The Effect of Ergonomic Worktools on Productivity In Today's Automated Workstation Design

Dr. Marvin J. Dainoff
Center For Ergonomic Research
Miami University
Oxford, Ohio

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EXECUTIVE SUMMARY

Introduction

As the primary tool in the office environment, the personal computer (PC) has enormous impact on organizational output. It is the focal point of office work today, directing most tasks. Out of this dependence on the computer for task accomplishment, have evolved changes in work habits and office routines. This is, to a large degree, a manifestation of the physiological demands that prolonged PC usage has on today's employees.

Those traditional routine breaks from prolonged sitting attributable to retrieving files, referencing information, faxing, copying and inter-office communicating are today routinely performed at the automated workstation. Consequently, the principal source of productivity in the modern office is the human in front of a PC, resulting in a large percentage of employees' workdays spent sitting in one basic posture in front of the computer.

Sitting for prolonged periods while performing repetitive tasks is known to be problematic. Injuries associated with various Cumulative Trauma Disorders (CTDs) caused by computer use have been clearly documented. However, the problem of fatigue from prolonged static postures has had less exposure.

Prolonged static posture from computer use induces static muscle exertion, which inhibits blood flow and causes muscle fatigue. This buildup of fatigue minimizes overall effectiveness through reduced work output and excessive workbreaks; the latter resulting from the need for movement to increase the rate of blood flow.

To take advantage of new automated technologies, today's organizations must address static muscle fatigue *in addition to* resolving the strains and injuries that result from constant computer use. To ignore either problem is to undermine the vast outlays in new technologies implemented for the purpose of improving productivity.

By enhancing the efficiency (and sense of well being) of the employee sitting in front of the PC, we improve individual and organizational productivity. This has determined new parameters in automated workstation design, which must be accomplished to provide an effective working environment.

This is a study of how ergonomic worktools can help accomplish that task.

Purpose

The emphasis of this study was on the role that ergonomic worktools can play in the performance of workstation design and its effect on worker productivity.

The study had two related goals. The first was to assess the effectiveness of periodically standing throughout the day as a means of providing the essential breaks from sitting in prolonged static postures. This would determine whether intermittent standing, *while working*, relieves fatigue without repetitively departing from the work area or from task accomplishment. The second goal was to examine the necessary attributes of ergonomic worktools, which help induce periodic standing into the daily work routine.

Methodology

The study was conducted in two parts. Part 1 was an analytical comparison of two types of keyboard supports to determine the requirements of *"usability,"* in terms of generating the necessary rate of adjustment for the purpose of regular periodic postural changes.

The first type represented the more traditional keyboard support. It has a Knob/lever-style of keyboard height and tilt adjustment located on the arm mechanism, under the keyboard platform. This was compared against a type with Flipper-style adjustment actuators for both height and tilt, located in front of the platform, directly under the palm support. In contrast to loosening and tightening knobs, Flipper-style adjustments are made by using the forefinger and thumb to squeeze the flippers against the palm support.

Part 2 of the study was an evaluation of intermittent standing as a means of reducing fatigue and, thus, increasing the time spent on task accomplishment. In addition, we examined various steps taken through a specific training methodology to produce a higher frequency of standing throughout the day in an actual office environment. This was achieved by a laboratory workplace simulation, in which professional clerical workers received training on the ergonomic worktools and then entered data for three days.

In Part 2, the subjects worked with the Flipper-style keyboard support and an adjustable monitor arm, which both raised to standing usage positions. The subjects began the three days of work after a 45-minute comprehensive and participative training program. The training was comprehensive, in that, along with *how* to make adjustments, it included *why* specific adjustments are made. It was participative, in that, it included a practice session for all adjustments, including stand-up.

On Day 1, directly following the training session, the subjects were asked to use the adjustable equipment to relieve fatigue while they worked. On Day 2, the subjects worked with the same ergonomic worktools; however, they were *directed* to stand several times throughout the day while working. On Day 3, the subjects were given no direction and told to work in whatever manner they chose.

Results -- *Part 1*

Part 1 of the study, the keyboard support comparison, determined that the *style* of adjustment mechanism, or *method* of adjustment, affects the *time* taken to make adjustments. In fact, the Knob/lever-style required 67% more time to adjust than the Flipper-style unit. Interviews, observation and analysis ascertained that the time required to make the adjustments was a manifestation of the *effort* inherent in making the adjustment.

During the interviews, all subjects consistently revealed a higher tendency to making the easier adjustment and indicated a direct relationship between the effort (ease or difficulty) of adjustment and the likelihood of making the adjustment and, thus, the *frequency* of adjustment. Qualitative data through daily interviewing also strongly indicated the connection between the effort in the adjustment and the preference of adjustment style.

The analysis of Part 1 of the study provided the basis for an expanded definition of usability and the features required to promote regular adjustments (postural changes) throughout the workday. In this context, usability is defined as:

1 – A minimum number of individual steps required for operation of controls;
2 – The ability to make the adjustment with one hand;
3 – The ability to make the adjustment rapidly;
4 – Keeping the adjustment mechanisms in close proximity to the keying position; and
5 – Keeping the adjustment mechanisms visible from the keying position.

Results -- *Part 2*

In Part 2, the workplace simulation, over one-third of the subjects (36%) stood on Day 1. This can only be attributed to the training, which emphasized intermittent standing, along with the provision of a keyboard support with stand-up capability. Of those subjects who stood on Day 1, *frequency* of standing increased about 40% on Day 3, after the directed standing of Day 2. The subjects revealed in the interviews that the benefits experienced by standing reinforced the action and resulted in an increased rate of standing, or simply, standing induced standing.

This data provides strong evidence that the provision of stand-up capability, with an effective training program, with a participatory approach, can affect periodic standing throughout the workday.

Over half (57%) of the subjects who did *not* stand on Day 1 stood on Day 3, after being directed to stand on Day 2. This data further supports the premise that work routines can be modified through positive reinforcement in the experience. More specifically, it suggests the effectiveness of the directed standing of Day 2. In fact, collectively, the subjects periodically stood almost 2.5 times more on Day 3 than on Day 1 (147% increase).

Analysis of the *duration* of each stand-up also supports this conclusion. The average duration of each stand-up increased from Day 1 to Day 2 by 65% and remained essentially the same on Day 3.

Increased Productivity through Reduced Workbreaks

In Part 2 of the study, the subjects were instructed to use the equipment to get relief from fatigue but that they were free to take breaks whenever required. Analysis of this data provides strong evidence that intermittent standing increases productivity through a reduction in workbreak time; through fewer and shorter breaks throughout the day. These results demonstrated that standing while working at the automated workstation (stand-up *working* breaks *from sitting*) can substitute for the traditional work break (*away* from the work area).

Standers vs. Non-Standers

Approximately half (54.5%) of the subjects regularly stood on Day 3. For reasons cited later in this study, the other half chose not to stand on Day 3. The data from Day 3 is significant as it was designed to simulate a real office environment in that the subjects were free to work in whatever way they preferred. Additionally, there was no instructor present and all training had been completed three days prior, in the morning of Day 1. The subjects who stood, did so for their own comfort, with no influence from the laboratory environment.

There was a significant variability of data amongst the different measures of these two groups; those standing on Day 3 vs. those who did not stand on Day 3 (referred to as Standers vs. Non-Standers) over the three days of the study. This provides a basis of comparison in the examination of the effects of intermittent standing.

A primary difference between the two groups regarded workbreaks. The Non-Standers took an average of *47% more workbreaks*, over the three days, than the Standers and the average *duration* of each workbreak was *56% longer* than that of the Standers. The effect on productivity is apparent as the Non-Standers took over *twice as much total time on workbreaks* as the Standers did during the three days. On Day 3 alone, which reflects a three-day cumulative effect of this data entry work effort, Non-Standers spent almost *4 times more on breaks* than Standers (288% increase in breaktime).

The notable increase in workbreak time by the Non-Standers demonstrates the considerable effect that fatigue has on productivity in today's computer-intensive environment. The increased time spent on task accomplishment by the Standers, through reduced breaktime, translates in the office to a significant reduction in fatigue-related productivity loss, through intermittent standing, by minimizing "*fatigue-induced work departures.*"

As previously mentioned, this study demonstrated the effect that comprehensive and participative training has on work routines, as one-third of the subjects stood as a result of training. However, the training placed as much emphasis on the need to make regular *sitting* adjustments throughout the day and the subjects made virtually no such *minor* adjustments (non-standing postural change). This suggests that there is another reason for the lack of making keyboard adjustments while sitting.

The answer may lie in the previously established notion that actions producing increased comfort lead to voluntary increases in that action, as observed with stand-up. In this context, it can be suggested that only *extreme* postural changes, such as that of standing, were beneficial (increased comfort). This explains why only stand-up adjustments were made and supports the premise that minor postural changes are seldom, if at all, made.

There is strong support for this garnered through the daily interviewing of Part 2. These questions focussed primarily on the benefits of "*adjusting* the computer equipment" for both relieving fatigue and productivity. A clear pattern was established, as with workbreaks, relative to the two groups of subjects.

The Standers expressed an increasing amount of relief from adjusting their equipment as the study progressed throughout the three days. The Non-Standers found decreased relief from adjustments. Thus, the only relief experienced from adjusting was from *stand-up* adjustment. This further confirms that only extreme postural changes are experienced as increasing comfort and, therefore, the only regular adjustments made.

The relationship between making adjustments, intermittent standing and productivity was further supported from the daily interviews. Standers felt they were more productive as a result of adjusting their equipment. Non-Standers felt less likely to believe that adjustments had positive effects on productivity.

Finally, the interviews of Part 2 confirmed the findings from Part 1 regarding usability as many of the subjects included the “ease of adjusting,” referring to the Flipper-style unit, as part of their responses to the reasons why they stood. This further confirms the attributes of ergonomic worktools, which most readily promote voluntary usage by employees.

Conclusion

This paper began with the reminder that productivity in the modern office is achieved by the efforts of individual human beings working for prolonged periods at the computer. This results in two criteria for efficient work: getting into an optimum initial posture and being able to move during the workday while accomplishing tasks. This research demonstrated that these two criteria can be met through the use of ergonomic worktools.

Optimizing posture at the computer reduces injury resulting from repetitive straining. Numerous studies have demonstrated the physiological strains that result from incorrect postures at the computer. A recent study of newspaper employees at computer terminals indicated that 30 – 40% of the workforce complains of symptoms of musculoskeletal disorders, or CTDs.

The costs of these injuries are not trivial. In his 1998 study of the expenses associated with these injuries, R.D. Fulwiler estimated a single diagnosed CTD case at $100,000. This included both direct costs (Worker’s Compensation, increased premiums, etc.) and indirect costs (lost work time, compensable time off for injured employee, hiring and training a replacement, etc.).

Using the right ergonomic worktools provides the ability to get into and maintain ergonomically correct postures. Meeting this first criterion for efficient work, along with an effective training program, will help reduce the incidence of CTDs.

The second criterion for efficient work, providing movement throughout the day while accomplishing tasks, is required to promote blood flow to muscles and relieve fatigue resulting from static exertion. The impact of fatigue can be more costly to organizations than CTDs, through decreased productivity.

One of the goals of this study was to assess the effectiveness of intermittent standing as a means for providing the required movement to relieve the buildup of fatigue.

The data from this study strongly suggests that standing *working* breaks (from sitting) substitute for non-productive workbreaks (*away from work area*) in alleviating fatigue. The result is decreased time away from task accomplishment and, thus, increased productivity.

Specifically, this study demonstrated that a keyboard support tray, along with a height adjustable monitor arm, can achieve this end. Both require stand-up capability and specific usability guidelines for height and tilt, in conjunction with a comprehensive and participative training program, to make this impact.

When these ergonomic worktools are integrated into the workstation design, the work environment accommodates the use of the PC in the modern office; allowing traditional office furniture to provide ergonomic solutions to today’s automated environment. This has been proven to increase the efficiency of the “person sitting in front of the computer” and, thus, organizational productivity.

BACKGROUND

The Problem

Sitting for prolonged periods while performing repetitive tasks, which requires constrained postures, is now known to be problematic with respect to overall wellness and work productivity. These problems can be expressed directly as lowered work output or indirectly as health/fatigue problems (Dainoff and Dainoff, 1986). The underlying explanations for these problems can be examined on two primary levels.

First, there is the problem of poor fit. Traditional (non-adjustable) workplace furniture was designed for traditional office equipment (pre-computer) on the basis of average body dimensions. However, the range of human anthropometric variability is such that most people cannot achieve a reasonable working posture when asked to interface with a computer placed on the traditional desk.

The furniture industry recognizes this problem and has attempted to resolve it by using supplemental keyboard support trays. The logic behind the keyboard support tray was that the traditional 28” – 30” desk top was too high for most people to get into a reasonable keying posture (the typing return, designed for a traditional typewriter, although lowered, is too small to support a desktop computer).

These first generation keyboard support trays have not been a good solution. The author conducts regular walkthroughs of organizations and constantly observes the inadequacies of these trays. Most recently, in two large public sector worksites in the Cincinnati area, fewer than 10% of keyboard trays provided to employees were used as intended. The most typical use – by female employees – was as a place to store a purse under the desk. The same individuals would place their keyboards directly on the desk top – accepting the resulting awkward posture. Interviews indicated that the trays were complicated and difficult to adjust; moreover, they placed the user too far from the desk, so that most of their work materials were beyond their work envelopes, or ergonomic reach zones.

Beyond the difficulty in adjustment and the resultant lack of usage lies another concern that has been expressed by several authorities (e.g. Greico, 1987; Winkle and Oxenburgh, 1990). Their studies demonstrated that maintaining fixed prolonged posture – even in an ergonomically optimal work configuration – was problematic for the body. The inherent problem is muscle fatigue from working in prolonged static postures; independent from healthy posture. The solution is to get the seated worker to maintain an efficient working posture while changing positions on a regular basis.

The Physiology of Static Muscle Fatigue

Muscular exercise requires energy. Energy is produced through oxidation of muscle fuels, which necessitates oxygen. Oxygen is transported to the muscles through the blood and diffused across the capillaries, which surround and penetrate the muscles, and into muscle fibers.

The blood flow to the muscles is regulated by the amount of energy required for muscle movement. However, muscle movement, determining the degree of capillary activity, requires both contraction *and* extension of muscles. Thus, muscles in prolonged static contraction receive less blood, and thus, oxygen, necessary to provide the energy for the exertion.

The lack of oxygenated blood to the exerted muscle results in fatigue, referred to as static muscle fatigue.

The nature of computer work, in which muscles in the arms and legs are often contracted for prolonged periods (static contraction), inhibits sufficient blood flow to these muscles. Consequently, the muscles become fatigued, which causes an antsy, anxious feeling that induces the need to exercise the muscles.

Static muscle fatigue is relieved only through muscle movement. During contraction and extension, the rate of blood flow to the muscles is increased to optimal levels.

The Effect of Fatigue

The natural response to the antsy feeling from static muscle fatigue is to subconsciously fidget, which usually entails automatically shifting postures within the chair. However, these minor postural changes typically do not provide adequate increases in blood flow to relieve the fatigued muscles.

This lack of relief ultimately causes employees to get up and walk from the work areas, referred to as *"fatigue-induced work departures."* These excessive workbreaks occur too frequently and last too long.

There is an apparent increased acceptance of time away from the work area. Work ethics have changed to excuse many employees from extended periods at the computer. Frequent breaks have become common and justified relative to the way we view the stress and strain of today's protracted computer work.

The author raises the question as to the degree that workstation design can alleviate the fatigue that precipitates the initial urge to depart from the work area. Could a more ergonomic environment minimize fatigue and reduce the need to walk away from the work area?

Many employees do not have the liberty to depart from the work area as required due to fatigue. Additionally, many employees work on deadlines and do not have the time to address fatigue-related problems. They continually "gut it out" for the sake of getting the job done as quickly as possible. A valid question is raised as to the long-term effects on the body due to the strain experienced during these periods.

Relieving Static Muscle Fatigue in the Workplace

The primary method of relieving fatigue from computer use is the workbreak. Departing from the work area requires standing and walking, which increases the blood flow to fatigued muscles and re-energizes them.

The National Institute for Occupational Safety and Health (NIOSH) promotes workbreaks as being beneficial both in terms of the direct effects on improving work output and the indirect effects on reducing musculoskeletal fatigue (Swanson, Sauter, and Chapman, 1989).

At issue, then, is the required amount and duration of workbreaks and their ultimate effect on time spent at the work area for task accomplishment. The underlying problem also is social in nature, involving the difficulty inherent in minimizing the workbreak time of potentially hundreds of employees in the same facility. The more an employee departs from the work area, the more he or she gathers around the "water fountain" in discussions which often extend the break beyond the time required to relieve fatigue.

Swanson et. al. (1989) indicate that replacing passive work breaks with activity through task changes is beneficial. However, since their writing, changes in the workplace, due to the prominence of the PC, have centered most employees' tasks on the use of the computer, limiting the flexibility to alter tasks as required due to fatigue.

Ultimately, the intensive workloads and demands on employees in today's office environment require relieving fatigue from static prolonged postures without habitually departing from the work area. This necessitates breaks from static postures *while maintaining the work effort* at the automated workstation.

Today's automated workstation design must be measured by its ability to provide these working breaks (from sitting) to relieve fatigue while increasing the time spent on task accomplishment.

Benefits of Standing

A major paper by Winkle and Oxenburgh (1990) outlined the benefits of alternating between sitting and standing. Their research determined the benefits of providing active (exercise) breaks vs. passive rest breaks from the point of view of maintaining the health of muscles and spinal disks. They argue that alternating between sitting and standing positions is the most effective way to maintain productive workflow.

DISCUSSION OF FINDINGS

The Link between Standing and Productivity

As in the work by Winkle and Oxenburgh, this study provides evidence for increases in comfort and productivity from alternating between sitting and standing. The subjects in our study consistently affirmed the benefits of intermittently standing. This was indicated throughout the study and particularly in the responses to the daily question: "What adjustments gave you relief, where did you experience that relief, and why?" Some of the responses include:

> "I stood because it kept my knees from getting tired."
> "Standing up gave me relief in my elbows and wrists."
> "Standing helped me… (It) relieved pressure in my forearms and lower back."
> "Adjusting the keyboard helped my wrists and shoulders while sitting and standing."
> "Standing up produced relief in my neck, shoulders, lower back and feet.
> "Standing up helped my knees; I was able to stretch and exercise my muscles.

In fact, 82% of the subjects had positive comments about standing in terms of providing relief and stated that they would stand in the future if their equipment adjusted to standup height.

These findings confirm previous works describing the health and productivity benefits of intermittent standing. However, this study expanded on existing research in that it also determined *how* to promote intermittent standing amongst computer users.

The first part of the study identified specific characteristics in the actuation of ergonomic worktools that encourage regular adjusting. The second part of the study, the workplace simulation, demonstrated that combining these attributes with a comprehensive (how and why adjustments made) and participative (experiencing product benefits) training program will increase the frequency of voluntary periodic standing throughout the day.

In examining the variability of the data in Part 2, it became clear that the subjects could be clustered into two basic groups: the half of the subjects who stood on Day 3 (Standers) and the other half who did not stand on Day 3 (Non-Standers). This is a valuable distinction as Day 3 was designed to simulate a real office environment: all subjects were free to work in whichever way they preferred, there was no trainer in the room and training had occurred three days prior (at the beginning of Day 1).

These two groups differed in the number of stand-ups and their average duration throughout the three days of testing. Most significantly, however, is the difference between the groups with respect to the amount of workbreaks and their average length throughout the three days.

The correlation between intermittent standing and reductions in non-productive workbreaks was clear in studying this data. Non-Standers averaged almost *50% more* breaks. Those breaks *lasted over 50% longer* than those of the Standers. The net effect is that Non-Standers took over twice the amount of breaktime than Standers during the three days of the study. This strongly suggests that intermittent standing can relieve fatigue and act as a substitute for the workbreak (away from the work area) taken as a result of fatigue.

As one of the subjects responded to the question of standing up while working in the future, "Yes, (it) saves you from interrupting workflow and taking extra breaks." To the question of why standing gave relief, another subject explained, "…I could get myself to stretch…(It) increased my productivity…(I) could do more work without stopping."

The significant reduction in non-productive breaktime, demonstrated in this study, provides a direct connection between periodic standing and increased productivity. Influencing the *rate* of stand-up, however, proved to be an issue of product usage.

Functionality vs. Utilization

Part 1 of the study helped to reveal the important distinction between function and utilization. Both keyboard supports *functioned* similarly in that two independent actuators were used to adjust the height and tilt per the procedural guidelines (adjusting to a comfortable position) in Part 1.

Being functionally equivalent, however, does not accommodate *how* those adjustments are made, or specifically, the *method* of adjustment. The distinction between two functionally similar products with differing methods of adjustment was demonstrated in Part 1 of this study, where the adjustment time was reduced by 50% with the more easily adjusted, or more usable, Flipper-style keyboard support.

As an example, two automobiles may have the same *function* regarding speed, acceleration and engine performance. However, if one car has an automatic transmission and one has a manual transmission, the *method* of achieving that performance will be different amongst different drivers.

In affecting a higher frequency of intermittent standing, this distinction is very important. Utilization is a manifestation of method. The subjects qualified the method of adjustment in the Flipper-style unit as easier and preferred. As one subject responded, "…(I was) not as willing to adjust (the Knob/lever-style) because there was more work involved. (The Flipper-style) was easier to move up and down."

The dynamics of the adjustments, along with the comparative and qualitative analysis, provided the valuable link between the *time* taken to make the adjustment, the *effort* inherent in the method of adjustment and the *tendency* to make the adjustment. This greater tendency was revealed to produce an increased likelihood of making the easier adjustment and, thus, an increased *frequency* of adjustment. This analysis provided the basis for a definition of usability, with respect to the method of adjustment and, consequently, a key requirement in keyboard support tray design.

However, usability alone did not prove to solely affect utilization. A specific training methodology was employed to achieve a rate of intermittent standing sufficient to produce the outcomes of this study.

Effective Training

The training procedures used in this study clearly had a marked effect on the frequency of intermittent standing as one-third of the subjects stood on Day 1, following the 45-minute training session.

The training was comprehensive as it not only detailed how to use the adjustments, but it also presented each subject with postural-related ergonomic guidelines and explained why the guidelines are important. Clearly, explaining how the controls operate is crucial to utilization. A typical response to the question: "Was training an improvement?" was one subject's answer, "Definitely, otherwise I wouldn't know what each thing was used for."

However, interview responses were just as strong as to the effect of explaining *why* the adjustments are important. As one subject explained, "(The training) helped me keep in mind how to sit and why I should stand...(It was) an improvement…I would have been in pain by now from all the typing…(I) felt like I was working faster."

There were two elements to the participatory nature of the training; the first of which was coaching the subjects as they practiced making the adjustments prior to the initial work effort. The act of doing, integrated into the training, ensured that each subject fully understood how the adjustments were made and increased the subjects' comfort levels in making them.

The second participative element of the training regarded *how* the subjects worked during Day 2 as they were directed to stand at approximate 35-minute intervals throughout the day. A highly successful training technique emerged out of this direction as approximately half of the subjects, who did not stand on Day 1, stood on Day 3 (with no direction) -- after the Day 2 directed standing.

It became clear from the interviewing sessions that the experience of standing (more specifically, the subsequent increased comfort from standing) led to the higher frequency of standing amongst the subjects. This reinforced the action and modified the behavior to voluntarily integrate stand-up postural changes into the daily routine. One subject explained, "(I) got relief in my back, arms and shoulders while standing. Muscles need to be periodically relieved. My muscles hadn't been used while sitting."

Further confirmation of the effectiveness of the directed standing is demonstrated by the 40% increase in the frequency of stand-ups on Day 3 amongst the subjects who stood on Day 1.

We can conclude that an effective ergonomic training program must be participatory in nature; including some form of short-term directive to intermittently stand. Employees will then experience the benefits of standing first-hand, which will counteract any preconceived misconceptions (i.e. short periods of standing are tiresome) and lead to voluntarily application into their daily routines.

The Requirement of Height and Tilt Adjustments in Tandem

The need to adjust the keyboard tilt whenever the keyboard height is adjusted is crucial to prevent harmful wrist bending. A straight line from the elbow, through the forearm, hand and keyboard plane, while keying, referred to as the neutral posture of the wrist, is a basic requirement of preventing potential musculoskeletal disorders, such as Carpal Tunnel Syndrome.

Whenever the height of the keyboard is adjusted from a fixed seated position, the forearm angle changes. This necessitates a change to the keyboard angle to maintain a straight line from the elbow to the fingers, which eliminates bending at the wrist.

There were numerous times, in both parts of the study, in which the subjects did not adjust the tilt on the Knob/lever-style unit. The videotape analysis of Part 1 showed that the Flipper-style keyboard support was adjusted correctly (both height and tilt) almost every time. Further, in Part 2, all but one subject revealed in the interviews that the tilt was adjusted (on the Flipper-style unit) every time the height was adjusted.

By examining the differences between the units in the Part 1 comparison, with respect to the height/tilt relationship, it became apparent that the usability features of the height adjustment must be equally applied to the tilt adjustment to ensure that height and tilt adjustments are made *in tandem*. Adjustment criteria require that the five usability features be applicable to *both* height and tilt. Additionally, to increase the prospect that both adjustments are used simultaneously, both actuators should be *consistent* in the *method* of operation.

It must be noted that in Part 1 the subjects were adjusting the keyboard supports to get into an *initial* comfortable posture, as in the first time a keyboard is adjusted prior to use. Therefore, this is an indication of what happens the first time that employees adjust new keyboard support trays; not just when making adjustments throughout the day. The data suggests that when the height and tilt actuators are not usable or consistent in method of operation, employees may not make both the height and tilt adjustments when they *first* adjust the unit. Thus, there is a stronger likelihood that employees will not get into a correct *initial* posture (never adjust the tilt) and, as a result, key with bent wrists (never use the keyboard support correctly).

Optimal Design for a Keyboard Support Tray

To summarize, there are two functional requirements for a workstation, which will optimize user productivity:

1 – Allow the user to achieve an efficient (not awkward) working posture;
2 – Allow the user to change positions during work.

This study focused on accomplishing these goals through the use of ergonomic worktools, which were integrated into the workstation design. Achieving this using a keyboard tray is supported through its relative low cost and flexibility.

A keyboard support tray, to fulfill these two functional requirements, must possess specific attributes. In achieving the first requirement, the keyboard support must provide a reasonable range of adjustment, including height, depth, tilt and swivel. This provides the correct alignment with the keyboard while viewing the monitor. It also offers access to the worksurface for other tasks, such as writing and referencing documents, within the work envelope, or ergonomic reach zone, to prevent straining from reaching.

To achieve the second requirement, the tray should raise high enough to allow working in a standing posture to provide healthy movement through active working breaks from the seated posture. If the keyboard platform has an acute negative angle (sharply tilted so front is higher than rear), the user may raise the keyboard so the arms may be dropped down somewhat *while maintaining* a neutral (straight) wrist posture. This provides a *range* of keyboard adjustment when standing to provide a different working posture (arms lowered) than when seated.

To achieve both of these goals, it is *essential* that the adjustments be utilized. Since utilization is dependent upon the method, the adjustment mechanisms *must* be easy to use. Thus, the requirement of usability in the adjustment controls – specifically to both height and tilt – is necessary to promote the adjustment to an ergonomically correct (optimal) *initial* posture and at the same time encourage intermittent standing (movement) throughout the day.

This study defines usability of adjustment with respect to the various attributes that affect the rate of adjustment. The subjects in our study had difficulty with adjustment controls, which were clumsy or non-intuitive. In fact, the Knob/lever-style keyboard support tray took 67% longer to adjust than the Flipper-style keyboard support tray.

On examination and interview analysis, we can define usability with respect to the use of ergonomic worktools as mechanisms requiring five attributes:

1 – A minimum number of individual steps required for operation of controls;
2 – The ability to make the adjustment with one hand;
3 – The ability to make the adjustment rapidly;
4 – Keeping the adjustment mechanisms in close proximity to the keying position; and
5 – Keeping the adjustment mechanisms visible from the keying position.

It must be emphasized that, with keyboard support trays, usability must be applied to both the height and tilt adjustment in order to prevent harmful, repetitive wrist bending while keying.

The Inherent Difficulty of Getting People to Stand

The outcome of Part 2 of the study is particularly valuable. In this component of the study, we attempted to simulate a realistic work environment in which, aside from the directed standing on Day 2, subjects were free to take breaks whenever they wished.

As stated previously, the Non-Standers took more breaks, took longer breaks, were less likely to feel that adjusting any of their equipment relieved fatigue, and were less likely to feel that adjusting their equipment enhanced their productivity. The initial observation was as if these people were simply not as accepting of our training and rationale as were those who did stand.

However, if we look at the interview comments in detail regarding the five Non-Standers, the picture is a bit less clear. Four of the five people actually had positive comments about the general benefits of standing. The reasons for not standing on Day 3 varied.

The first subject had difficulty seeing the copy material, but cited specific relief from standing otherwise (we later attached a copyholder to the monitor to eliminate this problem). The second person said she was tired, and standing made her aware of how tired she was. She said, however, that she would stand and work in the future because it "…saves you from interrupting work flow and taking extra breaks." The third person said she had trouble seeing the keyboard (although she was a touch-typist), however, she added that she would stand in the future if the

Flipper-style tray were available to her. The fourth simply didn't feel like it on that day, but also cited that she would use it in the future "…just to get relief from sitting."

In examining these outcomes, a more careful analysis of the general problem of standing as an alternative work posture can be valuable. We can readily understand the potential muscular benefits to be derived from alternating between sitting and standing positions. However, this is a perspective from the outside, looking in. We need to understand the problem from the sitter's perspective.

Sitting involves passive support throughout most of the bodily structures. Active motion is predominantly restricted to fingers and eyes –with supporting movements from forearm and head/neck muscles. Eventually there is a buildup of fatigue, but this process is far from understood. The problem is that fatigue –as generally acknowledged– would lead the worker to stop and rest rather than simply change working styles.

The problem was stated cogently in Branton's seminal analysis of seated posture (Branton, 1976). He indicated that naturalistic studies of sitting have identified a variety of spontaneous sitting postures. The initial explanation for such a combination of motions is: "...random changes of position, an 'urge to move' caused by ischemia..." (Branton, 1976, p. 203.) Ischemia refers to the results of restricting blood flow, as when one's foot falls asleep. The common term "antsy" is a good description of this phenomenon. However, ischemia is not sufficient for predicting the variability and spontaneity of this behavior.

The problem is that most postural adjustments occur at a lower level of consciousness (Bernstein, 1996). Getting workers to stand is akin to teaching people a new action pattern in sports. As an example, in tennis, bending the knees while making a shot is ultimately more efficient in that it requires less energy to hit the ball, by using the legs as well as the arms. However, it necessitates an additional local expenditure of energy, which acts against the principle of minimum action (it is easier to just stand and swing at the ball.) This principle can be taught to act at a lower level of consciousness (muscle memory)—it is the job of the coach to bring the alternative movement into higher levels of cortical motor control—at least until it itself becomes automatic.

However, the problem of getting people to stand is more difficult than the tennis example. The reason is related to sensory feedback. Both the crouching posture, in the tennis swing example, and standing, in response to feeling fatigued, are examples of perception-action cycles. The detection of a threshold level of sensory stimulation is necessary to trigger the corresponding action. In the case of the tennis crouch, the trigger is obvious and straightforward –it is part of a clearly defined pattern of reaction to an oncoming ball. The task of the player (helped by his coach) is to embed this action within the overall attack sequence.

In the case of standing, the trigger is much less clearly defined. The normal response to "antsiness" is to fidget –that is, to automatically shift postures within the constraints allowed by the chair-desk geometry. The major problem we have is to train the user to focus his/her attention on these sensations, and to use them as a trigger for executing a hitherto unfamiliar pattern of responses.

Ultimately, emphasizing intermittent standing through ongoing training efforts, along with the right worktools, can modify work routines so that the response to fatigue will evolve to include the action of standing while working.

A Note Regarding Sit/Stand Adjustable Worksurfaces

The benefits of postural changes throughout the day were clearly demonstrated in the context of providing relief from static exerted postures inherent in computer use. Simply stated, sitting in the same basic position for extended periods causes muscle fatigue while muscular movement (contraction/extension of the muscles) relieves fatigue.

Sit/stand adjustable work surfaces provide postural changes (muscular activity) primarily in the lower body (legs). Seldom, is any change affected in the upper body as the arms and shoulders maintain the same position (forearms parallel to the ground) after standing. This is an inherent limitation in the sit/stand worksurface.

This absence of muscle movement in the arms and shoulders has no positive effect in terms of increasing blood flow or relieving fatigue in the upper body.

The author suggests that there may be significant benefits in terms of increasing blood flow to fatigued muscles in the upper body, shoulders and arms when the keying surface can be raised to a standing posture at a somewhat lowered position, in which the arms would be angled downward. As most users key with their arms parallel to the floor while sitting, raising the keyboard to stand-up at a lower height (than the height where arms are parallel to floor) will provide a different keying position and, thus, muscle movement in the shoulders and arms.

It is the ability to acutely angle the keyboard platform negatively that distinguishes keyboard supports from sit/stand work surfaces in this application. When the keyboard is negatively angled, consistent with the downward angle of the arms, the user will maintain a neutral posture of the wrist.

Standing with the Flipper-style keyboard support in this study was accomplished by angling the arms downward at approximately 10° – 25° (depending on subject’s height) while tilting the keyboard surface negatively at the same angle to eliminate wrist bending.

DESCRIPTION OF STUDY

Part 1. Analysis of Comparative Usability

Determination of Products for Analysis

The most consistent complaint regarding the usage of keyboard support trays is that they are too cumbersome to adjust with any degree of regularity. In an effort to determine the features that would promote adjusting, we compared two functionally similar units, with diverse methods of actuation. That is, both supports had independent height and tilt adjustments, but a major difference in *how* they were adjusted. Comparing these units factored out the *function* and allowed a focus solely on the *method* of adjustment (adjustment style) as a determinant of the time taken to adjust (effort).

The first keyboard support provides height and tilt flippers in front of the unit, under the palm support. A one-step process, in which the forefinger and thumb are squeezed between flipper and palm support, activates the height or tilt adjustment. These flippers can be utilized independently or at the same time. The adjustment flippers, labeled “HEIGHT” and “TILT”, are visible from the keying position. Their placement under the palm support allows activation essentially at the keying position. This study refers to this unit as the Flipper-style keyboard support.

The second unit represents a common style of keyboard support, generally available from most systems furniture manufacturers. This keyboard support mechanism adjusts in height with a round knob on the right hand side of the height adjustable arm. Platform tilt adjustment is achieved using a ratchet-style lever on the left side of the arm. This study will refer to this unit as the Knob/lever-style keyboard support.

The Pre-Study Product Evaluation

(Consideration of available methods of adjustment actuation in alternate style units).

Prior to Part 1 of this study, a pre-study product evaluation was conducted to determine the keyboard support styles to be used in the comparative analysis. Two other styles of keyboard supports were considered, which also functioned similarly but had different adjustment actuators.

The first style, the most common unit today, uses one knob to adjust both height and tilt. The knob is positioned on the right side of the arm, under the platform. This unit was not used in the comparative analysis, due to its awkward adjustment and the resulting possibility of deviations in the adjustment time comparisons.

This keyboard support is adjusted by bending forward to reach the knob and loosen with the right hand and then simultaneously positioning the height and tilt in place with the left hand while tightening the knob. Often, the platform height and tilt position altered during the act of reaching to tighten the knob. This made the desired comfortable keying position difficult to accurately attain, requiring numerous attempts, as in a trial and error process. Thus, the extra time taken for additional adjustment sequences, to get into the preferred position, would skew the adjustment time results.

Another style of unit was considered for the comparative analysis. This keyboard tray uses the keyboard platform itself as the height adjustment actuator. With two hands, the keyboard platform is tilted upward to unlock the mechanism. The platform can then be raised or lowered before bringing the platform level to lock into position. The tilt adjustment, however, is controlled by a knob located at the far end of the arm, away from the user. To adjust the tilt, the user must first loosen the knob, then position and hold the platform at the desired angle while reaching to the back of the arm, under the surface, to tighten the knob, locking the tilt into position. This process was even more awkward as the aforementioned unit and required numerous attempts to attain the desired keying position.

The goal of the comparative analysis of the adjustment method was to determine the factors that affect the rate of adjustment and establish the requirements of usability. It was imperative to focus on the actuation style as a basis for the comparison and to factor out time for multiple adjustment sequences due to awkwardness of the adjustment controls. Thus, the styles described above were excluded from the comparative analysis of this study.

The Evaluation

The evaluation had two parts. The first part consisted of a detailed user analysis of the individual actions required to adjust each keyboard support. The second part consisted of an empirical study in which users were videotaped while adjusting each keyboard support six times. The keyboard support was placed in an extreme position, in which the platform was positioned as high and tilted as sharply as possible. The subjects adjusted the keyboard to a proper ergonomic keyboard height and angle position while seated, based on guidelines from a training session using a training video. The average time to adjust was recorded and compared. A detailed analysis of user adjustments for each unit will now be described.

Comparative Task Analysis in Adjustment of Keyboard Supports

Perceptual-Motor Analysis
Knob/Lever-Style Unit

The structure of these controls requires that the height and tilt adjustment be carried out in sequence. For this analysis, we assume, as is typical, that the height is adjusted first, followed by the tilt. If the final position is not correct, the entire process was repeated.

1 – Identify location of height adjustment control (visual and/or tactile perception).
2 – Loosen height adjustment control with right hand (rotary twist movement).
3 – Adjust tray height with left hand (grasp and move).
4 – Identify if height is appropriate (visual and kinesthetic perception).
5 – Tighten height adjustment control with right hand (rotary twist movement).
6 – Identify location of tilt adjustment control (visual and/or tactile perception).
7 – Loosen tilt adjustment control with left hand (rotary twist movement).
8 – Adjust tray height with right hand (grasp and move).
9 – Identify if tilt is appropriate (visual and kinesthetic perception).
10– Tighten tilt adjustment control with left hand (grasp lever and move up).
11– Identify if height is still appropriate (visual and kinesthetic perception).
12– If necessary, return to step 1 or 6 and repeat.

> *Comment:* Both height and tilt controls are located under the support tray with this unit. Thus, steps 1 and 6 will involve some “hunting.” Furthermore, since the two controls have different modes of action, there is a possibility of confusion in movement types.

Perceptual-Motor Analysis
Flipper-style Model

The structure of these controls is such that a trained user can adjust both height and tilt simultaneously. This is the scenario, which is described.

1 – Identify height and tilt controls (visual and tactile perception).
2 – Activate height and tilt adjustment mechanisms (right and left hand squeeze motions using forefinger and thumb).
3 – Adjust height and tilt into correct position (Raise/lower and tilt using forefinger and thumb).
4 – Lock height and tilt into place (Release right and left flippers).
5 – Identify if height and tilt are appropriate (visual and kinesthetic perception).
6 – If necessary, return to step 1 and repeat.

Comment: Step 1 should be relatively rapid since both the height and tilt controls are visually accessible. In addition, the adjustment action itself is faster since it requires a pinch and release. Further, adjusting the unit (raising or lowering) occurs in the squeezed, or pinched, mode and simply letting go locks the unit into place.

Thus, in effect, steps 1 – 4, the identification, activation, adjustment and locking of both height and tilt can be carried out as a single smooth event. Since this all happens while the user is in the keying position, validating the correct location for both height and tilt (step 5), is essentially part of the same action. This is in contrast to the Knob/lever-style system where each adjustment must be a separate event.

Experimental Comparison of Adjustment Times

Method

The laboratory setup contained two worktables in the same room. Each table contained a personal computer. The Knob/lever-style keyboard support was attached to the first and the Flipper-style was attached to the second. A height adjustable ergonomic chair was used for both workstations. A video camera was positioned so that a clear view of keyboard tray, hands and arms was obtained with respect to each workstation.

The subjects were eight advanced undergraduate students. Each had some general knowledge about the field of ergonomics, but did not have specific information about the two keyboard supports or the nature of the study. Each subject was introduced to both of the units. Four subjects used the Knob/lever-style first; the remainder reversed the order.

After a period of training involving a videotaped presentation, subjects were asked to adjust the keyboard height and tilt to a comfortable position. They then typed for several minutes after which the keyboard tray was re-positioned to it’s extreme height and tilt. Subjects were instructed to again re-adjust the height and tilt. Each subject adjusted the keyboard six times. At the conclusion of the adjustment session, the subjects were asked which keyboard support was easier to adjust, which they preferred and why.

Part 1 Results

Analysis of the videotape record was carried out in which the total time to perform the complete adjustment from start of adjustment until typing begins was recorded. Average (mean) adjustment time for the Flipper-style keyboard support was 11.76 seconds compared with 19.61 seconds for the Knob/lever-style keyboard support (67% longer).

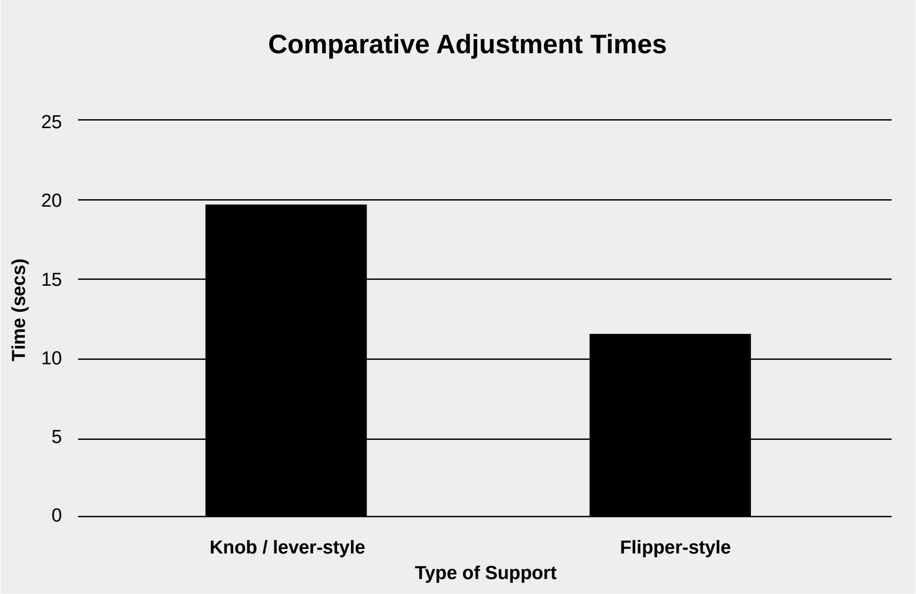


FIGURE 1

In addition, every one of the eight subjects indicated that the Flipper-style keyboard support was easier to use and was preferred to the Knob/lever-style due to the decreased effort in adjustment.

Defining Usability

The results of the comparative study give strong support to the argument that the Flipper-style actuation is more usable than the traditional, knob-style approach. Observation of the adjustment process and examination of the differences in the two units helped to determine the factors that led to defining usability in the context of the adjustment controls. This was coupled with analysis of the subjective data gathered from each subject with respect to what element of each unit led to a more or less usable adjustment, to complete our definition. The primary differences in the actuation controls, which affected adjustment, are detailed below:

(1) *A minimum number of individual steps required for operation of controls:*

The movement analysis indicates fewer steps with the Flipper-style keyboard support.

First, each independent adjustment, height or tilt, requires less steps. Knobs or levers require a clearly defined loosening step, an independent movement to the platform and, finally, a tightening step, which increases the number of actions required for adjustment. This analysis does not account for the degree of difficulty in the independent steps, specifically the turning of a knob, in comparison to the 2-finger squeezing of the flipper.

Second, the number of individual steps required to correctly adjust the entire unit, as previously listed, amount to 12 for the Knob/lever-style unit and 6 for the Flipper-style unit.

(2) *The ability to make the adjustment with one hand:*

In the Flipper-style keyboard support, adjustment of tilt and height could be carried out simultaneously, since each can be accomplished with one hand. The task analysis indicates that release/tightening of the adjustment mechanism and actual movement of the keyboard platform could essentially be part of the same motion. This contrasts with the traditional, Knob/lever-style mechanism in which these two functions require separate operations.

The actuation of the knob with one hand coupled with the movement of the platform performed with the other had a degree of awkwardness in adjustment with the Knob/lever-style, which affected the usability of this unit. This is primarily due to the location of the knob under the platform and the requirement to reach while adjusting the unit.

The subjects noted the difference in the *perception* of the ease in adjustment when performed with one hand, in contrast to the two-hand adjustment, as a factor in usability of the adjustment actuator.

(3) *The ability to make the adjustment rapidly:*

Adjusting the Knob/lever-style keyboard support takes almost twice as long as the Flipper-style keyboard support. The subjects' responses were consistent with respect to the relationship between speed of adjustment and the inclination to adjust in that a quicker adjustment is more likely to be adjusted. Thus, in the real work environment speed is a primary factor in the rate of adjustment.

(4) *Keeping the adjustment mechanisms in close proximity to the keying position:*

The short distance between the control levers and the keyboard is one variable accounting for the decreased adjustment time with the Flipper-style support. Not only is the travel time reduced, but also the initial detection of the control location is faster and easier.

Additionally, the close proximity of the adjustment to the keying position in the Flipper-style keyboard support allowed the subjects to adjust the unit from the keying position, without physically altering their posture (i.e., reaching under keyboard platform). This produced significantly more successful adjustments and minimized the need to re-adjust due to inadvertent initial adjustment to an undesirable position.

(5) Keeping the adjustment mechanisms visible from the keying position:

The user can see both controls from a keying posture with the Flipper-style unit. Thus, when adjustment is desired, controls can be immediately located. Further, having visible contact with both the height and tilt adjustments of the Flipper-style unit served as a constant reminder of the need to make each adjustment.

This was confirmed in the observation of the height and tilt adjustments made in tandem with the Flipper-style unit in contrast to the Knob/lever-style, in which the tilt adjustment was often forgotten. In response to the question of whether the height and tilt was adjusted together on the Knob/lever-style unit, one subject explaining the importance of visibility stated, "…out of sight, out of mind."

This analysis of comparative usability helped to determine the key attributes of keyboard support adjustment that promotes a higher rate of adjustment. The primary question then becomes one of actual usage in the workplace, specifically regarding the use of adjustments as a means to promote intermittent standing. This is the purpose of the next part of the study.

Part 2. Integrating the system into the workplace.

Goal: Work simulation with training.

In this part of the study, our objective was to set up a realistic simulation of an actual office environment while retaining the benefits of laboratory control. Within this workplace, 11 professional clerical workers (hired from a temporary agency) worked for three days performing data entry tasks.

The subjects, recruited from a temporary help agency, were required to type at least 30 wpm, and to be familiar with Microsoft Word. A $50 bonus was provided for subjects remaining in the study for all three days. Their task was to create a database of citations (author and title) of scientific articles using Microsoft Word. Lists of references to be entered were photocopied and placed on a copyholder. The task was described as straight typing without any requirement for formatting. Accordingly, it was not necessary for a mouse to be used. This was done to keep the task as simple as possible.

Each workstation consisted of a table containing the Flipper-style adjustable keyboard support tray (with stand-up capability), a height adjustable monitor arm, a copyholder, attached to the side of each monitor (not introduced until the fourth subject), and an adjustable task light. A personal computer was provided for each workstation; the CPU of which rested on a CPU holder on casters. An ergonomic chair was provided. The chair had a height adjustable seat pan, independent adjustability of back rest and seat pan angle (including forward inclination) and adjustable arms[1].

Prior to the work effort, the subjects received formal training, including one-on-one coaching on the use of ergonomic equipment. Videotaped instructions on how and why to adjust the chair, monitor arm and keyboard support tray were provided. The instructions were participative in that the tape was periodically stopped to allow subjects to practice the control operations shown in the tape. This part of the training emphasized the importance of intermittent standing and the subjects practiced standing during the videotape instruction period. In addition, a poster illustrating the major points of the videotape with examples of good working posture was placed on a separate copyholder adjacent to the workstation. The instruction period lasted about 45 minutes after which the subjects commenced their work.

The first three subjects in Part 2 (Subjects 1 – 3) were provided with a 15-minute scheduled workbreak in the morning and in the afternoon. This setup did not provide any data regarding workbreaks, as the subjects waited for the next break to relieve fatigue. Thus, there was no mechanism in place to measure the effect of fatigue on productivity (amount and duration of workbreaks). Additionally, a more accurate portrayal of what occurs with most employees in the real world would allow for workbreaks whenever required, as the most personnel can depart from their work areas as they choose. As a result, the testing procedure was modified for Subjects 4 – 11.

These subjects were instructed that there would be no scheduled rest breaks. They were told to use the equipment to get relief from fatigue but that they were free to take a rest break whenever needed. A container of coins was available so that free drinks or snacks from vending machines could be obtained when desired.

Throughout the course of this study, all subjects were continuously videotaped. They periodically filled out questionnaires throughout the day and were interviewed at the conclusion of each day.

On Day 1 of the study, directly following the training session, the subjects were asked to use the adjustable equipment to relieve fatigue while they worked. On Day 2, each subject was directed to stand while working. Approximately every 35 minutes, subjects were asked to get into a standing position. They were instructed to spend as little or as much time as they wanted while standing, but that they should at least try it out. On Day 3, the subjects were instructed to work how they preferred; no additional instructions or training were given and no instructor or monitor was in the lab.

[1] Please refer to Appendix 1 for a listing of products used in the evaluation.

Part 2 Results

1. *Frequency of Stand-up*

Table 1 gives a visual indication of the frequency of intermittent standing. This table indicates the number of times (frequency) that the subjects stood on each of the three days of the study.

	Subject	Day	Frequency
Scheduled Breaks	1	1	0
		2	9
		3	0
	2	1	3
		2	8
		3	6 ●
	3	1	3
		2	8
		3	5 ●
Unscheduled Breaks	4	1	0
		2	9
		3	2 ●
	5	1	0
		2	5
		3	2 ●
	6	1	0
		2	9
		3	3 ●
	7	1	0
		2	9
		3	0
	8	1	1 ■
		2	9
		3	0
	9	1	1 ■
		2	9
		3	0
	10	1	0
		2	9
		3	0
	11	1	0
		2	9
		3	1 ●

■ Indicates subjects who only stood on Day 1

● Indicates subjects who stood more frequently on Day 3 than Day 1

TABLE 1

There are several ways of looking at these results. The first analysis involves the number of subjects who stood in response to the training instructions. For this, it may be recalled that subjects received initial training on standing on Day 1 and were directed to stand on Day 2. Thus, looking at those people who stood on either Day 1 or Day 3 (marked either with ■ or ●) assesses the overall impact of the training program on standing. Table 1 shows that 8 out of the total of 11 people (73%) stood on either of these days.

A second way of examining the data is to look at the impact of the Day 2 directed standing. This is evident in the subjects who stood more frequently on Day 3 than on Day 1. Those subjects, marked with ●, include 6 out of a total of 11, for a percentage of 54.5. Those who stood only on Day 1 are marked with ■.

Collectively, participants stood on Day 1 a total of eight times. After the directed standing on Day 2, in which they experienced the benefits of intermittent standing, the participants stood 19 times for a 138% increase in total stand-ups. This can be attributed to the directed standing as much as to the reinforced benefits of standing throughout the three days of testing.

The following graph plots the increase per subject in the average number of stand-ups in Day 1 vs. the average number of stand-ups in Day 3 (only includes subjects who stood on both days):

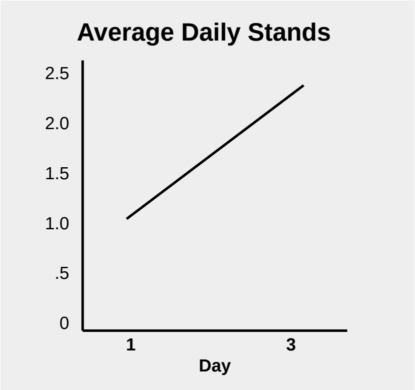


FIGURE 2

2. The Duration of Standing

Average daily standing time

The first analysis regarding the duration of standing involves the average length of the standing period for each day. For this analysis, we only included subjects who actually stood on a given day. That is, we did not include zero times in our average. The average daily standing time was 5.6 minutes. The breakdown by days, however, is more interesting and is contained in Table 2.

Table 2 represents the average standing times per day broken down by percentiles. This gives an indication of the variability in the data. The 50th percentile is the median and indicates total average standing time.

Day	25th Percentile (minutes)	50th Percentile (minutes)	75th Percentile (minutes)
1	2.32	3.67	5.89
2	3.19	6.07	12.37
3	2.95	5.50	20.67

TABLE 2

This table gives a clear indication that the directed standing was effective. The average length of a stand was 3.67 minutes for those who stood on the first day. It increased to 6.07 minutes when subjects were asked to stand on Day 2. However, the average standing time on Day 3 was only slightly less than on Day 2. Moreover, some people stood longer than they did on Day 2.

Figure 3 gives a more visual impression of this data. For each day, it indicates the number of people who stood and for how long they stood. The y-axis of each graph corresponds to the number of people, while the x-axis indicates the average standing time. The top section of the graph shows that, for Day 3, there were three people whose average standing times were between 17 and 26 minutes. It is apparent that these people experienced a significant benefit from standing.

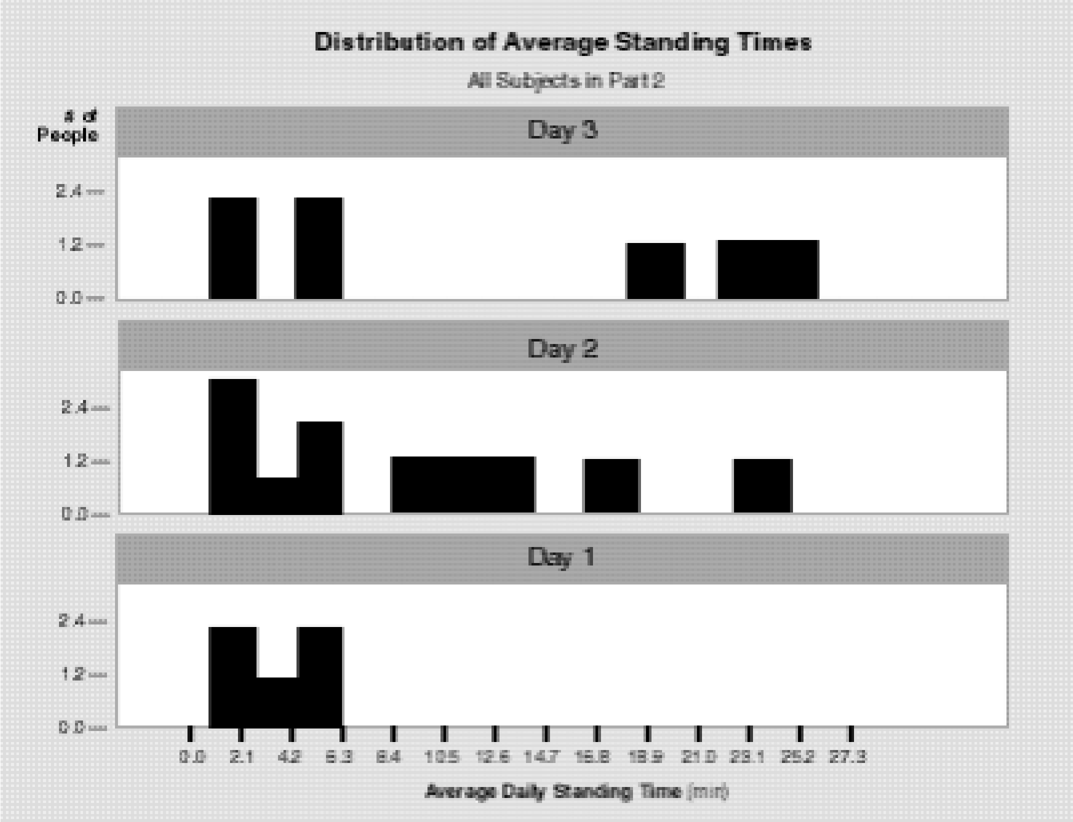


FIGURE 3

A different perspective on these results can be gained by examining Figure 4. This mode of presentation is called a "box plot." Average standing time is illustrated on the y-axis. The solid box contains 50% of the data – ranging from the 25th to the 75th percentiles. The horizontal line through the box represents the median (50th percentile). The remaining data is included within the brackets above and below the boxes.

This figure clearly illustrates the increase in standing time as the study progressed.

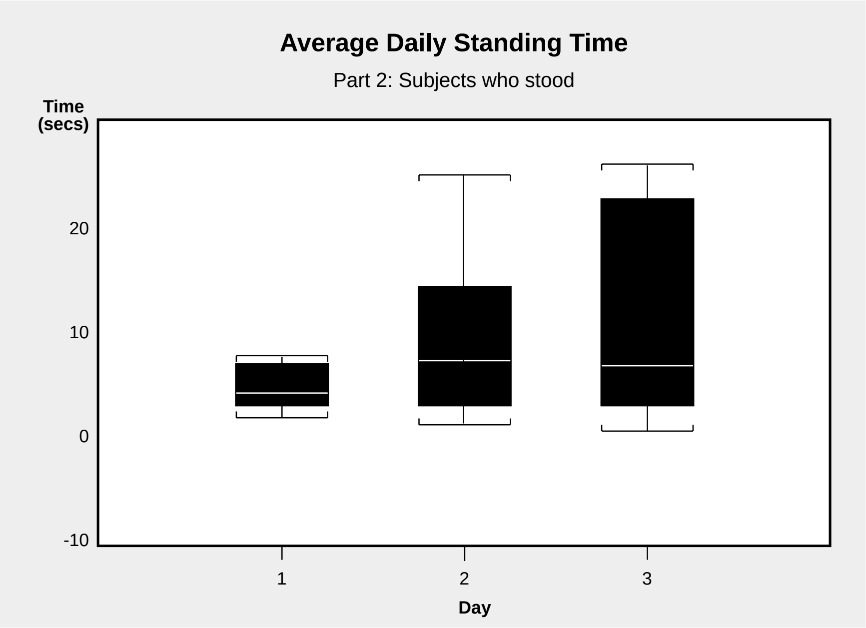


FIGURE 4

3. Breaks and Workpauses

As explained in the setup of Part 2, only Subjects 4 – 11, after the study was modified, were free to take breaks whenever desired. The only scheduled break was the pause for lunch. This amendment in Part 2 also allowed the videotape records to categorize type, frequency and duration of workbreaks by subjects for additional analysis. This analysis proved valuable in assessing the effect that intermittent standing has on the time spent away from the work area during workbreaks and workpauses and, thus, on productivity. This analysis only uses the data from the eight subjects who were free to break from work as required due to fatigue.

We were able to identify three types of breaks taken with any degree of regularity. The first type of break was where subjects actually left the room. We call these “Away” breaks. In addition, there were times where subjects paused for at least 10 seconds while remaining at their workstations. These breaks could occur either while subjects were standing or sitting. Finally, we combined all three of these categories into a total break time.

Table 3 indicates the overall frequency per day and the total and average time per day devoted to breaks averaged across the subjects. It can be seen that the average subject took fewer than two away breaks per day, and that these lasted less than six minutes. However, more time was spent in short (less than one minute) “minibreaks” while seated at their workstation. Very few such breaks were taken during the periods of standing.

At first glance, the frequency of minibreaks shows correct use of the workpause as a means for relieving fatigue. However, it soon became clear that the subjects who intermittently stood had a significantly reduced frequency of these minibreaks. Thus, we found that the reductions in output (non-productive time *at* the work area) associated with fatigue increased with the subjects who did not stand.

Break Type	Frequency	Time (minutes)	Average (minutes)
Away	1.75	10.1	5.77
Sitting	18.88	15.03	0.80
Standing	1.46	0.97	0.66
Total	22.08	26.1	1.18

TABLE 3

Differences in Subject Characteristics

In examining the variability among our different measures, it became clear that subjects could be clustered into two basic groups. Half of the Part 2 (after the modification) subjects did not choose to stand on Day 3; the other half did. There were some striking differences between those who stood on Day 3 (Standers) and those who did not stand on Day 3 (Non-Standers) throughout the three days of the study. The following analyses examine these differences.

Average Standing Time

As the following figure shows, there is a consistent increase in average daily standing time across the three days of the study for the Standers.

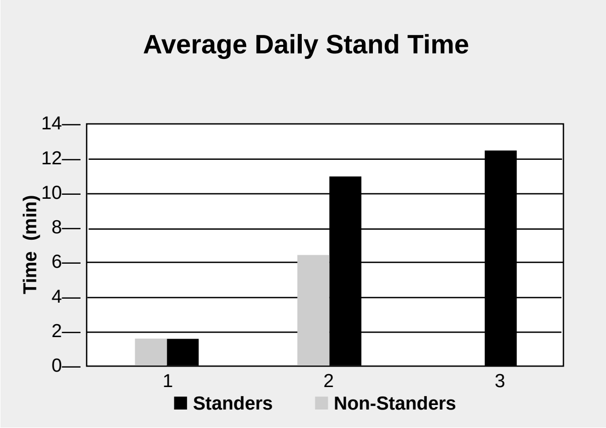


FIGURE 5

Frequency of Workbreaks

Further comparison of Standers vs. Non-Standers, over the three days, regarding the *frequency* of workbreaks shows that those who did not stand on Day 3 averaged 47% more workbreaks (26.25 total workbreaks per day) than those who did stand on Day 3 (17.9 total workbreaks per day).

The *cumulative effect* of standing on the number of workbreaks is through an analysis of Day 3 independently from the average of the three days. The subjects who stood averaged 19.75 workbreaks on Day 3 as compared to 34 .5 workbreaks for those who did not stand; a 75% increase in the amount of workbreaks.

The following graphs (Figure 6) illustrate the average number of workbreaks for the Standers vs. Non-Standers for the three days of the study. This is followed by the percentage increase in the average number of workbreaks by Non-Standers over Standers for the same period:

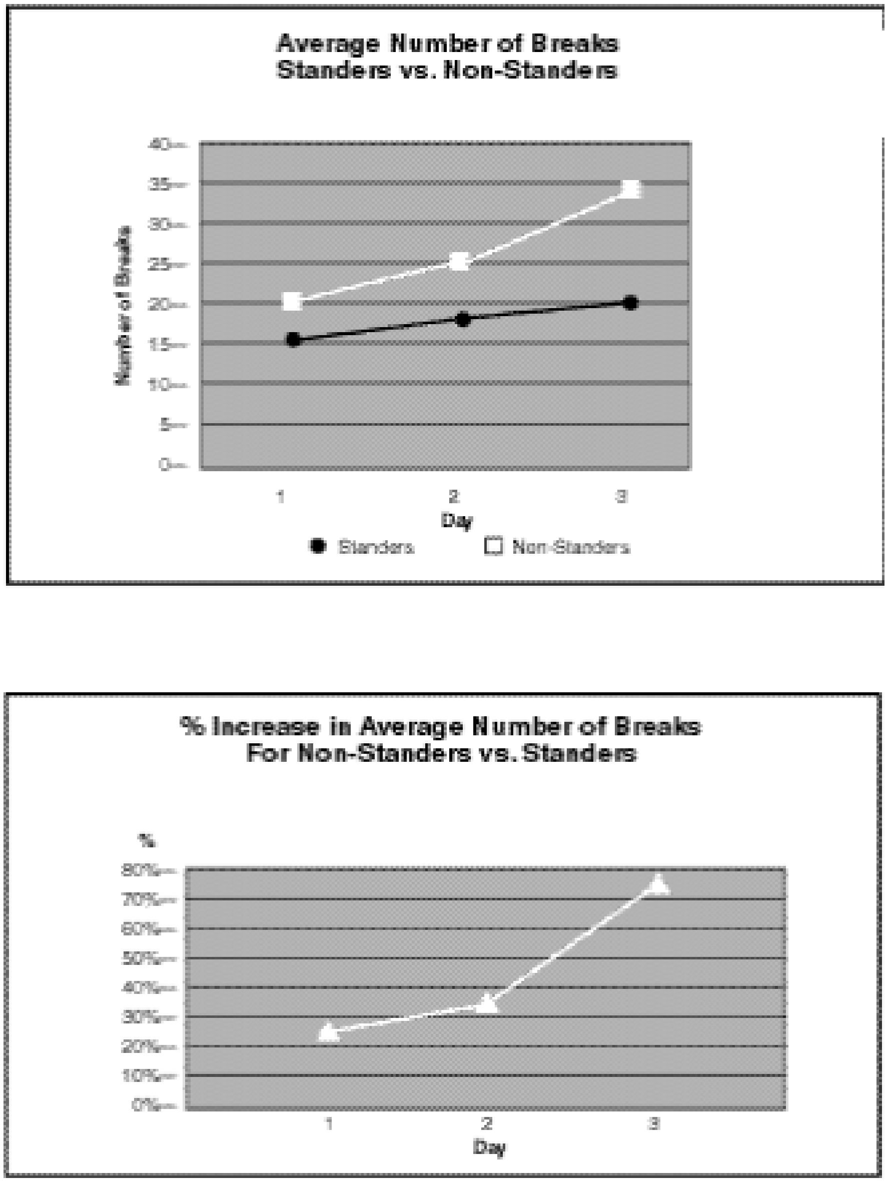


FIGURE 6

Duration of Workbreaks

An additional comparison of Standers vs. Non-Standers regarding the *duration* of workbreaks shows that those who did not stand on Day 3 spent twice as much total time per day on breaks (34.9 minutes), averaged over the three days, as those who did stand (17.25 minutes).

Analyzing the cumulative effect, on Day 3 alone, the subjects who stood averaged about 17.5 minutes on workbreaks. The subjects who did not stand on Day 3 averaged over 66 minutes on workbreaks (278% more unproductive time per day).

The comparison of total daily breaktime spent by the Standers vs. Non-Standers, for each day, is depicted along with the percentage difference in the amount of breaktime between the two groups in the following graphs (Figure 7):

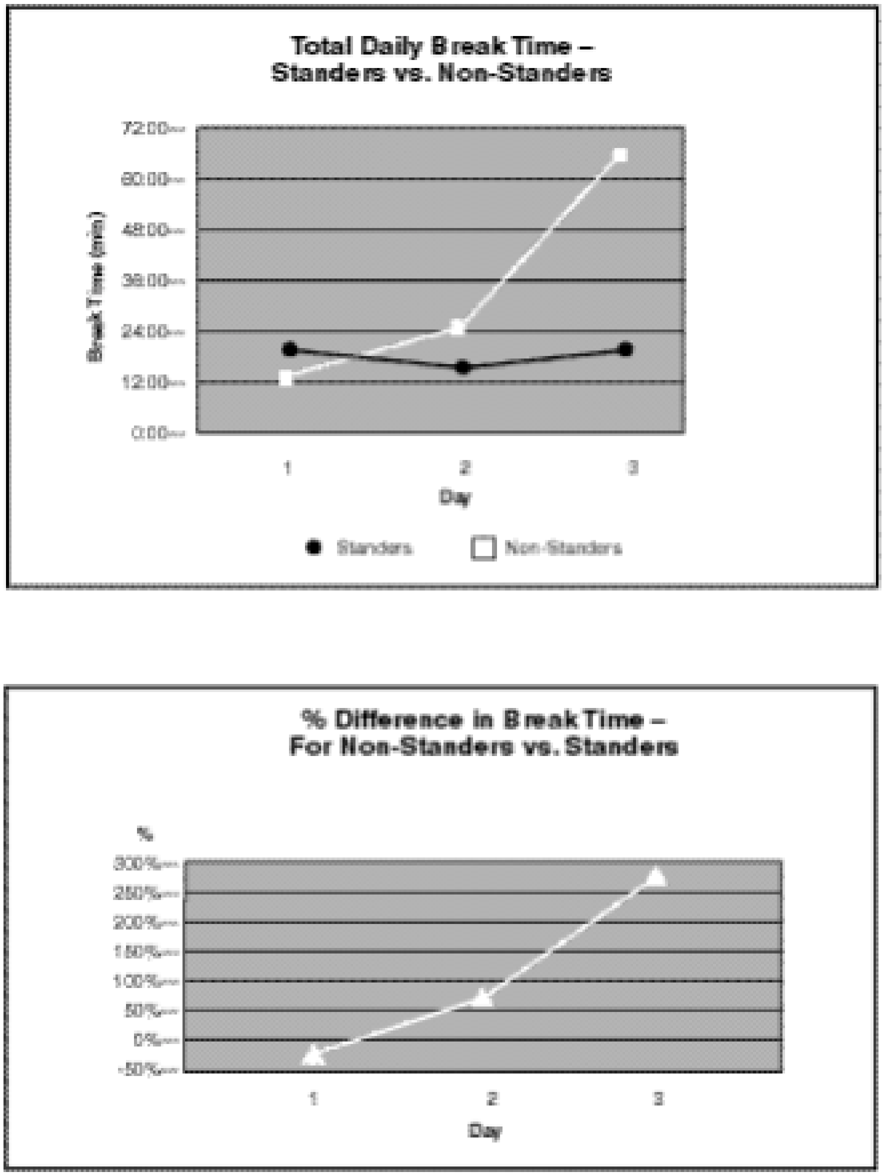

Total Daily Break Time –
Standers vs. Non-Standers
Break Time (min)
72:00
60:00
48:00
36:00
24:00
12:00
0:00
1
2
3
Day
Standers
Non-Standers
% Difference in Break Time –
For Non-Standers vs. Standers
%
300%
250%
200%
150%
100%
50%
0%
-50%
1
2
3
Day

FIGURE 7

Another interesting pattern is seen in Figure 8 where the difference between Standers vs. Non-Standers is plotted across days.

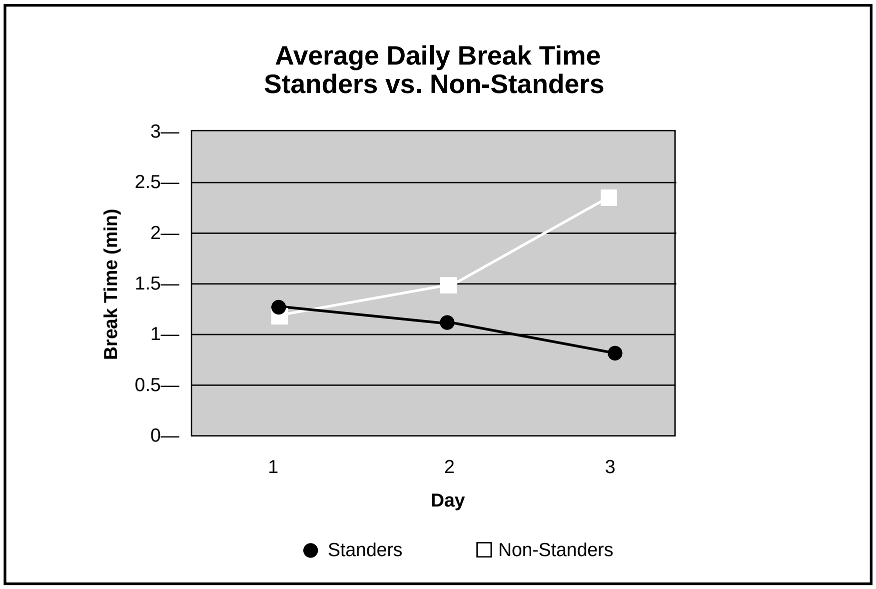


FIGURE 8

Here, the average duration of daily breaks seems to increase across days for those not standing on Day 3. On the other hand, there is a tendency for the opposite to occur for those standing on Day 3. This figure can be compared with the previous illustrations of standing times, frequency and duration of workbreaks across days and strongly suggests that, particularly on Day 3, those not standing are spending more time on breaks.

This impression is verified by Figure 9, which presents a combined look at both standing and breaks. In this figure, break time is plotted on the y-axis on the left side, and standing time on the right. (The scales are different for convenience of presentation.) The time data is plotted for each day of each subject in sequence. These data points are identified on the x-axis. The four left-most subjects are those who did not stand on Day 3. The differences between standing times and break times for the two groups of subjects are obvious. In addition, for the three of the four non-standing subjects, a clear trend can be seen in which break time increases across the three days. This trend is not seen in the right hand subjects.

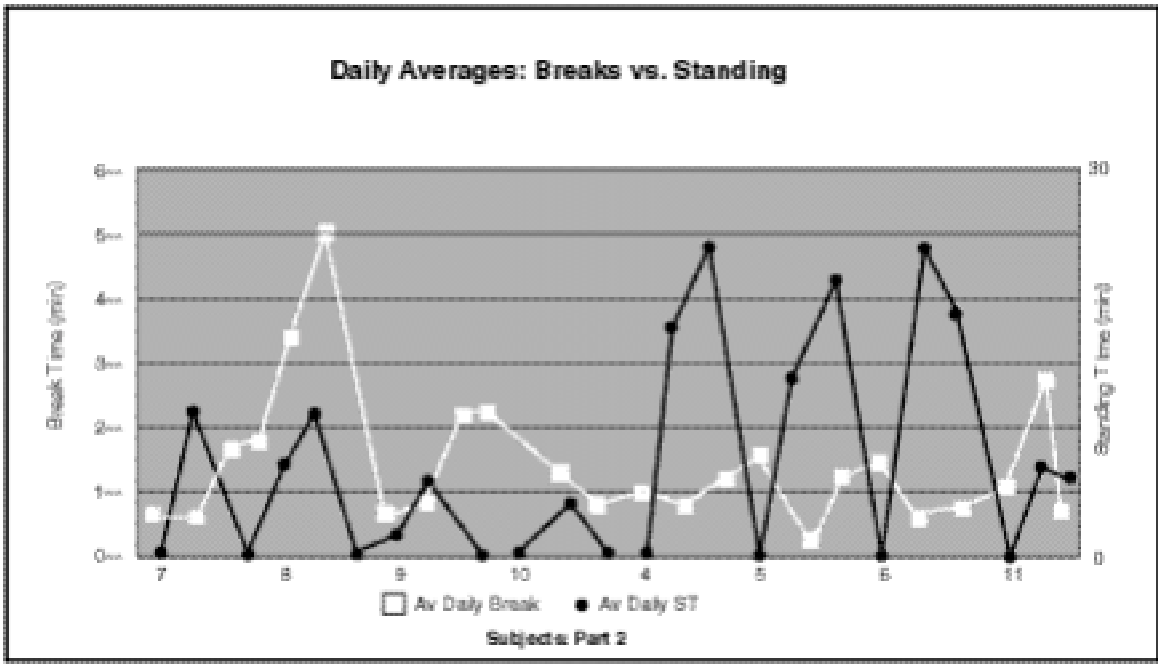


FIGURE 9

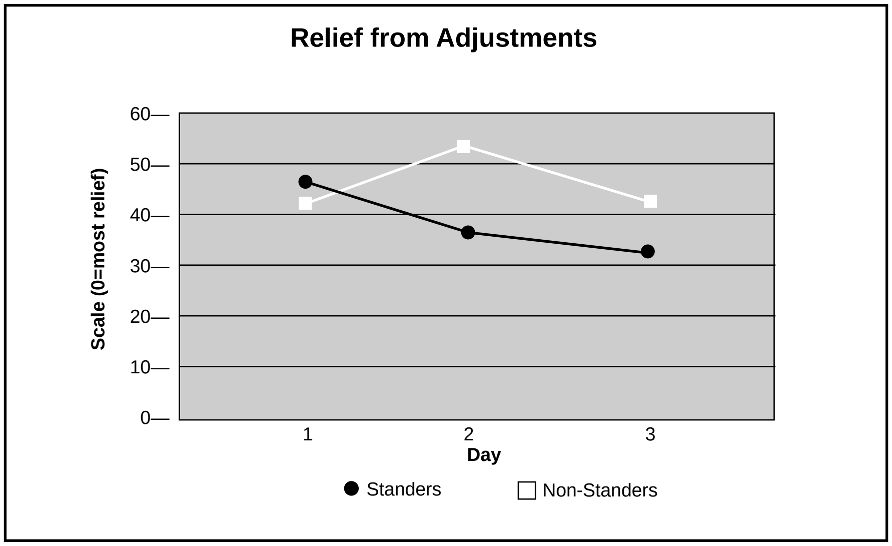
4. Interview Outcomes

At the conclusion of each day’s work, subjects were asked two questions, the answers to which could be quantified.

The first question was: “How much overall relief from fatigue or discomfort did you get as a result of adjusting your equipment?” Subjects were asked to mark an appropriate location on a 100-mm line in which “No relief” was printed at one end and “A lot of relief” at the other end. This translated directly to a relief score measured from 0 to 100.

The second question was: “To what extent did you feel that re-adjusting the equipment affected your work productivity?” Subjects were asked to mark an appropriate location on a 100-mm line in which “Hurt productivity” was at one end, “Helped Productivity” at the other, and “No effect” in the middle.

The average results from the answers to these two questions are plotted in the two graphs of Figure 10. In both scales, a lower number is more favorable –this allows a direct visual comparison with the graph for break times.



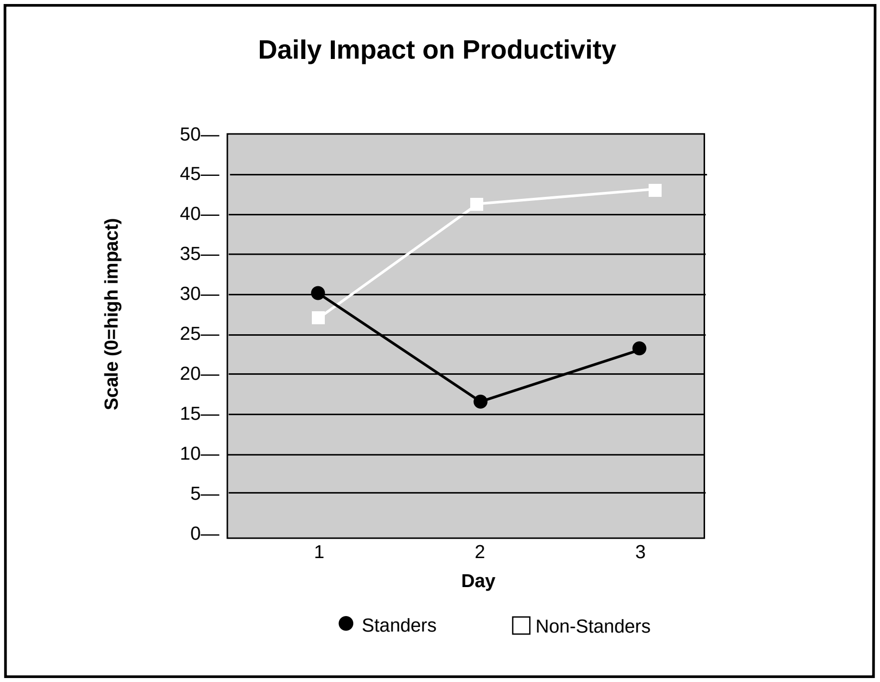


FIGURE 10

A sequence similar to that for breaks is evident, in that clearly different response patterns occur for the two groups. Subjects who stood on Day 3 show an increasing amount of relief from adjusting equipment as the study progressed. Subjects who did not stand find less relief from adjusting their equipment.

With respect to effects on productivity, the data is even more striking. At the end of Day 1, both groups have essentially the same impression; that of a positive but intermediate effect of adjustments on productivity. (Scores greater than 50 would indicate that adjustments harm productivity). However, as the study progresses, those who don't stand feel increasingly less likely to believe the adjustments have positive effects, whereas just the reverse occurs for those who stand.

CONCLUSION

This paper began with the reminder that productivity in the modern office is achieved by the efforts of individual human beings working for prolonged periods at the computer. The pace and structure of modern work requires extended periods in front of VDT screens. This can be stressful – a recent study of newspaper employees at computer terminals indicated that 30-40% of the workforce complains of symptoms of Cumulative Trauma Disorders (musculoskeletal disorders).

Two criteria for efficient work were defined earlier: getting into an optimum (ergonomically correct) initial posture, and being able to move during the workday. The goal of this study has been to demonstrate the effect on productivity when these criteria are met.

There was a 67% decrease in the time required to attain an ergonomically correct keying position through the use of a keyboard support tray. This was achieved using a Flipper-style keyboard support. Analysis of this unit in comparison to a Knob-lever-style along with qualitative data from the test subjects provided an expanded definition of usability for the purpose of promoting adjustment.

The usability and consistency (to the height adjustment) of the tilt adjustment was a key factor in the ergonomically correct use (keying with straight wrists) of the support tray. In conjunction with a wide range of adjustment to accommodate the user population and an effective training program, we were able to meet this first criterion.

In achieving the second criterion, this study examined the effectiveness of intermittent standing as a means for providing movement throughout the day to combat the buildup of fatigue.

The productivity benefits from providing the capability of taking standing breaks are two-fold. The first relates to prevention. Those costs of CTDs are not trivial. One authority (Fulwiler, 1998) estimates costs to an organization of a single diagnosed CTD case at $100, 000. This includes both direct costs (Worker's Compensation, increased premiums, etc.) and indirect costs (lost work time, compensable time off for injured employee, need to higher and train a replacement, etc.) If the person injured is in a critical work assignment, the secondary costs may be even greater.

The second benefit is that the prevention strategy of standing breaks keeps the employee at his or her desk and keeps them more productive while at the desk. The typical response to fatigue, strain and pain is to walk away from the desk, if at all possible, or to repetitively break from working (excessive workpauses) while remaining at the desk. The intention to walk away may be for only a few minutes, but distractions in the hall and at the water fountain may cause these breaks to extend. The use of the minibreak, or workpause, in combating fatigue can be helpful; however, the collective effect can produce similar downtime as walking away from the work area.

This study determined, through a measured reduction in the frequency and duration of workbreaks and workpauses along with perceived increases in comfort, that the ability to stand while working will provide the effect of an active work break. In this regard, the study has demonstrated that productivity is improved through intermittent standing as more time is spent on task accomplishment.

Specifically, 73% of the subjects took advantage of the opportunity to stand at some point in the study and 55% showed increased productivity through reduced workbreak time. Total breaktime decreased by 50% amongst the group of Standers (those who voluntarily stood on Day 3).

Moreover, if we look at the broader goals of the study, in combination with the interviews conducted at the conclusions of the work sessions, 91% of the participants benefited from either the usability feature or the standing feature of the Flipper-style keyboard support. In these interviews, all but one of the subjects who did not stand had very positive comments about the effectiveness of the simultaneous tilt and height controls with respect to achieving comfortable initial *sitting* postures.

This study also examined the necessary attributes inherent in adjustment controls that will increase the rate of adjustment through a more usable actuation. The initial focus of this element of the study was to determine how to achieve stand-up amongst employees in an actual workplace environment. Further examination of affecting the rate of standing generated a training technique, which significantly impacted the voluntary rate of standing amongst the subjects. By directing the subjects to stand, we required them to experience the benefits of standing. This counteracted the subjects' preconceived misconceptions of standing. As a result, 50% of the subjects who did not stand on Day 1, stood on Day 3, after the Day 2 directed standing.

Clearly, this study demonstrates that the integration of ergonomic worktools into automated workstation design can increase the efficiency of PC use in the modern office. In contrast, traditional office furniture, without the ability to stand while working with the computer, decreases time for task accomplishment. This tends to undermine advanced technology purchases aimed at increased individual productivity.

However, through the use of stand-up and ease in adjustments (usability), these worktools allow traditional office furniture to provide ergonomic solutions to today's automated environment. In conjunction with a comprehensive and participative training program, we can increase the efficiency of the "person sitting in front of the computer" and, thus, organizational productivity.

The bottom line: standing can provide real relief from fatigue. When it is accomplished at the workstation, while continuing to work, it increases productivity.

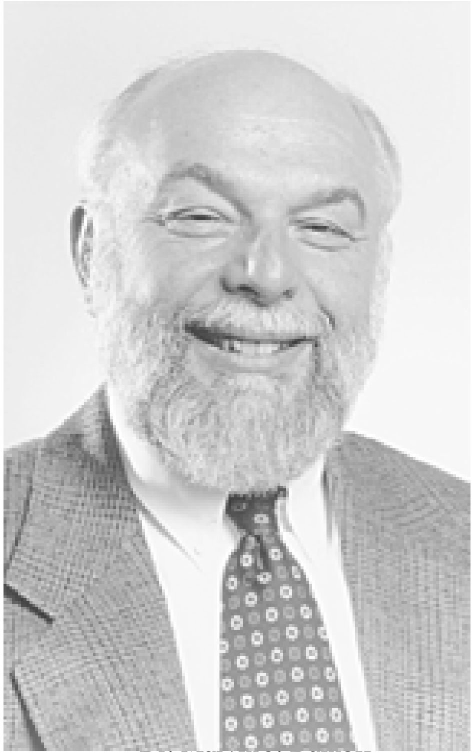
One of our subjects said it best. In response to the interview question: "Did standing affect your work productivity?" he responded: "It sure did. If I couldn't have stood, I wouldn't have lasted through the day."

CREDITS

The study was conducted by the Center for Ergonomic Research, Department of Psychology, Miami University. Marvin J. Dainoff, Ph.D., CPE is Director of the Center and Professor of Psychology. Project manager for the study, conducted under the supervision of Prof. Dainoff was Janina Paasche, who was assisted by Kevin Simons. Olga Cubells also provided valuable help to this research effort.

ABOUT THE AUTHOR

Marvin J. Dainoff, Ph.D., CPE



Marvin J. Dainoff is an applied experimental psychologist specializing in the field of ergonomics applied to the workplace. He is currently Professor of Psychology and Director, Center for Ergonomic Research, Miami University, Oxford Ohio, and President, M. Dainoff Associates, Consultants in Workplace Ergonomics. He is Vice-Chair of the ANSI/HFES 100 Revision Committee for the American National Standard on Visual Display Terminal Workstations. He is an elected member of the ANSI Z365 Accredited Standards Committee of the National Safety Council on Control of Cumulative Trauma Disorders and has been appointed as the official liaison to this committee from the Human Factors and Ergonomics Society. He has participated in the formation of a new national standards committee: ANSI/HFES 300 Anthropometry and Biomechanics, and serves as Secretary of that committee. He has recently been appointed Interim Secretary to the U.S. Technical Advisory Group to Subcommittee 3 (Anthropometry and Biomechanics) of the International Standards Organization (ISO) Technical Committee 159 on Ergonomics. He is a Certificant, Board of Certification in Professional Ergonomics. In 1995, he was elected Fellow of the Human Factors and Ergonomics Society. He received the 1992 award for Professional Accomplishment (Academic) from the Technical Societies Council of Cincinnati, an association of twenty-three different technical groups.

In 1976, he began a relationship with the Applied Psychology and Ergonomics Branch of the National Institute of Occupational Safety and Health (NIOSH), turning his research interests toward the office workplace. In 1980, he accepted a two-year appointment as visiting researcher at NIOSH. While there, he performed the first controlled laboratory experiment demonstrating a correlation between improved ergonomic conditions, decreased health complaints, and increased work performance in an office situation. He received an award from the Assistant Surgeon General of the United States Public Health Service for "contributions in enhancing public understanding of ergonomic issues."

He is one of two U.S. members of the steering committee of an international study group: Musculoskeletal Discomfort and Eye Strain in VDT Operators Working in Optimized Workplaces (MEPS). This group, comprised of medical, optometric, ergonomic and psychosocial researchers from six countries, has created the protocol for a multinational multidisciplinary investigation of effectiveness of optimal ergonomic interventions. Dainoff headed the team, which implemented the protocol in a major field investigation at the U.S. Internal Revenue Service.

He has frequently been asked to review, summarize and conceptualize the general field of office ergonomics for his own professional colleagues. He was host and chairman of a NIOSH-sponsored conference on *Promoting Health & Productivity in the Computerized Office: Models of Successful Ergonomic Interventions*. Dr. Dainoff co-edited a book summarizing the results of this conference, which attracted internationally recognized experts in the field. He is on the editorial board of the *International Journal of Human-Computer Interaction*, and the *Journal of Occupational Rehabilitation*. He is a reviewer for *Applied Ergonomics*, *Behaviour and Information Technology* and *Human Factors*, and is on the Board of Directors of HCI International. He is co-author, with Bryce Rutter, of *The Ergonomic Office*. He has been a regular columnist for *Ergonomic News*.

He has been a member of the International Facility Management Association, and was chairman of the association's Ergonomics Subcommittee of the Committee on Codes and Regulations. He participated in drafting a position paper on "Human Factors and RSI" for the American Society of Interior Designers. He also co-authored, with Leonard Mark, Ph.D., an overview article on ergonomics of seating in *Innovation*, a periodical oriented toward the industrial design community.

A central concern is presenting ergonomic information to the lay public, to end users, and to other interested professionals (e.g., equipment designers, architects, system designers, managers). The publication, with Marilyn Dainoff, of *People & Productivity: A Manager's Guide to Ergonomics in the Electronic Office* represents a major effort in that direction. He has given lectures on ergonomics to a variety of groups, including labor union members, corporate executives, and government officials. He has written a number of articles on ergonomics for national newspapers and specialty/trade magazines, and has been widely quoted in others. He has appeared on television on the Today Show, CNN News, New Jersey Public Television, and Ontario Hydro TV, and on several radio broadcasts.

Dr. Dainoff heads the consulting firm of Marvin Dainoff Associates, Inc. He has served as a consultant for the Internal Revenue Service, the National Security Agency, the Social Security Administration, the Office of Technology Assessment of the U.S. Congress, the Center for Women in Government of the State of New York, and the Cincinnati Public School District. His private sector clients have included IBM, Westinghouse Office Systems, the American Productivity Center, Vogel-Peterson Company, Harter Corporation, GF Business Equipment, Fixtures Furniture Company, Liquid Carbonic, CNA Insurance, Federal Express, Global Furniture, FMC Corporation, Procter & Gamble, Williams College, the United Bank of Denver, The Wilson Bohannan Company, Adjusto Furniture Company (now Biofit), Centercore, the Detroit News Agency, Teknion, Cincinnati Bell Telephone Company, the American Society of Interior Designers (ASID), Ford Motor Company, BodyBilt, Inc., AnimaX International, and the design firm of Herbst, LaZar, and Bell.

APPENDIX 1

LISTING OF PRODUCTS USED IN STUDY

Flipper-style keyboard support:	Ergo Systems
Knob/lever-style keyboard support:	Webber-Knapp
Height adjustable monitor arm:	Ergo Systems
Adjustable copyholder:	Atlas
Task Light:	Dana
Personal Computer:	Apple Power Mac
CPU Holder:	Ergo Systems
Ergonomic Task Chair:	Global
Worktable:	Globe Business Furniture

APPENDIX 2

REFERENCES

Fulwiler, R.D. (1998) People, public trust, and profit. Occupational Hazards, 60 (4), 36-39.

Bernstein, N. (1996). On dexterity and its development. In: M.L. Latash, and M.T. Turvey (Eds.) Dexterity and its Development. Mahwah, N.J.: Earlbaum.

Branton, P. (1976). Behaviour, body mechanics and discomfort. In E. Grandjean (ed.), Sitting Posture. London: Taylor and Francis, Ltd.

Dainoff, M. J., & Dainoff, M. H. (1986). People and Productivity: A Manager's Guide to Ergonomics in the Electronic Office. Cincinnati: MDA Books.

Greico, A. (1986). Sitting Posture: An old problem and a new one. Ergonomics, 29, 345-362.

Winkle, J., and Oxenburgh, M. (1990). Towards optimizing physical activity in VDT/office work. In: Sauter, S.L., Dainoff, M.J., and Smith, M.J., (Editors) Promoting Health and Productivity in the Computerized Office. London: Taylor and Francis.

Swanson, Sauter, and Chapman (1989). The design of rest breaks for video display terminal work: A review of the relevant literature. In: Mital, A., (Editor) Advances in Industrial Ergonomics and Safety I. London: Taylor and Francis.

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