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A Motion-Analysis and Electromyographic Study of the Upper Trapeziues and Forearm Musculature while Typing at Different Heights on a Laptop Computer

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A MOTION-ANALYSIS AND ELECTROMYOGRAPHIC STUDY OF THE UPPER TRAPEZIUES AND FOREARM MUSCULATURE WHILE TPYING AT DIFFERENT HEIGHTS ON A LAPTOP COMPUTER

by

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This Independent Study, submitted by Scott Joseph Kolar 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: A Motion-Analysis and Electromyographic Study of the Upper Trapezius and Forearm Musculature While Typing at Different Heights on a Laptop Computer.

Department: Physical Therapy

Degree: Master of Physical Therapy

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ABSTRACT

Laptop computers have become a common feature in both the workplace and the home. Computer technology has brought about vast benefits in terms of productivity and efficiency; however, the benefits have not come without repercussions. The wide use of laptop computers has without a doubt created an environment in which the user is susceptible to upper extremity cumulative trauma disorder (UECTD), also referred to as repetitive trauma disorder or overuse syndrome. The cost of UECTD to the individual and potentially his/her employer is enormous costing the United States alone an estimated $42 billion per year. Through ergonomic considerations, an optimal work environment for laptop use can reduce injury, worker's compensation costs, medical visits and employee absenteeism while improving comfort and productivity. **Purpose:** The purpose of this study was to determine the most ergonomically correct posture for laptop computer use. **Methods:** Ten subjects, both male and female, between the ages of 22 and 29 years old, were tested. Electromyographical (EMG) and motion analysis data were collected from each subject. Each subject typed one sentence in the four following positions: 1) in the "industry standard" position for the head, neck, eyes, shoulders, forearms and wrists on a desktop computer; 2) in the "industry standard" position for the shoulders, forearms and wrist on a laptop computer; 3) in the "industry standard" position for the head, neck and eyes; 4) laptop computer positioned 30 inches in height from the floor. **Results:** The study revealed that the “industry standard” position for the shoulders, forearms and wrists may be the most ergonomically correct position for laptop use due to the least amount of overall EMG activity in the studied musculature—upper trapezius, flexor digitorum superficialis, extensor digitorum. **Conclusion:** Laptop computer use, in the researcher's opinion, has no ergonomically correct position--due to the strain still endured by the head, neck and eyes--but rather a most ergonomically "forgiving" position which is the “industry standard” position for the shoulders, forearms and wrists.

CHAPTER 1

INTRODUCTION

The use of the computer is a common feature today in both the work place and the home. Between 1990 and 1997 alone, households owning computers more than doubled from 15 to 35 percent.[1] Computer technology has brought on vast benefits to both the work place and to individual users in terms of efficiency and productivity while becoming a full-time task for many workers whether in their office or at home. However, these technological advances have not come without repercussions. The wide use of computers has created an environment in which the computer user is susceptible to injury, more specifically, upper extremity cumulative trauma disorder (UECTD). Injury resulting from computer use is so evident that it has been recognized as "the industrial injury of the Information Age."[2]

Upper extremity cumulative trauma disorder --also referred to as repetitive trauma disorder, repetitive strain injuries and overuse syndrome--is defined as musculoskeletal injuries resulting from high speed, repetitive activities for lengthy, uninterrupted periods of time in static work postures which are often deviated from an ergonomically correct posture.[2-5] Some of the more common characteristic postural deviations of the body include forward displacements of the head and shoulder girdle, scapular protraction, elbow flexion, forearm pronation, ulnar deviation at the wrist with hyperflexion or hyperextension.[4] Initially, UECTD presents as intermittent discomfort and may go undetected for quite some time. Yet over a period of weeks, months or years—soft tissues adapt to these postural deviations and consequently result in muscle imbalances, joint dysfunctions, nerve entrapments along with cumulative inflammation and or damage to muscles, tendons, tendon sheaths, nerves, bursea and blood vessels.[2,4,6]

In the middle of the 1980's, there was an increase in reported UECTD among Australian computer operators.[3] Since that time, the number of office workers reporting musculoskeletal disorders from 1989 to 1993 more than doubled according to the Bureau of Labor Statistics.[7] The reason for this dramatic increase, again, is due primarily to the popularity of the computer in the office and home. The disappointing realization today is that the number of UECTD is only expected to rise; over 60 million Americans, estimated to be almost half of the entire United States (US) workforce, already use computers on a daily basis whether at work or in their home.[4]

The cost of UECTD to the US has been estimated at $42 billion per year in lost wages, medical expenses and administration fees.[6] Upper extremity cumulative trauma disorder not only effects the individual or employee, but also the employer. The employer is faced with the impending medical costs (worker's compensation), temporary disability costs, the decrease in productivity, time required to train a new employee for the job, possible attorney and litigation fees, settlements, and administration costs.[8] To illustrate the cost an UECTD from a monetary standpoint, if a business is operating at a 4% profit margin and one of the business' employees requires one carpal tunnel release surgery as a result of an UECTD with a total cost of $20,000, the business would have to generate an additional $500,000 in sales to compensate for the cost of the surgery.[9] Due to an interesting figure such as this, practical thinking would be to prevent a UECTD before one is incurred; and on an enlightening note, UECTD are close to being entirely preventable through ergonomic considerations.

The term ergonomics is derived from the Greek words ergos meaning "work" and nomos meaning "natural laws of" or "study of."[9] Thus, ergonomics means the natural laws of or the study of work with emphasis between the relationship of the worker and his/her environment. Ergonomics seeks to find the optimal environment suitable for human living and work. A non-optimal environment may cause unnecessary stress to the individual causing injury which in turn can affect the individual's work through a reduction in efficiency and production. An optimal work environment with ergonomic considerations can result in reducing occupational injury and illness, reduce worker's compensation costs, reduce medical visits, reduce employee absenteeism, improve productivity, improve quality of product, and improve worker comfort.[9,10] Importantly, all of these improvements are directly related towards the business' future profitability. Through ergonomics, corrections can be made between the computer and the user to create a more optimal environment to decrease the frequency and prevalence of UECTD to benefit both the individual user and the employer.

While ergonomics is clearly not a new subject for discussion, the development of research in ergonomics involving the most optimal set up of a computer workstation still lacks, especially when looking at laptop computers, also known as notebooks. The emergence of laptop computer users continues to grow rapidly due to the laptop being portable and yet technologically capable to complete most computer tasks. Knowing that

UECTD and laptop computers are becoming more and more prevalent, further research should be accomplished to identify the most ergonomically correct position for laptop computer use.

Problem Statement

There is limited published research that clearly establishes the most ergonomically correct posture for the use of a laptop computer.

Purpose of Study

The purpose of this study is to determine the ergonomically correct posture during laptop computer use by measuring muscle activity when the height of the laptop is: 1) in the "industry standard" position for the shoulders, forearms and wrists; 2) in the "industry standard" position for the head, neck and eyes; 3) 30 inches in height from the floor.

Significance

The significance of the study is threefold. First, the intent of this study is to develop a better understanding of the ergonomic considerations involved with the use of laptop computers. Second, the results of the study and implementation of the ergonomic considerations will directly benefit the individual user of the laptop by providing an environment which decreases the risk of personal injury, more specifically upper extremity cumulative trauma disorder. Third, as a result in a decreased risk of injury, the laptop user may become more efficient and productive during laptop computer use.

Research Questions

1. Is there a difference in muscle activity during laptop computer use when the height of the laptop is: a) in the "industry standard" position for the shoulders, forearms and

wrists; b) in the "industry standard" position for the head, neck and eyes; or c) 30 inches in height from the floor?

2. If there is a difference in muscle activity, which position is the most ergonomically correct for the use of the laptop computer?

Hypotheses

Null Hypothesis: There is no difference in muscle activity during laptop computer use when the height of the laptop is: a) in the "industry standard" position for the shoulders, forearms and wrists; b) in the "industry standard" position for the head, neck and eyes; or c) 30 inches in height from the floor.

Alternative Hypothesis: There is a difference in muscle activity during laptop computer use when the height of the laptop is: a) in the "industry standard" position for the shoulders, forearms and wrists; b) in the "industry standard" position for the head, neck and eyes; or c) 30 inches in height from the floor.

CHAPTER 2

LITERATURE REVIEW

There have been multiple studies completed to address the ergonomically correct posture when using a traditional desktop computer, but what about laptop computers? For example, a traditional desktop computer typically includes a tower, keyboard and visual display terminal (VDT) all of which can be separately and properly placed enabling the user to be in an ergonomically correct posture. However for a laptop computer user, the laptop's VDT and keyboard are connected forcing the user to work in an ergonomically incorrect posture possibly resulting in an UECTD.

Much of the attention towards the ergonomic set-up of a computer has been drawn towards the position of the keyboard. The majority of the previous literature addresses the proper positioning of the keyboard by developing guidelines in two ways: 1) by upper extremity positioning, and 2) by specified heights of the keyboard. First, looking at the upper extremity positioning guidelines, there are four areas to consider which include the shoulders, elbows, wrists and fingers. The shoulders are suggested to be kept down with the chest open and wide.[11] The elbows are to be flexed at approximately 90 degrees; or in other words, the forearms should be parallel to the floor.[11-13] The wrists should be kept in a neutral position.[11,13] This position is approximately 0-20 degrees of extension and slight ulnar deviation.[14] Finally, the fingers should be kept in slight flexion with the second through fifth metacarpal joints in slight ulnar deviation.[11,14] Thus, the keyboard should be set to accommodate these body positions placing the user in an ergonomically correct posture resulting in no unnecessary strain to the computer user. The second set of guidelines is established by determining the height of the keyboard. Keyboard height should be adjustable with a range of 24.5 to 32 inches from the floor to the home row of the keyboard.[15,16] This range in height should accommodate most people. However, this method does not take into consideration the actual size of the computer user. Subsequently, each individual should be given a specified keyboard height.

Next, when looking at VDT placement, the guideline format is rather similar to that of the keyboard. Again, the majority of the previous literature addresses the proper positioning of the VDT by developing guidelines in two ways: 1) by the positioning of the head, neck and eyes, and 2) by specified heights of the VDT. To first look at the guidelines by the positioning of the head, neck and eyes-- the head should be positioned directly over the shoulders, more specifically the earlobe should be above the acromion when looking in the sagittal plane.[11,12] Also to take into consideration is the level of gaze by the eyes of the computer user. The computer user's normal line of sight is typically 10 to 15 degrees below the horizontal eye level with 15 degrees of vision both above and below the normal line of sight.[12,17] Therefore, the VDT should be within a 30 degree cone lowered 10 to 15 degrees below the horizontal promoting visibility and minimizing any strain placed upon the head, neck and eyes. The second VDT positioning guidelines are determined by specified heights from the floor to the center of the screen. A range of 31 to 41.7 inches is preferred.[15] However, this method, again, fails to consider the size of the computer user. Another factor to consider is the angle of the VDT. The appropriate angle to minimize glare is tilting the VDT 15 degrees forward or backward from vertical.[15]

After reviewing the optimal set-ups for both the keyboard and the VDT, one can clearly see the problem laptop computer users are confronted with—the VDT is attached to the keyboard. Ergonomically, it is impossible to achieve an optimal position while using a laptop computer. With the laptop positioned correctly for the shoulders, forearms and wrists—the head, neck and eyes are forced into an ergonomically incorrect posture. From the other viewpoint, if the head, neck and eyes are positioned correctly, unnecessary strain is placed upon the shoulders, forearms and wrists. Due to this dilemma, the intent of the researcher is to perform a study to examine the level of EMG activity in the upper trapezius and forearm musculature. By determining the level of EMG activity, the researcher will identify which of the three laptop positions: 1) the "industry standard" position for the shoulders, forearms and wrists, 2) the "industry standard" position for the head, neck and eyes, or c) 30 inches in height from the floor is most optimal for laptop computer use. The position that elicits the least amount of overall EMG activity is the optimal position.

As for previous EMG studies involving the set-up of a traditional computer, Sekiya[18] found in 1998 that the optimal position for the elbows were at 90 degrees of flexion; since, this was the position that elicited the least amount of muscle activity between the following muscle groups: upper trapezius, extensor digitorum, extensor carpi radialis and brevis, and flexor superficialis. When looking at the position for the head and neck, Chaffin[19] in 1973 reported that fatigue ensues earlier with the increase in neck flexion. In addition, Schuldt[20] found that a vertical cervical spine compared to flexed with the trunk vertical gave lower EMG activity in cervical erector spinae and trapezius musculature.

CHAPTER 3

METHODOLOGY

This project was reviewed and approved by the University of North Dakota Institutional Review Board Prior to the initiation of the study (See Appendix A.)

Subjects

Eleven students from the University of North Dakota Department of Physical Therapy in Grand Forks, ND volunteered to participate in this study. Ten of the eleven subjects met the participation guidelines: negative history of major upper extremity injury, negative history of neck injury, negative history of an allergic reaction to rubbing alcohol, and negative history of an allergic reaction to adhesive tape. This was determined by a questionnaire that was filled out prior to testing (See Appendix B). In addition to filling out the questionnaire, each subject signed a letter of informed consent prior to the testing procedure (See Appendix C). A letter giving permission to use pictures of set-up and positioning was also signed by the appropriate subject (See Appendix D). Of the ten subjects who participated in the study, there were six females and four males. The mean age of the subjects was 24.4 while the mean height was 68.4 inches. Characteristics of the subjects are summarized in Table 1.

Table 1. Characteristics of Subjects (n=10)

Subject	Age (years)	Gender (M/F)	Height (inches)
1	23	F	66
2	24	M	76
3	24	M	73
4	23	F	64
5	26	F	70
6	23	F	68
7	22	F	69
8	29	M	69
9	25	M	65
10	25	F	64

Instrumentation

Multiple pieces of equipment and software programs were used in the process of data collection during this study. Additional information for the equipment and software programs which includes the manufacturer and the manufacturers' location can be found in Appendix E.

Motion Analysis

The collection of data involved the use of one PULNix video camera with optional 60/120 Hz scanning frequencies (Figure 1). Due to the slow speed of gross body movement in the typing position, the 60 Hz setting was used with the shutter speed set at 1/250 of a second. The camera was placed perpendicular to the sagittal plane of the subject. Video information was recorded on the video tape using a JVC Model BR-S378U S-VHS VCR. In order for synchronization of the EMG and motion analysis data to take place, the PEAK Event Synchronization Unit was used while a Horita TG-50 SMPTE Time-Code Play Speed Reader, Generator Window produced the time code on the video tape to aid in the transfer and synchronization of the data (Figure 2). After the

Figure 1. Photograph showing set-up of PULNix video camera

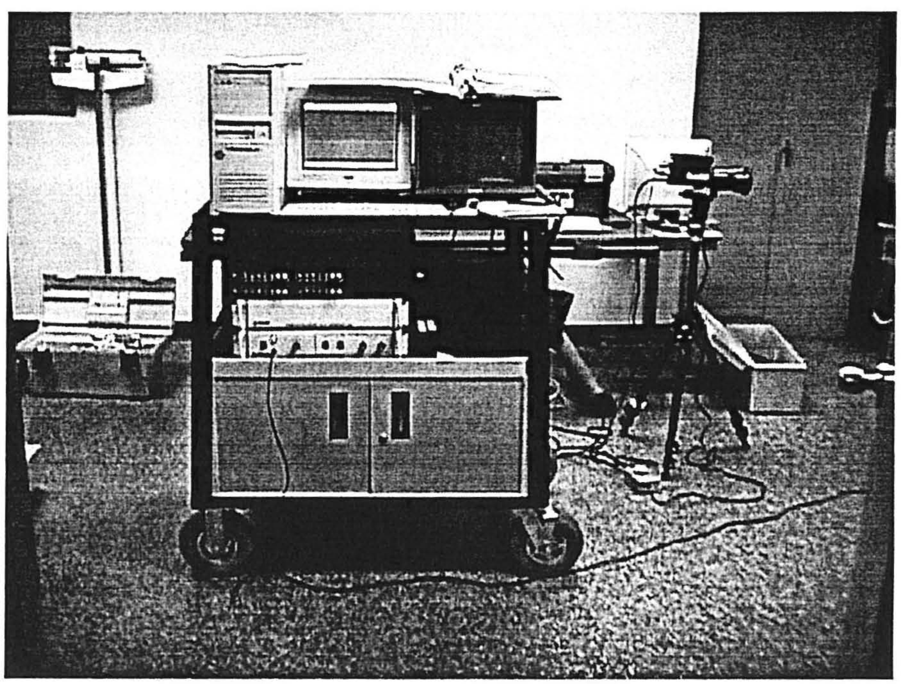

Figure 2. Photograph showing set-up of the data collection equipment

recording of each individual trial, the video taped data was transferred via a Sanyo Model GVR-S955 SVHS VCR and a Sony Trinitron Color Video Monitor to the PEAK Technologies System. The motion analysis data was interpreted using the PEAK Technologies System equipped with the Peak Motus 2000 Version.

Electromyography

Electromyographic (EMG) signals were used to determine the activity of the upper trapezius, flexor digitorum superficialis and extensor digitorum musculature. Self-adhesive pre-gelled surface electrodes were placed on the subjects to record the EMG activity. The EMG data was collected using a Noraxon Telemyo 8 telemetry unit. The telemetried EMG data was connected by a NorBNC and accepted by a PEAK Analog Module.

Procedure

Prior to the initiation of the study, the motion analysis and EMG equipment was pre-tested for proper collection and calibration by the researcher. Subjects were asked to report to the University of North Dakota Department of Physical Therapy. The purpose and procedure of the study were explained to the subjects prior to individual testing. Each subject then signed a statement of informed consent and filled out the questionnaire.

The subjects, both females and males, were asked to wear black lycra pants. The females in the study were required to wear a halter top to protect their modesty; while the males were instructed to be tested without any form of a shirt. Upon returning with the appropriate attire, surface EMG sites were prepared by shaving excess hair from the area followed by scrubbing the site with rubbing alcohol to aid in signal conduction. Surface EMG electrodes were placed over predetermined motor points on the subject's right side.

The motor points were marked as follows: 1) the cervical trapezius (wide) placement[21] is defined as having one electrode placed in the middle cervical area approximately at C-4 and about 1 cm from the middling over the muscle mass, while the second electrode is placed over the upper fibers of the trapezius approximately half the distance between the cervical vertebra at C-7 and the acromion (See Figure 3); 2) the flexor digitorum superficialis placement[22] is defined as placing two electrodes 2 cm apart when palpating for the greatest movement in the middle of the forearm on the ventral side when asking the subject to flex only the fingers and not the wrist (See Figure 4); 3) the extensor digitorum placement[21] is defined by placing two electrodes 2 cm apart on a line one-fourth the distance from the lateral epicondyle to a point midway between the radial and ulnar styliods (See Figure 5).[20,21] A ground electrode was placed over the olecranon. The respective leads from the electrodes were connected to the transmitter.

Following the placement of the electrodes, reflective markers were placed on the subject's right side to record for motion analysis data. Markers were placed over the following landmarks: 1) anterior to the external meatus; 2) posterior to the cannula of the eye; 3) acromion; 4) lateral epicondyle of elbow; 5) ulnar styliod; 6) fifth metacarpal head; and 7) greater trochanter (See Figures 6 & 7). In addition, a marker was placed on the side of the desktop computer and laptop computer screens one-third from the top.

Once the placement of the electrodes and reflective markers was completed, the subject was ready to begin typing the four trials, one on a desktop computer and three on a laptop computer. Subjects were instructed to type the sentence, "*The boy climbed up to the top of the mountain.*" The keyboard used in the desktop trial was a Dell Quiet Key

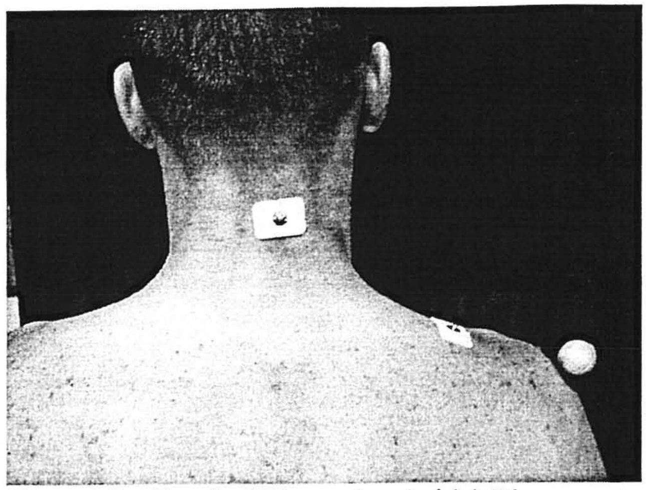

Figure 3. Cervical Trapezius (wide) Placement

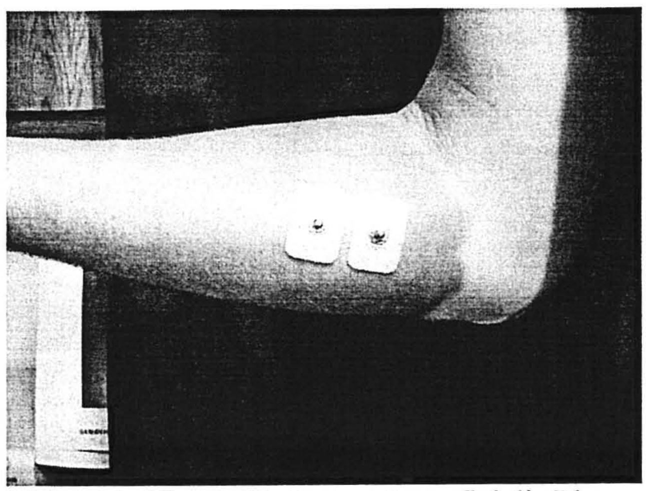

Figure 4. Flexor Digitorum Superficialis Placement

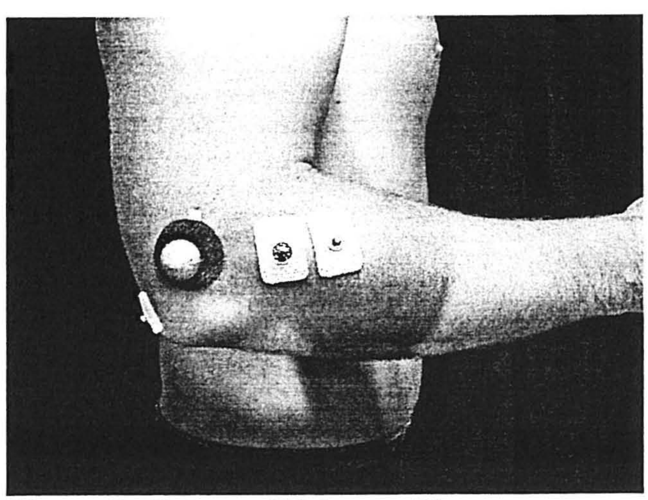

Figure 5. Extensor Digitorum Placement

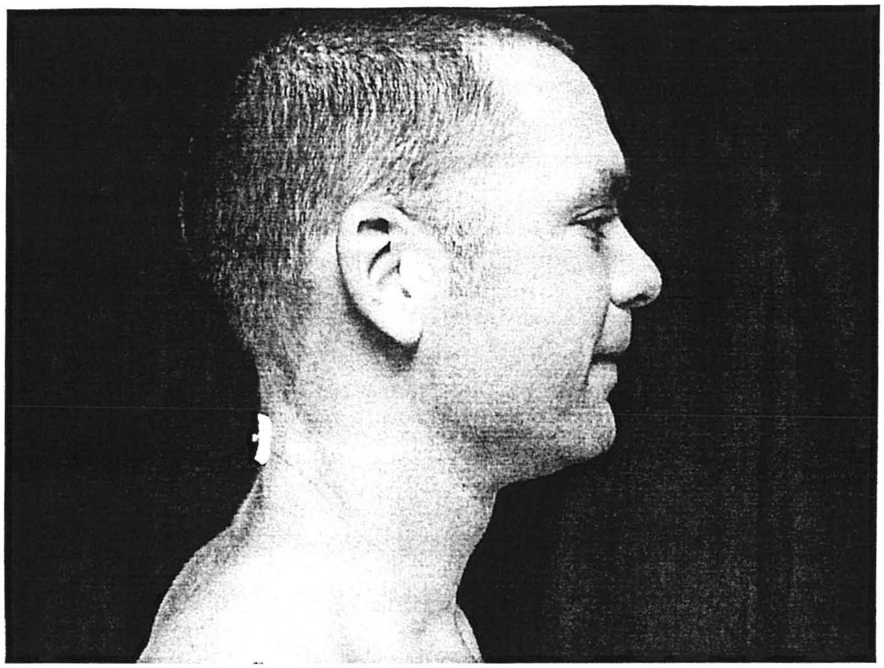

Figure 6. Reflective marker placement of external meatus and cannula of eye

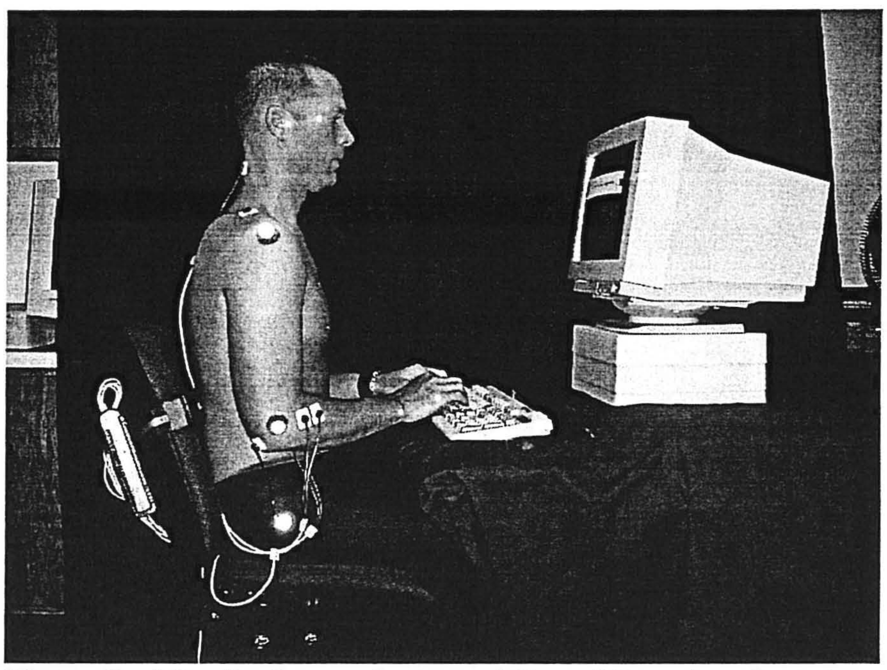

Figure 7. All reflective markers consisting of the external meatus, cannula of eye, acromion, lateral epicondyle, styloid process of ulna, fifth metatarsal head, greater trochanter, and one-third from the top of the screen

and the laptop was a Toshiba Satellite Pro 400CDT. Each subject was asked to practice typing the sentence once prior to the start of each trial. Also, the subjects were informed to continue typing regardless of spelling or grammatical errors incurred during the trial. The first trial was typing in an "industry standard" position on a desktop computer for comparison of the three different trials on the laptop computer. Following the desktop trial, each of the three laptop computer trials were performed in a rotating sequence by each subject thus providing randomization. Therefore, the first computer trial to be discussed is typing in an "industry standard" position on a desktop computer. The subject was first positioned on a height adjustable office chair and was positioned with the knees at 90 degrees, hips at 90 degrees while the subject's feet were flat on the floor. The monitor was positioned with the subject's eyes horizontal to the top of the screen, while the keyboard was placed at a height that allowed the subject's elbows to be at 90 degrees with the wrists in a neutral to slightly extended position (See Figure 8). The first respective laptop trial to be discussed is with the laptop computer placed in an "industry standard" position for the shoulders, forearms and wrists. The laptop was positioned with the subject's elbows at 90 degrees regardless of the position of the head and neck (See Figure 9). The second respective laptop computer trial performed by the subject was typing in an "industry standard" position for the head, neck and eyes. The laptop computer was positioned with the subject's eyes horizontal to the top of the screen irregardless of the position of the elbows and wrists (See Figure 10). The third and final respective laptop trial consisted of the subject typing on a laptop computer 30 inches from the ground which is considered a common table height for laptop computer use (See Figure 11).

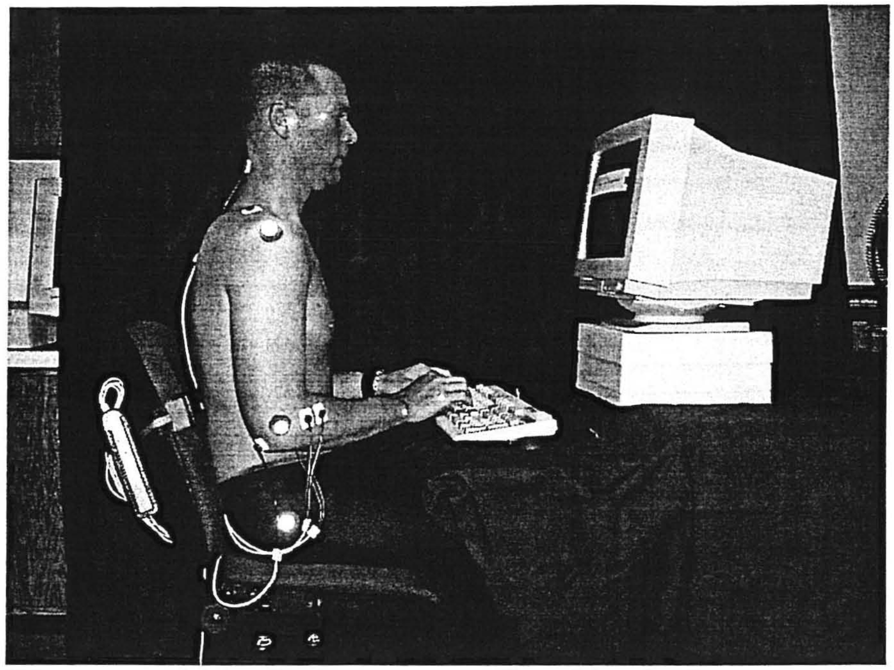

Figure 8. Trial 1 – "Industry standard" position for the head, neck, eyes, shoulders, forearms and wrists on a desktop computer

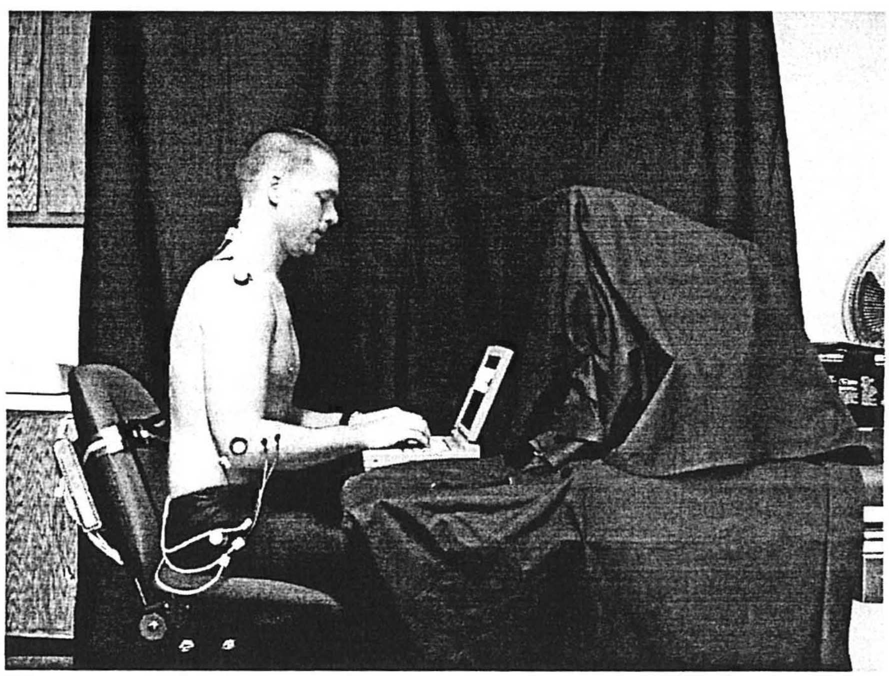

Figure 9. Trial 2 (respective) – "Industry standard" position for the shoulders, forearms and wrist on a laptop computer

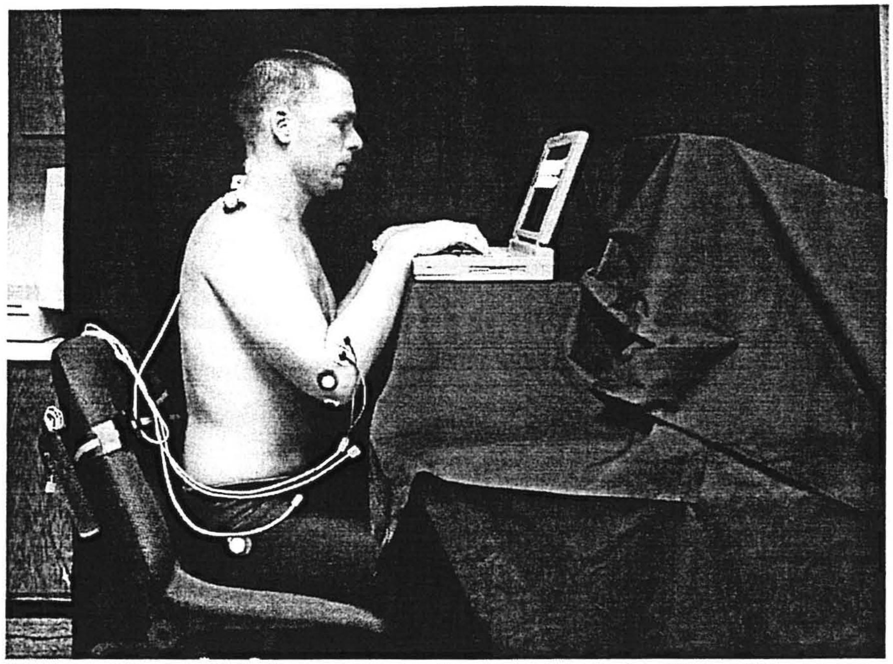

Figure 10. Trial 3 (respective) - "Industry standard" position for the head, neck and eyes on a laptop computer

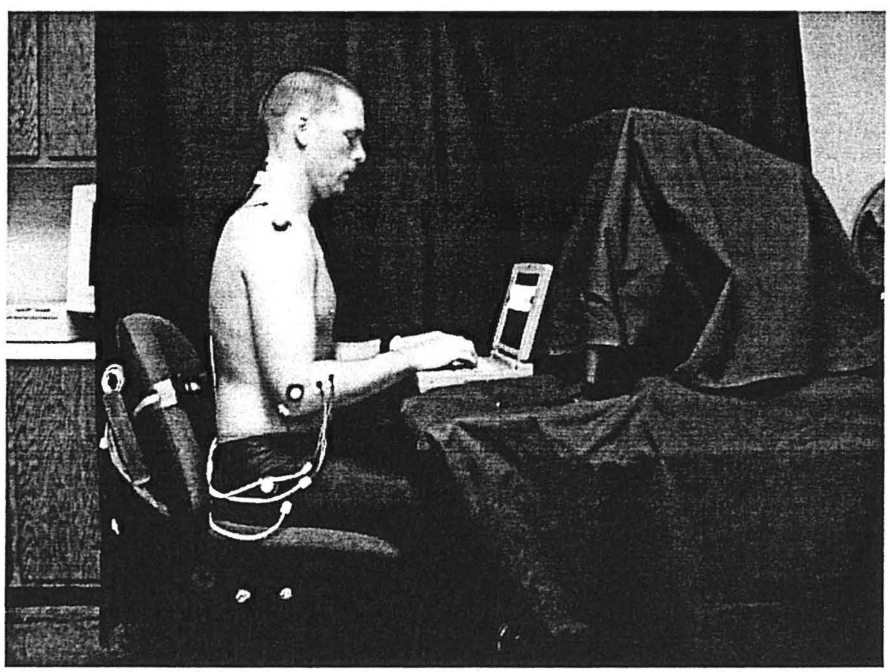

Figure 11. Trial 4 (respective) – Laptop computer positioned 30 inches from the ground

Following the fourth trial, the EMG electrodes and reflective markers were removed from each subject, and the skin was cleansed with rubbing alcohol where the EMG electrodes and reflective markers were attached. The subjects were advised that minimal redness of the skin in the area of the electrode was normal; however, if redness persisted or a rash developed, he/she should contact the researcher for possible medical follow-up. Each subject was then thanked for his/her participation in this study.

Data Analysis

Motion Analysis

The motion analysis data compiled from the study was transferred to the SPSS Version 10.0 for Windows for statistical analysis. For each of the four trials, the mean and standard deviation was completed for each angle studied.

Electromyographic

The EMG data compiled from the study was represented in graph form showing the mean raw muscle activity for each muscle studied during each of the four trials.

CHAPTER 4

RESULTS

Motion Analysis

The results of the following angles, represented in degrees of range of motion (ROM), measured upper and lower neck flexion, shoulder flexion, wrist flexion and extension, elbow flexion, and the subject's line of sight. The angle of upper neck flexion was formulated using Reid's line in relation to the horizontal plane.[23] Reid's line is defined by a line connecting the outer canthus of the eye and the center of the external meatus and is approximately 10 degrees above the horizontal. The measurement of lower neck flexion was derived by taking the angle of the external meatus and greater trochanter with the acromion as the vertex. Shoulder flexion is defined as the angle between the lateral epicondyle and greater trochanter again with the acromion as the vertex. As for the angle of wrist flexion and extension, the styloid process of the ulna was used as the vertex with the lateral epicondyle and the fifth metatarsal head utilized as vectors. Elbow flexion was defined as the angle between the acromion and styloid process of the ulna with the lateral epicondyle as the vertex. Finally, the angle which represented the line of sight was determined by the angle between Reid's line and a plane from a predetermined point on the screen, one-third from the top, and the outer canthus of the eye.[23] The motion analysis results for the four laptop positions are listed in Table 2. The number on top is the actual angle while the number below is the standard deviation.

Table 2. Motion Analysis Results

	Trial 1 *"Desktop"*	Trial 2 *"Shoulders/ Forearms/ Wrists"*	Trial 3 *"30 inches in height"*	Trial 4 *"Head/ Neck Eyes"*
Upper Neck Flexion	169.6 3.4	180.8 1.4	175.3 2.4	166.9 2
Lower Neck Flexion	161.7 2	155.1 1.4	151.9 2.1	133.4 2.6
Shoulder Flexion	5.4 1.1	8.4 1.1	17.3 1.1	43.4 1.3
Elbow Flexion	96 2.2	90.6 1.8	89.2 2.8	109.4 5.2
Wrist Extension	11.4 4.4	-7.5 2.9	-17.7 3	-33.3 3.9
Line of Sight	162.3 3.7	140.1 1.3	144.2 2.4	157.6 2.3

Electromyographic

The EMG results illustrating the comparison of muscle activity for the wrist extensors, wrist flexors and upper trapezius between the four typing trials: 1) "industry standard" position typing on a desktop computer; 2) "industry standard" position for the shoulders, forearms and wrists typing on a laptop computer; 3) typing on a laptop computer positioned 30 inches from the ground; and 4) "industry standard" position for the head, neck and eyes can be seen in Figures 12-14 respectively. The results shown reflect the raw EMG mean for the ten subjects.

When comparing the activity of the wrist extensors between the four trials, there appears to be a similarity in the amount of muscle activity for the three laptop trials regardless of the different positions. However, there seems to be a modest increase in the amount of wrist extensor muscle activity in the desktop trial when compared to the three laptop trials. When looking at the muscle activity of the wrist flexors, there appears to be no noticeable difference between any of the trials regardless of laptop placement. Finally

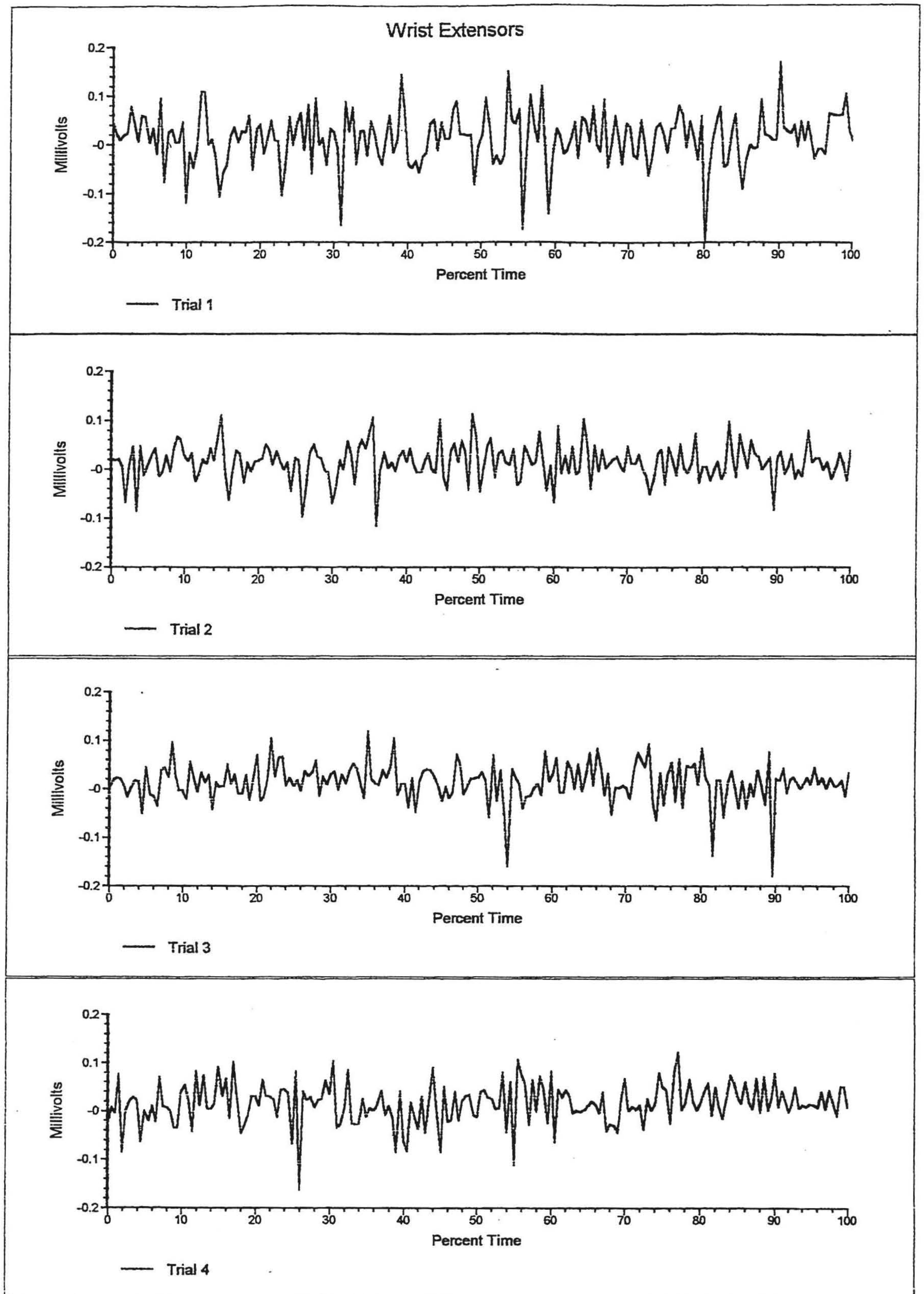

Figure 12. Wrist Extensor Raw EMG Mean

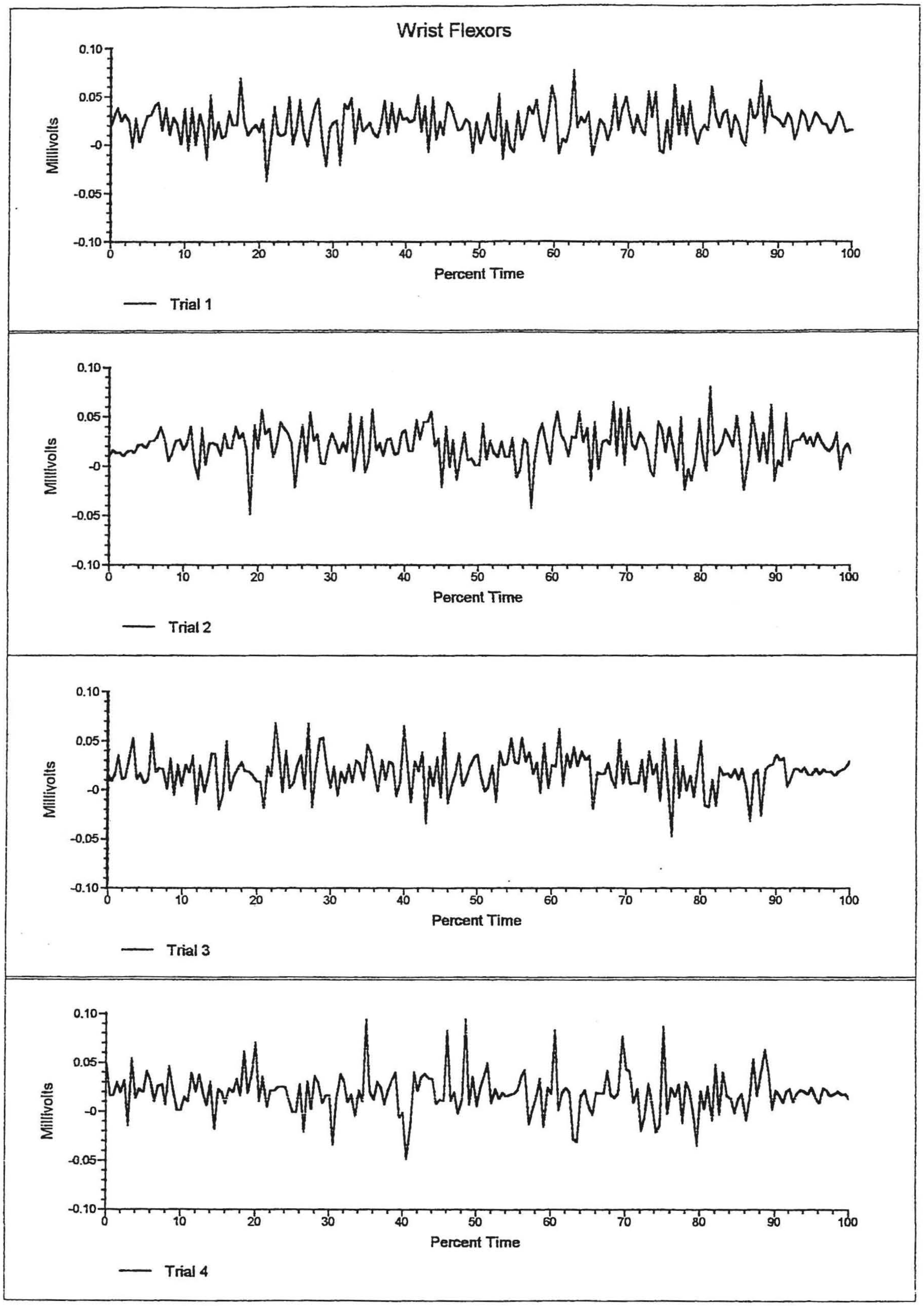

Figure 13. Wrist Flexor Raw EMG Mean

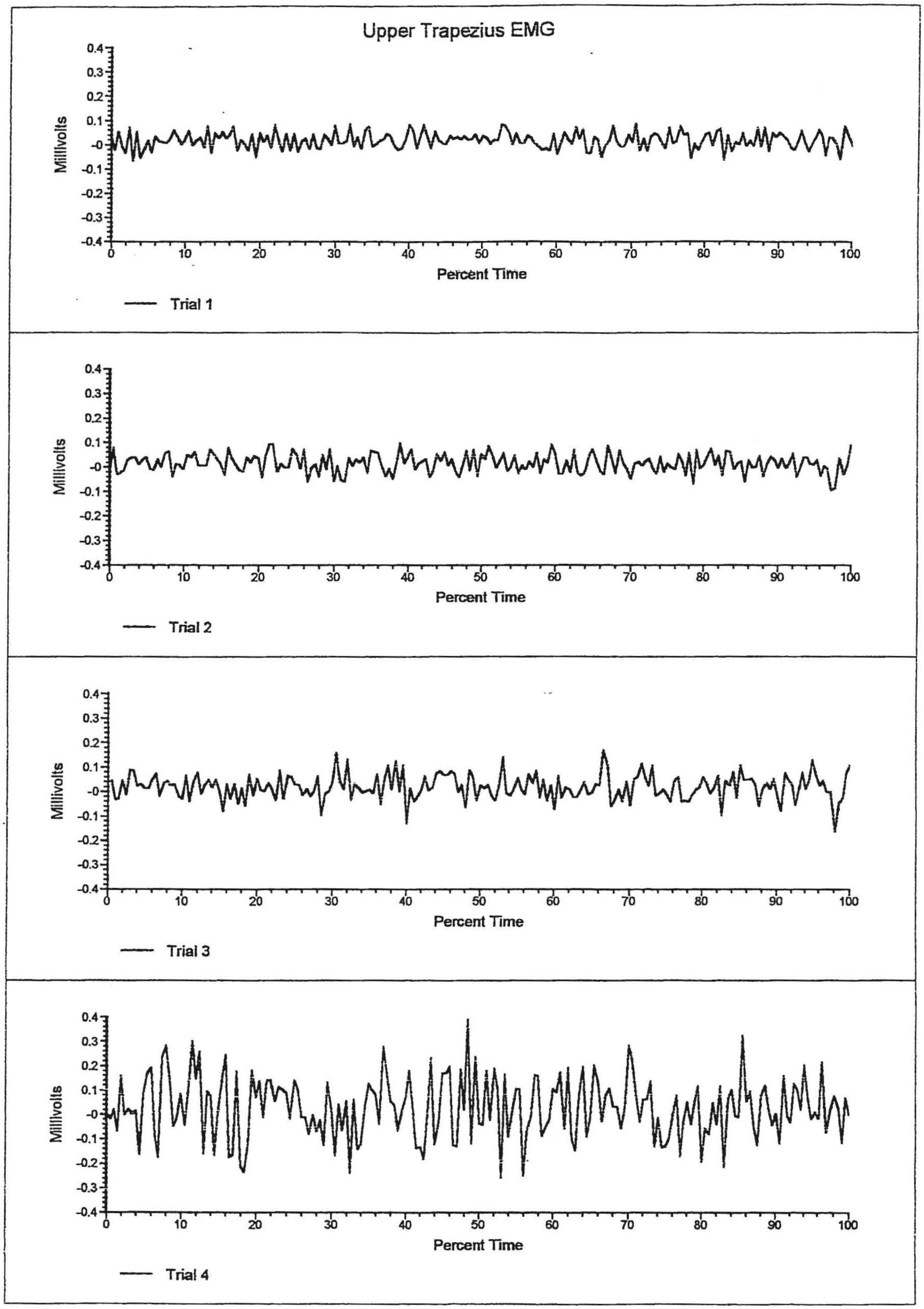

Figure 14. Upper Trapezius Raw EMG Mean

when studying the upper trapezius, similarity is not the case. There is clearly an increase in muscle activity between the four trials. Upper trapezius activity increased as the height of the laptop increased during the four typing trials.

CHAPTER 5

DISCUSSION

The EMG results revealed that there is a difference in muscle activity when comparing the four typing trials. Thus, the answer to research question #1-- is there a difference in muscle activity during laptop computer use when the height of the laptop is: a) in the "industry standard" position for the shoulders, forearms and wrists; b) in the "industry standard" position for the head, neck and eyes; or c) 30 inches in height from the floor-- was "yes," thereby supporting the alternative hypothesis. With the first research question being answered, what becomes true for research question #2-- if there is a difference in muscle activity, which position is the most ergonomically correct for the use of the laptop computer? The researcher found that the "industry standard" position for the shoulders, forearms and wrists may be the most ergonomically correct position for laptop computer use due to the least amount of overall muscle activity. There was not an apparent difference in muscle activity between the laptop trials when comparing both wrist flexors and extensors making these muscles a so-called proverbial "wash." Therefore, when looking at the difference in muscle activity for the upper trapezius during the laptop trials, the position that elicited the least amount of EMG activity was to be defined as the most ergonomically correct posture which ultimately was the "industry standard" position for the shoulders, forearms and wrists.

Limitations

Undoubtedly as with any study, this study was faced with limitations, all of equal importance, impeding the overall goal to find the most ergonomically correct position for laptop computer use. First, the number of subjects participating was exceedingly small. For future studies, it is recommended that data be collected from more subjects and across different age groups. Second, there should be an equal number of males and females participating in the study. As for the third limitation, a second camera should be implemented to monitor shoulder abduction along with EMG electrodes placed to record the muscle activity of the middle deltoid and supraspinatus. Fourth, the integration of EMG data would enable the data collected from the muscle activity to be statistically tested for significance. Finally, while the "industry standard" position for the shoulders, forearms and wrists may be the most ergonomically correct position for laptop computer use—the amount of strain, due to the excessive amount of downward gaze, placed on the eyes should also be monitored and taken into consideration.

Conclusion

The wide use of laptop computers has without a doubt created an environment in which the user is susceptible to upper extremity cumulative trauma disorder. Upper extremity cumulative trauma disorders not only effect the user, but may also effect his/her employer. Therefore, the employer may be faced with the impending medical costs, temporary disability costs and decreases in productivity.[8] Through ergonomic considerations, an optimal work environment for laptop computer use can reduce injury, worker's compensation costs, medical visits and employee absenteeism while improving comfort and productivity.[9,10] The purpose of this study was to determine the ergonomically correct posture for laptop computer use due to the limited amount of published research. Following the completion of the study and considering the limitations, the following conclusion is made: the "industry standard" position for the shoulders, forearms and wrists may be the most ergonomically correct position for laptop computer use. Regardless, the laptop computer, in the researcher's opinion, has no ergonomically correct position but rather a most ergonomically "forgiving" position. Less overall strain to the body is endured with the laptop placed in the "industry standard" position for the shoulders, forearms and wrists; but the head, neck and eyes still are not in an ergonomically correct position.

The real question that should be considered is in the design of the laptop computer itself. From an ergonomics standpoint, the laptop computer should fit the user; the user should not have to fit the laptop computer. The laptop computer should take a design more similar to the desktop computer in that the laptop should have a telescoping screen enabling proper positioning of the head, neck and eyes as well as proper positioning for the shoulders, forearms and wrists; yet at the present, none are seen on today's market.

Currently, there are docking bays that allow laptop users to attain an ergonomically correct posture; however, a laptop was designed to be portable so the user does not need to have an accompanying docking bay and additional monitor. Another key point to remember is that each computer user, laptop or desktop, should take necessary breaks and perform stretching and strengthening exercises regularly. However, further discussion of these exercises does not fall within the immediate scope of this study. On a final note, the researcher strongly promotes the need for additional studies and improvements in design for the pursuit of an ergonomically correct posture for the use of laptop computers.

APPENDIX A

x EXPEDITED REVIEW REQUESTED UNDER ITEM ____ (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

Please include ALL information and check ALL blanks that apply.

PRINCIPAL INVESTIGATOR: Scott Joseph Kolar TELEPHONE: 787-5532 DATE: 5-27-00

ADDRESS TO WHICH NOTICE OF APPROVAL SHOULD BE SENT: 322 North Columbia Road, Grand Forks, ND 58203

SCHOOL/COLLEGE: Univ. of North Dakota (E.g., A&S, Medicine, EHD, etc.) DEPARTMENT: Physical Therapy PROPOSED PROJECT DATES: 6/15/00 – 12/31/00 (Month/Day/Year)

PROJECT TITLE: A Motion-Analysis and Electromyographic Study of the Neck, Upper Trapezius, and Forearm Musculature While Typing at Different Keyboard Heights on a Laptop Computer.

FUNDING AGENCIES (IF APPLICABLE): NA

TYPE OF PROJECT (Check ALL that apply):

___ 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 ___ INVOVLES A COOPERATING INSTITUTION

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

[ ] MINORS (<18 YEARS) [ ] PREGNANT WOMEN [ ] MENTALLY DISABLED [ ] FETUSES [ ] PERSONS WITH MENTAL RETARDATION

[ ] PRISONERS [ ] ABORTUSES [x] UND STUDENTS (>18 YEARS)

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

IF YOUR PROJECT HAS BEEN\WILL BE SUBMITTED TO ANOTHER INSTITUTIONAL REVIEW BOARD(S), PLEASE LIST NAME OF BOARD(S): ____________

Status: ___ Submitted; Date ________ ___ Approved; Date ________ ___ Pending

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

The purpose of this study is to determine the optimal position while typing on a laptop computer which presents with the least amount of health risk to the individual. This optimal position will combat the effects of upper extremity cumulative trauma disorder, often found to present in individuals who perform high speed repetitive activities for lengthy periods of time on computers. Thirty students regularly performing keyboarding activities will be tested to determine the level of muscle activity of the cervical extensors, upper trapezius, wrist flexors and wrist extensors as well as monitor the angle of the neck, elbow and wrist while typing on a laptop computer. Muscle activity will be measured using surface electromyography (EMG) while joint angle will be monitored using motion analysis. Three different laptop heights will be used: optimal position for the forearm and wrist, optimal position for the neck, and fifty percent in between. This study will to add to the knowledge of ergonomics by determining the optimal position for laptop use by the individual and to reduce the amount of health risk.

PLEASE NOTE: Only information pertinent to your request to utilize human subjects in your project or activity should be included on this form. Where appropriate attach sections from your proposal (if seeking outside funding).

2. **PROTOCOL:** (Describe procedures to which humans will be subjected. Use additional pages if necessary. Attach any surveys, tests, questionnaires, interview questions, examples of interview questions (if qualitative research), etc., the subjects will be asked to complete.)

Subjects:

The study will recruit subjects from UND through class announcements. The subject will participate voluntarily receiving no monetary reward, however the subject will gain experience and knowledge of becoming part of a research team. In addition, subjects must present with no history of upper extremity or cervical injury.

Methods:

The study will be conducted in the Physical Therapy Department at the University of North Dakota. Upon entering, the subject will be given verbal instructions on the purpose and procedure of the experiment and will then be asked to sign a consent form and fill out the questionnaire. While typing, we will measure EMG activity in the selected muscles: 1) cervical extensors, 2) upper trapezius, 3) wrist flexors and 4) wrist extensors to measure the amount of muscle activity.

To record EMG activity, adhesive electrodes will be placed over each muscle. The precise electrode placement will be determined from standard electrode placement charts. Prior to placing the EMG electrodes, the skin over each placement site will be prepared by cleansing the skin with rubbing alcohol. The EMG signals will be transmitted to a receiver unit and then fed into a computer for display and recording of data. The subject will perform a maximum voluntary contraction, standard protocol, against the testers resistance for each muscle tested. This value will be considered 100% and allows for a comparison measure.

As for motion-analysis, reflective markers will be attached to the hand, wrist, elbow and neck. This will allow the motion-analysis video equipment to monitor the joint angles of the subject. Men will not wear any clothing from the waist up while women will be required to wear a halter top to protect the subject's privacy.

The subject will then type a predetermined paragraph in each of the three positions: 1) optimal position for the shoulders, forearms and wrists, 2) optimal position for the neck, and 3) fifty percent in between. Following the activity, the subject will be instructed to stretch the used muscles to reduce any potential muscle soreness.

Data Analysis:

The mean activity of each monitored muscle will be calculated. The EMG data collected during the experiment will be expressed as a percentage of the EMG activity recorded during the maximal contraction prior to the typing trials. The video image will be converted to a stick-man like figure, from which we can determine joint angles. The EMG data is synchronized with the video data to determine the level of EMG activity during the three typing trials.

3. **BENEFITS:** (Describe the benefits to the individual or society.)

The study will provide further information to the growing field of ergonomics. The results should add to the current knowledge of ergonomics and assist in the prevention of cumulative trauma disorder with laptop computer users. The subject will also gain experience and knowledge of becoming part of a research team. We also hope to add to the subjects knowledge of ergonomics to minimize potential health risks.

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 psychological, 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 protect the confidentiality of data obtained, debriefing procedures, storage of data, how long date will be stored (must be a minimum of three years), final disposition of data, etc.)

The risk to the subject in this study should not exceed that of a regular work day. The activity of typing itself may contribute to cumulative trauma that occurs secondary to repetitious movements. Again however, the amount of typing would not exceed a normal work day. The subjects will be asked to stretch the respective muscles which are used during typing. Also in rare instances, irritation from the surface EMG electrodes may occur. This will be minimized by adequate preparation of the skin surface. The subject has the option to halt the study at any time for any reason. As for confidentiality, the subject will be known only as an identification number rather than name throughout the study, and the subject's file will be locked in the Associate Professor's office at the University of North Dakota School of Medicine and Health Sciences Physical Therapy Department.

5. **CONSENT FORM:** Attach 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 how long (must be a minimum of 3 years), including plans for final disposition or destruction.

Signed consent forms and videos will be kept locked in the Associate Professor's office at the University of North Dakota School of Medicine and Health Sciences Physical Therapy Department from collection until a period of three years. Following the three year period, the files will be shredded and videos will be erased. Again, confidentiality will be maintained at all times with the use of identification numbers rather than name.

6. For **FULL IRB REVIEW** forward a signed original and fifteen (15) copies of this completed form, including fifteen (15) copies of the proposed consent form, questionnaires, examples of interview questions, etc. and any supporting documentation to the address below. An original and 19 copies are required for clinical medical projects. In cases where the proposed work is part of a proposal to a potential funding source, one copy of the completed proposal to the funding agency (agreement/contract if there is no proposal) must be attached to the completed Human Subjects Review Form if the proposal is non-clinical; 7 copies if the proposal is clinical medical. If the proposed work is being conducted for a pharmaceutical company, 7 copies of the company's protocol must be provided.

Office of Research & Program Development
University of North Dakota
Grand Forks, North Dakota 58202-7134

On campus, mail to: Office of Research & Program Development, Box 7134, or drop it off at Room 105 Twamley Hall.

For **EXEMPT** or **EXPEDITED REVIEW** forward a signed original, including a copy of the consent form, questionnaires, examples of interview questions, etc. and any supporting documentation to one of the addresses above. In cases where the proposed work is part of a proposal to a potential funding source, one copy of the completed proposal to the funding agency (agreement/contract if there is no proposal) must be attached to the completed Human Subjects Review Form.

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:

Principal Investigator ______________________ Date ________

Project Director or Student Adviser ______________________ Date ________

Training or Center Grant Director ______________________ Date ________

(Revised 2/2000)

STUDENT RESEARCHERS: As of June 4, 1997 (based on the recommendation of UND Legal Counsel) the University of North Dakota IRB is unable to approve your project unless the following "Student Consent to Release of Educational Record" is signed and included with your "Human Subjects Review Form."

STUDENT CONSENT TO RELEASE OF EDUCATIONAL RECORD[1]

Pursuant to the Family Educational Rights and Privacy Act of 1974, I hereby consent to the Institutional Review Board's access to those portions of my educational record which involve research that I wish to conduct under the Board's auspices. I understand that the Board may need to review my study data based on a question from a participant or under a random audit. The study to which this release pertains is A Motion-Analysis and Electromyographic Study of the Neck, Upper Trapezius, and Forearm Musculature While Typing at Different Keyboard Heights on a Laptop Computer.

I understand that such information concerning my educational record will not be released except on the condition that the Institutional Review Board will not permit any other party to have access to such information without my written consent. I also understand that this policy will be explained to those persons requesting any educational information and that this release will be kept with the study documentation.

Date ______________ Signature of Student Researcher ______________

[1]Consent required by 20 U.S.C. 1232g.

REPORT OF ACTION: EXEMPT/EXPEDITED REVIEW
University of North Dakota Institutional Review Board

Date: June 13, 2000 **Project Number:** IRB-200006-241

Name: Scott Joseph Kolar **Department/College:** Physical Therapy

Project Title: A Motion-Analysis and Electromyographic Study of the Neck, Upper Trapezius, and Forearm Musculature While Typing at Different Keyboard Heights on a Laptop Computer

The above referenced project was reviewed by a designated member for the University's Institutional Review Board on June 15, 2000 and the following action was taken:

☒ Project approved. EXPEDITED REVIEW Category No. 2+4
Next scheduled review is on: June 2001

☐ Project approved. EXEMPT REVIEW Category No. ______
This approval is valid until ______ as long as approved procedures are followed. No periodic review scheduled unless so stated in the Remarks Section.

☐ Project approved PENDING receipt of corrections/additions. These corrections/additions should be submitted to ORPD for review and approval. **This study may NOT be started UNTIL final IRB approval has been received.** (See Remarks Section for further information.)

☐ Project approval **deferred. This study may not be started until final IRB approval has been received.** (See Remarks Section for further information.)

☐ Project **denied.** (See Remarks Section for further information.)

REMARKS: Any changes in protocol or adverse occurrences in the course of the research project must be reported immediately to the IRB Chairperson or ORPD.

PLEASE NOTE: **Requested revisions for student proposals MUST include adviser's signature.**

Douglas Peters 6-15-00
Signature of Designated IRB Member Date
UND's Institutional Review Board

cc: Beverly Johnson, Adviser
Chair, Physical Therapy
Dean, School of Medicine

If the proposed project (clinical medical) is to be part of a research activity funded by a Federal Agency, a special assurance statement or a completed 310 Form may be required. Contact ORPD to obtain the required documents.

1(1/98)

APPENDIX B

Questionnaire

Name: ____________________

Age: ______

Height: ______

Do you have a history of major upper extremity injury? Yes No

If yes, please explain:____

____

Do you have a history of neck injury? Yes No

If yes, please explain:____

____

Are you allergic to rubbing alcohol? Yes No

Are you allergic to adhesive tape? Yes No

Thank you for agreeing to participate in this study. A copy of the results will be made accessible to you when the study is complete. If you have any questions or comments, please feel free to contact me at the UND Physical Therapy Department.

University of North Dakota
Physical Therapy Department, Box 9037
Grand Forks, ND 58202
(701) 777-2831
Attn: Scott Kolar

APPENDIX C

INFORMATION AND CONSENT FORM

A Motion-Analysis and Electromyographic Study of the Neck, Upper Trapezius and Forearm Musculature While Typing at Different Heights on a Laptop Computer.

Principal Investigators: Scott Kolar and Bev Johnson from the Department of Physical Therapy at the University of North Dakota

You are being invited to participate in this study of the measurement of muscle activity and joint angle while typing on a laptop computer. The purpose of this study is to determine the optimal position while typing on a laptop computer. We hope that the results of this study will aid physical therapists in assisting laptop users in need of ergonomic training. We also hope to further educate those involved in the production of laptop computers to minimize personal injury.

You were chosen because: 1) of your experience in keyboarding and computer use, 2) you lack of history of major upper extremity injury in the past year

As a subject for this study, you will be asked to report to the Physical Therapy Department at the University of North Dakota, located in the Medical Science North Building. Your age, height, and weight will be recorded. Following this, you will be asked to remove your shirt for application of electrodes and reflective markers. This may involve some clipping of excess hair and cleaning of the area with an alcohol swab. Two sets of four electrodes (8 in all) will be attached to the skin over the forearm, shoulder and neck. The electrodes are attached to the surface of the skin with an adhesive material. We will also attach reflective markers at various points on your upper extremity. Your muscle activity will be monitored and one camera will be filming your activity to measure the angles of your joints. You will be asked to type a predetermined paragraph at three different heights on a laptop computer. The testing should take approximately one hour.

Although the process of physical performance testing always involves some degree of risk, the investigators in this study feel that, because of your prior training, the risk of injury or discomfort is minimal. Minor muscle soreness may result following the repeated activity. However, to minimize this, you will be taken through a brief warm-up and cool-down consisting of stretches prior to and following the testing.

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. The data will be identified by a number known only to the investigators. The investigators or participant may stop the experiment at any time if the participant is experiencing discomfort, pain, fatigue, or any other symptoms that may be detrimental to his/her health. Your decision whether or not to participate will not prejudice your future relationship with the Physical Therapy Department at the University of North Dakota. If you decide to participate, you are free to discontinue participation at any time without prejudice.

The investigators involved are 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 Scott Kolar or Beverly Johnson at (701) 777-2831. At your request, you will be given a copy of this form for future reference.

In the event that this research activity results in a physical injury, medical treatment will be as available as it is to a member of the general public in similar circumstances. You and your third party payer must provide payment for any such treatment.

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. I have read all of the above and willingly agree to participate in this study as it is explained to me by Scott Kolar.

____

Subject's signature Date

____

Witness' signature Date

APPENDIX D

RELEASE STATEMENT

I hereby give my permission to the University of North Dakota, its agents, successors, assigns, clients and purchasers of its services and/or products, to use my photograph (whether still, motion or television)

Name:

Signed:____

Date:____

Address:_______________________________________

City:____

State and Zipcode:________________________________

APPENDIX E

PULNiX Video Camera
PULNiX America Inc.
1330 Orleans Drive
Sunnyvaly, CA 94089

JVC Model BR-S378U S-VHS VCR
JVC of America
41 Slater Drive
Elmwood Park, MD 07407

PEAK Event Synchronization Unit
PEAK Performance Technologies
7388 S. Revere Parkway, Suite 601
Englewood, CO 80112-9765

Horita TG-50 SMPTE Time-Code Play Speed Reader, Generator Window Inserter
Horita
P.O. Box 3993
Mission Viejo, CA 92690

Sanyo Model GVR-S955 SVHS VCR
Sanyo Fisher (USA) Corporation
1200 W. Artesia Boulevard
Campton, CA 90220

Sony Trinitron Color Video Monitor
Sony Corporation

PEAK Motus 2000 Version
PEAK Performance Technologies
7388 S. Revere Parkway, Suite 601
Englewood, CO 80112-9765

Noraxon Telemyo 8 telemetry unit
NORAXON USA, INC.
13430 North Scottsdale Road
Suite 104
Scottsdale, AZ 85254

NorBNC
NORAXON USA, INC.
13430 North Scottsdale Road
Suite 104
Scottsdale, AZ 85254

PEAK Analog Module
PEAK Performance Technologies
7388 S. Revere Parkway, Suite 601
Englewood, CO 80112-9765

Dell QuietKey Keyboard
Dell Home Systems
P.O. Box 149261
Austin, TX 78714

Toshiba Satellite Pro 400CDT
Toshiba America Information Systems, Inc.
9740 Irvine Boulevard
Irvine, CA 92618-1697

SPSS for Windows
SPSS Inc.
233 S. Wacker Drive
11th Floor
Chicago, IL 60606

REFERENCES:

1. Rubey TC. Profile of computer owner's in the 1990's. Available at: http://stats.bls.gov/opub/mlr/1999/04/atissue.htm. Accessed May 17, 2000.

2. Thompson JS, Phelps TH. Repetitive strain injuries: how to deal with the "epidemic of the 1990's". *Postgrad Med.* 1990;88(8):143-149.

3. Zecevic A, Miller DI, Harburn K. An evaluation of the ergonomics of three computer keyboards. *Ergonomics.* 2000;43(1):55-72.

4. Keller K, Corbett J, Nichols D. Repetitive strain injury in computer keyboard users: pathomechanics and treatment principles in individual and group intervention. *Hand Therapy.* 1998;11(1):9-26.

5. Ho SF. What you need to know: work with visual display units--what are the health concerns? *Singapore Med J.* 1999;40(9):612-613.

6. Marcus M, Gerr F. Upper extremity musculoskeletal symptoms among female office workers: associations with video display terminal use and occupational psychosocial stressors. *Am J Ind Med.* 1996;29(2):161-170.

7. Serina ER, Tal R, Rempel D. Wrist and forearm postures and motions during typing. *Ergonomics.* 1999;42(7):938-51.

8. Ross P. Ergonomic hazards in the workplace: assessment and prevention. *AAOHN.* 1994;42(4):171-176. Cited by: Sekiya KM. An Electromyographic Study of the Forearm and Upper Trapezius Musculature While Typing at Different Keyboard Heights. Thesis (M.P.T.)--University of North Dakota, 1998.

9. Issuree R. Ergonomics. Unpublished Lab Manual. Work taken from: Roy Matheson's 1998 Ergonomic Evaluation Professional Residency Program.

10. Ong CN. Musculoskeletal disorders in operators of visual display terminals. *World Health Forum.* 1994;15(2):161-164.

11. Pascarelli E, Quilter D. *Repetitive Strain Injury: A Computer User's Guide.* New York, NY: John Wiley and Sons, Inc.; 1994:161.

12. Ala M, Ala M, Bagot G. Ergonomics in the laboratory environment. *Nurs Manag.* 1994;25(7):50-52.

13. Schaffer WA, Cross R. *Ergowise: A Personal Guide to Making Your Workplace Comfortable and Safe.* New York, NY: American Management Association; 1996:60-61.

14. Kaltenborn FM. *Manual Mobilization of the Extremity Joints.* N-0182 Oslo 1, Norwawy: Olaf Norlis Bokhandel; 1989:52,70.

15. Tijerina L. *Video Display Terminal Workstation Ergonomics.* Dublin, OH: OCLC; 1984:17-18.

16. Anderson MA. Ergonomics: analyzing work from a physiological perspective. In: Isernhagen, SJ. *The Comprehensive Guide to Work Injury Management.* Gaithersburg, MD: Aspen Publishers, Inc.; 1995:3-39.

17. Huchingson RD. *New Horizons for Human Factors in Design.* New York, NY: McGraw-Hill Book Company; 1981:198, 200.

18. Sekiya KM. An Electromyographic Study of the Forearm and Upper Trapezius Musculature While Typing at Different Keyboard Heights. Thesis (M.P.T.)--University of North Dakota, 1998.

19. Chaffin DB. Localized muscle fatigue--definition and measurement. *J Occup Med.* 1973;15:346-354. Cited by: Villanueva MB, Sotoyama M, Jonai H, et al. Adjustments of posture and viewing parameters of the eye to changes in the screen height of the visual display terminal. *Ergonomics.* 1996;39(7):933-945.

20. Schuldt K. On neck muscle activity and load reduction in sitting postures: an electromyographic and biomechanical study with applications in ergonomics and rehabilitation. *Scand J Rehabil Med Suppl.* 1988; 19:1-49. Cited by: Villanueva MB, Sotoyama M, Jonai H, et al. Adjustments of posture and viewing parameters of the eye to changes in the screen height of the visual display terminal. *Ergonomics.* 1996;39(7):933-945.

21. Cram JR, Kasman GS. *Introduction to Surface Electromyography.* Gaithersburg, MD. Aspen Publishers, Inc.; 1998:246-249,323-324.

22. Basmajian JV, Blumenstein R. *Electrode Placement in EMG Biofeedback.* Baltimore, MD. The Williams and Wilkins Company; 1980:72.

23. Villanueva MB, Sotoyama M, Jonai H, et al. Adjustments of posture and viewing parameters of the eye to changes in the screen height of the visual display terminal. *Ergonomics.* 1996;39(7):933-945.