENDER	44.8%	42.9%	44.0%
	HIGH	Count	32	24	56
		% within Predicted group	57.1%	42.9%	100.0%
		% within GENDER	55.2%	57.1%	56.0%
Total		Count	58	42	100
		% within Predicted group	58.0%	42.0%	100.0%
		% within GENDER	100.0%	100.0%	100.0%

Chi-Square = 0.038, df = 1, p = 0.845

Table 4-12 Crosstabulation between gender and actual risk

			GENDER		
			F	M	Total
PAIN	LOW	Count	19	18	37
		% within paingrp1	51.4%	48.6%	100.0%
		% within GENDER	40.4%	58.1%	47.4%
	HIGH	Count	28	13	41
		% within paingrp1	68.3%	31.7%	100.0%
		% within GENDER	59.6%	41.9%	52.6%
Total		Count	47	31	78
		% within paingrp1	60.3%	39.7%	100.0%
		% within GENDER	100.0%	100.0%	100.0%

Chi-Square = 0.331, df = 1, p = 0.127

To determine if the Computer Operator Risk Index accurately predicts persons to be or not to be at risk was determined using cross tabulation (Table 4-13) in comparing participants in the study who have been previously medically diagnosed with a computer related injury or disease. Nearly one-tenth of the total population of this study had been previously medically diagnosed with some form of computer related injury or disease. All participants in this study that were previously medically diagnosed with a computer related injury or disease was correctly predicted to be at risk using the Computer Operator Risk Index. This is 100% validation with respect to the validity of the Computer Operator Risk Index correctly identifying participants known to be at risk.

Of those not medically diagnosed, 52.2% were classified as at risk. According to Table 4-13, 48 participants were predicted to be at risk even though they had no previous medical diagnosis. However, there is quite a bit of variability in this determination. It is not of much concern that there are participants that have been incorrectly identified as not

Table 4-13 Comparison of medically diagnosed participants to CORI

			Medically Diagnosed		
			No	Yes	Total
Predicted group	Low Risk	Count	44	0	44
		% within Predicted group	100.0%	.0%	100.0%
		% within Medically Diagnosed	47.8%	.0%	44.0%
	High Risk	Count	48	8	56
		% within Predicted group	85.7%	14.3%	100.0%
		% within Medically Diagnosed	52.2%	100.0%	56.0%
Total		Count	92	8	100
		% within Predicted group	92.0%	8.0%	100.0%
		% within Medically Diagnosed	100.0%	100.0%	100.0%

Chi-Square = 6.683, df = 1, p = .01

at risk. For instance, many computer operators may be at risk, but have not yet felt the need to seek medical advice. This does not mean they are not at risk, but only states they may be at risk and have not yet received a medical diagnosis confirming that belief.

4.6 Reliability Testing

To be certain that the tools being used in this study were reliable, Cronbach's alpha was used to test for reliability. According to Nunnally a Cronbach's alpha of 0.5 to 0.7 is of modest reliability and one of 0.8 or higher is of excellent reliability (Nunnally 1967). Cronbach's alpha for the pain/discomfort scale was 0.806, which showed excellent reliability. Cronbach's alpha for the self-evaluation stress test was 0.879, which again showed excellent reliability. And Cronbach's alpha for the Likert-type scale for the environment factor on the CORI form was a modest 0.692. However, the reliability alpha for the environmental factor is not surprising with five items on a four point scale.

4.7 Analysis Summary

In summary of the verification and analysis viewed in this chapter, the pain/discomfort scale correlated with the risk factors of the CORI form showing that the more points accrued in risk factors, the more pain/discomfort accrued to the participant. It was also determined that low and high pain groups were able to be predicted using the risk factors of the CORI form. This was calculated using logistic regression and in process determined the coefficients for the CORI mathematical model to predict risk in computer operators. Two of the risk factors were not significant in the logistic regression analysis although they were significant in Pearson's correlation. However, they were still used in the final model. This may cause a slight inflation of the calculated risk index and will be further addressed in future research studies.

Gender was another issue. It was previously believed from research in this study that females were more at risk for computer related injuries or disease than their male counterparts. There was no evidence showing this to be true with respect to this study. And finally, it was determined that the Computer Operator Risk Index does accurately predict risk for computer operators. This was achieved by using computer operators that had been previously medically diagnosed with a computer related injury or disease, and comparing them to the risk factors from the CORI form. It was believed that those participants who had been previously medically diagnosed for computer related injury or disease would be more likely to be at risk than those participants who had not been previously medically diagnosed. Therefore, those participants should have fallen into the "at risk" category when using the CORI equation, and they did just that.

STUDY SUMMARY, DISCUSSION, CONCLUSIONS AND FUTURE STUDY RECOMMENDATIONS

Chapter 5

5.1 Study Summary

The purpose of this study was to develop a risk index for persons that spend a large part of their workday at a computer. This was completed by taking a sample from the computer operator population and using that sample to analyze risk factors associated with daily computer work.

There were several methods used to collect the data from computer operators. A demographic questionnaire was distributed to collect information regarding age, gender, working hours and a brief medical history. Once the questionnaire was completed the operator was asked to complete a form that associated pain and/or discomfort with various body parts. This form was a combination of Corlett and Bishop's body chart (1976) and Borg's CR-10 rating scale (1990) and was used as one method to test validity of the risk index. Both the body chart and the rating scale are used frequently in ergonomic assessments and have been validated prior to this study. A self-evaluating stress test was given to the computer operator following the pain rating scale. The stress test, which has been validated by Yang (2003), was used to determine the stress factor associated with risk to computer operators. The computer operators were then asked to complete a Likert-type questionnaire that pertained to their working environment. This outcome was also included in the risk index. The last part of the study was completed by the principle investigator. This included the remaining factors, time and posture, of the risk index analysis. The principle investigator observed the computer operator working and filled in applicable scores in relation to posture. The time factor was obtained either by company records or direct questioning. Once all four factors were calculated, they were entered into a logistic regression equation that resulted in a risk index. A score of 1 or greater meant that the computer operator was at risk for injury or disease.

The data that was collected and entered into SPSS, a statistical computer software program, produced outcomes from the variable scores using Chi-Square testing, t-Tests, logistic regression, and Cronbach's alpha. The results showed statistical significance in several categories, including the variables used in the model for computer operator risk index.

5.2 Discussion

It was determined after reviewing previous research that a risk index was needed to aid in the prevention of pain and/or injury. The risk index would give the computer operator field an instrument that would be able to predict whether or not a computer operator was at risk for pain. There are already risk indexes for manual lifting (NIOSH Lifting Index) and carpal tunnel (CTD Risk Index), but none were discovered through research for computer operators. However, the research used in this study was invaluable in determining the variables that were used in the Computer Operator Risk Index.

The importance of a risk index specifically for computer operators is embedded in the fact that each individual operator can be affected differently by a variety of risk factors. The questions contained in the assessment of risk indicated which risk factors were contributing to the computer operator's present or possible future computer related injury or disease. This study used four major factors in determining risk for computer operators: time, posture, stress and environment. Previous studies have used only one or at most two of these risk factors together in determining risk for a computer operator.

In completing this study, 100 computer operators participated. Of the 100 computer operators, 58% were female and 42% were male. The females ranged in age from 27 years to 64 years, with an average age of 48 years, while males ranged in age from 20 years to 62 years, with an average age of 42 years; therefore, in general, female computer operators are older than males.

Ten percent of females were left-handed and 14% of males were left-handed. The female ethnicity included 3% of females that were African-American, 1% that were Hispanic, and the remaining females (96%) were Caucasian. The male ethnicity included 2% of males that were African-American, 2% that were Asian, and the remaining males (96%) were Caucasian. Overall, the majority of computer operators (95%) were Caucasian.

Eight percent of the population had been previously medically diagnosed with a computer related injury or disease and all 8% were still working at a computer despite still having pain and/or discomfort. All 8% were also predicted to be at risk for computer related injury or disease according to the computer operator risk index.

Seven percent of females took at least one scheduled break per workday; the remainder took no scheduled breaks. Seven percent of males also took at least one scheduled break per workday; the remainder takes no scheduled breaks. Many operators stated that they normally have a working lunch. This means that they are eating lunch, but still working at their computer.

Thirteen percent of the population had recent changes to their workstation area. The time period since the changes were made ranged from 1 week to 2 years. Of those operators that had changes to the workstation, over half (53%) rated their discomfort or pain level improving 80% or better. Of those changes to the workstation, most were either new chair, new monitor, and new keyboard and mouse.

Computer operators work no less than 8 hours per day with an average 8.37 hour workday. There was one exception to this finding in this study and that was an operator that only worked a total of five hours per day. Computer operators spend an average 6.2 hours per day at a computer at work and 1.5 additional hours at a computer other than at work.

Pearson's correlation indicates that posture was the largest contributor to computer related pain. The workplace environment is a close second to posture in contributing to computer operator pain. Overall stress was also a significant factor in the risk analysis of computer operators. In Chi-Square testing for associations between gender and pain, there was no association discovered with predicted pain or actual pain.

The work performed by a computer operator ranges from secretarial, office type tasks to extremely intense computer programming. In this study alone, there were too many to mention in this section and have therefore been appended (Appendix E).

As the demand for increased productivity is continually on the rise, the computer operators must push themselves to operate the computer at faster speeds. The technology industry can barely produce a faster processor when more need for speed arises. The human body, on the other hand, can only perform so fast before it begins to fatigue and show signs of distress. These signs of distress are seen and felt by the computer operator as pain and/or discomfort. The result of extended pain or discomfort may cause permanent damage to the computer operator if appropriate measures are not taken to correct it. The variables that cause the pain/discomfort are identified as risks to the computer operator. The variables were collected and grouped accordingly in order to produce a risk index to assist the computer operator in decreasing the probability of injury or disease related to computer work. The risk index will indicate whether or not there is a risk present to the computer operator.

If the computer operator is proven not to be at risk, it is assumed that the working methods and environment are not cause for change. If the computer operator is calculated to be at risk, then precautionary measures need to be performed to assure a change in present working conditions. These changes should be completed by a professional who is well experienced in ergonomic methods of computer workstation setup. The areas that require change will be obvious to an experienced ergonomic professional from the scores of the Computer Operator Risk Index form. Therefore, not only is the Computer Operator Risk Index form a valuable, valid instrument for predicting risk in computer operators, but it also allows the professional to readily see exactly where the changes need to occur to decrease the computer operator's pain.

The study also offered revisions of current assessment tools used as part of the overall risk index assessment, such as Corlett and Bishop's body chart (Corlett and Bishop 1976), Borg's CR-10 Rating Scale (Borg 1990; Yang 2003), and Yang's Self-Evaluation Stress Test (Yang 2003), which in turn produced increased reliability and credibility to the work of others.

5.3 Conclusions

There were four questions that required answers from this research. The first one inquires if a relationship existed between the CORI factors and the Pain/Discomfort Rating Scale. This was answered by using Pearson's Correlation to produce a one-to-one relationship between each of the four risk factors, as well as a relationship between the four risk factors and pain. There was a significant difference found between the four risk factors and pain at $p < .05$ and $p < .01$ levels. This concludes that due to the significance between the four risk factors and pain, a valid statement can be made suggesting that as pain increased for the computer operator, risk also increased.

The second question inquired if pain groups could be predicted using the factors in the CORI model. Since the prediction of two groups was desired, logistic regression was used in determining the answer to this question. The regression analysis showed that the overall model significantly predicted the dependent variable of high or low pain at $p < .001$. The logistic regression equation used in the CORI model was also developed from this analysis.

Chi-Square testing was used to determine the answer of the third research question which asks if there is a relationship between gender and those participants found to be at risk. From the 100 participants used in this study a crosstabulation was performed that compared gender to predicted risk as well as to actual risk. The Chi-Square testing showed that there was no association ($p = 0.845$) between gender and those participants predicted to be at risk using the CORI equation, as well as no association ($p = 0.127$) between gender and those participants that were at actual risk.

The last research question asked if the CORI model accurately predicts participants who have been previously medically diagnosed with a computer related injury or disease, and thereby actually at risk, to be at risk. Crosstabulation was used to determine the response to this question. Eight percent of the participants had been previously medically diagnosed as having a computer related injury or disease. Of those 8%, all of them were correctly identified as “at risk” as predicted by the CORI model. This was a complete validation of the CORI model when comparing those participants medically at risk to those predicted to be at risk.

5.4 Future Study Recommendations

The future recommendations of this study are recommended as a result of the findings throughout this study.

Although “Time” was a significant risk factor in this study through correlation testing, the original intention was to use overall wrist motions as a risk factor with “Time” as part of the wrist motion factor. The overall wrist motion was to be determined by the time spent at the computer, and the strain caused to the wrist due to two variables: keystrokes and mouse clicks. Due to the extremely limited research in the area of mouse clicks, it was not feasible to use those variables at this time. Future research in this area would include conducting extensive research on average mouse clicks per hour and average keystrokes per hour, coupled with a strain threshold. Once these two variables were established, they could be incorporated into the Computer Operator Risk Index in place of the “Time” factor.

Posture was the most significant risk factor of all those used in this study. The variables in the “Posture” section of the risk index form were all excellent indicators of possible risk for computer operators. However, there are some other variables proposed by the expert panel used in this study that should be included in future studies. A few of these would include, but are not limited to: whether or not a phone is used often while working, since working at a computer and cradling a phone between your ear and shoulder can wreak havoc on the neck and shoulder muscles; whether or not a document holder is used so the eyes and neck are not constantly strained; more specifics about the office chair, such as the inclusion of arm rests; whether or not a lumbar support is used for additional lower back support and if the chair is adjustable and has easily accessible controls; whether or not there is enough space between the operators leg and the front edge of the chair; whether or not the chair has a waterfall edge; whether or not the computer operator is dynamic in posture instead of just one static position all day; and the keyboard and mouse being specifically positioned due to job function, for example, since some computer operators are more mouse intensive than others then their mouse position should take priority over their keyboard position.

The only recommendation for advancing the stress factor would be to use a more intensive self-evaluating stress test, such as the Nordic Questionnaire used in a study by Kaewboonchoo, et al. (Kaewboonchoo, Yamamoto et al. 1998). However, this is a fairly extensive stress evaluation and will increase the time to perform the overall risk evaluation.

The evaluation factor is a self-reporting mechanism in the current risk index model, but might be more efficient with a professional analyst actually measuring light, noise, and temperature for appropriate working levels.

The last future recommendation would be to have separate evaluations for work and home/other and then combine the two for one overall risk index.   This would be a difficult concept to accomplish since it would require the analyst to observe the computer operator in an environment other than on the job.

THE STUDY IN RETROSPECT

Chapter 6

This chapter reviews, in retrospect, the strengths and weaknesses, the surprises and expectations, as well as any other factors that may or may not have been directly related to the study but still carry an importance. The purpose of this study was to develop an instrument that would allow a relatively quick, although valid, way of predicting risk for individual computer operators. In essence, if risk can be predicted, it can in turn be prevented. Participants in this study were persons who had working at a computer at part of their job.

6.1 Importance of the Study

The most important reason for this study was to give the computer operator a tool which could give their profession an indicator to possible injury or disease. The computer operator is the most essential part in making this successful. There are so many ergonomic guidelines and furniture and almost everything one can imagine to make sure that the computer operator is working safely, but they are all generalized; none is specific to the individual operator. For instance, a computer operator may have the perfect size chair, the perfect monitor, the best lighting, but still this operator sustains a computer related injury. This is most likely due to the inappropriate use of all, or even one, of these perfections. Or, it may not be anything to do with the setup or work area of the computer, it may be stress induced. It could even be caused by some combination of physical and mental conditions. For these reasons, the individual computer operator plays a key role in preventing their own injury. Another reason for this study was to compile a list of risk factors relevant to all computer operators and then dissect those factors into subgroups. By giving each subgroup a specific point value, an analyst can very easily see which risk factors are most prominent and take immediate action to remedy these. When computer operators are working virtually pain and/or discomfort free they are more likely to have higher production outputs and lower stress levels. Many of the computer operators that participated in this study had no idea why they were in pain or experiencing frequent or constant discomfort. They had not even realized that their actions were contributing to their pain/discomfort. Several reported unofficially, after their participation had ended, that a simple remedy such as changing the way they sat or adjusting their monitor, had made great improvements in their pain/discomfort level. They were very grateful for the knowledge. For instance, one participant had her monitor positioned almost a head higher then her line of sight. After completion of the study she was questioned as to why it was so high. She replied that that's just the way it had been setup and she didn't know or think to change it. So she had been working that way for at least two years and had terrible pain in her neck and shoulders. She asked me where the monitor should be positioned and I told her of the ergonomic guidelines. She called someone to correct it for her and within two weeks she stated that her pain/discomfort had decreased dramatically. Until that time she had been self-medicating with aspirin or ibuprofen and had been considering going to visit her medical doctor for stronger relief medication. This was just one example; there were many similar to this one. It is amazing that there is so much "ergonomically correct" information available and still injury and disease continue to wreak havoc on the computer operator. More often than not, by discovery in this study, all it took was a little individual attention to get the computer operator pointed in the right direction away from pain and/or injury.

This is the first known study that deals with predicting risk of individual computer operators using a theoretical framework. The theoretical framework is of considerable importance due to the fact that specific purposes can be anticipated based on the research and theory of others. Previous models are also a valuable asset in this type of study.

6.2 Observations about the Study

This study was limited in developing the CORI instrument for predicting risk. Once it was narrowed down to validating only the CORI form there were still problems that arose. For one, the original frequency factor that was intended for use, using keystrokes per hour and mouse clicks per hour was not able to be used due to lack of research in that area. Another thing was the variables in the posture factor. Some variables had to be removed and others added. The environmental factor went from a yes/no type of survey to a Likert-type scale. Then the problem came of finding participants. Many companies or institutions were reluctant to involve their employees due to their belief that too much time would be taken away from work. Others just had so much red tape to go through that it would have taken longer to get permission than it would have to survey the entire sample required for the study. The departments of Information Technology at Maryville College, Maryville, TN, and the University of Tennessee, Knoxville, TN, were both invaluable resources in the recruitment of volunteers to participate. Other participants were from Farragut High School, Knoxville, TN, and Sparks Resources, LLC, Knoxville, TN. All of these participants were very receptive to the idea of an instrument to predict risk for computer operators.

This study took quite a bit more time to complete than anticipated. Each individual participant had to be surveyed and observed by the principal investigator. Nearly all participants had many questions about their computer work methods and their workstation area. Although the desire was there to help them rearrange their workstation to best suit their needs, it was neither practical time-wise, or allowable in the consent form. It was conveyed that the results would be available later this year.

6.3. Strengths and Weaknesses of the Study

The strengths of this study will be more evident the more the CORI instrument is used and quantified. As of now, the study shows that computer operators are more than willing to help themselves work safer and smarter; they just need education and verification, as well as some individualized attention to their specific work concerns.

The CORI form is fairly easy to complete for the professional analyst and could be taught to managers or the like that would be in supervisory positions. The main thing is that CORI can predict risk for computer operators, but in addition to that it can also let the analyst readily see the areas of concern. Upon observation of the participants, it was noticed that most things that were causing pain and/or discomfort could be changed for little to no cost. Some of the items that required change but also had cost associated with it were new monitors and furniture, usually just a chair.

The CORI form could have added more risk factors to be even more inclusive of all computer work variables. For instance, there is nothing to indicate whether or not the operator used a phone for long periods throughout the day; this could be causing neck problems. There is nothing to indicate whether or not the operator wore bifocals; this could be causing neck pain and/or eye strain. There is also nothing to indicate whether or not the computer operator had to read from documents while typing or mousing; this could have caused pain and/or discomfort in the wrists, shoulders, neck, and/or arms. There was also no indication of how long the analyst should observe the computer operator. Although the operator may be working in one position at 8:00 in the morning, they may be in an entirely different position by that afternoon. At the very least, the operator should be questioned about dynamic posture. There could also have been a variable that discovered what other tasks the computer operator was doing when they were not using the computer; these additional tasks could be contributing to the overall pain and/or discomfort. The computer operator should be questioned on after working hour's activities since after hour's computer use was taken into account; these activities could induce even more pain and/or discomfort to the operator. The operator's after working hour's computer use should also include a separate CORI form since the work and home computer related environment may be completely different. And finally, more participants could be used to have an even higher validity confidence.

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APPENDICES

APPENDIX A

COMPUTER OPERATOR SURVEY

Please read the following questions and reply by filling in the correct answer, circling the correct answer, or making an *X* (or color in) the answer that best applies. Thank you for your participation in this survey.

DEMOGRAPHIC INFORMATION

1. Gender: M F

2. Age: __________

3. Ethnicity:
   ☐ American Native/Alaskan Native ☐ Arab/Indian ☐ Other
   ☐ African American ☐ Caucasian
   ☐ Asian/Pacific Islander ☐ Hispanic

4. Right or Left Handed: R L

5. On average, how many hours per day do you use a computer at work?

   0 1 2 3 4 5 6 7 8 9+

6. On average, how many hours per day do you use a computer other than work?

   0 1 2 3 4 5 6 7 8 9+

7. On average, how many hours per day do you work?

   0 1 2 3 4 5 6 7 8 9+

8. What type of computer related job do you have (i.e. programmer, graphic artist, secretary)? ____

9. Has anything to do with your computer workstation changed recently, i.e. different chair, monitor, desk, keyboard, or mouse? Y N
   (If you answer "No," proceed to question #14)

10. If you answered "Yes" to question #9, how long has it been since it was changed? ____

11. If something was changed, what was changed? ________________________

12. On a scale of 1 to 10 (with 10 being helped most), if something was changed, has it helped any pain or discomfort you may have been experiencing?

1 2 3 4 5 6 7 8 9 10

13. How many *scheduled* breaks do you take per work day? ________

14. Have you previously been medically diagnosed with any computer related injury or disease? Y N (If you answer "No", stop here)

15. What was the medical diagnosis? Describe

____

____

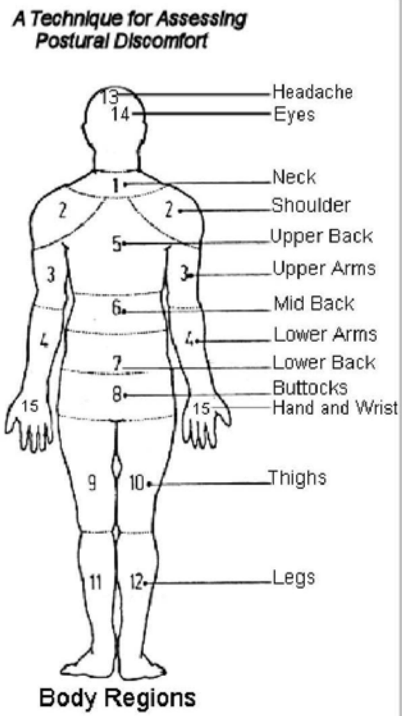
16. How long ago were you diagnosed? ________________________________

17. Are you still experiencing problems with diagnosed issues? Y N

APPENDIX B

PAIN/DISCOMFORT RATING CHART
FOR COMPUTER OPERATORS

Indicate any areas where pain or discomforts are felt before, during, and/or after working at a computer by marking through the *Severity Level* most applicable to the respective area of pain or discomfort.



Number On Chart	Severity Level → / Area of Pain Or Discomfort ↓	Nothing at all	Extremely Weak (just noticeable)	Very Weak	Weak (light)	Moderate		Strong (heavy)		Very Strong			Extremely Strong (almost maximal)	Maximal
1	Neck	0	.5	1	2	3	4	5	6	7	8	9	10	12
2	Shoulder	0	.5	1	2	3	4	5	6	7	8	9	10	12
3	Upper Arms	0	.5	1	2	3	4	5	6	7	8	9	10	12
4	Lower Arms	0	.5	1	2	3	4	5	6	7	8	9	10	12
5	Upper Back	0	.5	1	2	3	4	5	6	7	8	9	10	12
6	Mid Back	0	.5	1	2	3	4	5	6	7	8	9	10	12
7	Lower Back	0	.5	1	2	3	4	5	6	7	8	9	10	12
8	Buttocks	0	.5	1	2	3	4	5	6	7	8	9	10	12
9	Thigh	0	.5	1	2	3	4	5	6	7	8	9	10	12
10	Thigh	0	.5	1	2	3	4	5	6	7	8	9	10	12
11	Leg	0	.5	1	2	3	4	5	6	7	8	9	10	12
12	Leg	0	.5	1	2	3	4	5	6	7	8	9	10	12
13	Headache	0	.5	1	2	3	4	5	6	7	8	9	10	12
14	Eyes	0	.5	1	2	3	4	5	6	7	8	9	10	12
15	Wrist and Hand	0	.5	1	2	3	4	5	6	7	8	9	10	12

* The graphical model was developed by Corlett and Bishop (1976) and the Severity Scale is likened to Borg's (1990) CR-10 scale

APPENDIX C

Computer Operator Risk Index (CORI)

1) NAME:		DEPARTMENT:
2) OCCUPATION:		
3) DATE:		
4) ANALYST		

5) Total hours at work per day	
6) Hours at the computer at work per day	
7) Hours at the computer other than work, i.e. home per day	
8) Total Computer Exposure Time (TCET) = Total Computer Exposure at Work (TCEAW) + Total Computer Exposure Other than at Work (TCEOW) (TCET=TCEAW + TCEOW)	
Time Factor (TF)	

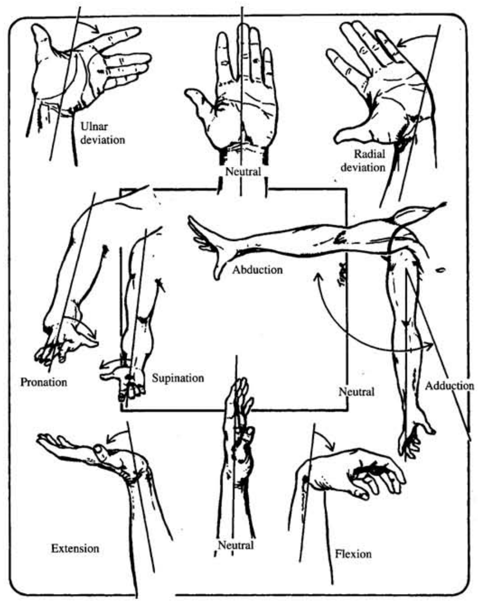
(Circle or check appropriate response)	Points			
	0	**1**	**2**	**3**
9) Sitting Posture (back posture)	Sit upright $\pm 5^{\circ}$	Lean back $\leq 30^{\circ}$	Lean back $> 30^{\circ}$	Lean forward
10) Wrist Radial/Ulnar Deviation*	Straight (neutral)	Radial (inward)	Ulnar (outward) $\leq 10^{\circ}$	Ulnar (outward) $> 10^{\circ}$
11) Wrist Flexion/Extension*	Straight (neutral)	Flexion	Extension $\leq 10^{\circ}$	Extension $> 10^{\circ}$
12) Shoulders Position with respect to body	Relaxed	Tense (hunched up)		
13) Arm(s) Position with respect to the body while typing/mousing **	Close	Forward $\leq 15^{\circ}$	Forward $> 15^{\circ}$ and out to the side $\leq 10^{\circ}$	Forward $> 15^{\circ}$ and out to the side $> 10^{\circ}$
14) Knee Position ***	$\approx 90^{\circ}$	$> 90^{\circ}$	$< 90^{\circ}$	
15) Neck Position	Straight (neutral)	Lean forward	Lean back	Turned to one side
16) Mouse level with & close to keyboard	Level and Close	Level & Away $\leq 5''$	Level & Away $> 5''$	Not Level w/ Keyboard
17) Keyboard is accessible w/o extending arms or leaning of the torso	Yes	No		
18) Monitor Distance from Eyes is 24"-39"	Yes	No		
19) Monitor/Keyboard positioned directly in front of user	Yes	No		
20) Monitor Positioned so View angle is from $0^{\circ} - 30^{\circ}$ below horizontal	Yes	No		
21) Modern Type Adjustable Chair	Yes	No		
22) Feet Flat on Floor or Platform	Yes	No		
23) **Total Points for Circled Conditions**				
Posture Factor (PF)				

24) Stress Factor for Computer Operators (separate questionnaire)	
Stress Factor (SF)	

Self-Reported Environmental Factors				
Do you have ...	**Very Much Agree**	**Slightly Agree**	**Slightly Disagree**	**Strongly Disagree**
25) Appropriate Lighting				
26) Comfortable Temperature				
27) Several Breaks per Day				
28) Quiet Work Environment				
29)Comfortable Workstation Area				
(30)Total Environmental Points				
Environmental Factor (EF)				

$$CORI = 2 \times \left(\frac{e^{(-4.761+0.191(TF)+0.175(PF)+0.054(SF)+0.133(EF))}}{1+e^{(-4.761+0.191(TF)+0.175(PF)+0.054(SF)+0.133(EF))}} \right)$$

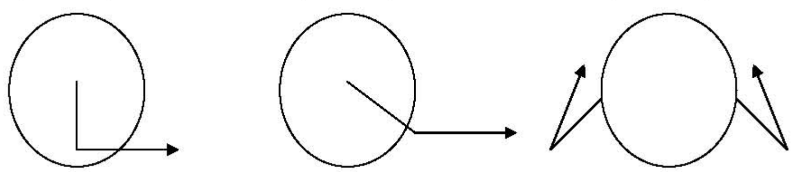
In reference to variables 10, 11 of CORI



* (Niebel and Frievalds 2003)

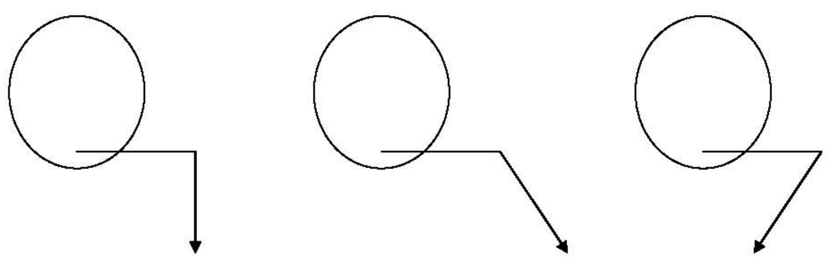
In reference to variable #13:

** Arms close to body (side view) | Arms forward (side view) | Arms Away from body (back view)



In reference to variable #14:

*** Knee at 90 degrees | Knee greater than 90 degrees | Knee less than 90 degrees



APPENDIX D

Self-Evaluation Chart to Measure Stress Levels

No Stress = 0 A Little Stress = 1 Some Stress = 2
A good deal of Stress = 3 A great deal of Stress = 4

Place a check in the box that best fits your stress levels, as it applies to you currently, for each situation.

	Levels of Stress →	**0**	**1**	**2**	**3**	**4**
	Situations of Possible Stress ↓					
1	Personal Injury/Disease					
2	Injury/Disease/Death of Family Members					
3	Burden of Work					
4	Burden of Household Duties					
5	Conflict with Domestic Partner					
6	Conflict with Family Members					
7	Economic Problems/Managing Expenses					
8	Increase in Unresolved Issues					
9	Lack of Education					
10	Tedious Life					
11	Lack of sufficient time for own interests					
12	Lack of entertainment					
13	Poor work outcomes					
14	Decreases in Pay					
15	Low Income					
16	Difficulty in Managing/Organizing Work					
17	Job Security					
18	Lack of Communication at Work					
19	Alienation from Other Workers					
20	Lack of Adequate Help					
21	Increase in Debt					
22	Lack of Savings					
23	Lack of Regular Income					
24	Lack of Regular Breaks from Work					
	POINT TOTALS					
	Sum up Point Totals to get STRESS LEVEL					

APPENDIX E

OCCUPATION

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	ACCOUNTANT	2	2.0	2.0	2.0
	ACCOUNTING	4	4.0	4.0	6.0
	ADMIN ASSIST	4	4.0	4.0	10.0
	ADMINISTRATIVE COORDINATOR	1	1.0	1.0	11.0
	ADMINISTRATIVE WORK	1	1.0	1.0	12.0
	ANALYST	1	1.0	1.0	13.0
	BOOKKEEPER	1	1.0	1.0	14.0
	BUSINESS DEVELOPMENT DIRECTOR	1	1.0	1.0	15.0
	CLERICAL SECRETARY	1	1.0	1.0	16.0
	COMPUTER MANAGER	1	1.0	1.0	17.0
	COMPUTER TECHNICIAN	2	2.0	2.0	19.0
	COUNSELOR	3	3.0	3.0	22.0
	CUSTOMER SUPPORT	1	1.0	1.0	23.0
	DATABASE ADMIN	5	5.0	5.0	28.0
	DIRECTOR OF IT DEPT	1	1.0	1.0	29.0
	ENGINEER	1	1.0	1.0	30.0
	GRAPHIC ARTIST	1	1.0	1.0	31.0
	HELP DESK MANAGER	1	1.0	1.0	32.0
	INFORMATION SECURITY ANALYST	2	2.0	2.0	34.0
	INFRASTRUCTURE ADMIN	1	1.0	1.0	35.0
	IT ADMINISTRATOR	1	1.0	1.0	36.0
	IT MANAGER	3	3.0	3.0	39.0
	IT SECURITY	1	1.0	1.0	40.0
	IT SPECIALIST	1	1.0	1.0	41.0
	IT TECH II	1	1.0	1.0	42.0
	LIBRARIAN	1	1.0	1.0	43.0
	MANAGER DATABASE ADMIN	1	1.0	1.0	44.0
	MANAGER DEA SYSTEMS ADMIN	1	1.0	1.0	45.0
	MATH CONSULTANT	1	1.0	1.0	46.0

OCCUPATION (continued)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	MEDIA SPECIALIST	1	1.0	1.0	47.0
	NETWORK ADMIN	1	1.0	1.0	48.0
	NETWORK SECURITY SPECIALIST	1	1.0	1.0	49.0
	NETWORK/COMPUTER TECH	1	1.0	1.0	50.0
	OPERATOR	1	1.0	1.0	51.0
	PAYROLL ASSISTANT	1	1.0	1.0	52.0
	PC SUPPORT / HELP DESK	1	1.0	1.0	53.0
	PROCRUREMENT & INVENTORY SPECIALIST	1	1.0	1.0	54.0
	PROGRAMMER	2	2.0	2.0	56.0
	PROGRAMMER/ ADMINISTRATOR	1	1.0	1.0	57.0
	SALES ASSISTANT	1	1.0	1.0	58.0
	SECRETARY	9	9.0	9.0	67.0
	SECURITY ANALYST	2	2.0	2.0	69.0
	SECURITY ANALYST ASSIST	1	1.0	1.0	70.0
	SECURITY ANALYST/ PROGRAMMER	1	1.0	1.0	71.0
	SR. PAYROLL ASSISTANT	1	1.0	1.0	72.0
	STAT CONSULTANT	2	2.0	2.0	74.0
	STATISTICAL CONSULTANT	1	1.0	1.0	75.0
	STATITICIAN	1	1.0	1.0	76.0
	SYSTEM ADMINISTRATOR	6	6.0	6.0	82.0
	SYSTEMS PROGRAMMER	1	1.0	1.0	83.0
	TEACHER	12	12.0	12.0	95.0
	TEACHER/SMALL BUSINESS OWNER	1	1.0	1.0	96.0

OCCUPATION (continued)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	TECHNICIAN/ SPECIALIST	1	1.0	1.0	97.0
	TECHNOLOGY COORDINATOR	1	1.0	1.0	98.0
	TRAINER, CUSTOMER TECHNOLOGY SUPPORT	1	1.0	1.0	99.0
	UNIV STUDENT	1	1.0	1.0	100.0
	Total	100	100.0	100.0	

APPENDIX F

CORI Instructions for Use and Example

The Computer Operator Risk Index (CORI) is designed to be used by a professional analyst in the field of ergonomics, health and safety, or engineering. It may also be used by an office manager or any other supervisory job, but it would then require some type of training on the aspects of how to measure angles and the explanation of certain terms, such as flexion and extension. This study focused on the professional analyst using the CORI form and the directions for use will adhere to that method.

The CORI form contains four major sections, or risk factors. Within these sections are subcategories of risk factors associated with each major risk factor. Each subcategory is numbered and instructions will align with the accompanying variable. Instructions are as follows:

1. Name of computer operator and department
2. Job title
3. Date of analysis
4. Name of analyst
5. Total number of hours the computer operator spends at work
6. Number of hours the computer operator is at the computer at work
7. Number of hours the computer operator is at the computer other than work
8. Sum of all hours at the computer per day (Add #6 and #7). This is the Time Factor to be entered into the CORI equation.

9. Sitting posture is the manner in which the computer operator positions himself while at the computer

- 0 points for sitting erect and leaning either forward or back no more than 5 degrees in either direction
- 1 point if the operator leans back while working at less than or equal to 30 degrees
- 2 points if the operator leans back while working but more than 30 degrees
- 3 points if the operator leans forward while working at the computer

10. Wrist radial/ulnar deviation is the sideways position of the wrist while typing on the keyboard
    - 0 points for no turning of the wrists to the right or left
    - 1 point for turning the wrists in the radial direction, or an inward turn
    - 2 points for turning the wrists in the ulnar direction, or in an outward turn, less than or equal to 10 degrees
    - points for turning the wrists in the ulnar deviation (outward) more than 10 degrees

11. Wrist flexion/extension is the forward or backward bending of the wrist, respectively
    - 0 points for no bending of the wrists, neither forward or back
    - 1 point for bending the wrists forward
    - 2 points for bending the wrist back at less than or equal to 10 degrees
    - 3 points for bending the wrists back at more than 10 degrees

12. Shoulders should be relaxed while working at the computer.
    - 0 points for the computer operator having relaxed shoulders while working
    - 1 point for the computer operator having tense, or hunched up shoulders while working

13. The arms position with respect to the body should not only be relaxed, but be positioned close to the body neither reaching forward nor outstretched to the side. Diagrams are accompanying the CORI form.
    - 0 points for the arms held close to the body and not outstretched in a forward manner
    - 1 point for the computer operator's arms that are outstretched forward less than or equal to 15 degrees from the body
    - 2 points for the computer operator's arms that are outstretched forward greater than 15 degrees and held out to the side less than or equal to 10 degrees from the body.
    - points for the computer operator's arms that are outstretched forward greater than 15 degrees and out to the side greater than 10 degrees.

14. The best position for the computer operator’s knees to be in while working is at approximately 90 degrees
    - 0 points for the computer operator whose knees are at approximately 90 degrees
    - 1 point for the computer operator whose knees are greater than 90 degrees
    - 2 points for the computer operator whose knees are less than 90 degrees

15. The neck should be held erect, neither leaning forward, backward, or twisted to one side
    - 0 points if the neck is held erect while working
    - 1 point if the neck is leaned forward while working
    - 2 points if the neck is leaned back while working
    - 3 points if the neck is turned to one side or the other while working

16. The computer mouse should be on the same plane as the keyboard
    - 0 points is the mouse is level to and positioned close to the keyboard
    - 1 point if the mouse is level with the keyboard but positioned away from the keyboard but no more than 5 inches
    - 2 points if the mouse is level with the keyboard but positioned away from the keyboard more than 5 inches
    - 3 points if the mouse is not on the same plane as the keyboard

17. The keyboard should be accessible without extending the arms forward or require any leaning of the torso
    - 0 points if the keyboard is easily reached without extending the arms or requiring the torso to be leaned forward
    - 1 point if the operator has to reach for the keyboard or lean forward to reach it

18. The monitor should not be too close or too far away from the computer operator’s line of vision
    - 0 points if the monitor is within 24-39 (60-100 cm) inches from the computer operator’s eyes
    - 1 point if the monitor is closer than 24 inches or farther than 39 inches from the computer operator’s eyes

19. The monitor and keyboard is best positioned directly in front of the computer operator
    - 0 points if the monitor and keyboard are positioned directly in front of the operator
    - 1 point if the monitor or keyboard are positioned anywhere else

20. The view angle of the monitor should be no more than 30 degrees below the horizontal line of sight
    - 0 points if the view angle from the horizontal is no more than 30 degrees
    - 1 point if the view angle is anything else

21. The chair that the computer operator is using should be a modern type chair with adjustable controls and arm rests
    - 0 points if the computer operator's chair is a modern type chair with either cushioning or mesh type material, has arm rests, and has easily accessible controls
    - 1 point for anything other type of chair

22. The feet should rest flat on the floor or on some type of platform that prevents the feet from hanging down
    - 0 points if the computer operator's feet are resting flat on the floor or on a platform that allows them to rest flat
    - 1 point for any other position

23. Sum the points from #9-22 to attain the Posture Factor. This is to be entered into the CORI equation.

24. Enter the score obtained from the self evaluating stress test. This is the Stress Factor to be entered into the CORI equation. For stress questions 1, 2, 14, and 15, add 1 additional point for extra weight.

25. Does the operator feel that the lighting in their work area is appropriate? i.e. does it cause a glare or reduce contrast.
    - 0 points if the computer operator very much agrees
    - 1 point if the computer operator slightly agrees
    - 2 points if the computer operator slightly disagrees
    - 3 points if the computer operator strongly disagrees

26. Does the operator feel that the temperature in their work area is comfortable? i.e. not too hot or too cold.
    - 0 points if the computer operator very much agrees
    - 1 point if the computer operator slightly agrees
    - 2 points if the computer operator slightly disagrees
    - 3 points if the computer operator strongly disagrees

27. Does the operator take frequent rest breaks throughout the day as needed?
    - 0 points if the computer operator very much agrees
    - 1 point if the computer operator slightly agrees
    - 2 points if the computer operator slightly disagrees
    - 3 points if the computer operator strongly disagrees

28. Does the operator feel that their work area is a quiet place within which to work?
   - 0 points if the computer operator very much agrees
   - 1 point if the computer operator slightly agrees
   - 2 points if the computer operator slightly disagrees
   - 3 points if the computer operator strongly disagrees

29. Does the operator feel that their computer workstation is spacious enough and has an element of comfort to it?
   - 0 points if the computer operator very much agrees
   - 1 point if the computer operator slightly agrees
   - 2 points if the computer operator slightly disagrees
   - 3 points if the computer operator strongly disagrees

30. Sum of #25-29. This is the Environmental Factor to be entered into the CORI equation.

The CORI equation is:

$$CORI = 2 \times \left(\frac{e^{(-4.761+0.191(TF)+0.175(PF)+0.054(SF)+0.133(EF))}}{1+e^{(-4.761+0.191(TF)+0.175(PF)+0.054(SF)+0.133(EF))}} \right)$$

Where: *TF = Time Factor*
PF = Posture Factor
SF = Stress Factor
EF = Environmental Factor

Once all four of the risk factors are calculated and placed into the CORI, a score will result. If the score is less than 1, the computer operator will not be at risk for computer related injury or disease; if the score is 1 or greater, the computer operator may be at risk for computer related injury or disease. If the computer operator's score indicates probable risk then the analyst will look back over the CORI form to discuss with the operator which factors need to be addressed to reduce the chance of risk.

EXAMPLE

Computer Operator Risk Index (CORI)

1) NAME:	**Joe Computer Person**	DEPARTMENT:	**Instructional Technology**
2) OCCUPATION:	**Computer Programmer**		
3) DATE:	**March 4, 2006**		
4) ANALYST	**John Analyst**		

5) Total hours at work per day	**9**
6) Hours at the computer at work per day	**6**
7) Hours at the computer other than work, i.e. home per day	**2**
8) Total Computer Use Time (TCUT) = Total Hours of Computer Use at Work (WHAC) + Total Hours of the Computer Use Other than at Work (OHAC) (TCUT=WHAC + OHAC)	**8**
Time Factor (TF)	**8**

(Circle or check appropriate response)	Points			
	0	**1**	**2**	**3**
9) Sitting Posture (back posture)	Sit upright $\pm 5^{\circ}$	Lean back $\leq 30^{\circ}$	Lean back> 30° ✓	Lean forward
10) Wrist Radial/Ulnar Deviation*	Straight ✓ neutral)	Radial (inward)	Ulnar (outward) $\leq 10^{\circ}$	Ulnar (outward) $> 10^{\circ}$
11) Wrist Flexion/Extension*	Straight (neutral)	Flexion	Extension $\leq 10^{\circ}$	Extension > 10° ✓
12) Shoulders Position with respect to body	Relaxed	Tense (hunched up)		
13) Arm(s) Position with respect to the body while typing/mousing **	Close	Forward $\leq 15^{\circ}$ ✓	Forward $> 15^{\circ}$ and out to the side $\leq 10^{\circ}$	Forward $> 15^{\circ}$ and out to the side $> 10^{\circ}$
14) Knee Position ***	$\approx 90^{\circ}$	$> 90^{\circ}$	$< 90^{\circ}$ ✓	
15) Neck Position	Straight (neutral)	Lean forward	Lean back ✓	Turned to one side
16) Mouse level with & close to keyboard	Level & Close ✓	Level & Away $\leq 5''$	Level & Away $> 5''$	Not Level w/ Keyboard
17) Keyboard is accessible w/o extending arms or leaning of the torso	Yes ✓	No		
18) Monitor Distance from Eyes is 24"-39"	Yes	No ✓		
19) Monitor/Keyboard positioned directly in front of user	Yes ✓	No		
20) Monitor Positioned so View angle is from $0^{\circ} - 30^{\circ}$ below horizontal	Yes ✓	No		
21) Modern Type Adjustable Chair	Yes ✓	No		
22) Feet Flat on Floor or Platform	Yes	No ✓		
23) **Total Points for Circled Conditions**	**0**	**3**	**6**	**3**
			Posture Factor (PF)	**12**

24) Stress Factor for Computer Operators (separate questionnaire)	
Stress Factor (SF)	**22**

Self-Reported Environmental Factors				
Do you have ...	**Very Much Agree**	**Slightly Agree**	**Slightly Disagree**	**Strongly Disagree**
25) Appropriate Lighting		✓		
26) Comfortable Temperature				✓
27) Several Breaks per Day			✓	
28) Quiet Work Environment		✓		
29)Comfortable Workstation Area	✓			
(30)Total Environmental Points	**0**	**2**	**2**	**3**
			Environmental Factor (EF)	**7**

$$CORI = 2 \times \left(\frac{e^{(-4.761+0.191(8)+0.175(12)+0.054(22)+0.133(7))}}{1+e^{(-4.761+0.191(8)+0.175(12)+0.054(22)+0.133(7))}} \right) = 1.456$$

The example in Appendix F is what a completed CORI form might look like and it can be seen how the factors fit into the CORI equation.

In the example, the Time Factor is calculated as 8, out of a possible 24 points; the Posture Factor is calculated to be 12 out of a possible 27 points; the Stress Factor is calculated to be 22 out of a possible 100 points; and the Environmental Factor is calculated to be 7, out of a possible 15 points. These scores are placed into the CORI equation and the calculation results in a risk index of 1.456. Since this score is over 1, the computer operator is determined to be at risk and appropriate measures must be enacted upon to detract from any further possibility of risk.

APPENDIX G

CONSENT FORM

The University of Tennessee
Department of Industrial and Information Engineering

Title of Project: The Development of a Computer Operator Risk Index to Assist Computer Operators

Principal Investigator: Sandra Rudd (865-691-4542, srudd@utk.edu)
Other Investigators: Dongjoon Kong, Ph.D. (865-974-3079, dkong@utk.edu)
Robert Ford, Ph.D. (865-974-7567, cford@utk.edu)

You are invited to participate in a research study of evaluating computer workstation risk. The purpose of this study is to investigate risk factors that may cause computer related working disorders, whether it is pain or discomfort. Information retrieved during the survey, pain/discomfort chart and stress test will be used to better understand the physical and psychological relationship between the computer operator and his/her workstation and work area in general. This will ultimately provide a safer working environment for you, the computer operator.

Procedures

The participant agrees to the following procedures in order to participate in this study. The survey contains demographic and basic operator information that consists of fill in the blank questions about the operator and/or their respective work habits. The Pain/Discomfort Chart contains a graphic representation of the body, with specific risk areas marked off, and an accompanying chart to fill in with respect to any pain and/or discomfort that is felt by the computer operator. The Computer Operator Risk Index Form consists of several short questions that require numerical answers that are to be calculated to indicate whether there is a risk to the operator while working. There is also a sub-section to this form to evaluate stress.

Risks

The participant may experience minimal discomfort and fatigue of the eyes and hand while filling out the survey, pain/discomfort chart, stress form and/or a small part of the computer operator risk index form. Otherwise, no pain, discomfort, injury, or risks in any way are anticipated in participation. If significant pain, injury, or discomfort is experienced during completion of any of the previously mentioned forms, I will stop immediately and notify the investigator of the situation. I may refuse to answer any questions and may discontinue this study at any time.

Benefits:

There are no benefits to the participant other than the psychological benefits that come from knowing that they assisted in a study that could possibly help present and future computer operators. The benefits to the computer operators as a whole will be to limit or completely stop any pain, discomfort, and/or injury that they may experience while working at a computer workstation.

Alternative Procedures

There are no alternative procedures incorporated into this study.

__________ Participant's initials

Emergency Medical Treatment

The University of Tennessee does not "automatically" reimburse subjects for medical claims or other compensation.

Time Duration for Completion of Forms

To complete the survey, the pain/discomfort chart, the stress test form, and the computer operator risk index form approximately ten minutes, thirty minutes maximum.

Confidentiality Statement

Your participation in this study is confidential. The investigators will be the only persons with access to your identity and to any information that may be associated with your identity. All of your records associated with this study will be subject to the usual confidentiality standards applied to normal research studies. In the event of any publication resulting from this study, no identifiable information will be disclosed.

Right to Ask Questions

You have the opportunity to ask any questions that you may have regarding this study and am confident that they will be answered to your satisfaction.

Compensation

There is no compensation, monetary or otherwise, for participating in this study. You also understand that in the event of any physical or emotional injury resulting from my participation in this study will result in neither financial compensation nor free medical treatment from the University of Tennessee.

PARTICIPATION

Your participation in this study is voluntary; you may decline to participate without penalty. If you decide to participate, you may withdraw from the study at anytime without penalty and without loss of benefits to which you are otherwise entitled. If you withdraw from the study before data collection is completed, your data will be returned to you or destroyed. Participation in this study will require approximately ten minutes and no more than 30 minutes.

CONSENT

I have read the above information and agree to participate in this study. I have received a copy of this form.

Participant's name (print) ________________________________

Participant's signature ________________________________ **Date** ____________

I, the undersigned, have defined and explained the studies involved to the above participant.

____
Investigator Date

VITA

Sandra Louise Rudd was born in Knoxville, Tennessee on July 25, 1957. She attended elementary school at Sacred Heart Cathedral School, junior high school at Bearden Junior High, and high school at Bearden High School, all of Knoxville, TN. She graduated from Bearden High School in 1974.

Sandra married, had 4 children, and worked for the next two decades in manufacturing. She returned to college and graduated in 1995 with an A.S. in Engineering from Pellissippi State Community College. She furthered her academic career by attending the University of Tennessee and graduating with a B.S. and an M.S. in Industrial Engineering in 1996 and 2001 respectively. She also earned a M.S. in Math Education in 2001 from the University of Tennessee and is licensed and certified as highly qualified to teach high school mathematics.

Sandra has earned a doctorate in Industrial Engineering at the University of Tennessee at Knoxville and currently assumes the position of a high school mathematics teacher.