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An Electromyographic Study of Associated Musculature while Computer Keyboarding at Different Positions

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AN ELECTROMYOGRAPHIC STUDY OF ASSOCIATED MUSCULATURE WHILE COMPUTER KEYBOARDING AT DIFFERENT POSITIONS

by

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An Independent Study

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This Independent Study, submitted by David E. Nelson in partial fulfillment of the requirements for the Degree of Master of Physical Therapy from the University of North Dakota, has been read by the Faculty Preceptor, Advisor, and Chairperson of Physical Therapy under whom the work has been done and is hereby approved.

(Faculty Preceptor)

(Graduate School Advisor)

(Chairperson, Physical Therapy)

PERMISSION

Title	An electromyographic study of associated musculature while computer keyboarding at different positions.
Department	Physical Therapy
Degree	Master of Physical Therapy

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Signature Dave Nelson

Date 12/21/98

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ABSTRACT

Purpose: The purpose of this study is to monitor the level of muscle activity in upper trapezius and forearm musculature of subjects while typing at different keyboarding positions through the use of surface electromyography (EMG). **Methods**: Thirteen female and fourteen males took part in this study ranging from 22 to 43 years of age. Subjects were asked to type at four different keyboarding positions (90 degree, 110 degree, Powerboard 1, Powerboard 2). A device called a Powerboard was used for two of the positions tested. Repeated-measures Analysis of Varience statistics were calculated with significance established at $p < .05$. **Conclusion**: The Powerboard provided for the best overall positioning while computer keyboarding, although the researcher feels that the keyboarding position should be varied depending on the particular symptoms and needs of the client.

Chapter 1

Introduction

Today's computer age has brought knowledge, ease, and innovation to all aspects of society but this progress has not come without a price. Terms such as cumulative trauma disorder (CTD), repetitive strain injury (RSI), and overuse syndrome are all too common in today's workforce. These terms include, but are not limited to, diagnosis such as carpal tunnel syndrome, tendonitis, tenosynovitis, Dequarvain's disease, and muscle strain.[1,2] Consequences of the syndromes and/or diseases often involve negative effects for insurance providers, employers, and employees alike.

Expenses associated with these diagnosis can be divided into both direct and indirect costs. Direct costs associated with these disorders include compensation for lost wages and medical care costs.[3] Indirect costs include decreased productivity, training of unskilled workers to replace disabled workers, claims processing, OSHA penalties, attorney and litigation fees, and decreased employee self-esteem.[3,4] Federal Bureau of Labor Statistics in 1995 reported an incidence of 31,000 cases of carpal tunnel syndrome alone, with 48.5% of these cases resulting in 31 or more days away from work.[5,6] Data from Liberty Mutual Insurance Company suggested that total workers' compensation costs for upper extremity CTDs in the U.S. in 1989 were approximately $563 million.[3]

Cumulative trauma disorder is thought to be caused by inadequate time for the body to repair itself between episodes of heavy usage.[1] It has been estimated that an individual performing data entry and/or word processing tasks typing an average of 60, six character words per minute for eight hours averages about 173,00 key strokes per day. This is comparable to 173,000 steps taken by the fingers daily which would be approximately 75 miles of finger walking.[7]

Individual, organizational, and ergonomic factors are thought to influence the risk of acquiring CTDs.[8] Individual factors include age, gender, smoking, physical conditioning, joint hypermobility, and a negative disposition.[8,9] Organizational factors such as adequate and flexible rest breaks, task variability and flexibility, and overtime hours are also thought to have an impact.[8] All of the above mentioned individual and organizational factors are addressed by physical therapists in the clinic and workplace but are beyond the scope of this paper. The focus of this study is on the role of ergonomic factors in the workplace.

As stated by Ross[4] ergonomics is "an applied science concerned with the design of workplaces, tools, and tasks to match the physiologic, anatomic, and psychological characteristics and capabilities of the worker." In simpler terms ergonomics involves adjusting the work environment to fit the individual and his/her tasks in the hopes of preventing future injury. It includes, but is not limited to, addressing static work postures, hand positioning, repeated work movements, the keyboard and visual display terminal (VDT) position.[1,8] Sauter et al [10] stated, "the height discrepancy between the elbow and keyboard (relative keyboard height) was significant in predicting bilateral arm discomfort" in VDT users. It is extremely difficult to provide an optimum ergonomic environment for every individual person therefore ergonomics focuses on the 5^{th} and 95^{th} percentiles of the population with the intention of targeting 90% of individuals.[2]

The importance of ergonomic considerations has prompted the Occupational Safety and Health Commission to include ergonomics in its expectations by stating that it is the general duty of the employer to "provide their employees with a workplace free from… [which] includes prevention and control of ergonomic hazards."[1]

The fast growing field of ergonomics has resulted in changes and innovation in the workplace and its design. Many ergonomic ideas have been formed over the years including height suggestions for chairs, keyboards, and visual display terminals and also angle recommendations for seat, trunk, keyboard, and eye gaze. Innovative designs for wrist rest, mouse input devices, and keyboards have also come about, all with ergonomic considerations in mind. Although many changes and innovations have taken place over the years the literature is still unclear about exact posture and equipment to be used to get the best results. The need is still present to address and answer these questions.

The **purpose of this study** is to monitor the level of muscle activity in upper trapezius, deltoid, extensor digitorum communis, and forearm flexor musculature of subjects while typing at differing positions, through the use of surface electromyography (EMG). This study will be of **significance** to society by helping to add to the body of knowledge concerning ergonomic considerations in computer keyboarding by identifying the most efficient posture for the keyboardist. This information will assist in decreasing the occurrence of keyboarding related injuries in the workplace. Consequently the direct and indirect costs resulting from the treatment of injuries related to computer keyboarding will be decreased.

The following question will be addressed in this study. What is the effect of posture and keyboard height on muscle activity in the upper trapezius, deltoid, flexor digitorum superficialis and profundus, and extensor digitorum communis musculature? The researcher is operating under the alternate hypothesis that position will have an effect on muscle activity of the associated musculature.

Chapter 2

Literature Review

The widespread use of computers as we know it today has been due to a recent boom in technology and resultant availability to businesses and the general public alike. Although this rapid increase in computer usage has just recently come about, the study of ergonomics related to keyboarding has been around since the early 1970s. In this chapter we will take a close look at past studies concerning visual display terminal and keyboarding ergonomics and also the relationship between keyboarding and the pain-spasm cycle. This will give us a thorough background in what has been done and what needs to be done concerning keyboarding ergonomics.

The pain-spasm cycle is a continuous series of interactions that take place within the musculoskeletal system resulting in increasingly greater functional impairment for the individual. The pain-spasm cycle addressed in this study was modified from Caillet's 1973 interpretation by Grieco, 1986 (see figure 2.1).[11] A computer keyboardist may enter this cycle at the area of muscular tension due to constant static postures held by the musculature and high repetition. This tension results in an ischemic process, edema formation, and catabolite accumulation which all lead to an inflammatory response within the musculature and associated tissues. The inflammatory response within the tissues ultimately results in pain and functional impairment for the individual and causes a return

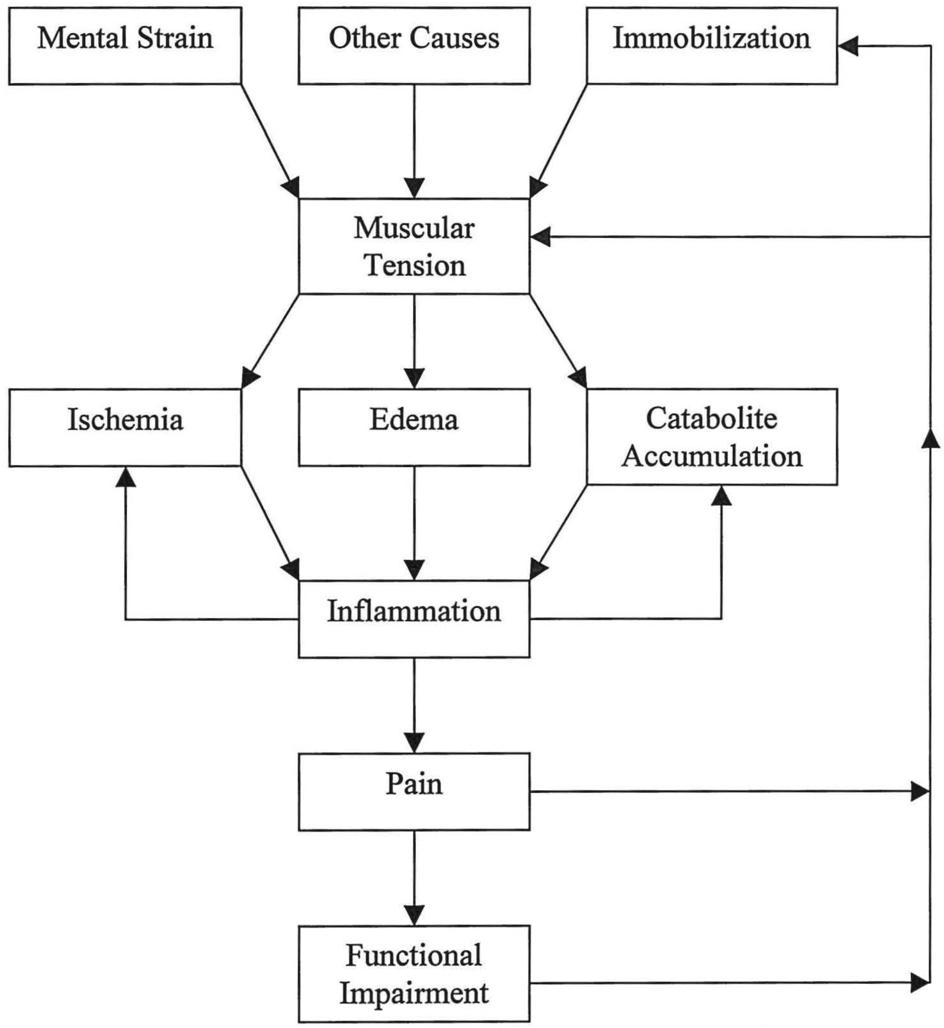

Figure 2.1 Pain-spasm cycle (modified from Grieco 1986 and Caillet 1973)

to the entry point of the cycle with a further increase in muscular tension and possibly immobilization. Once this cycle has begun and as time passes it becomes increasingly difficult to break this cycle, thus the purpose of keyboarding ergonomics is to keep this cycle from occurring[11].

As we retrace the pain-spasm cycle back we recall that the keyboardist's entry point was muscular tension due to static work postures and high repetition which resulted in an ischemic process within the musculature. Hamilton[12] suggested that if the standard mechanical definition of Work = Force x Distance is implemented then a static contraction, which by definition involves no distance being moved, involves no actual work being done. Hamilton[12] felt that the stress being imparted to the muscle by it performing a static contraction needs to be measured in terms of tension, as measured by percent of a maximal voluntary contraction (% MVC), and hold time.

It has become widely accepted within the medical community, due in large part to a study by Barnes,[13] that isometric contractions less than 20% MVC result in increased blood supply to the muscle while those greater than 20% MVC result in decreased blood flow to that muscle. It has been suggested that sustained contractions of 20% MVC or greater are often times achieved during keyboarding activities.[14] A study by Hagberg[15] et al found a decreased performance of the musculature for both sustained isometrics and dynamic exercises when contractions were above 15-20% MVC. This study also showed a quicker fatigue time for sustained versus intermittent isometric exercises.[15] In a similar study which looked at muscular endurance of elbow flexors Start[16] et al concluded that endurance scores were higher for a nonoccluded blood supply group as compared to an occluded group. All of the above mentioned studies suggest that muscular contractions of 15-20% MVC or greater may be the critical level at which a muscle's performance is negatively affected and thus cause the muscle to enter the pain-spasm cycle at the muscular tension and ischemia points as discussed previously.

Although percentage of a maximal voluntary contraction has been a "gold standard" in interpretation of EMG data in past years a differing method of analysis has been gaining acceptance in the research community. This newer method of analysis involves comparing EMG activity at differing trials with the EMG activity at a set standard trial. This method of comparison and analysis was utilized in a study by Janda et al[17] when analyzing grip strength. The study obtained EMG data from different grip positions and normalized the data to the value obtained at an open grip position. In the study of different postures with computer keyboarding EMG activity with differing positions could be compared with the current set standard of EMG activity while typing with the elbows, hips, and knees in the 90 degree position. In other words, the EMG data obtained from different keyboarding positions would be normalized to the value obtained at the 90 degree position. This approach of EMG analysis has been selected due to the inherent difficulty in eliciting a "true" MVC. This inability to elicit a "true" MVC would result in inaccurate %MVCs being calculated and the inability to make comparisons within and across studies. This new method of analysis will result in a more accurate interpretation and representation of the EMG activity present with performance of a particular activity.

With a muscle's level of EMG activity being a prime factor influencing an individual's chance of entering the pain-spasm cycle one must decide the most effective way to minimize the level of muscle activity required to perform keyboarding tasks. It has been widely accepted in the field of ergonomics that the most effective way of minimizing muscle activity needed to perform these tasks is through proper positioning of the body. This has resulted in a wide array of keyboard designs and positioning suggestions targeted at the computer keyboardist.

Positioning recommendations include numerous aspects of the work station such as keyboard slope, screen height, seat pan angle, and chair backrest angle.[18] As one searches through the literature for the appropriate positioning they find that the recommendations appear countless and vary from source to source.[10,12,18,19,20,21] Miller and Suther[19] performed a study of 37 subjects composed of 22 men and 15 women display station users. The subject's work station was adjusted until a position which the subject preferred was achieved. The preferred keyboard height, as measured from the floor to the home row of keys, was found to be a range between 63cm to78cm. On the other hand, Graandjean et al[21] conducted a study of 48 females and 20 males from four different companies and discovered a range between 73cm to 85cm was preferred by subjects. Also, Carter and Banister[18] display recommendations integrated from numerous sources suggesting a seat height of 38cm to 57cm but, on the other hand, Hamilton et al[12] concludes that a seat height of only 42cm to 50cm is appropriate according to the dimensions envelope they developed from various sources. Although there appears to be no one specific and perfect recommended posture a common theme shows through from every source. The workstation needs to be widely adaptable to accommodate a wide variety of individual sizes and preferences. A taller individual would obviously need different heights and depths than a shorter individual. A person who prefers a lower seat height may need a different keyboard slope than a person with a higher seat preference.[19] Versatility appears to be a key to work station positioning and decreasing a keyboardist's symptoms and chance for injury.

A study conducted by the South Australian Health Commission[22] from 1984 to 1986 looked at the most frequent areas of the body experiencing symptoms among keyboard workers and clerical workers. The experimental group consisted of 126 female keyboard operators while the control group was composed of 85 female clerical workers of various backgrounds. The study found that among the keyboard worker group the most frequent areas of the body experiencing symptoms were the upper trapezius (41%), shoulders (32%), wrist/hand (27%), and the forearms (22%) with other studies reporting similar findings (Fig. 2.2)[8,10,11,12,21,23]. Sauter et al,[10] upon assessing worker posture and workstation design among 40 VDT users, found a reduced discomfort as the keyboard was lowered to elbow level and also found that ulnar deviation was a predictor of discomfort in forearm musculature. All subjects in the study were female and performed computer entry of handwritten alphanumeric information from tax forms or traffic citations. In a similar study comparing a group of full-time typists and one control group composed of traditional office work, Hunting et al[23] discovered an increased frequency of medical findings in the forearm musculature when ulnar deviation was greater than 20 degrees, as measured through palpation and subjective report.

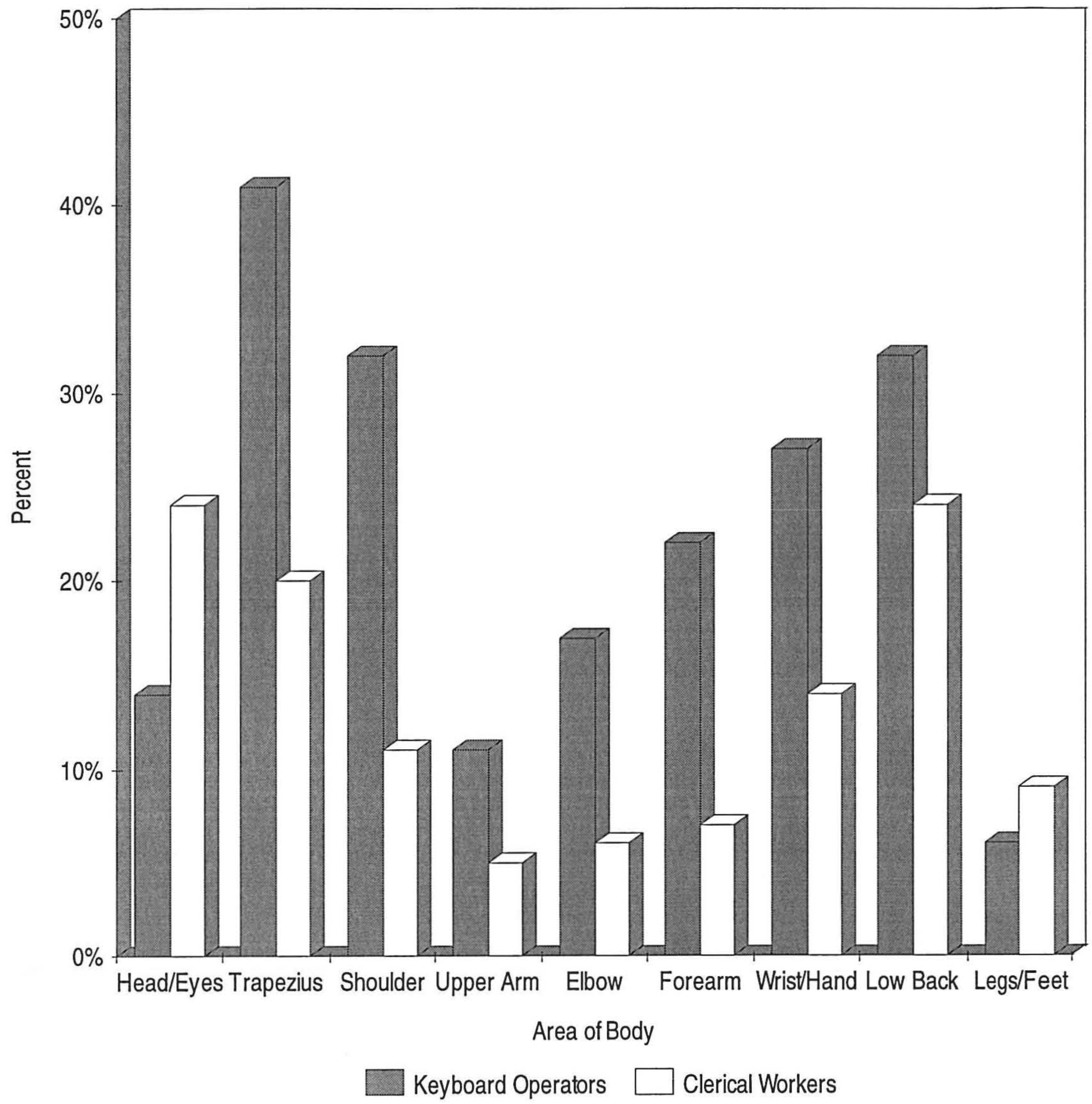

Figure 2.2 Complaint Distribution (Bullock[22])

In studying standard keyboard layout one discovers that the keys are evenly spaced over about 21cm for both hands but with the arms comfortably at the average keyboarder's sides the elbow separation is much greater than the keyboard width.[24] This results in the forearms being turned inward across the front of the body and the wrists going into ulnar deviation.[24] In 1926 Klockenberg suggested that two halves of the keyboard should be separate, angled back 15° from center, and tilted down laterally.[25] A study by Nakaseko et al[26] found that 40 out of 51 subjects preferred a split keyboard design with an open angle of 25° and lateral inclinations of 10° which resulted in ulnar deviation decreasing from 20° to 10° compared to a standard keyboard layout.

Kroemer[25] suggested that the keyboard should be lowered as close to the desktop as possible, or even sunken into the bench top if possible, and also felt that the key surface should be sloped slightly forward. The average negative slope chosen by subjects in a study by Hedge et al[27] was 12° below the horizontal, which resulted in a flattened angle of the key tops secondary to the key tops' built in positive slope. This preferred negative slope resulted in an average dorsal wrist extension of -1° as compared to and average dorsal wrist extension of 13° without the negative slope.[27]

A recent development in the field of keyboarding ergonomics is a device called a Powerboard developed by a physical therapist by the name of Ann Grassel. Ms. Grassel states that the Powerboard is, "a wooden platform, with a corduroy covered bean bag underneath, which holds the keyboard comfortably and securely on the lap" (see Fig. 2.2, 2.3). The Powerboard was developed due to the high number of repetitive stress injuries associated with computer keyboarding Ms. Grassel was seeing in her practice. She feels that the Powerboard's design, "allows the user of the Powerboard to easily adjust the keyboard to be in the optimal ergonomic position, thereby minimizing the risk of repetitive stress injuries."

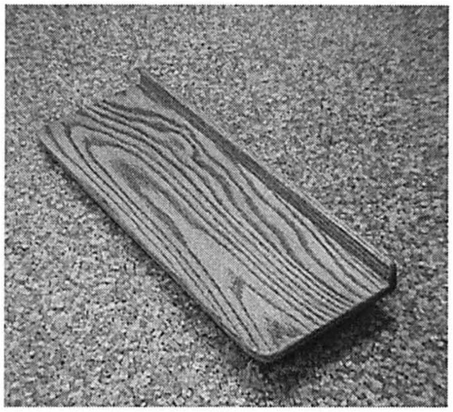

Figure 2.3 Powerboard (top view)

Figure 2.4 Powerboard (bottom view)

Although much research has been done in the field of ergonomics there is a lack of literature comparing EMG activity of the associated musculature while keyboarding at various positions using a standard layout computer keyboard. Also, with the recent development of the Powerboard by Ann Grassel, PT, which will be discussed in the following chapter, research needs to be done to discover the affect it has on muscle activity with different keyboarding positions. The information gathered in this study will be novel and unique thus adding to the body of knowledge surrounding ergonomics and workstation design.

Chapter 3

Methodology

Subjects selected for participation in this study were physical therapy students at the University of North Dakota Physical Therapy Department. Thirteen females and fourteen males took part in this study with ages ranging from 22 to 43 years and heights ranging from 5-2 ½ to 6-4. Subjects were asked to participate on a voluntary basis with the only criteria being a lack of symptoms of cumulative trauma disorder, or related diagnosis, within the past year and introductory level typing skills. A control group was unnecessary for this study due to differences between position groupings and not subject groupings being studied. All subjects read and signed a statement of informed consent prior to participation in this study (Appendix A).

Electromyographical signals were used to determine muscle activity while keyboarding at four different positions. A Noraxon Telemyo8 telemetry unit (Noraxon USA, 13430 North Scottsdale Rd., Scottsdale, AZ, 85254) was used to collect the EMG data. The Noraxon Telemyo8 receiver collected the telemetried information from the electrodes. This information was then digitized by a DT2801-Analog to a digital interface board installed in a NET 486DX computer. The Norquest and Myosoft data collection software that accompanies the Telemyo8 EMG system was used to analyze the digitized EMG signals in a variety of forms.

Prior to running the experiment skin preparation was performed to the right upper extremity and associated musculature. This included shaving any excess hair in the area of electrode placement, if needed, and aggressive cleaning of the area using isopropyl rubbing alcohol.[28] After the skin was thoroughly prepared electrodes were placed over the appropriate motor points. Placement of the electrodes followed recommendations made by Basmajian and Blumenstein.[29] Measurements were performed using a standard tape measure with a positive and negative electrode being placed at each motor point in a parallel arrangement in relation to the muscle fibers.[28]

Positioning of the subjects involved the hips and knees being flexed to 90 degrees with the feet positioned directly beneath the knees. Joint measurements were taken using a large plastic goniometer as per guidelines set forth by Norkin and White.[30] To assure proper joint position for measurement of the hip angle the fulcrum of the goniometer was centered over the lateral hip joint with the proximal arm aligned with the lateral midline of the pelvis and the distal arm aligned with the lateral midline of the femur. The knee angle involved the fulcrum of the goniometer being centered over the lateral epicondyle of the femur with the proximal arm aligned with the lateral midline of the femur and the distal arm aligned with the lateral midline of the fibula. The final goniometric measurement was of the elbow flexion angle. For this measurement the goniometer fulcrum was centered over the lateral epicondyle of the humerus with the proximal arm aligned with the lateral midline of the humerus and the distal arm aligned with the lateral midline of the radius.

The first position involved the knees and hips being flexed to 90°, feet flat on the floor, and the elbows flexed to 90°. The top of the computer monitor was positioned just above eye level and the backrest angle was approximately 90° (See Fig. 3.1). The second position included the same adjustments as made for the first position with the exception of elbow flexion increasing from 90° to 110° (see Fig. 3.2).

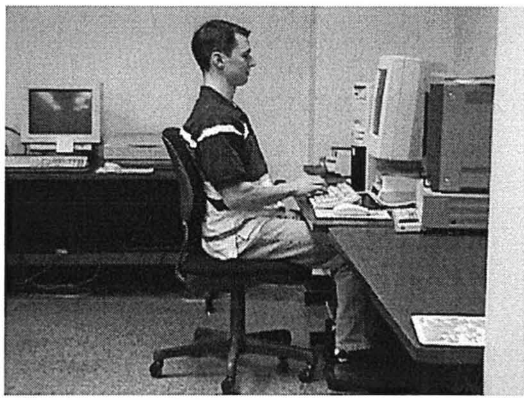

Figure 3.1 90 degree position

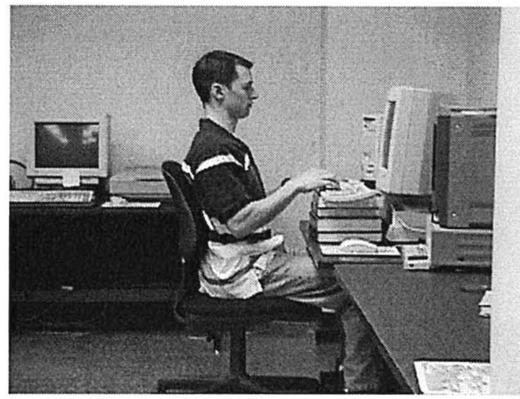

Figure 3.2 110 degree position

The third and fourth positions involved the use of the Powerboard developed by Ann Grassel, PT. In positioning for the third trial subjects were given an overview of the purpose and application of the Powerboard. No specific positioning recommendations were given, including no recommendations for the hip, knee, and elbow positions. Subjects were instructed to find a position which felt comfortable to themselves using the Powerboard on their lap. This position will be referred to throughout the paper as the Powerboard 1 position (see Fig 3.3).

For the fourth trial subjects were positioned according to recommendations set forth by Ann Grassel, PT for proper use of the Powerboard. These recommendations included flexing the hips and knees to 90 degrees with the feet flat on the floor directly under their knees. A towel was then folded up and placed on the posterior ½ of the chair seat under the ischial tuberosities allowing the hips to be elevated slightly higher than the knees. The subject was then instructed in a positioning technique called arching. Arching involved the subject moving from an extreme slumped, flexed posture with a posterior pelvic tilt to an exaggerated extended, forward posture with an anterior pelvic tilt. The subject alternately moved from one posture to the other to "get the feel " for the differing postures. Next the subject was asked to move from the extension to flexed posture and stop at the point where they were sitting on the front edge of the ischial tuberosities with their abdominal muscle engaged. Grassel feels that this is the optimum position for keyboarding while using the Powerboard due to its ability to "unlock" the lumbar spine allowing for better trunk mobility and a more functional posture (see Fig. 3.4). The Powerboard was then placed on the subject's lap in a negative tilt position with the keyboard set on top. This position will be referred to as the Powerboard 2 position throughout the remainder of this paper.

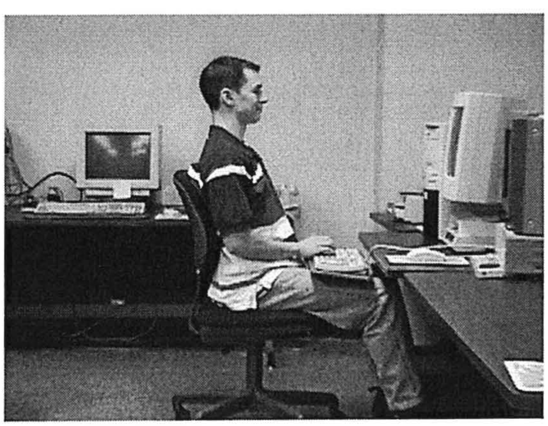

Figure 3.3 Powerboard 1 position

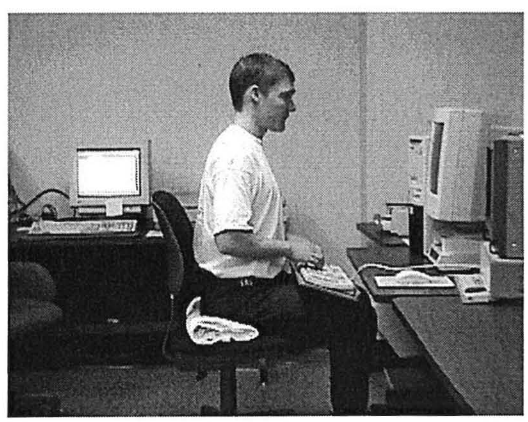

Figure 3.4 Powerboard 2 position

For each of the four trials the subject was set up in the appropriate position as described above and given a one minute warm-up. Prior to keyboarding subjects were instructed not to correct errors made while keyboarding. Following the warm-up period the subjects were asked to relax their upper extremeties and trunk with forearms resting on their lap. Recording began with the subject as relaxed as possible and then the subject was instructed to begin typing. Typing took place for 20 seconds, the subject was asked to stop and relax, and recording was stopped. This was the sequence of events for each of the four trials, for each subject.

Following the collection of data, repeated-measures analysis of variance (ANOVA) statistics were calculated to interpret the data and look for relationships between differing factors. Separate statistical testing was carried out for each muscle studied drawing comparisons between position(nominal) and EMG activity(interval/ratio) at an alpha= .05 level of significance with a nondirectional critical region. The Tukey's Honestly Significant Difference test described the significant differences between any two typing positions. Other descriptive statistics taken into consideration included means and standard deviations.

Chapter 4

Results

EMG data (μV) collected in this study from different positions was normalized to the value obtained at the 90 degree position. Each muscle was normalized separately for each subject. Thusly, the muscle activity at the 90 degree position was considered to be 100% of the available muscle activity for that particular muscle. For each subject the EMG activity at a given position for a given muscle was divided by the EMG activity at the 90 degree position for that same muscle and multiplied by 100. This resulted in a percentage of 90 degree EMG activity being calculated. These calculated percentages were the values used in the data analysis:

$$(\mu V_1 / \mu V_2)100 = \%\ 90 \text{ degree position}$$

were: μV_1 = muscle activity at a given muscle and position
μV_2 = muscle activity at the same muscle as μV_1 at the 90 degree position

These calculated percentages were the values used in the data analysis. The average % 90 degree position was also calculated for each position and muscle (Figure 4.1).

The average % muscle activity was highest for the upper trapezius at the 110 degrees (335%), the deltoid at 110 degrees (121%), the extensor digitorum at the Powerboard 1 position (127%), and the forearm flexors at 110 degrees (112%). On the other hand, % muscle activity was, on average, lowest for the upper trapezius at the Powerboard 1 position (66%), the deltoid at the Powerboard 1 position (88%), the

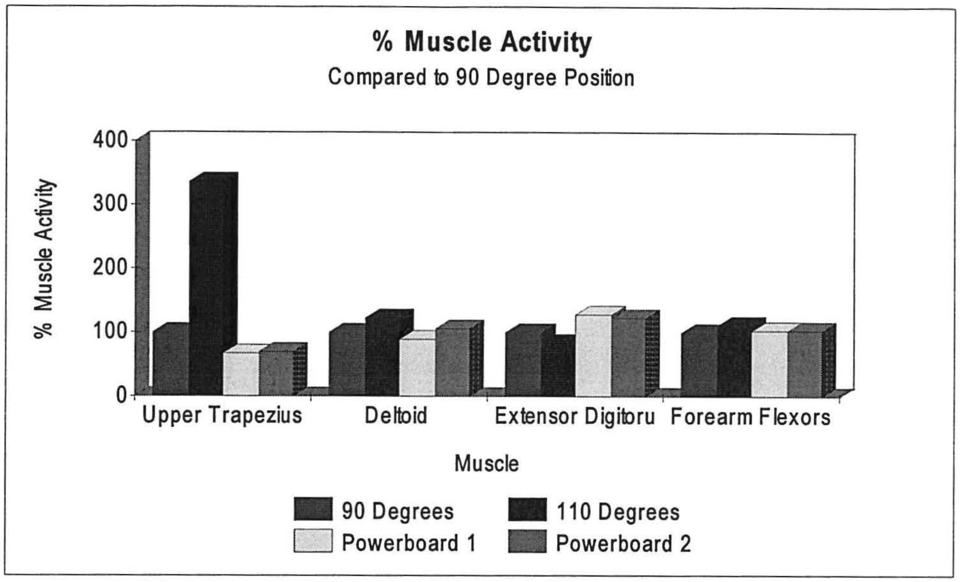

Figure 4.1 % Muscle Activity Compared to the 90 Degree Position

extensor digitorum at 110 degrees (82%), and the forearm flexors at 90 degrees (100%).

Repeated-measures Analysis of Variance statistics were calculated with significance established at $p < .05$. The repeated-measures design allows for individual differences to be eliminated from the possible causes of differences found between treatment groups. This is possible since repeated-measures uses the same individuals in every treatment condition. Thusly, differences found between treatment conditions could only be attributed to a treatment effect or experimental error.[31] Tukey's Honestly Significant Difference post hoc test was utilized to determine if there was a significant difference between specific keyboarding positions (Table 4.1).

The upper trapezius musculature activity was found to be significantly higher ($p < .05$) at the 110 degree position (335%) than at the 90 degree position (100%). No significant difference was found when comparing the 90 degree position (100%) to either

Table 4.1 Significance between test positions

	Upper Trapezius	Deltoid	Extensor Digitorum	Forearm Flexors
90° : 110°	♦	NS	♦	♦
90° : PB 1	NS	NS	♦	NS
90° : PB 2	NS	NS	♦	NS
PB 1 : PB 2	NS	NS	NS	NS

♦ denotes significant difference ($p < .05$)
NS denotes no significant difference

the Powerboard 1 position (66%) or the Powerboard 2 position (69%). Likewise, no significant difference was found when comparing the Powerboard 1 (66%) to the Powerboard 2 (69%) positions. It is interesting to note that on average activity at the Powerboard 1 and Powerboard 2 positions was 32-35% less than the activity at the 90 degree position, although statistical significance was not found.

Upon comparison of deltoid musculature activity no significant difference was found at the 110 degree (121%), Powerboard 1 (88%), or Powerboard 2 (105%) positions when compared to the 90 degree (100%) position. It is again of interest to point out that, on average, muscle activity was 20% higher at the 110 degree position than the 90 degree position. Also, Powerboard 1 muscle activity was 12% lower than muscle activity at the 90 degree position even though statistical significance was not found.

Muscle activity of the extensor digitorum was found to be significantly different ($p<.05$) when comparing the 90 degree (100%) position to the 110 degree (82%), Powerboard 1 (127%), and Powerboard 2 (121%) positions. Activity was significantly lower at the 110 degree position and significantly higher at the Powerboard 1 and Powerboard 2 positions. No significant difference was found statistically between muscle activity at the Powerboard 1 (128%) and Powerboard 2 (121%) positions, although activity was 6% lower at the Powerboard 2 position on average.

Compared to the 90 degree position (100%) forearm flexor activity was found to be significantly higher at the 110 degree (112%) position with $p<.05$. No significant difference was found upon comparing the 90 degree (100%) position to either the Powerboard 1 (102%) or Powerboard 2 (102%) positions, nor was a significant difference found when comparing the Powerboard 1 (102%) to the Powerboard 2 (102%) position.

Chapter 5

Discussion/Conclusion

The goal of analyzing different keyboarding positions is to find the "optimum" position which will help to keep a person out of the pain-spasm cycle described in chapter two. As you recall, a keyboardist enters the pain-spasm cycle at the point of muscle tension due to static work postures and high repetition. The key to decreasing the likelihood of entering this cycle is to find the position which results in the least amount of muscle activity, the "optimum" position. It has been accepted throughout the ergonomic arena that the 90-90-90 keyboarding position is the "optimum" position for keyboarding.[32,33] This position places the knees, hips, and elbows all at 90 degrees of flexion. This position has not been challenged by researchers and professionals to a great extent, thus, little change has taken place.

Much of the research has suggested ranges such as the keyboard height should be 60-85 cm above the floor or seat pan angle should range from 8° back to 15° forward.[18] These studies and results are very useful when an employer is looking to purchase workstation equipment, but it does the keyboardist little good in finding their "optimum" position. It is surprising to find what little has been done to challenge the 90-90-90 position and find a better position recommendation for the keyboardist. All of the best equipment can be bought for workstation design and versatility, but this is of little value in the prevention of injury if the keyboardist is not in the best position. This study addresses that problem and attempts to find a solution.

When analyzing the data for this study one must keep in mind the following consideration. Is finding statistical significance between muscle activity the most important indicator of finding the "optimum" position or are there other, more important, factors to consider when analyzing the data? The researcher feels that statistical significance fails to look at all of the variables that are present in an activity such as keyboarding. Other factors that need to be considered include such things as the duration of the keyboarding activity and individual differences in how their muscles respond to various loads and activities. Statistics can not account for these variables which are very important when looking at differences between keyboarding positions. For example, a 10% average difference in muscle activity may not have statistical significance but when you factor in an 8 hour workday and individual muscle differences that 10 % difference may have "real life" significance. This is a very important consideration when analyzing data and comparing it to activities in the real world.

Upper Trapezius

Upon analysis of the upper trapezius musculature at different positions it was found that the Powerboard 1 and Powerboard 2 positions displayed less muscle activity than the 90 degree position. Although these differences were not found to be statistically significant the researcher feels that "real life" significance was found. The Powerboard 1 position displayed the least amount of muscle activity, with an average 34% less than that found at the 90 degree position, and would be the "optimum" position for the upper trapezius.

Deltoid

No statistical significance in deltoid muscle activity was found when comparing the 90 degree position to any of the other positions. The Powerboard 1 position displayed the least amount of activity at 12% less than that found at the 90 degree position. The researcher feels that this difference would be significant in the workplace and that the Powerboard 1 position is the "optimum" position for the deltoid musculature.

Extensor Digitorum

Analysis of the extensor digitorum musculature displayed a statistical significance between all positions when compared to the 90 degree position. The least amount of muscle activity was at the 110 degree position. These findings suggest that the 110 degree position would be "optimal" for the extensor digitorum musculature.

Forearm Flexors

The least amount of muscle activity in the forearm flexors was found at the 90 degree position. The activity was 2% less than that found at both the Powerboard 1 and Powerboard 2 positions. It is questionable as to whether or not this small of a difference would be significant in the workplace. The average muscle activity suggest that the 90 degree position would be the "optimum" position for the forearm flexor musculature, but the small difference displayed between the 90 degree and Powerboard positions suggests that either position may be equally effective.

In reviewing the data from this study one realizes that no one particular position was optimal for every muscle. The Powerboard 1 position appeared to be the best choice if one position needed to be chosen for keyboarding. This position provided the least amount of muscle activity for the upper trapezius and deltoid and was only 2% higher than the optimum forearm flexor position. The drawback of this position is its relatively high extensor digitorum activity.

The fact that each muscle has its own best position leads one to believe that an "optimum" position for all muscle together may not be available. It is the researcher's opinion that positioning may need to be varied depending on the symptoms that each individual person is experiencing. If a person is experiencing symptoms due to overuse of the upper trapezius then the Powerboard positions should be utilized. Likewise, if a person has symptoms secondary to extensor digitorum overuse then the higher, 110 degree, position should be utilized. It would depend on individual problems and judgement as to which position would best benefit that person.

The Powerboard is very beneficial in positioning due to its versatility. It can be utilized for both the Powerboard 1 and Powerboard 2 positions and by simply removing the keyboard and placing it on the desktop the 90 degree position can also be attained. The simplicity, ease of use, and affordability make the Powerboard an essential component of ergonomic design and function.

The biggest limitation of this study has to do with analysis and interpretation of the data. It is currently unknown exactly what percent difference is large enough between positions to constitute a significant difference in a real world activity, taking into consideration the duration of the activity and individual differences in a muscle's response to the activity. Is a 5% difference between positions significant or not? Until studies are done to answer this question it is difficult to have objective, definitive results to back up conclusions. Another limitation was the subjects chosen for participation in this study. This study had a range of keyboardists with different levels of experience, speed, and proficiency. The sample may have been a good representation of the general population, but a different subject pool may want to be targeted to obtain a more accurate representation of keyboardists in the workplace.

Future studies should be directed at discovering the percent difference which is significant between positions keeping dynamic, real life variables in mind. Also, studies should look at a different population sample, such as professional keyboardists, and continue to study the Powerboard and its role in the field of ergonomics.

In conclusion, the researcher feels that the Powerboard 1 position provided the best overall positioning , although a single "optimum" keyboarding position may not be available at this time. The keyboarding position should be varied depending on the particular symptoms and needs of the client. The Powerboard plays an essential role in ergonomic positioning due to its versatility, simplicity, ease of use, and effectiveness.

APPENDIX A
Information and Consent Form

INFORMATION AND CONSENT FORM

TITLE: ***An Electromyographic Study of Associated Musculature While Computer Keyboarding at Different Positions.***

You are being invited to participate in a study conducted by ***David Nelson, a physical therapy student*** at the University of North Dakota. The purpose of this study is to monitor the level of muscle activity in your upper shoulder and forearm musculature while you perform typing activities at differing positions. Your muscle activity will be monitored and recorded through the use of surface electrodes. *These electrodes only record information from your muscles and joints, they do not stimulate the skin.* The researcher hopes to discover new information concerning ergonomic considerations involved with computer keyboarding. This information will add to the body of knowledge concerning computer keyboard ergonomics and help decrease the occurrence of keyboarding related injuries.

You will be asked to attend one research session, approximately one hour in length, at a predetermined site. Prior to the start of the session you will be asked to change into a short sleeved tee shirt, or tank top. During the session you will be asked to type a paragraph for four trials consisting of the following positions: *1)* Elbows at 90 degrees of flexion *2)* Elbows at 110 degrees of flexion *3)* Nonsuggested position with the Powerboard device *3)* Suggested position with the Powerboard device. Each trial will last approximately 3-5 minutes with a short rest period in between trials. You will also be given a brief practice time before each trial to become accustomed to the differing positions.

Although the process of physical performance testing always involves some degree of risk the researcher feels that the risks of discomfort and/or injury in this study are minimal to none and encountered daily in the physical therapy or work office environment. **The participant or the researcher may stop the session at any time, for any reason.** The researcher will be using surface electrodes to record the muscle activity. The electrodes will be attached to your shoulders and forearms, along with a measuring device at the elbow, with an adhesive material. Hair interferes with the collection of this type of data so a patch of skin about 2in. by 2in. may need to be shaved. *These electrodes only record information from your muscles and joints, they do not stimulate the skin.*

Your name will not be used in any reports of the results of this study. Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission. If you decide to participate you are free to discontinue participation at any time. Your decision whether or not to participate will not prejudice your future relationship with the Physical Therapy Department or the University of North Dakota.

The researcher involved is available to answer any questions you have concerning this study. In addition, you are encouraged to ask any questions concerning this study that you may have in the future. Questions may be asked by calling ***Dave Nelson at (701) 777-9102 or Bev Johnson at (701)777-2831.*** A copy of this consent form is available to all participants in the study.

ALL OF MY QUESTIONS HAVE BEEN ANSWERED AND I AM ENCOURAGED TO ASK ANY QUESTIONS THAT I MAY HAVE CONCERNING THIS STUDY IN THE FUTURE. MY SIGNATURE INDICATES THAT, HAVING READ THE ABOVE INFORMATION, I HAVE DECIDED TO PARTICIPATE IN THE RESEARCH PROJECT.

I have read all of the above and willingly agree to participate in this study explained to me by ***Dave Nelson.***

____

Participant's Signature Date

____

Witness (not the scientist) Date

APPENDIX B
Questionnaire

QUESTIONNAIRE

NAME: ____________________ **HEIGHT: ____________________**

AGE: _____ **WPM TYPED: _______**

SEX: M / F **DOMINANT HAND: Right / Left**

WEIGHT:___________

Place an 'X' on the line in the spot which best represents your level of muscular discomfort while keyboarding on average.

no discomfort -- significant discomfort

Have you ever been treated for neck, shoulder, arm, wrist, and/or hand problems? YES / NO If yes Explain.

____

____

If answered yes to the above question. Have you been symptom free for at least 1 year? YES / NO

Do you have any allergies (gels, adhesive, tape, or rubbing alcohol)? YES / NO If yes list.

____

APPENDIX C

Human Subjects Form

_X_ EXPEDITED REVIEW REQUESTED UNDER ITEM _3_ (NUMBER[S]) OF HHS REGULATIONS
___EXEMPT REVIEW REQUESTED UNDER ITEM ____ (NUMBER[S]) OF HHS REGULATIONS

UNIVERSITY OF NORTH DAKOTA
HUMAN SUBJECTS REVIEW FORM
FOR NEW PROJECTS OR PROCEDURAL REVISIONS TO APPROVED PROJECTS INVOLVING HUMAN SUBJECTS

PRINCIPAL INVESTIGATOR: David E. Nelson **TELEPHONE:** 777-9102 **DATE:** 4/14/98

ADDRESS TO WHICH NOTICE OF APPROVAL SHOULD BE SENT: 550 Carleton Crt. #118/ Grand Forks/ ND 58203

SCHOOL/COLLEGE: UND **DEPARTMENT:** PT **PROPOSED PROJECT DATES: 4/98-10/98**

PROJECT TITLE: An Electromyographic Study of Upper Trapezius and Forearm Musculature With the Use of Different Style Computer Keyboards

FUNDING AGENCIES (IF APPLICABLE): N/A

TYPE OF PROJECT:

__ NEW PROJECT __ CONTINUATION __ RENEWAL __ DISSERTATION OR THESIS RESEARCH _X_ STUDENT RESEARCH PROJECT

__ CHANGE IN PROCEDURE FOR A PREVIOUSLY APPROVED PROJECT

DISSERTATION/THESIS ADVISER, OR STUDENT ADVISER: Beverly Johnson

PROPOSED PROJECT: ___ INVOLVES NEW DRUGS (IND) ___ INVOLVES NON-APPROVED USE OF DRUG _X_ INSTITUTION

IF ANY OF YOUR SUBJECTS FALL IN ANY OF THE FOLLOWING CLASSIFICATIONS, PLEASE INDICATE THE CLASSIFICATION(S):

_ MINORS (<18 YEARS) __ PREGNANT WOMEN __ MENTALLY DISABLED __ FETUSES MENTALLY RETARDED

_ PRISONERS _ ABORTUSES _ UND STUDENTS (>18 YEARS)

IF YOUR PROJECT INVOLVES ANY HUMAN TISSUE, BODY FLUIDS, PATHOLOGICAL SPECIMENS, DONATED ORGANS, FETAL MATERIAL, OR PLACENTAL MATERIALS, CHECK HERE __

1. ABSTRACT: (LIMIT TO 200 WORDS OR LESS AND INCLUDE JUSTIFICATION OR NECESSITY FOR USING HUMAN SUBJECTS.)

Purpose: The purpose of this study is to monitor the level of muscle activity in upper trapezius and forearm musculature of subjects while typing on different style computer keyboards through the use of surface electromyography (EMG). **Treatment Techniques:** Subjects will be randomly selected to participate in this study and will be asked to type using three different style computer keyboards in four different positions. Muscle activity will be monitored while performing these tasks through surface EMG. **Subjects:** Thirty subjects of either sex between the ages of 20-60 years, able to type a minimum of 60 words/minute, and without symptoms of cumulative trauma disorder, or related diagnosises, within the past year will participate in this study. **Significance:** This study will help add to the body of knowledge concerning ergonomic considerations in computer keyboarding, thus helping to decrease the occurrence of keyboarding related injuries in the workplace.

2. PROTOCOL: (Describe procedures to which humans will be subjected. Use additional pages if necessary.)

□**Subjects:** Thirty subjects of either sex between the ages of 20-60 years, able to type a minimum of 60 words/minute, and without symptoms of cumulative trauma disorder, or related diagnosises, within the past year will be randomly selected to participate in this study. **Instrumentation:** Upper trapezius and forearm musculature activity will be monitored and recorded through the use of surface electromyography (EMG). Standard EMG protocol will be followed. **Procedure:** Each subject will be seen for approximately one hour and will be asked to type on three different style computer keyboards in four different positions while surface EMG is used to monitor and record their muscle activity. Following the session each subject will be instructed in exercises designed to decrease fatigue and strain factors associated with computer keyboarding. **Data Analysis:** Data collected would be analyzed using analysis of variance testing to compare the differences in muscle of activity between subjects. Patient confidentiality would be practiced as discussed in the "Risks" section of this form.

3. BENEFITS: (Describe the benefits to the individual or society.)
The results of this study will help add to the body of knowledge concerning ergonomic considerations in computer keyboarding, thus helping to decrease the occurrence of keyboarding related injuries in the workplace. This will help decrease the number of days lost from work and the amount of money spent on the treatment of injuries related to computer keyboarding.

4. RISKS: (Describe the risks to the subject and precautions that will be taken to minimize them. The concept of risk goes beyond physical risk and includes risks to the subject's dignity and self-respect, as well as psycho-logical, emotional or behavioral risk. If data are collected which could prove harmful or embarrassing to the subject if associated with him or her, then describe the methods to be used to insure the confidentiality of data obtained, including plans for final disposition or destruction, debriefing procedures, etc.)

* Allergic reactions to gels and adhesives utilized while performing surface EMG are possible but would be minimized by questioning of subjects prior to the study. The patient would be given control to stop all trials and/or their participation in the study at any time if so desired. Research trials would always be performed in a professional and dignified manner to ensure that the patient's modesty was protected at all times. Furthermore, all of the information collected in this study would be kept confidential by means of the patient-therapist agreement adhered to by all professionals and by locking away of all information obtained in this study as describe in the "Consent Form" section of this form.

All risks associated with this study are minimal and are encountered daily either in the physical therapy or general office work environment.

5. CONSENT FORM: A copy of the **CONSENT FORM** to be signed by the subject (if applicable) and/or any statement to be read to the subject should be attached to this form. If no **CONSENT FORM** is to be used, document the procedures to be used to assure that infringement upon the subject's rights will not occur. Describe where signed consent forms will be kept and for what period of time.

Patients' signed consent forms will be kept in a file cabinet in a locked office, along with all other information obtained in this study, for a period of five years at which time all information will be shredded and disposed of in the garbage.

6. For **FULL IRB REVIEW** forward a signed original and thirteen (13) copies of this completed form, and where applicable, thirteen (13) copies of the proposed consent form, questionnaires, etc. and any supporting documentation to:

Office of Research & Program Development
University of North Dakota
Box 8138, University Station
Grand Forks, North Dakota 58202

On campus, mail to: Office of Research & Program Development, Box 134, or drop it off at Room 101 Twamley Hall.
For **EXEMPT** or **EXPEDITED REVIEW** forward a signed original and a copy of the consent form, questionnaires, etc. and any supporting documentation to one of the addresses above.

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The policies and procedures on Use of Human Subjects of the University of North Dakota apply to all activities involving use of Human Subjects performed by personnel conducting such activities under the auspices of the University. No activities are to be initiated without prior review and approval as prescribed by the University's policies and procedures governing the use of human subjects.

SIGNATURES:

______________________________ **DATE:** __________
Principal Investigator

______________________________ **DATE:** __________
Project Director or Student Adviser

______________________________ **DATE:** __________
Training or Center Grant Director

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