Preventing Carpal Tunnel Syndrome
Through Workstation Design

Keyboard Support Systems:
Why they are an Essential Part of an Ergonomic Work Environment

Training Focus:
- Successful Implementations at Applied Materials, Inc.
- 5 Critical Components of Office Ergonomics Training

On Design with George Mileos
Today’s Work Environment is Changing for the Better, and Ergonomics is Responsible. Intuitive, easy-to-use work tools that encourage low-risk postures and adjust effortlessly are the result of ergonomic design, and years of human factors research.

This research also shows that sound ergonomic workspace is built around four key components: task chair, articulating keyboard/mouse support, adjustable monitor arm, and task light. Each of the four components collectively supports the health and comfort of computer users as part of the whole. However, take away any one of these tools and the benefits of the others may be compromised.

In this Fall 2006 issue of DESIGN AT WORK, we take a closer look at one of these essential tools—keyboard support systems. And, realizing that no product is truly ergonomic if it is not used properly, we also examine the critical supporting role that user training plays in successful ergonomic implementations.

At DESIGN AT WORK our goal is to provide expert insight, research, and discussion on the most salient issues to help keep you informed and improve health and comfort in your workplace.

Thank you for reading!

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An articulating keyboard/mouse support system is one of the most important components of an ergonomically sound workstation. And while the keyboard certainly plays a critical role in our work environment, it’s really the position of the keyboard that begs our attention.

For people who work on a computer for 2 or more hours per day, a well designed articulating keyboard system—with intuitive adjustability, mouse support and total knee clearance—can provide serious protection from a variety of musculoskeletal disorders, including carpal tunnel syndrome (CTS), neck pain, and upper and lower back pain. As computer use among office workers continues to increase so will the need to support these workers with ergonomic products, such as keyboard systems.

Facility Managers, Architects & Designers, and Health & Safety leaders each play an important role in recommending, purchasing and implementing these products. But with so many keyboard systems claiming to be ‘ergonomically designed’, what are the features that truly separate the real thing from false marketing pitches?

Scott Valorose, ASP, CPE, of Ergonomics Outreach, recommends we look for the following features, and tells us why each is critical to ergonomic keyboard/mouse support design:

**Height and tilt adjustments:** Height and tilt adjustments play a key role in the user’s ability to assume neutral upper extremity postures. Regarding height, we usually try to lower it with the use of such a support. By moving the keyboard from a fixed work surface and onto an adjustable platform, the lower height usually enables one to sit supported by the backrest of the chair with their arms resting by their sides. The range or degree of tilt a platform provides is critical as well. With a lower keying height, it’s important that the platform be flat or angled away from the user. This allows the hands to extend along the same plane as the forearms—keeping the wrists straight.

Research shows that wrist- and posture-friendly computing is best supported when the keyboard is angled away from the user and placed below desk level, allowing the users’ wrists to remain straight and the elbows opened to a greater-than-90-degree angle. This posture is best achieved with the use of an articulating keyboard holder with negative tilt adjustability.

Beware of a positive-tilt keyboard arrangement in which the keyboard is angled toward the user. This dangerous position causes the wrist to bend up and toward the body, increasing the amount of pressure on the median nerve, and thus increasing the risk for carpal tunnel syndrome. An ergonomic keyboard support should never allow the keyboard to be angled in this way.

**Location of mouse:** The keyboard support needs to provide a support for the mouse or other input device near or next to the keyboard and at or about the same height as the keyboard or just above the numeric pad. Increased shoulder abduction or lateral rotation of the upper arm results when the mouse is not located close to the keyboard. These postures, especially when held for a prolonged period of time, increase muscle tension and strain on shoulder motion units. Look for a mouse platform that offers maximum adjustability for user comfort and support, and can be easily placed on either side of the keyboard for left or right-handed mousing.

**Controls:** Controls should be limited in number—hopefully just one. At a minimum, controls should also be easily found and manipulated, and function in stereotypical directions.

In addition, Valorose says ease of use must always be considered.

“The easier it is to properly adjust increases the users’ ability to do so. However, just because the product is easy to adjust, does not mean the user knows where to adjust it and then work efficiently.”

Along with the implementation of a keyboard system, Valorose recommends training that goes beyond general awareness of postural guidelines, and addresses how to fully utilize keyboard supports. Implementation accompanied by training, he says, ensures maximum ergonomic benefits for the worker, and ultimately, return on investment.
Preventing Carpal Tunnel Syndrome Through Workstation Design

By Hayley Korn, MS, CAE
Associate Ergonomist, Humanscale Consulting

Computer use among office workers has increased to unprecedented levels over the past several decades, and has been linked to the development of work-related musculoskeletal disorders. While our society has seen great advances in computer technology, furniture standards have remained relatively constant. Our working population, for example, ranges in height from less than 5 feet tall to well over 6 and a half feet tall, and yet most workers position their work tools on fixed height worksurfaces. The lack of fit that exists between most computer users and their work environments is driving a need for improved ergonomic design.

Carpal tunnel syndrome (CTS), one of the more publicized musculoskeletal disorders, has been associated with computer use, and involves the compression of the median nerve. The carpal tunnel is fluid filled and formed by a series of carpal bones on the topside of the wrist and by a ligament on the underside of the wrist, referred to as the transverse carpal ligament. Deviations in posture have been shown to increase pressure inside the tunnel resulting in tendon inflammation and subsequent nerve impingement. Postural risk factors include wrist extension, ulnar/radial deviation, and contact stress at the crease of the wrist. These risk factors are most prevalent while keying or mousing on fixed height worksurfaces.

CTS is the most debilitating work-related musculoskeletal disorder with associated costs averaging $35,000 per claim. The Bureau of Labor Statistics reports that CTS results in an average of 31 lost workdays, the highest median number of lost workdays for any injury or illness combined. Believe it or not, amputation ranks second among the highest number of lost days, averaging just 21. This is because nerves, unlike other body tissues, do not recover once damaged. Carpal tunnel surgeries often provide only mild relief of symptoms and tend to leave patients with permanent loss of grip strength. Proactively minimizing CTS risk factors before symptoms occur is therefore critical for maintaining the health and comfort of computer workers. Providing employees with a solid understanding of CTS risk factors combined with improved design can significantly reduce the prevalence of CTS.
CTS Risk Factors
The mechanisms through which the median nerve is compressed and subsequently damaged are well understood.

The first and most common postural risk factor is the bending of the wrist back towards the body, referred to as wrist extension. Wrist extension has been linked to increased intracarpal tunnel pressure. According to research conducted by Weiss et al., intracarpal tunnel pressure is lowest at 2 degrees of wrist extension angle, and pressure increases considerably as extension increases. In addition, average carpal tunnel pressures for CTS patients are twice those found in healthy subjects, linking increased intracarpal tunnel pressures with the prevalence of CTS.

The Carpal Tunnel: Highly Sensitive to Postural Change. A 2002 study by Kair and Wells showed that 30° of wrist extension correlates to a 27.5% increase in forearm muscle activity, and a two-fold increase in intracarpal tunnel pressure. Pressure in the tunnel translates to pressure on the nerve, and it is damage to this nerve that constitutes a diagnosable case of CTS.

Several earlier studies, namely those conducted by Chaffin et al. 1984, and Armstrong et al. 1979, have also linked wrist extension with the development of CTS.

Research conducted by Dr. Alan Hedge, Director of the Human Factors and Ergonomics Laboratory at Cornell University, has found that average wrist extension angle while typing on a conventional keyboard positioned on a standard height desk ranges between 13 and 33 degrees, a range associated with the development of chronic wrist symptoms. Aside from problems with keyboard positioning, Simioneau et al. found that the design of the keyboard itself, which typically is sloped towards the user, also contributed to increased wrist extension angles.

Wrist anchoring, or the resting of the wrist crease on a worksurface, has also been indirectly linked to median nerve compression via increases in intracarpal tunnel pressure. In fact, wrist anchoring while keyboarding or mousing has been shown to increase intracarpal tunnel pressure.

Repetitive movements of the wrist while typing or mousing can also cause inflammation of the flexor/extensor tendons. This, in turn, can result in further compression and subsequent neuropathy of the median nerve.

Proactive Prevention
Given that the activities that expose us to postural risk are relatively unavoidable, how can an organization proactively prevent carpal tunnel syndrome? First and foremost, it is important that a company provide training to its employees. People are inherently resistant to change, so in order to ensure the success of an ergonomic intervention, the employees must first understand the consequences of awkward postures and the means

Need to Know:
Keyboard Support Systems

With Alan Hedge, PhD, CPE, Cornell University

What ergonomic features are most critical to the design of keyboard trays and supports?

AH: Easy height adjustment, easy angle adjustment (downwards not upwards), easy slide in/out adjustment, easy mouse platform positioning and adjustment.

Why is a well-designed keyboard tray ultimately better for the user than having a keyboard on a height adjustable work surface?

AH: A height adjustable flat surface only allows keyboard height to be adjusted, not keyboard slope. A negative-slope keyboard tray allows keyboard slope to be adjusted so the keys can be accessed with the hands in a neutral posture when sitting back in a chair.

Alan Hedge, PhD, CPE, is Director of the Human Factors and Ergonomics Laboratory at Cornell University, and a leading expert on the essential components of an ergonomic work environment.
through which to prevent them. Success rates for product interventions lacking adequate employee training are alarmingly poor. Five of every ten employees that are provided with an articulating keyboard tray, for example, will reject the tray immediately when not provided with training. When training is provided, however, research has shown that more than 90% of computer users will embrace the change and prefer it to their previous system.

In addition to providing employees with adequate ergonomics training, organizations must also invest in proper equipment and acknowledge that training alone cannot overcome poor design. The most proactive method for reducing the prevalence of CTS is to simply provide employees with articulating keyboard supports.

**The Keyboard Support Solution**
The goal of a well-designed keyboard tray is simply to mimic the posture that one has when their hands are resting in their lap. In this position, the elbows are close to the body and wrist posture is optimal. Lowering the keyboard position necessitates the angling of the support away from the body to minimize wrist extension angle. Properly designed supports offer between 0 and –15 degrees of tilt adjustment allowing virtually all workers to achieve a neutral wrist posture. A 1995 study conducted by Dr. Hedge showed that use of such a product positioned users’ hands in neutral postures more than 62% of the time compared with only 42% for a keyboard on the desktop. Carpal tunnel pressure remained below the critical threshold 82% of the time compared with only 48% for subjects without an adjustable keyboard tray and participants reported significant improvements in upper body comfort. Furthermore, more than 90% preferred having the keyboard tray and felt that it helped their work performance. Hedge & Rudakewych explored the benefits of an articulating keyboard support further in a 2001 study of 356 New Jersey office workers. Results showed a 40% reduction in musculoskeletal symptoms of the wrist, hand, arm, and shoulder among those workers properly using an articulating keyboard tray.

With the knowledge that carpal tunnel syndrome is so easy to prevent, yet very difficult and costly to treat, it is only logical for companies to be more proactive about preventing awkward wrist postures among their employees before symptoms occur, rather than once damage has occurred. A simple design solution such as a keyboard tray can have a dramatic effect on reducing employee discomfort, injury prevalence, and the associated costs.

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Humans inherently resist change, even when it’s in our best interest.

Take for instance learning to use a new keyboard support system that—if properly utilized—will improve our posture, overall comfort and work efficiency. Cognitively, we can understand the potential benefits. But without adequate instruction or motor skill adaptation, we may never fully utilize the equipment, and will therefore miss out on the ergonomic benefits.

Office Ergonomics Training Insights

Q & A with Manny Halpern, PhD, CPE, New York University

The Truth About Coupling...
Research has shown that when implementation of an ergonomic product is coupled with how-to-use training, an overwhelming majority of employees accept and utilize the product. And a 2003 study, Effect of Office Ergonomics Intervention on Reducing Musculoskeletal Symptoms, by Robertson et al., concluded office workers that were given a highly adjustable ergonomic chair, along with relevant office ergonomics training “experienced reduced musculoskeletal symptom growth over the workday.”

With this in mind, how can we best tailor our office ergonomic interventions to help workers understand the consequences of awkward posture, how to remedy it, and how prevention through the proper use of an ergonomic product will benefit them?

DESIGN AT WORK Editor Dan Cannon recently explored this further with Manny Halpern, PhD, CPE, of NYU School of Medicine, and Manager of Ergonomic Services at the Occupational & Industrial Orthopedic Center. Halpern, a leading researcher in the field of human factors and ergonomics, has focused much of his effort on office ergonomics interventions, computer workstation design and training programs.

In your experience, is there value in supporting the implementation of ergonomic products with how-to-use training, specific to those products?

Absolutely, supplying products is not enough. Most products are not intuitive, so some users abandon them. And some products are designed for specific situations, therefore some users may misuse them.

Why do we need training in how to use ergonomic products?
Consider what we mean by ‘ergonomic’ products: The fundamental purpose of ergonomic design is to make the equipment adaptable to users of different sizes and capabilities. In many cases, the adaptability is accomplished by designing equipment with adjustable features. Unfortunately, this may also make the devices more complicated. Aside from making products intuitive to use (i.e., making them more ‘user friendly’), it is necessary to inform users about the purpose of the features and when these features are appropriate for use.

The challenge for many workers is not in understanding potential benefits of an ergonomic product, rather it’s embracing change and utilizing something new.
That’s right. And this is why skill training is useful if it is constructed and delivered in a way that enables acquisition of motor skills, not merely conveying knowledge. In other words, written instructions address knowledge through cognitive processes; training how to use the equipment to one’s own needs may be approached as a motor skill. Hence, practice and feedback are two basic principles of motor learning that we need to apply to training office employees in how to use their ergonomic equipment.

What do you consider the five key points to address when doing office ergonomics training?

1. We need to educate users as to what the equipment is designed for, as well as how to best use it. The challenge lies in conveying to the user what the ergonomic equipment is good for.

2. In ergonomics of computer workstations, we need to convey to the users that there are three ways in which they interface with the workstation: the viewing conditions (e.g., viewing distance, quality of the display, the monitor, hard copies, ambient lighting, visual acuity), the manipulations they are required to perform (usually hand/fingers operating input devices such as keyboards and mice), and the general positioning of the body (standing, sitting, sit-stand). These interfaces are linked; any change in one may cause a chain reaction elsewhere. Consequently, the instructions are not readily amenable to a simple set of ‘to do’s, not even ‘if-then’s. It is a cognitively complex exercise of looking at three interfaces simultaneously.

3. While the interactions can be described in written material and the resultant behavior can be conveyed in class format, the users need to experience the consequences of the behavior on their own. To initiate behavioral changes, the training has to enable guided trial and feedback on errors. Any individual ergonomic assessment has this element built into it since it is context-specific; the challenge is to enable it pro-actively, company-wide.

4. Context-specific content is needed. If one is using a laptop, different rules apply; if one does not have a fixed workstation, another set of rules; if one is working at home as well as an office, the training should address these environments. Different setups may be needed for CAD tasks as opposed to copy-editing or data entry. The software one is using may give an indication as to what equipment is mission-critical.

5. Group size is an important factor too. My preference is for small-group training (up to 10), preferably a homogeneous group where all do similar tasks. The training consists of general context-specific education on what the ideal setup should be, followed up with a group walkthrough where the participants observe each other, apply under guidance what they learned in the lecture, and come up with suggestions on what needs to be done to correct it.

AT ISSUE
Deanna Long rarely has much downtime these days. This is understandable, as she manages ergonomics programs and provides training for Applied Materials, Inc., the global leader in nanomanufacturing technology solutions for the electronics industry, whose workforce consists of approximately 14,000 people worldwide.

As Corporate Ergonomics Program Manager for Applied Materials, Deanna Long has many responsibilities; one of which is developing, maintaining and supporting global implementation of the Corporate Office Ergonomics Program. This involves responsibility for all written documents, program requirements, process flows, and—key to the success of Applied Materials’ ergonomic efforts—the training of all environmental health and safety (EHS) staff on successful implementation of the program, including how to perform office ergonomics evaluations. The next major project is developing and implementing the non-office ergonomics program which addresses all ergonomics issues outside of the office including manufacturing, warehouses, R & D labs and customer sites.

Focused on Training

In her role as ergonomics program manager, Long places a great deal of importance on coupling how-to-use training with the implementation of ergonomic tools. Her hands-on approach is supported by ergonomics labs used as testing grounds for various products, and an in-house database that she helped develop to aid in case management and provide solutions to a broad range of office ergonomic issues.

The strategy is simple: provide EHS managers and staff with comprehensive training, then provide ongoing support for them as they train and evaluate Applied Materials’ worldwide workforce. According to Long, this forms the solid foundation on which their successful efforts are built.

“Crucial to the success of our program is the training provided by the ergo-evaluators on a daily basis. This includes teaching workers how to use their existing equipment correctly to gain the products’ intended benefits.”

Ergo-evaluators guide workers in areas such as correctly adjusting the angle and height of a keyboard tray, keyboard and mouse locations, monitor height and distance and other workspace adjustments that encourage the best postures.

Long explains that the training continues after products have been delivered.

“Our evaluators follow-up with all cases to ensure workers received the necessary products and are using them as intended, thus reducing their risk of injury.”
Overcoming Training Challenges

A large part of Long’s work involves training evaluators around the globe. However, providing training to a diverse workforce where English is a second language can present challenges, so efforts are often supplemented with photos and illustrations.

“To help ensure quality and minimize confusion, I host ergonomics roundtable meetings, via net meeting, for the U.S., Europe and Asia. Attendees include regional evaluators, EHS managers and ergonomics coordinators. The meetings provide everyone an opportunity to discuss new research and products, and a question and answer session where evaluators share concerns they need help addressing and successes other evaluators can learn from.”

Long also hosts “stakeholder” meetings with her EHS managers, as needed. These are especially important during the critical, initial stages of development of ergonomic programs and help lay a solid foundation for success during program implementation.

Resources at the Ready

A priority for Long is to make ergonomic resources readily available to Applied Materials’ EHS managers and workforce. She does this by maintaining helpful, informative content on the corporate ergonomics internal website, including: tips on using products and setting up employee workstations, travel tips, ergonomics at home, an approved products list, product order forms, a regional ergonomics contacts list, a link to the evaluation request form, and ergonomics standards.

Ergo ROI at Applied Materials

As with most company-wide ergonomic interventions, the real bottom line is injury prevention.

“The main goal of our program is to prevent injuries through early intervention and education.”

In each issue of DESIGN AT WORK we profile leaders from companies that are part of Humanscale’s Global Account Program. These companies have made creating a healthy, comfortable and productive workplace a top initiative.

Deanna Long utilizes ergonomics labs for a hands-on approach to ergonomics training with EHS managers, who in turn become ergo-evaluators and train the Applied Materials workforce worldwide.

With Deanna Long leading their global ergonomic initiatives and successful training programs, the return on investment for Applied Materials should continue to be a healthy, comfortable and more productive workplace.
George Mileos is changing the way office work is done. His Freedom Arm was the first keyboard support to offer knob-free adjustability and total knee clearance, and it completely transformed the way articulating keyboard support mechanisms were designed. Likewise, Mileos’ 2G, 4G and 5G keyboard mechanisms, all designed for Humanscale, have revolutionized the product category and remain the industry standards today. His award-winning designs for the office environment also include workstations, task seating, and a dictating machine, part of the Museum of Modern Art’s permanent collection.

Much of your work as a designer has centered around products for the office environment. How did this become such a focus for you?

My first design position was with a consulting office that designed office products. Over several years, I designed dictation equipment, fax machines and office seating. One of my most interesting projects was a very early CAD workstation. It was used for drafting electronically. It was an integrated unit about the size of a small upright piano and had all the electronics, which were very bulky, and two black and white television picture tubes built in. One tube was large, which showed a detail area of the drawing, and the other was smaller and showed the entire drawing. You worked directly on the large tube with a light pen similar to drawing on paper. It also had an area where you could attach a 30” x 40” print as a reference. The whole project was about ergonomics and I learned that there’s more than one way to a good, ergonomic, solution.

What progression do you follow in your design process?

The work progression that I use now is the result of many years of experience during which I developed a way to approach design that takes into consideration the basic building elements of function, appearance, cost, manufacturing and quality control from the very beginning of the project. In looking for a solution, I start without preconceptions and let the ideas become the final product as the result of the process rather than using the process to execute preconceptions. The first thing that I do is to take the client’s requirements and start to define the problem. I call it “problem” rather than “project” because I see it as a problem that requires a solution. This takes a significant amount of time and it involves no design at all. I believe that if you properly define the problem, you are half way into a good solution.

I do my own design engineering, and beginning at the concept stage, I start incorporating the input of all the critical participants: the prototype shop, the supplier’s production engineers and quality control and, of course, the client who
sets the marketing requirements and makes the final decisions. It’s a true team approach that is very lean and does not require large and frequent meetings, conference calls, and unnecessary trips.

I don’t really know what the product will look like until the end of the process but if the process is done well, the result is a product that works well, looks good and is cost effective.

“"In looking for a solution, I start without preconceptions and let the ideas become the final product as the result of the process rather than using the process to execute preconceptions.””

The Freedom Arm quite literally changed keyboard mechanism design. What were some of the constraints you addressed to create such an innovative design?
I started with a blank slate. First came the definition of the problem. How do you make a keyboard available to the user in the right place for proper and convenient use? This, of course, is an ergonomics driven question. What is the right place for a keyboard? That was the easy part. Once I had defined that, I had to figure out two things, how to hold it there and how to adjust it.

So the challenge was to design a floating keyboard? Levitation was the best solution (laughs) but I didn’t think we would be able to manufacture it and ship it. I had to come up with a structure to hold it in place and there were a lot of restrictions. The most important was that I could not have large sections of structure protruding below the keyboard that you could bump your legs into.

The second question was, how do you adjust it? Of course, you could unlock it, adjust it, and re-lock it by turning knobs. Everybody did that. It was a structural solution but users don’t care about structural solutions. A user would rather be able to just move it up and down and, somehow, it would stay where it was left—like levitation. After a long series of tedious geometric experiments, I came up with the idea of the main structural support not being fixed at the back end but resting on circular cams wherever you happened to place it. All you had to do was push up on the keyboard tray and let go. To make it go back down you just tilted the front of the keyboard tray up slightly (to unlock the cams) and allowed it to go down.

It was design from the users point of view and it made a tremendous impact on the industry.

What role do keyboard supports play as part of an ergonomically sound workspace?
The keyboard support is one of the most critical components of an ergonomic workstation. My goal in designing the 2G and subsequent keyboard supports was to let users easily and optimally adjust the position of the keyboard and mouse in relation to themselves and their other workspace tools.

What innovations have been made leading up to the 5G?
We have improved the ease of use with greatly simplified keyboard angle adjustment, improved appearance, and significantly increased stability of the keyboard support.

Where does ergonomic design for the office environment go from here?
The computer workstation is still at an early stage. It has yet to find it’s natural expression. It is still centered around the traditional desk. In time, it will find it’s own unique form and ergonomics will play a central role. It’s similar to the development of the early cars, which were created by adding mechanical components to the chassis of a horse drawn carriage. The function and ergonomics, and as a result, the form of the car, changed with experience. That’s why ergonomics should not become rigid and dogmatic. I believe in flexible ergonomics because there is more than one way to approach a particular work task. I’m interested in producing good solutions. The Ford Model T had good ergonomics for it’s time but they are very different from those of a present day Ferrari.
“The keyboard support is one of the most critical components of an ergonomic workstation. My goal in designing the 2G and subsequent keyboard supports was to let users easily and optimally adjust the position of the keyboard and mouse in relation to themselves and their other workspace tools.”

—George Mileos, Designer, Humanscale

Our Design Philosophy: At Humanscale, we believe the best designs in the world are based on purpose and function. If a design solves a functional problem as simply and elegantly as possible, the resulting form will be honest and timeless.