Oh, My Aching Laptop: Expanding the Boundaries of Campus Computing Ergonomics

Pat Wyatt
B.D. Owens Library
Northwest Missouri State University
Maryville, Missouri 64468
660-562-1669

pjp@nwmissouri.edu

Kim Todd
Information Systems
Northwest Missouri State University
Maryville, Missouri 64468
660-562-1434

kdt@nwmissouri.edu

Tabatha Verbick
Information Systems
Northwest Missouri State University
Maryville, Missouri 64468
660-562-1434

tab@nwmissouri.edu

ABSTRACT

Feeling pins-and-needles in your fingers, having a sore back, blurry vision or aching wrists are common symptoms for many employees in the technology field. Such aches and pains are often warning signs that significant injuries are just one more mouse click away. Until recently, such ailments have not traditionally been considered common symptoms for students. Yet, with the rapid growth of game-playing software, computer-related coursework and online classes, which cause students to spend longer hours in front of a computer, repetitive stress injuries are inevitable. Consequently, such injuries should and must be considered in the educational environment by department heads and information technology personnel. Repetitive stress injuries are of particular concern at Northwest Missouri State University, where all campus-housed residents are provided with campus-owned notebook computers. Notebook computers can increase the chances of injury since the monitor and keyboard cannot be positioned separately. Also, due to the notebook computer's portability students can work in locations and positions that can increase the risk of acquiring repetitive stress injuries from neck pain to carpal tunnel syndrome. Computer users need more education and training in the science of ergonomics in order to avoid injuries.

In this paper, users and educators will learn techniques for adapting workspaces and habits in order to perform at optimum efficiency. The paper will define the problems and costs associated with workspace ergonomics and offer solutions to these problems. Additionally, the authors will discuss techniques to avoid repetitive stress injuries and how to effectively train users before injuries occur.

Categories and Subject Descriptors

K.4.2 [**Computers and Society**]: Social Issues – *assistive technologies for persons with disabilities, handicapped persons/special needs.*
K.7.0 [**The Computing Profession**]: General.
K.8.m [**Personal Computing**]: Miscellaneous.

K.4.1 [**Computers and Society**]: Public Policy Issues –*computer-related health issues, human safety.*
K.3.2 [**Computers and Education**]: Computer and Information Science Education –*information systems education.*
K.3.1 [**Computers and Education**]: Computer Uses in Education.
J.7 [**Computers in Other Systems**]: Consumer Products.

General Terms: Management, Performance, Economics, Reliability, Human Factors

Keywords: Computer ergonomics, ergonomics, repetitive strain injuries, workplace, computer lab design, workstation design, computer setup, cumulative trauma disorder, workplace injuries, notebook computers, ergonomics education, classroom design, RSI, CTD, classroom computing.

1. INTRODUCTION

Prior to the 1990s when students were asked to describe a classroom, they typically talked about rows of wooden desks with straight-backed chairs and a teacher lecturing in front of a blackboard. A place where pencils, rulers, 3-ring notebooks and white, ruled notebook paper were standard classroom equipment and overhead projectors and possibly a television with a VCR was the extent of high-tech in the classroom. However, with the growth of the personal computer industry, educational institutions across the nation began to recognize the learning potential of both computers and the internet. Consequently, as computers began making their way into the workplace and home, they also began making inroads into the classroom. With increased use of the computer for academic and work-related tasks, as well as recreation, students—like their adult working counterparts—are sometimes spending eight or more hours per day staring at monitors and hunched over their keyboards.

The Baby-Boomers of today did not have computers in the classroom. For them, computer usage injuries are due to unhealthy work environments not recreational computing activities.

College students today have spent a significant portion of their life working at a computer for academic, work and recreational purposes. Repetitive strain injuries (RSI), such as carpal tunnel syndrome and tendonitis, have been seen in adults who work with computers and are also increasing in number among college age and younger students. Therefore, prevention is key and educational institutions need to develop a strategy to educate students on ergonomic issues, while providing ergonomically designed classrooms and computing labs. Consequently, the days of the straight-backed-chair classroom are undoubtedly numbered, if not actually a potential health hazard to students expected to use computers on a daily basis to complete class assignments.

According to the U.S. Occupational Safety and Health Administration (OSHA), nearly two million people have work-related musculoskeletal disorders, including RSI injuries caused by computer use [9]. In the past, RSI injuries or cumulative trauma disorders (CTDs) were typically thought to be primarily an adult problem. However, computers in every classroom were the stuff of educators' wishful-thinking and dreams, since such equipment was expensive and usually too bulky to fit into an average classroom. Now that computers have become more commonplace in schools across the nation, the risk of students suffering such RSI and other related injuries is of growing concern.

The furniture an educational institution chooses for its classrooms and computing labs is a critical component of both the technology's overall success and student health. However, very few higher education institutions significantly invest in or devote enough consideration to ergonomic electronic classroom and computing lab design. According to an article by Mike Kennedy, the "influx of computers into classrooms means schools need to pay more attention to ergonomic furnishings" [15].

Besides furniture, educators and students need to be cognizant of ergonomics in connection with the computer's design. Notebooks have become extremely popular due to their portability. However, according to Professor of Ergonomics at Cornell University, Alan Hedge, notebook computers are ergonomically incorrect. "Laptops inherently violate one of the rules of ergonomics," because the "keyboard is attached to the monitor" and this makes it "virtually impossible to position both correctly at the same time" [15].

When notebook computers were first designed, they were considered to be secondary machines to the desktop [15]. Consequently, ergonomics were not taken into account. Since the new millennium, notebook computers have become the favorite choice among on-the-go, space-conscious, computer users. Notebook computers are rapidly replacing their more bulky desktop counterparts in offices, both at home and at work, as well as, in classrooms and campus dorm rooms. With more and more computer users adopting the ergonomically incorrect notebook computer as their main computing machine, CTDs are inevitable.

Technology innovations, such as notebook computers and palm pilots, are revolutionizing today's traditional blackboard classrooms. Classrooms in the future will need to adapt to these innovations by implementing not only the new technologies, but ergonomic designs and ergonomic awareness education that takes into consideration the use of those technologies.

2. HEALTH HAZARDS OF COMPUTING

Repetitive strain injuries typically do not develop overnight, but gradually occur and are only noticeable after weeks, months or even years of work at a computer involving repetitive motion and improper use of muscles, tendons, nerves and joints.

Computers have become ubiquitous in today's society. Currently, 90% of the US workforce uses computers to perform at least some aspects of their jobs with over 40% of the individuals using the computer for at least 4 hours per day [23]. Contrary to popular myth, RSI is not dependent upon long hours spent over a keyboard or mouse. "One man who only used computers a couple of hours a day and never more than 40 minutes at a stretch eventually became so disabled he could barely turn the pages of a magazine" [17]. If spending less than two hours per day at a computer can cause such severe disabilities, imagine what spending four plus hours per day typing and mousing away can do to one's health. Even something as

simple as long fingernails can cause improper positioning of the fingers and hands, thereby causing stress on the hands and wrists [17].

Employers spent approximately "20 billion dollars in workers compensation in 2002" for injuries associated with computer-related muscle and joint disorders with "indirect costs of 60 billions dollars annually" [23]. Beyond the exorbitant costs to employers', an employee forced to suffer a debilitating CTD due to performing their job suffers a tremendous psychological, physical and personal toll.

Musculoskeletal injuries due to computer usage can affect most areas of your body from your head to your toes. Common areas of discomfort or injury include head, eyes, neck, back, shoulders, arms, elbows, wrists, hands, hips, legs, knees, feet and ankles. In the following sections, the common injuries along with their causes will be discussed.

2.1 Eyes

Lack of awareness of computing ergonomics is particularly true with regard to visual ergonomics. Computer vision syndrome (CVS)[1] has become of far greater concern with the growing dependence upon computers for everything from chatting with friends via instant messenger to taking notes on a notebook computer.

CVS problems can result from sitting too close to your monitor, working too long without resting your eyes, not blinking frequently enough, wearing glasses or contact lenses with out-of-date prescriptions, inadequate lighting or too much lighting and poor contrast or refresh rate on a computer screen. According to one ergonomist, 39% of monitors were placed too close to the user and 53% of workers were subject to too much glare from their computer screens. These conditions can cause eyestrain and aggravate vision problems such as astigmatism, hyperopia and myopia [6, 2].

Staring at a computer screen for long periods of time can cause fatigue, eyestrain, headaches, increased sensitivity to light, double or blurred vision, difficulty shifting focus between the computer monitor and paper documents and other problems. CVS can be caused by looking at a dirty computer screen or having the monitor situated at a poor angle. While not considered to have long-term consequences, CVS can be uncomfortable, personally and professionally disruptive and can dramatically reduce overall work productivity [1].

2.2 Head and Neck

Common complaints of users who spend long hours at their computers are headache and neck pain. Reaching for that bottle of Ibuprofen is fine for occasional head and neck pain. When head and neck pain are persistent, finding the underlying cause of the problem and correcting it is imperative. For instance, incorrect positioning of your computer monitor can cause a user to twist and tilt in their chair to view the screen and thus, cause neck pain, which in turn can induce a headache.

According to one ergonomist's report, 65% of monitors were placed too high [6]. Likewise, if a user's chair is too far away from the keyboard or tilted backward, it can cause arms to be outstretched awkwardly forcing the neck and shoulders to work hard to support

---

[1] The American Optometric Association defines CVS as the "complex of eye and vision problems related to near work, which are experienced during or related to computer use."

their weight and thus, place extra stress and strain on the neck. Leaning too far forward can also result in such discomfort. Often computer users will multi-task while working at a computer. They may be answering the telephone or assisting patrons. When using both a telephone and a computer simultaneously, a common practice is to cradle or support the telephone between the head and shoulder creating an angle which can lead to neck pain, headaches and potential shoulder issues [16].

2.3 Shoulders, Upper Arms and Elbows

Tennis elbow is no longer restricted to tennis players. In fact, someone who spends long periods of time keyboarding and mousing may suffer the same painful condition as someone swinging a tennis racket each weekend.[2] Pain in the elbows, shoulders and upper arms are also common complaints of computer users. Such discomfort is the result of repetitive motion and typically improperly designed workstations. Just reaching for a mouse can lead to shoulder discomfort if the mouse is unsuitably positioned. According to an ergonomist's report, 51% had keyboards that were too high for true shoulder comfort [6].

Ninety-percent of all American computer workstations have design problems that can promote pain and fatigue in the muscles, tendons and joints of shoulders, upper arms and elbows. Only 11% of workstations in the same report had desk or other work surfaces with adjustable heights [6].

2.4 Forearms, Wrists and Hands

According to the latest statistics, a significant percent of the population of the United States suffers from some sort of wrist, forearm or hand pain due to repetition of motion needed for computing tasks. Approximately 3 to 5% of that population has carpal tunnel syndrome, which causes numbness, tingling, pain and weakness in the thumb, index, middle and ring finger [19]. The symptoms can worsen over time, flaring up when someone least expects it, such as when driving a car or simply cleaning up after dinner. According to one study, "conditions diagnosed as 'carpal tunnel syndrome' resulted in the highest median number of days lost from work than all other injuries and illnesses combined" [23].

Worker's compensation claim information from 1986 to 1993 revealed a significant increase in CTDs associated with mousing. Zero cases were reported in 1988 and by 1993 over 325,000 were reported. According to the report, 51% were for wrist injuries and 46% were the result of mouse-related activity. Thirteen percent involved carpal tunnel syndrome [13]. With the passage of 13 years and the expansion of the internet, mouse usage has increased dramatically and thereby increasing wrist injuries.

Yet, the mouse is not the only CTD culprit. Striking the keys of a keyboard with too much force may also cause unnecessary pressure to fingers, wrists and palms promoting numbness in the fingers, aches in the knuckles and wrist discomfort. Trackballs can also produce pain in a user's fingers, particularly the thumb.

2.5 Hips, Legs, Knees, Feet and Ankles

Although the lower extremities are not often cited as typical CTDs, improperly-designed computer workstations can cause problems just like with the wrists and back for these areas. For example, if a

CPU is placed under the desk, it can force the user's legs into an uncomfortable position leading to poor circulation and thus, to cramping and knee pain. Adequate space beneath a desk is important, particularly if a user has long legs. Legs need sufficient movement for adequate blood flow. Furthermore, if the work chair does not have an adjustable backrest and is not padded sufficiently, a user may suffer from hip pain. If a user's chair is too high, legs will dangle and cause poor circulation and wide-ranging discomfort from the toes to the lower back [11].

Since notebook computers are portable, users often work with them in positions and places that are not conventional. Thus, notebook computers due to common personal usage practices are even less conducive to good ergonomics with regard to the hips, legs, knees, feet and ankles.

2.6 Upper and Lower Back

Working at a computer while in an awkward position, on a desk that is too high or too low or without an ergonomically-designed chair to support and promote good posture can cause minor to major back pain. Some causes of upper and lower back pain include an improperly adjusted chair height, inadequate lumbar support and dangling feet that do not reach the floor. According to an ergonomic report, 56% of chairs could not be correctly adjusted. More than 70% of adjustable chairs were not properly adjusted [6]. Additionally, if a keyboard or mouse is located too far away, reaching for the keyboard or mouse can cause a user to slump or lean forward.

People come in all shapes and sizes and workstations need to accommodate different body types for ease of movement and to avoid CTDs. Too often the upper and lower back will suffer strained muscles because of a workstation's ergonomic inadequacies. Unfortunately, inadequate workstations may also mean long-term back difficulty for the unaware user.

3. DETECTING INJURIES

Ergonomics have often been defined as the science of fitting the task to the worker, which in turn increases physical comfort while reducing the possibility of injury. Too often institutions fail to invest the time and money in good ergonomic design and awareness education, both of which can drastically save that institution money and manpower in the long-term. Moreover, detecting and diagnosing injuries due to repetition or cumulative trauma can be challenging. In the early stages, the symptoms include minor body aches and slight fatigue that disappears when you are away from work. As the injuries progress in severity, the pain from the injury returns soon after starting work and the injury site feels weak, both of which often last long after work has ended. In the more severe stages of injury, the injured area hurts and is weak even when it is at rest. At this stage, sleep often becomes impaired and the performance of simple tasks are often painful and difficult [8].

For those at risk of acquiring carpal tunnel syndrome, such as anyone who uses a computer frequently, awareness of the problems that can arise from highly repetitive movements is a critical component to preventing such injuries. Too often computer users, particularly students, are ignorant of the damage that can come from long hours spent keyboarding, mousing or using a joystick for game-playing. Proper use of the keyboard, mouse or joystick is imperative to prevention of carpal tunnel and other joint pain such as tendonitis.

---

[2] Tennis elbow is defined by Merriam-Webster Online as "inflammation and pain over the outer side of the elbow usually resulting from excessive strain on and twisting of the forearm."

The importance of early detection and prevention cannot be stressed enough. In the first two stages of injury, complete recovery is common when the injury is treated promptly and preventative measures are put in place and practiced to keep the injury from reoccurring. In the final stage, the rate of recovery is varied depending upon the severity of the injury. Oftentimes, surgery, medications, time away from work and other treatments are required and result in anywhere from a partial to full recovery [8]. After noticing symptoms of RSI or CTD, seeking the immediate assistance of a health care professional trained in RSI and CTD is imperative for long-term health and for a complete and fulfilling career free of disabilities caused by such injuries.

4. PREVENTING AND HEALING INJURIES

In any higher education institution or business, height of a male or female may "range from as little as 4 feet to well over 6 feet" and "forward grip reach may range from 26 to 34 inches." Additionally, sitting eye height may "range from 27 to 34 inches" [6]. Consequently, computer users do require furniture and equipment that meets their particular body type specifications. If the accommodations do not meet individual user's needs, CTDs can be the result.

When considering all the effects of computer use, the treatment and prevention of injuries is imperative, especially considering the wide range of solutions available. Many companies, schools or colleges are lax when educating their staff or faculty about the hazards associated with computing. If faculty and staff are uninformed about computer ergonomics, they will not be able to successfully educate students and customers about appropriate solutions. In the following sections, many suggestions for improving the computing workspace environment will be discussed, including tips for purchasing furniture, mice, keyboards, software and other needed materials to make work less hazardous and more productive.

4.1 Workspace Accommodations

Ergonomic considerations should never be dismissed as unimportant or unnecessary because a work area's past history has been relatively free of injuries. According to OSHA estimates, the loss of productivity, due to physical aches and pains and lowered employee morale, "costs up to three times as much each year as the $15 million paid out in workers' compensation claims" [6]. Although injuries may not be reported, discomfort may be prevalent and result in more sick days, lack of productivity and overall dissatisfaction with the job and environment.

Though appropriate workspace accommodations might be an added up-front expense, the long-term costs are relatively low when compared to the cost of healthcare for treating CTD injuries and the lifelong impact such injuries can have on an individual. Through careful planning, computer users and institutions can make adjustments in workspace areas to fit individual ergonomic needs without breaking the bank.

4.1.1 Furniture

Depending upon the size of budget, furniture accommodations can be a major expense or just a minor inconvenience. For faculty and staff, a basic desk is usually a given, but typically is not ergonomically correct for computing. Students may or may not have a suitable desk. Often, students are seen working while sitting in a chair or laying on a sofa or the floor. These computing positions are ergonomically detrimental. The best way to work at a computer is to use appropriate furniture and posture. According to *CergoS*, the workstation should support the user with adjustable desks, chairs and footrests [7].

Since every user is different and workstations are often used by more than one individual, the height of a workstation needs to be adjustable. One way to accommodate users of varying heights would be to purchase monitor risers, adjustable chairs and footrests. Footrests can be purchased from a variety of vendors. However, if cost is a concern, a simple footrest can be constructed from some plywood and carpet remnants.

Adjustable chairs can range anywhere from $29 to $1000. The adjustability of the chair height, armrests and seat depth should always be taken into consideration before purchasing. Many students will often to buy the less expensive chair from a discount store, when they really should consider purchasing a higher-quality chair that will last them throughout their academic career. Less expensive chairs generally do not have adjustable seat depth, arm height or possibly even seat height.

According to Richard W. Boss, the desk or work surface is typically the first consideration when designing a computing workspace [6]. The desk needs to be wide and deep enough to accommodate whatever type of computer the user selects. Boss notes that the minimum desk size should be at least 60 x 30 inches. Also within these considerations, the desk needs to be adjustable or should be the appropriate height for the majority of users. One should also look at whether or not the desk has a separate keyboard tray. If the desk does not come with a keyboard tray, the desk should be tall enough to accommodate the mounting of a separately purchased keyboard tray. The ideal keyboard tray can be tilted in negative position or left in a neutral position. Positive keyboard tilts cause the hands to bend upward, thereby putting stress on the hands, wrists and forearms [26].

4.1.2 Keyboards and Mice

Several different types of keyboards are available to users today. Many considerations should be taken into account when thinking about purchasing a keyboard. When a buyer selects a complete computer system, the keyboard is generally included. The keyboard included with the system is typically a basic 104+ keyboard, which does not meet ergonomic needs. Many users may find that the standard keyboard does not fit as well as a split or curved keyboard.

While standard keyboards come with most computers, users can purchase a keyboard that meets their ergonomic needs. Natural and other ergonomically-designed keyboards can be purchased from various vendors such as Ergonomic Resources: http://www.ergonomicsmadeeasy.com.

One of the first considerations when selecting a keyboard is to determine whether the user is right or left-handed. Hand domination can be an issue with respect to the number pad. A split keyboard that has the number pad on a separate cord that can be moved to either side of the keyboard works well for a left-handed user, since a standard keyboard has the number pad on the right side.

Regardless of the type of keyboard selected, the keyboard and tray should set up at the appropriate height, so as not to cause shoulder or hand pain. Also, consider whether or not the wrists are bent. The wrists should be kept in a neutral or negative position and the forearm should be the only part of the arm to rest on the keyboard tray [11].

Another issue facing users is the type of mouse connected to the computer. Laptop users have the built-in touchpad, but will sometimes attach a separate mouse of choice. Many people cannot grip the standard mouse for a variety of reasons or injuries. According to *AbilityNet,* users should try several different mice to find the appropriate pointing device for them. Some users will choose to use the standard mouse, while others may pick a trackball or ergonomic mouse, such as the Whale Mouse or the Cirque Cruise Cat touch pad. Other types of mice available to users include a touch window, which requires special software, touch screens, joysticks, foot driven mice and electronic pens [14]. Ultimately, the decision concerning the correct mouse is entirely up to the preference and ergonomic needs of the user.

4.1.3 Monitors and Lighting

Monitors and lighting vary from one workstation to another. Monitors should always be set directly in front of the user and not at an angle. Having the monitor off to the side causes the user to turn their body in an unnatural way and can lead to a CTD [6]. In addition to horizontal positioning of the monitor, the height of the monitor is also of concern. A too high monitor can be resolved by raising the chair height and thus bringing the user to a more level viewing position. To accommodate a low monitor, a monitor riser can be utilized or an adjustable chair can be lowered. An inexpensive monitor riser is a large phone book or a sturdy box. A new solution for monitor positioning that has appeared in many of the ergonomic catalogs today is the rollout flexible arm for flat-panel monitors [25]. Another solution for a monitor that takes up too much of the depth of the workstation is to purchase a flat screen monitor [16].

For users wearing bifocals or trifocals, a lower monitor position can help the user be more comfortable. Another alternative for vision considerations is to purchase special computer glasses that would eliminate the need for bifocals or trifocals while using a computer.

The user should also consider the screen resolution of the monitor. College students will many times set the display for 1024 X 768 pixels, which is not conducive to promoting good visual ergonomics.

According to a website sponsored by *Healthy Computing*, the monitor glare can also be a major problem at the workstation. By dimming the lights, many times the glare is eliminated. Also, windows can be the culprit for causing glare on the monitor. Whenever possible, do not place computers in front of a window regardless of whether or not, the monitor is facing the window. If windows are unavoidable, try adding shades or curtains to the windows to darken the room slightly and filter out the harshest of the suns rays. Fluorescent overhead lighting can also cause dramatic glare. Task lighting is often the best solution to remove glare [11].

4.1.4 Document Holders and Telephones

Another ergonomic device that has been around for a long time is the document holder. The traditional document holder can still be found, but in today's catalogs new more ergonomic versions can be purchased. Some of the new versions include document holders that are attached to the monitor, both on the side and in front. The new document holders allow the document to be placed in a position that does not cause awkward movements of the head, which will eventually cause pain in the shoulders, neck and back.

Other ergonomic options to alleviate head and neck pain caused by traditional telephone usage are headsets and speakerphones. While both solutions facilitate simultaneous use of the computer and telephone without the high risk of CTDs, protecting the privacy of the conversation is difficult with a speakerphone. Speakerphones work best in quiet environments since too much noise will diminish the sound quality [11]. Another suggestion for better ergonomic telephone usage is to place the telephone in a secondary work zone, so the user is forced to step away from the computer, allowing somewhat of a rest while answering calls [16].

4.1.5 Software

Many new ergonomic software packages have been developed to help computer users. For users with CTDs or other disabilities, *Dragon NaturallySpeaking* is a way to complete duties and assignments with minimal use of a keyboard or mouse. *Dragon NaturallySpeaking* offers users the ability to dictate Word documents, surf the web and use email. Though an expensive software package, *Dragon NaturallySpeaking* is the highest recommended software package of its type. Other less expensive software packages are available, but are more limited in usability.

Users often work at their computers for extended periods of time without taking a break which leads to CTDs. Software packages are available to remind users to take a break and do some simple exercises and stretches. One program that receives the highest reviews is *Stretch Break*. *Stretch Break* offers short video clips of exercises to help relieve tension caused by computer use. Another highly recommended software package is called *Stop Now*. Like *Stretch Break, Stop Now* reminds the user to stop and take a rest break. The good news is anyone can search the web and find a software package to meet their rest and exercise needs. Often these programs can be downloaded as freeware or shareware.

4.2 Notebook Computers

The notebook computer while promoting mobility may also inadvertently be promoting disability in the form of CTDs. While notebook computers are certainly marvelous work and educational tools, they were originally designed as a short-term, travel solution for business tasks. Notebook computers were not meant to replace the desktop or be used as the primary machine for daily computing activities [15]. However, with the advent of notebook universities and the increasing use of notebook computers in the workplace due to space and portability considerations, the notebook computer is steadily taking over the territory which was once the exclusive dominion of the desktop computer. Unfortunately, notebook computers can be ergonomic nightmares as the result of the very assets that make them attractive to space-conscious, on-the-go users. Due to their smaller size and portability, the potential for aches, pains and ultimately acquiring a CTD are much higher.

According to a survey in the International Journal of Industrial Ergonomics, 60% of Australian students, age 10 to 17 years, reported discomfort with use of their notebook computers. The study indicated this was a result of the length of time students worked on their notebook computers combined with the greater flexibility in posture and the variety of non-traditional computer usage locations. The non-traditional locations included lying down on a bed, sitting on a beanbag chair or riding in a car [10].

Not only can someone work in an unorthodox space or manner, but the notebook computer also has ergonomic design flaws that can contribute to developing a CTD even if a user is seated at an ergonomically correct computer desk. Screens are smaller and attached to the keyboard, making it often impossible to position the

screen to eliminate both glare and head and neck pain without inconveniently repositioning the keyboard as well. Glare filters, which can filter 99% of reflected light, are good solutions to lighting issues, allowing a user to see their screen more clearly and thus, prevent CVS.

Another ergonomic design flaw of the notebook computer is the touchpad is attached to the keyboard and thus, a user cannot reposition either the keyboard or touchpad independently. Setting up a docking station for a user's notebook computer is one way to help resolve this problem by allowing an external mouse, monitor or keyboard to be attached to the notebook computer to promote good ergonomics.

The heat of some notebook computers can also cause superficial skin burns, even through clothes, if left long enough on a user's lap. Evidence can be found that states repeated exposure to the heat of a notebook computer, which is positioned on the thighs for long hours over a significant period of time, may reduce fertility in teenage boys and young men [12].

Suggestions for improving this situation and reducing or eliminating any potential side-effects of exposure to such heat can be as simple as placing a cooling pad on your lap. Another alternative is to use a lap tray or a TV tray.

Adjusting personal habits is also important in preventing notebook computer CTDs from developing. By taking frequent breaks and doing basic, stretching exercises, a user can help to reduce and even prevent the aches and pains often associated with working with equipment or in an environment that has ergonomic disadvantages. While students commonly like to lay on the floor or sit on the couch when working with a notebook computer, these behaviors need to be modified to incorporate good workspace ergonomics.

4.3 Computer Lab Solutions
Prior to 2000, a lot of time and attention was given to acquiring computers and internet access in educational institutions, but little attention was generally paid to the environment that housed these powerful tools. In fact, school administrators and computing personnel often do not even have ergonomic information to guide their decisions when purchasing furniture and computing equipment for classrooms and computer labs. The failure to adjust for differences among computer users, including those with disabilities, when designing an office, classroom or computer lab will eventually result in the rise of CTDs, particularly among technologically proficient Net Generation students who have never known what it was like not to have a computer for academic, personal and professional usage.

The same types of solutions for workstations mentioned in this paper previously can be applied to creating ergonomic computing labs. Variety and flexibility are essential to providing an ergonomically successful computing lab. For example, adjustable computing tables and chairs can help students with different body types work comfortably and help reduce or eliminate many problems associated with CTDs. Similarly, different types of keyboards and mice can be used to offer a wider variety of choice to lab users who may find a natural keyboard or an optical or wireless mouse preferable to a standard keyboard or mouse.

Flat screen monitors can be used to reduce glare, especially in areas with lots of windows and natural sunlight. Solutions can be as simple as adding shades and glare filters to windows. Likewise,

glare filters can be added to monitors and light diffusion filters to overhead light sources.

Other considerations for promoting an ergonomically healthier computer lab environment are to incorporate document holders. One simple, inexpensive document holder solution is to add a paper clamp to the left or right corner of the monitors, especially in computer labs where potential theft may be a concern.

Educators and computing personnel also need to be pro-active about disseminating ergonomic information to their lab users. Signs urging computer users to take a break or how to do an easy stretching exercise can be utilized. Additionally, brochures can be distributed to promote more detailed information about CTDs and prevention measures.

4.4 Exercises as a Preventative Measure
Through the use of exercise and voice activated software, ergonomic devices and appropriate workstation design, users can lessen or avoid injuries while using computers. Looking back at some of the suggestions in this paper, one can see that doing as little as altering the height of the monitor or finding the right keyboard is a worthwhile implementation of some of these simple ergonomic suggestions.

A number of simple exercises can be done in the user's work area without having to purchase exercise equipment that would take up space and be costly to the user. The benefits of taking exercise breaks while working at a computer include increased circulation, improved alertness, better concentration and prevention of CTDs. Some of the exercises concentrate on the eyes and stretching the back, neck, shoulders and legs [4].

4.4.1 Eye Exercises
The eyes can be rested by placing the palms of the hands over the eyes for a few seconds and then slowly uncovering the eyes. Another simple exercise is to roll the eyes around while closing them. Moving the eyes in all directions will help to reduce the strain of having stared at the computer screen too long. The simplest exercise of all is to look away from the computer screen and focus on something at least 20 feet away [4].

4.4.2 Stretching Exercises
Since the body becomes tense and inflexible after sitting for long periods of time, stretch exercises should be performed at least every hour. Several exercises can be performed while sitting at the desk. To alleviate stress and strain on the wrists, flex the wrists in both directions and rotate them in a circular motion. To allow the hands a rest from keyboard and mouse usage, spread the fingers several times and open and close the hands. Another exercise a user can perform is to shrug the shoulders up-and-down and push the elbows back and forth, working the upper back to increase mobility. To work the triceps, bend the arm at the elbow and place it over the opposite shoulder. Place the hand of the arm not being stretched on the elbow and gently push the elbow toward the chest. Hold the position for a few seconds and then repeat the process on the opposite arm [4]. The arms can also be extended over the head while arching the back over the back of the chair to stretch back muscles. Using the arms of the chair, slowly twist from side to side.

Computer users should also stretch the leg muscles to increase blood flow and promote good circulation. After setting in the chair for long periods of time, both knees and ankles become cramped and uncomfortable. While sitting in the chair, extend the legs and flex the feet. Another leg exercise is to gently pull the knee of one leg

up to the chest holding it with both hands. Repeat the process on the opposite leg [4].

Exercises of this type can be found by searching for ergonomic exercises on the internet or consulting books. Computer users who experience persistent discomfort should consult a physician or physical therapist for information about exercises that would help to increase mobility and flexibility at work. Before performing computer stretches, make sure enough room is available to move about easily. If the exercises are to be performed in a public area, closing the door of the area being used if possible will ensure privacy and lack of disruption to others.

5. EDUCATING STUDENTS, FACULTY & STAFF

Computer ergonomics is a new concept for many students and even some higher education administrators and educators. According to Ergonomics Consultant, Inger Williams, "Ergonomics has become a buzzword in business, but not yet in schools. Most schools are not aware of these issues. We have a long way to go to educate schools" [15]. According to one educational institution's study, very rarely are schools even making the effort to teach instructors and students about ergonomic issues associated with computing [5].

According to the Commerce Department's Census Bureau, there was a "ratio of 9-in-10 school-age children" aged 6 to 17 years who had "access to a computer in 2000, with 4-in-5 using a computer at school and 2-in-3 using one at home." According to this same Census Bureau report, "54 million households, or 51%, had one or more computers in the home in August 2000," which was an increase from 42% in December 1998. Ninety-four million people used the internet at home in 2000, which was a significant increase from the 57 million who used it in 1998. Two-thirds of households with school-age children had a computer in the home with "53% having internet access." Perhaps most surprisingly, computer usage in schools was "nearly equal across various income, race or ethnic groups," since educational institutions were making an effort to bridge the feared digital divide [24].

Since the new millennium, computer ownership has risen even further and has changed to include notebook computers and PDAs. Likewise, the use of the internet has dramatically increased both at home and abroad. Between May 2002 and April 2003, 95% of Australian students between the ages of 5 and 14 reported using a computer and the internet with consistent frequency. According to the report, 82% of the students used the computer and internet at home and 89% of the students used them at school [22]. In short, computers are changing the nature of education globally. Therefore, tech-savvy student users need to be made fully aware of what can happen physically if they spend long periods of time game-playing, surfing the internet, chatting to a friend on instant messenger or typing a paper without ergonomic considerations being met.

CTDs in the United States were found to have risen "14-fold from 1972 to 1994." Fifty-four percent of undergraduate students had CTDs associated with computer use. Nine-percent of those with tendonitis were under 25 years of age. The report also indicated that "13% had symptoms after computing for as little as one hour or less" [21]. Thus, providing ergonomics prevention awareness and designing more ergonomic environments for students is imperative to prevent long-term problems that could negatively impact students while at school and upon graduation, in the workplace.

"Schools that don't practice ergonomics in the classroom could be putting students at risk for future injuries. Neglecting ergonomics…means schools might be contributing to such long-term health problems as repetitive-stress injuries and near-sightedness" [18]. This quote says it all. The responsibility of educators to both practice and preach the appropriate ergonomic standards to avoid seeing a generation of people disabled is imperative and relatively easy.

Though not mentioned before in this paper, one of the poorest practices of students today is to carry the backpack over one shoulder. Several problems can result from this practice, such as back strain, shoulder injuries and recurring rotary cuff pain. For example, a 130 pound person should not carry over 19.5 pounds of weight in the backpack. Fifty-five percent of students carry more than the recommended amount of weight in their backpacks. Students should be not be carrying more than 10-15% of their body weight. Sadly, students and adults carry as much as 40 pounds on an average day. The strain of carrying this weight will most likely leave these students with injuries that will plague them as they grow older [3]. Adding to the backpack burden is the move towards mobile computing by schools and universities. Notebook computers commonly weigh around 7 to 10 pounds and are being added to the backpacks, which already hold books and other school supplies.

If instructors would take the time to tell students about backpack safety early in the semester, perhaps more students would understand the importance of carrying a backpack properly. One of the first things students should learn about backpacks is to carry them over both shoulders to distribute the weight properly. Put heavier items in the bottom of the bag so that it sits against the small of the back and not up around the shoulders. Students should also look at the type of straps on their backpacks. The strap should not be thin, but wide, with padding so as not to strain the shoulders. Some of the new bags even include lumbar support.

6. COMPUTER ERGONOMICS AT NORTHWEST

Northwest Missouri State University is particularly aware of notebook computer ergonomics since the university's notebook computer initiative went into affect in January 2005. The initiative placed notebook computers in the hands of every student living on-campus with a rental program for off-campus students [20].

An additional tool that will be used at Northwest Missouri State University in the fall of 2006 will be voice-activated software that is included in the Microsoft Office Suite. In a Freshman Seminar initiative, students will learn about different types of ergonomic computing issues, how to use the dictation mode of Microsoft Office and the type of backpacks that work best for college students. The added expense to the students for the headset required to use the Microsoft Office dictation feature will be less than $20 and is a purchase that may save their hands during their college career. This software component does not allow students to surf the web in the way that *Dragon NaturallySpeaking* does.

Though many users will develop CTDs over the next decade, by practicing good computer ergonomics, the chances of debilitating injuries lessen. At Northwest's Owens Library, the director, staff and faculty have gone to great lengths to prevent more CTD injuries due to several staff members already suffering from RSIs. New workspaces were purchased for library offices with adjustable keyboard trays and task lighting. *Stretch Break* was loaded onto all computers used by the library staff and, when warranted, staff members were given copies of *Dragon NaturallySpeaking* and trained on how to use the software package. Some staff members

with back problems were allowed to select new adjustable chairs with lumbar supports and at least 3 adjustment positions. The director took the initiative to purchase a foot driven mouse for a staff member that had carpal tunnel syndrome and had to wear braces that did not allow enough flexibility to use a hand-operated mouse while working.

Nearly every single staff workstation in Owens Library has a foot rest, foam keypad trays and gel filled chair arm covers. Due to ergonomic concerns and the difficulty of students working in groups around a single computer monitor, two group workstations with additional monitors were set up for group projects. Because the setup is so popular with the students, plans for additional stations are in the works for upcoming trimesters.

Like the Owens Library staff members, the Client Computing department was very concerned about the development of CTDs by student and professional staff members, as well as, the computer lab patrons. The general purpose computer lab was originally designed with a stand-up consultant desk that required the student staff to either stand or utilize a tall bar-stool type chair during their work shifts. The workstation counter extended to include the printers for the computer lab. After a wheel-chair bound patron expressed concerns about not being able to reach her printouts without the assistance of a consultant, Client Computing investigated the situation and determined even more concerns existed, including hip and leg pain for the student consultants that were seated in the bar-stool chairs. The desk area was redesigned to be more ergonomically friendly, which included adjustable chairs for the staff members, a lower workspace area and even lower tables for very the tall printers.

Another area of concern that was addressed by Client Computing was the glare on computer screens around the perimeter of the computer lab. The u-shaped computer lab has exterior windows along the u portion of the lab and faces the East. To solve the glare problem, window blinds were installed around the perimeter of the lab. A second solution was to replace the monitors of the computers around the perimeter of the computer lab with flat screen monitors, which tend to be less susceptible to glare.

To accommodate users of various sizes adjustable chairs were purchased and placed in the computer lab. However, the initial chairs purchased were not suited for many users due to a small seat pan. New adjustable chairs, along with adjustable tables, were purchased to accommodate users of all sizes and needs. The adjustable tables allow students with wheelchairs and other disabilities to manipulate the height of the tables as needed.

7. ADDITIONAL RESOURCES

When researching ergonomics and its effect on students, one can find lots of information, both in libraries and on the internet. The list below is only a small sample of the resources found to be helpful.

- *Healthy Computing* [http://healthycomputing.com/] Use this web site to find information and advice about injuries, exercises and computer ergonomic set-up tips. The web site also addresses issues for children concerned about ergonomics.

- *Working Well Ergonomics Information web site* [http://www.working-well.org/] On this web site, discussions can be found detailing ergonomic injuries, helpful suggestions for avoiding injuries and helpful treatment tips. This web site was developed by two educators wanting to inform the public of the many issues concerning ergonomics.

- *Easy Ergonomics for Desktop Computer Users* [http://www.dir.ca.gov/dosh/dosh_publications/ComputerErgo.pdf] The pamphlet, available via the internet in PDF format, is a 38 page booklet containing diagrams and information about ergonomics and the desktop computer. This helpful resource is sponsored by the Department of Industrial Relations-California/OSHA Consultation Service.

- *CUErgo* [http://ergo.human.cornell.edu/] Use this web site to find information about ergonomic issues researched and conducted by the students and faculty in Cornell University's Human Factors and Ergonomics Research Group (CHFERG). The research group focuses on promoting and improving all aspects of ergonomics classroom and workplace design.

- *The Computer User's Guide to an Ergonomic Workstation* [http://www.dpa.ca.gov/Benefits/health/WorkComp/Pubs/CompUsersHndbk/dpahandb.pdf] Use this web site to find information about ergonomic issues dealing with workspace design and computer/desk exercises. The handbook was produced to provide users with information on how to reduce CTDS associated with computer usage.

- *USERNOMICS* [http://www.usernomics.com/ergonomic-products-software.html] Researchers will find this web site offers reviews about ergonomics software, organizations and affiliations, educational programs, online forums, the human factors and internet searches, as well as, other ergonomics data.

8. CONCLUSION

Oh, my aching laptop! Northwest students can often be heard muttering or in some cases groaning this maxim whenever bulky computer bags dangle from their shoulders or after being hunched over keyboards for lengthy computer sessions. While this play on words is certainly funny, the situation prompting it is far from humorous, particularly when that student may be developing a CTD due to ergonomically-incorrect computing activities.

With extensive research, one can find a multitude of information offering preventative measures and exercises that can be done to eliminate or alleviate some of the painful injuries and problems that can be caused by long-term, improper computer use, poor workspace design or inadequately-designed hardware. Whether a user has already acquired a computer-related injury or wants to prevent potential damage, not all solutions work for everyone and thus, an individualized solution needs to be developed. If a user is already injured, the first step is to contact a physician for an evaluation and find out what solutions are suggested and best meet that user's specific needs.

Everyone knows that some form of mild to moderate exercise is good for the body's overall health. Moreover, exercise can reduce or prevent the acquisition of a CTD. However, all the exercise software packages in the world cannot force the computer couch potato out of the chair to do preventative exercises. The best solutions are those of choice. The user must choose to exercise common sense when working at the computer. Consequently, taking breaks is important to remember. Walk away from working at the computer when feeling pain or numbness and actually use the software packages after they have been purchased.

In the end, educators must become proactive ergonomics advocates. Sharing ergonomic knowledge whenever there is an opportunity is crucial to helping others prevent CTDs. Informing students about

the potential health hazards associated with poor ergonomics in connection with computing is especially important. Too often students do not even know what ergonomics is about, much less how to protect themselves against acquiring a painful CTD. In short, educators in every field, but particularly those in computing, need to take the initiative and expand the boundaries of campus computing ergonomics.

9. REFERENCES

[1] Anshel, J. "Computer Vision Syndrome," *HealthyComputing.com, Inc.,* 2001, http://www.healthycomputing.com/articles/computer_vision_syndrome.htm (accessed June 8, 2006).

[2] Anshel, J. "Visual Conditions Affecting Computer Users," *HealthyComputing.com, Inc.,* 2001, http://www.healthycomputing.com/articles/visual_conditions.htm (accessed June 8, 2006).

[3] "April is National Backpack Safety Month," *Working Well Ergonomics Information Website,* 2003, http://www.working-well.org/articles/backpacks.html (accessed June 15, 2006).

[4] Becker, S. "The Computer User's Guide to an Ergonomic Workstation," *State of California: Department of Personnel Administration,* October 2002, http://www.dpa.ca.gov/Benefits/health/WorkComp/Pubs/CompUsersHndbk/dpahandb.pdf (accessed June 8, 2006).

[5] Bennett, C. "Classrooms and Computers: An Elementary School Case Study." In Proceedings of the International Society for Occupational Ergonomics and Safety XV Annual Conference (Fairfax, Virginia, 2001).

[6] Boss, R. "Ergonomics for Libraries," *Library Technology Reports, 37.6* (November-December 2001), 1-65.

[7] "Computer Ergonomics for Elementary School Students," *Oregon Occupational Safety and Health Division,* http://www.orosha.org/cergos/ (accessed June 8, 2006).

[8] "Computer Workstation Ergonomic Training and Evaluation Program: Part 1 Ergonomic Information," *Harvard University's On-line Training Program,* http://www.uos.harvard.edu/ehs/training/ergo_info.html (accessed June 8, 2006).

[9] Goldsborough, R. "Computing 'til It Hurts: Why PCs Can Be Hazardous to Your Health," *Incentive, 174,* 11 (November 2000), 152.

[10] Harris, C. and Straker, L. "Survey of Physical Ergonomics Issues Associated with School Children's Use of Laptop Computers," *International Journal of Industrial Ergonomics, 26* (2000), 337-347.

[11] "Healthy Computing: The Premier Source for Computer and Office Ergonomics," *HealthyComputing.com, Inc.,* 2001, http://www.healthycomputing.com (accessed June 8, 2006).

[12] Hedge, A. "Ergonomic Tips to Choosing and Using Laptop Computers," *Spine Universe,* February 21, 2006, http://www.spineuniverse.com/displayarticle.php/article3205.html (accessed June 8, 2006).

[13] Hedge, A., Muss, T., and Barrero, M. "Comparative Study to Two Computer Mouse Designs," *Cornell University Ergonomics Web,* July 1999, http://ergo.human.cornell.edu/Pub/HFlabReports/MouseRep.pdf (accessed June 9, 2006).

[14] "Help with Using Your Keyboard and Mouse: Alternative Mice," *Ability Net,* http://www.abilitynet.org.uk/myway/keyboard/instead/alt-mice.htm (accessed June 14, 2006).

[15] Kennedy, M. "High-Tech Comfort," *American School & University, 73.6* (February 2001), 26-30.

[16] "OSHA Ergonomic Solutions: Computer Workstations eTool," *U.S. Department of Labor: Occupational Safety & Health Administration,* http://www.osha.gov/SLTC/etools/computerworkstations/index.html (accessed June 8, 2006).

[17] Quilter, D. "Are You at Risk for Computer Injury?," *HealthyComputing.com, Inc.,* 2001, http://www.healthycomputing.com/articles/computer_injury.htm (accessed June 8, 2006).

[18] Rasicot, J. "How to Guard Against Health Problems in the Computer Lab," *Electronic School,* January 2000, http://www.electronic-school.com/2000/01/0100f2.html (accessed June 7, 2006).

[19] Rempel, D. "Carpal Tunnel Syndrome," *HealthyComputing.com, Inc.,* 2001, http://www.healthycomputing.com/articles/carpal_tunnel_101.htm (accessed June 8, 2006).

[20] Rickman, J., Miller M., Verbick T. and Todd K. "Notebook Universities Do Not Have To Be Expensive." In Proceedings of ACM SIGUCCS 2006 Fall Conference (Edmonton, Alberta, Canada, November 2006).

[21] Robertson, M., Amick III, B., Hupert, N., Pellerin-Dionne, M., Cha, E. and Katz, J. "Effects of a Participatory Ergonomics Intervention Computer Workshop for University Students: A Pilot Intervention to Prevent Disability in Tomorrow's Workers," *Work: A Journal of Prevention, Assessment and Rehabilitation, 18,* 3 (2002), 305-314.

[22] Straker, L., Pollock, C. and Burgess-Limerick, R. "Towards Evidence Based Guidelines for Healthy & Wise Use of Computers by Children," *Cyberg 2005: Keynote Address,* 2005, http://cyberg.wits.ac.za/cb2005/key1.htm (accessed June 9, 2006).

[23] Strasser, A. "Computers and the Body: The Ergonomics Solution," *Spine Universe,* February 8, 2006, http://www.spineuniverse.com/displayarticle.php/article3189.html (accessed June 8, 2006).

[24] "United States Department of Commerce News," *U.S. Census Bureau: Public Information Office,* October 10, 2001, http://www.census.gov/Press-Release/www/2001/cb01-147.html (accessed June 16, 2006).

[25] "Useful Tools," *Computers in Libraries, 24,* 5 (May 2004), 45.

[26] Wagner, F. and Ong, F. "Easy Ergonomics for Desktop Computer Users," *California Division of Occupational Safety and Health,* http://www.dir.ca.gov/dosh/dosh_publications/ComputerErgo.pdf (accessed June 8, 2006).