



Solutions to Office Thermal Comfort,
Ergonomic and Air Quality Issues

Risk Control





The purpose of this guide is to provide you with an overview of common causes and solutions to ergonomic, indoor air quality (IAQ) and thermal comfort issues in the office environment. It also will provide guidance on rapid and effective solutions to many of the more common problem initiators.

Office Thermal Comfort

Adverse thermal comfort, ergonomic and air quality issues in the office environment can influence employee productivity, efficiency, comfort and morale. Once the risk factors relating to these working and system conditions are understood, solutions to the issues often become apparent.

CNA's experience with hundreds of investigations in office and commercial buildings has found that modifications, adjustments and maintenance of heating, ventilation and air conditioning (HVAC) systems can provide rapid solutions to most indoor air quality (IAQ) and thermal comfort issues. Furthermore, designing work spaces that follow ergonomically sound guidelines can significantly reduce the risk factors contributing to musculoskeletal strain.

Thermal Comfort: I'm Too Hot! I'm Too Cold!

In a 2003 survey, the International Facility Management Association (IFMA) found thermal comfort issues, too hot and too cold, as the top two office complaints.¹ Due to the complexity of modern HVAC systems, simple adjustments to thermostats do not necessarily solve the complaints. If they did, thermal concerns would not be such a common issue.

Many CNA office air quality assessments have found that well-intentioned but improper system adjustments made to address thermal complaints often lead to system imbalances and poor airflow. Such adjustments often lead to more widespread thermal complaints and can, in the longer term, lead to airflow restrictions. Such restrictions often lead to air quality complaints.

Many factors can influence thermal comfort and the perception of thermal conditions. Such factors include temperature, radiation, humidity, air movement, vertical and horizontal temperature differences, temperature drift, personal activity and clothing.

Temperature, temperature drifts and humidity factors are fairly well controlled by simple building system adjustments. Radiation or solar window loading is normally addressed and readily controlled by window treatments, such as blinds and curtains. Activity levels and clothing are occupational factors. However, air movement and air distribution are areas that are commonly overlooked. These factors, when not properly adjusted, can cause thermal discomfort.

For most individuals, comfort can be maintained when the following conditions are met in the office:

- Air temperature ranges from 73° to 77° Fahrenheit (F).
- Relative humidity is from 30 to 60 percent.
- Maximum airflow is 50 feet per minute (fpm) for cooling and 25 fpm for heating.
- A 5° F maximum temperature gradient is maintained from the floor to 6-foot level.

The above assumes sedentary to slightly active individuals are appropriately dressed for the season.

Controlling drafts can significantly reduce the amount of thermal discomfort complaints. A major source of drafts in office environments is a phenomenon known as "cold air dumping." Cold air dumping is conditioned air delivered generally to occupied spaces via ceiling-mounted diffusers. The usual delivery temperature ranges from 55° F to 60° F.

An adverse feature of cold air dumping is a localized draft. A common intuitive action during cold air dumping would be to further reduce airflow or exit velocity; however, the appropriate action would be to increase air velocity from the diffuser. Most variable air volume (VAV) box minimum flows should be proximate to 20 to 40 percent of maximum, minimizing cold air dumping and preventing deficiencies in total air delivery.

¹ American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE). *ASHRAE Transactions*, Volume III, Issue 2, 2004.

A common phenomenon similar to cold air dumping is cold air bounce. This can occur when walls or obstructions are placed too close to air supply outlets. Here, the cold air from the diffuser strikes the obstruction and dumps down onto a nearby workstation, causing localized discomfort. Such conditions often occur following office re-stacking when partition walls are moved. Other causes of dumping can occur when:

- Pattern deflectors are partially obstructed, missing or improperly aligned.
- A supply air terminal has an exit velocity set too low.
- A supply duct, diffuser or terminal is obstructed.
- A supply fan malfunctions or the fan's belt slips.

What Can Be Done to Correct These Problems?

- Check to determine if the VAV box is reducing airflow too much.
- Evaluate the VAV box minimum setting.
- Check to see if the diffuser is too large and check installation.
- Check if the diffuser pattern or throw is incorrect.
- Check proper alignment of vane deflectors.
- Check to see if the temperature sensor is located correctly or if it needs calibration.
- Check for obstructions.
- Check fan belts, if any.

CNA customers have found the following actions most successful in quickly controlling office thermal discomfort:

- Confirm there are no drafts exceeding 50 fpm for cooling or 25 fpm for heating in the complaint areas.
- Position a temperature/relative humidity chart recorder and a thermal comfort chart in a visible position in the area of complaint.
 - Share the monitored results with those concerned. The occupants will often accept the results and adjust appropriately.
 - If the chart results are outside the criteria, the system can be adjusted.

Feedback from those CNA customers who have implemented the above actions reflect a dramatic 90 percent reduction in thermal complaints. If the above solutions are less than fully effective, consider having the air distribution system balanced by a professional air balance contractor. Balance contractors who are members of the Associated Air Balance Council (AABC) can be found at www.aabchq.com or members of the National Environmental Balancing Bureau (NEBB) can be found at www.nebb.org.

Office Indoor Air Quality Issues

IAQ refers to the quality of air in nonindustrial environments, particularly office environments. Over the last half century, significant changes have occurred in construction techniques. Building materials; heating, ventilation and air conditioning (HVAC) systems; and building system operations have led to the build-up of contaminants. Various contaminants include volatile organic compounds (VOCs) sourced from building materials, office supplies and human bioeffluents, i.e., body odor and microbial allergens.

A wide array of nonspecific discomfort concerns often occur due to a build-up of multiple contaminants. Symptoms often include headaches, nausea, fatigue, watery or irritated eyes, noses and throats, sneezing, congestion and other upper-respiratory irritations. Such symptoms, intermittently experienced by a portion of the workforce, are known as sick building syndrome (SBS).

SBS typically has physical symptoms without any clearly identifiable causes. Experience has found that SBS symptoms often exist for several months to several years prior to the initiation of an IAQ complaint. IAQ complaints are triggered by an unusual event, often found not to be the primary cause of the problem.

Poor ventilation can be a contributing factor to lowered productivity. Inadequate supply of outdoor air has been estimated to result in a 3 percent decrease in occupant productivity and efficiency. Providing code-required supplies of outdoor air annually costs less than \$0.50 per square foot of office space.

The Cause

Identifying the specific cause of SBS is difficult, if not impossible. Despite the inability to identify a specific cause, it has been found that modifications to HVAC systems generally solve the majority of SBS problems.

The Solution

No one solution to IAQ problems exists, however, the overwhelming majority of IAQ issues have been shown to be correctable when existing operation and maintenance standards are put in place. Adjustments to the HVAC system in order to meet International Mechanical Code guidelines, the American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE) guidelines and local building code standards most often resolve the problem without investing significant time. The amount of fresh outdoor air that is provided to a building varies by area and the number of occupants. A recap of the ASHRAE's published Standard 62, "Ventilation for Acceptable Indoor Air Quality Guidelines," is provided in Table 1 on the following page.

Occupant salaries and benefits can cost more than \$300 per square foot. A 3 percent decrease in productivity would result in a \$9 per square foot annual loss. With a \$0.50 annual code-required cost versus a potential \$9 per square foot loss, the economic advantages of good ventilation present obvious benefits.

Investigating IAQ Problems

As with any problem, one must investigate its nature and scope. This may require the combined efforts of local management and the individuals most familiar with maintaining building systems, which often is the facility manager or contract HVAC service company.

During or following the initial investigation, certain HVAC issues commonly found to contribute to IAQ problems should be closely assessed.

Additional review may be necessary if the initial investigation, characterization and inspection of the HVAC systems do not reveal possible corrective actions. Listed below are downloadable resources from the Environmental Protection Agency (EPA).

- "Indoor Air Quality Building Education and Assessment Model (I-BEAM)"
www.epa.gov/iaq/largebllds/ibeam_page.htm
- "Building Air Quality: A Guide for Building Owners and Facility Managers"
www.epa.gov/iaq/largebllds/baqtoc.html
- "The Building Air Quality (BAQ) Action Plan"
www.epa.gov/iaq/largebllds/actionpl.html



Table 1 — Required Outdoor Ventilation Air International Mechanical Code and ASHRAE 62, Selected Sections from the American Society of Heating, Refrigeration and Air-Conditioning Engineers

How Much Fresh Outdoor Air Is Needed?

Occupancy/Classification	Estimated Maximum Occupant Load Persons/1,000 Sq. Ft. ^(A)	Outdoor Air Cubic Feet Per Minute (CFM)/Per Person
Office		
Conference Room	50	20
Office Spaces	7	20
Reception Areas	60	20*
Telecommunication Centers and Data Entry	60	20
Retail Stores, Sales Floors and Showroom Floors		
Basement and Street	—	0.30 CFM/sq. ft.
Dressing Rooms	—	0.20 CFM/sq. ft.
Malls and Arcades	—	0.20 CFM/sq. ft.
Shipping and Receiving	—	0.15 CFM/sq. ft.
Workrooms		
Bank Vaults	5	15
Darkrooms	10 CFM per person	0.50 CFM/sq. ft.
Duplicating, Printing	—	0.50 CFM/sq. ft.
Pharmacy	20	15
Public Spaces		
Corridors and Utilities	—	0.05 CFM/sq. ft.
Locker and Dressing Rooms	—	0.50 CFM/sq. ft.
Toilet Rooms	—	75 CFM per water closet**
Smoking Lounges	70	60

Note: The International Mechanical Code is adopted by most local and state building codes as ordinances. It is produced by the Building Officials and Code Administrators International, the International Conference of Building Officials and the Southern Building Code Congress International.

(A) Based upon net occupied heated or air conditioned space.

* ASHRAE 62 = 15 CFM for large areas

** ASHRAE 62 = 50 CFM per urinal or water closet

Investigation Checklist

The first and most critical step of the investigation is to define the nature and scope of occupant complaints and concerns.

- Who is being affected?
- Where are they located?
- What are their jobs?
- What is the nature of the symptoms?
- When do the symptoms occur? When do they abate?
- Is there any temporal rhythm (time of day, day of week, season) to the symptoms?
- When were problems first noted? Was anything occurring simultaneously, i.e., construction activity?
- Did temperature comfort complaints precede or parallel these symptoms?
- What do the occupants and local management team consider to be the source of the problem?

The second step is to characterize the facility.

- How many people occupy the building? What is the estimated maximum occupancy density?
- What is the distribution of occupancy? Are there occupancy zones of higher or lower occupancy?
- How many people were interviewed? Of these, how many have complaints?
- What is the type and size of the building, i.e., number of floors, square footage, age, ceiling height and types of activity?
- Did the occupants recently move into this building? If so, were there any problems in their prior building?
- Are the problems isolated to only a portion of the building?
- What is the building's smoking policy?
- Who is responsible for cleaning and maintaining the building, the interior plants and the HVAC systems? What are their names and phone numbers?
- What is the frequency of carpet cleaning? How frequently are rest room and utility room floor drains cleaned?
- Who has access to building plans, as-built plans, HVAC plans, the HVAC heat load and cooling load calculations, and the original and the most recent test and balance report?

The third step is to characterize and understand how HVAC systems work.

- How is the air supplied to and distributed throughout the building? Does each room have a source of air?
- What type of heating, cooling, humidification and dehumidification is used? Is it a constant volume system? Is it a variable air volume (VAV) system? If it is a VAV system, what are the maximum and minimum settings on the VAV boxes?
- Is the air moving through the diffusers and grills? Does the air continue to move when you adjust the thermostat up and down? Is there a thermostat fan switch that is positioned to "on" or "occupied" and not "auto" or "off" or "unoccupied"?
- Are grills and diffusers blocked or taped? Are return air registers available in each room? Are some diffusers and return air grates positioned closer together than others?
- Do the windows open?
- Who maintains the system? How often is the unit inspected and cleaned? How well is the air filtered? How often are the filters cleaned? What types of filters are used? What are their dust spot and efficiency ratings?
- Are there any kitchen or lab hoods or other exhausts proximate to the outside air intake?
- What are the individual unit and total system capacities in refrigeration tonnage? You can estimate about 400 cubic feet per minute (CFM) of capacity per ton of refrigeration capacity for approximate total air movement.
- How much outside air is being brought into the building? Does the flow rate per person or per square foot meet the building's design rate and the ASHRAE standard?
- Has total quantity of air supply been measured? Has the percentage or quantity of outside air (OA) been calculated? Can the percent of OA be roughly estimated by comparing the OA damper area against the return duct cross-sectional area?

HVAC Air Handling Unit (AHU) Checklist

Here are some questions you can ask to help troubleshoot issues.

- Is the system turned on?
- Is the fan subbase switch in the “on” or “occupied” position during operating hours?
- Are outdoor dampers properly and visibly opened?
- If outdoor air dampers are controlled by an economizer, is the minimum economizer damper position appropriate and visibly opened? This is best checked when outside temperatures are above 70° F or below 40° F.
- Is there moisture, debris or microbial growth in or near the unit?
- Are the coils clean?
- Is the drain pan clean and functioning?
- Are there any contaminant exhaust ducts or sources within 30 feet of the outdoor air intake that have less than a 10-foot height differential?
- Is combustion equipment properly vented with no flue leaks or backdrafting?

Interior Areas Checklist

- Is the area or office equipped with supply air outlets but no return air inlets?
- Is the area population greater than original design, i.e., more than seven people per 1,000 feet¹ for offices?
- Is the area used for occupancy not considered in the original design, i.e., conference room where HVAC designed for office occupancy?
- Are offices under slight positive pressure in relation to outdoors or stairwells and utility shafts?²
- Is the air flowing continuously from all of the supply air outlets?
- Are there concealed spaces above the dropped tile ceiling? If cool air or drafts are evident, supply leakage is probable and may need correction.
- Has the air delivery system had a test, adjust and balance (TAB) assessment within the last five years? Have there been frequent cold air draft complaints? If so, this may indicate a need for a TAB assessment.
- If a variable air volume (VAV) delivery system is used, are the VAV box minimum delivery volumes proximate to 40 percent of maximum?
- Are there perimeter fan-powered units or induction units that restrict HVAC air delivery during the heating seasons?

Conclusion

It has been estimated that up to a third of U.S. commercial office buildings have IAQ problems. Intermittent, non-definitive SBS symptoms are prominent in such buildings. The symptoms are often existent for prolonged periods prior to occupants voicing concerns. A functional knowledge of HVAC system design, operation and maintenance procedures most often leads to a rapid and less expensive resolution of most SBS problems.



¹ A testing, adjusting and balancing (TAB) assessment should be conducted for a new building. It is also important to have a TAB whenever there has been a change to the HVAC system and during remodeling where people are relocated because the working conditions have changed. The qualifications of the individuals who provide the TAB service should meet the National Environmental Balancing Bureau criteria. During the TAB phase, testing and balancing of all equipment, systems, sub-systems and system components must be accomplished and reported. If acceptable performance cannot be achieved because of design or system deficiencies, the test data must be documented in writing and distributed to the appropriate parties for resolution.

² Commercial buildings are almost always designed to operate at a slight positive pressure to prevent infiltration of moisture and outdoor, stairwell or utility shaft contaminants. Since toilets are required to provide exhaust, negative pressures can develop if adequate compensating outdoor air is not provided.

Office Ergonomic Issues

Designing for Comfort

Over the past 20 to 25 years, there has been a dramatic change both in office environments and how employees perform their job tasks. These changes have led to more specialization and isolation of employees, limiting the variety of tasks each performs. The computer is now the focus of job tasks with employees often spending 8 to 10 hours a day keying in data or staring at the screen.

As job tasks become more repetitive, physical limitations of some employees could prevent them from meeting their job expectations. This is why it is so important to recognize the daily interface of employees and their machines. The relationship between computer monitors and working conditions can cause eye strain, fatigue, discomfort; muscle and skeletal stress; and mental stress. These health problems can be reduced when work environments and tasks are designed and organized to help computer monitor users be more comfortable and work more efficiently.

What are Cumulative Trauma Disorders?

Cumulative trauma disorders (CTDs) occur over a period of time. Minor stressors (micro-traumas) to the body, when repeated and combined, can lead to an accumulation of trauma that causes a variety of symptoms. CTDs can affect any part of the body that moves; however, in this guide, the focus is on the wrist, fingers, elbow, neck and back.

Workplace factors that lead to the development of CTDs include improperly adjusted equipment, repetitive work, inadequate work-rest cycles, deviated postures of the wrist, lack of task variability and awkward sitting postures. Such factors are not new and have been tied to many occupations for years.

Automation in the workplace has increased repetitive duties and reduced duty rotation. With more workers using computers to complete their job tasks, the same motions are often performed thousands of times a day. These repetitive duties repeat demands on the same parts of the body.

Why Repetitive Motion Diseases are More Prevalent in the Office Today

Consider how typists completed their jobs 20 to 30 years ago. Their routines varied throughout the day. For each typing task, they inserted the paper by rolling it into the typewriter, then typing, then pressing or hitting the return lever. All of these tasks involved varying movements with different body groups that were then allowed to rest.

Today, with the use of computers, there is far less variation in the job task. Employees can sit at their workstations for three to four hours without taking a break or removing their hands from the keyboard. Printers automatically print with a touch of a keystroke and the return is done automatically at the end of another keystroke. In today's office environment, workers are not afforded the opportunity for a recovery period to relax soft tissues and muscles.

Workstation Design as a Factor

Workstation design also can be a factor. If the office was designed with men in mind and not women, chairs and desks were typically designed for an individual approximately 5 feet 10 inches tall with a work height of 29 to 31 inches. In some cases, when chairs and workstations are inherited from a prior worker, few adjustments are made by the new employee.

Anatomy and Mechanisms of CTDs

The areas where CTDs occur the most are the muscles, tendons and nerves. The force and posture of the hands are maintained by a delicate mechanical equilibrium between the flexor muscles, located on the inside of the forearm, and the extensor muscles, located on the outside of the hand. Repeated exertions of the hand can lead to fatigue of these muscles. Fatigue is characterized by discomfort, reduced strength and lack of endurance and control. Continued exertions beyond normal fatigue levels can result in muscle damage, discomfort and impaired performance. This is the kind of fatigue that can occur with poor work-rest cycles.

Exertion of the fingers from keying on a cumulative basis produces tension on the tendons. Also, certain wrist exertions and deviated wrist postures can cause the tendons to press and rub against other anatomical surfaces. The tendons are protected by synovial or bursal membranes that surround them and secrete synovial fluid. This fluid lubricates and nourishes the tendons. Despite this protective fluid, prolonged and repeated exertions can cause irritation of a tendon or tendon sheath, which can facilitate tendonitis or tenosynovitis. Disorders of the tendons and sheaths can also result from body contact with external objects that have hard or sharp edges, including desk work surfaces.

Deviated postures of the hand and wrist can induce elevated fluid pressures around the nerves, which can be compressed by inflamed tendons and tendon sheaths. Prolonged or repeated nerve trauma can also lead to the development of carpal tunnel syndrome or cubital tunnel syndrome. Carpal tunnel syndrome is defined as compression of the median nerve, and cubital tunnel syndrome is the compression of the ulnar nerve. Carpal tunnel syndrome can develop with repeated or sustained work with the wrist in an extended or flexed posture while exerting force with the base of the palm. Cubital tunnel syndrome can develop from resting the forearm/elbow on a hard surface and/or sharp surface that can be encountered with a keyboard on a fixed level work surface such as a desktop.

Risk Factors of the Wrist and Hand

There are five risk factors to focus on in CTDs of the hands and wrists.

- Repeated and sustained exertions.
- Forceful exertions.
- Localized contact stress.
- Wrist postures.
- Cold temperatures.

Repeated and Sustained Exertions

Highly repetitive work and prolonged static exertions can lead to physiological and mechanical imbalances within the musculoskeletal system. These risk factors have been reported as tendon and nerve disorders of the upper extremity. Following are four classifications that can be used as a guide to understanding the repetitiveness of a task.

- High: The hands and fingers are in constant rapid motion; wasted motions would result in the worker falling behind immediately.
- Medium: The hands are in steady motion, but there is no difficulty keeping up; the worker may pause or rest as necessary.
- Low: Conspicuous pauses in each keying cycle.
- Very Low: The hands are idle most of the time.

Forceful Exertions

High force or increased tension causes deformation of tissues, metabolic demand of muscles, reduced circulation and nourishment of the soft tissue. Force increases risk of localized fatigue and risk of muscle, tendon and nerve disorders. Force exacerbates itself when employees use more force than necessary when keying data into a computer. The excessive force is transmitted to tendons and tissues in the fingers and hands.

Localized Contact Stresses

Contact stresses (soft tissue squeezed between bone and external objects) are produced in situations where the keyboard is on a fixed level surface and the wrist or forearm is positioned on the edge of the work surface or when a mouse is on the fixed level surface and the forearm is positioned on top of the desk.

Wrist Postures

When working on the keyboard or mouse over extended periods of time, deviated postures of the wrist can occur as depicted in Figure 1. Employees who adopt poor postures can experience long-term effects on soft tissues such as muscles, joints and nerves.

Cold Temperatures

Cold temperatures reduce the manual dexterity of the fingers and hands, as well as accentuate symptoms of nerve or soft tissue impairments. In the office environment, the most obvious method of experiencing this is having an air-conditioning duct blowing directly on a workstation.

Figure 1 — Deviated Postures



Layout Guidelines for Computer Workstations

Worktables: Vertical Aspects

The best worktable is one whose height is easily adjustable by the user. Height-adjustable tables are becoming commonplace in both office and industry environments and, if considered at the design stage of facilities, add little cost. Worktables that can be adjusted with the help of maintenance personnel are more common in office environments. These can be set to a single level that is satisfactory for most of the tasks performed by the individual. However, if workstations are shared, this type of worktable is less appropriate and may require that workers of similar size be matched for sharing workstations. If this height does not coincidentally suit an individual, adjustments to other components will become necessary to compensate. A fixed worktable that is too low for a worker should be replaced with a more suitable component. Adequate thigh clearance for individuals is vital to comfort and the ergonomic soundness of the workstation.

Since the publication of the ANSI/HFS 100 standard in 1988, the Human Factors and Ergonomics Society (HFES) has further developed and published technical standards for use by individuals concerned with the design and use of computer workstations. This publication, BSR/HFES 100, *Draft Standard for Trial Use*, recommends that for a non-adjustable or fixed height, the underside of the worktable should not be lower than 26 inches from the floor. This will accommodate 95 percent of the male workforce in terms of needed thigh clearance, as well as most females. However, this means that five percent of males, the largest or tallest males, will still require a higher desk surface height to sit comfortably at the workstation.

Worktables: Horizontal Aspects

The horizontal space provided by the worktable should allow the components, such as the monitor and keyboard, to be adjusted forward and backward at least several inches. Room for a wrist rest in front of the keyboard should be available. Crowding that requires a fixed horizontal location for components should be avoided. Adequate space for working documents or a vertical document holder also should be available.

According to the BSR/HFES 100 standard, the available horizontal leg room should be at least 23.5 inches from the edge of the table to any obstruction or component wall. The minimum horizontal width for the opening under a worktable for the worker's chair and legs is 20 inches. A wider workstation may be more comfortable for some operators.

Keyboards

The keyboard location and design largely determines hand and wrist postures during use. For this reason, adjustment of the keyboard is important to minimize wrist flexion, extension and ulnar deviation, a sideward bending of the wrist toward the smallest finger.

Keyboards: Alternative Designs

In addition to conventional keyboards, a variety of alternative style keyboards have become available in recent years. Alternative style keyboards include the standard QWERTY keyboard, which is designed so that key arrangements are split into two or three separate sections or even separate keyboards — one for the left hand, one for the right and a numerical keypad. Some split the keyboard into sections fixed upon a single board. Alternative keyboard designs, in an attempt to better fit the hand, are also available. Still, other designs dispense altogether with a single key for each character, and instead offer only a few keys that must be pressed or played in chords to produce specific characters. Future research may demonstrate the relative safety effects of radical keyboard redesigns.

Keyboards: Slope

Adjustment of keyboard slope or angle is provided by conventional keyboards in only two positions, angled up about 10 degrees, positive angle, or flat. Positioning that allows a hand and wrist posture closest to neutral should be chosen. The BSR/HFES 100 standard recommends that a keyboard slope is 0 to 25 degrees, positive angle, from the plane of the keyboard platform. However, there is evidence that a negative angle on a conventional keyboard, the back of keyboard being lower than the front, offers significant wrist posture improvement.¹ This can be accomplished by placing a keyboard into a tray that offers negative angle adjustment, which flattens the angle of key tops.

Keyboards: Height from Floor

Keyboard height from the floor should be adjustable separately from the worktable. A minimum range for keyboard height adjustability is from 23 to 28 inches, per BSR/HFES 100 standard. However, a better range of 22 to 29 inches from the floor is recommended in order to accommodate more of the working population. The unusually large or small worker may require keyboard heights that are outside even this range. A range that is inclusive of almost any worker is from 20 to 33 inches from the floor.

The range of adjustability should allow workers to position keyboards somewhat below elbow height, corresponding to results of studies performed in other environments. For example, the best location for hand work is generally somewhat below elbow height for light assembly work. According to the article "Musculoskeletal Disorders among Visual Display Terminal Workers," individual preferences should decide the precise vertical location of the keyboard height.² This contradicts the convention that keyboards should be at exactly elbow height for all individuals.

For keyboards that are not positioned on a tray or platform, but directly on the worktable, adjustment is possible by lowering the table height as necessary and adding items under the keyboard to raise the keyboard to the most comfortable position.

Keyboards: Trays or Articulating Arms

Keyboard platforms, trays or articulating arms can allow a wide range of angle and height adjustability. These are often attached to the worktable and have several movable joints or articulations that effectively allow a large number of possible positions. For continuous or conversational computer work, articulating arms are recommended for workstations without adjustable tabletops. Attachable keyboard trays can be used to cost effectively retrofit existing workstations by adding adjustability. Negative angle trays offer postural advantages over conventional keyboard trays.

To further promote neutral postures of the torso and upper extremities, the keyboard tray should be adjusted to allow the arms, wrists and hands to assume a stress-free, neutral posture without the need for extended reaches, awkward wrist postures and twisting of the torso and head. Employees should be instructed on how to adjust their keyboard trays so that they can take full advantage of the adjustability that is provided. The mouse should be located adjacent to the keyboard to eliminate awkward and extended reaches. If the keyboard is not wide enough, then a separate keyboard tray should be acquired.

Monitors

Monitors can be placed on an articulating platform or arm that allows easy adjustability in three dimensions. All three dimensions can be adjusted without an articulating platform by simply moving the monitor closer or farther away, from side to side or up and down. If a monitor placed directly atop the desk is still too high for an operator, either the desk should be lowered to the extent possible or the chair height can be raised. However, this may also require the addition of a footrest and adjustment to the location of the keyboard and mouse.

1 Hedge, A., and Powers, J. *Ergonomics*, Volume 38(3), 1995.
2 Berquist, U. Wolgast, E., Nilsson, B. and Voss, M., 1995.

Monitors: Vertical Location

According to the BSR/HFES 100 standard, the monitor should be located so that the line of sight angle to the monitor is between 0 and -60 degrees below horizontal eye level. Further, the top of the monitor viewing area should be at or slightly below eye level. A wide range of preferences for specific monitor location has been revealed through various studies. In general, forward tilting of the head should be minimized by selecting a comfortable screen height. To facilitate this, monitor height should be adjustable. Most monitors can be adjusted vertically by adding items under the monitor, such as a telephone book, ream of paper or monitor riser. Note that there is no functional requirement to locate monitors atop the central processing unit (CPU).

Monitors: Distance from Operator

There is evidence that visual conditions affect not only visual symptoms but also muscle pain in the head, neck and upper back regions.¹ Researchers have found that mental workload may have some influence on musculoskeletal symptoms so it is not surprising that visual strain, a form of mental strain, has been shown to effect muscle pain in the head, neck and upper back. Operators should be able to select a preferred distance anywhere between 20 to 40 inches from the screen and software should allow operators to adjust character size. Placement of the monitor at arm's length will allow the distance to fall within the recommended guideline.

Monitors: Tilt

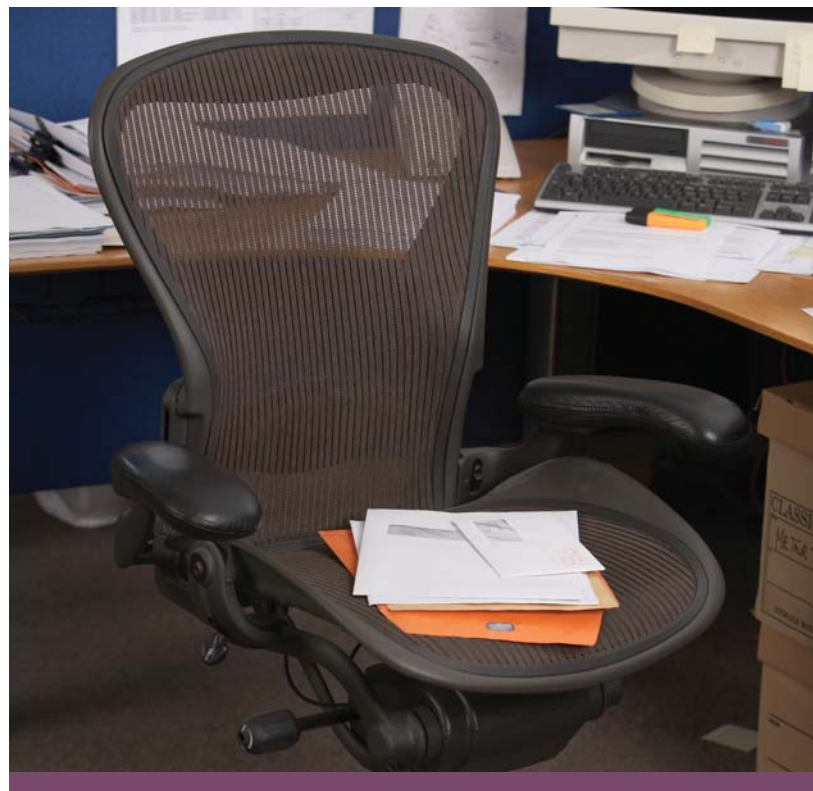
Monitor tilt is important for the reduction of reflected glare. This feature can be used to reorient the screen to change the slope of the surface with respect to nearby light sources. The recommended tilt will depend on the lighting conditions and the preferences of the operator. Keep in mind that fixed monitors should be avoided.

Chairs

Adjustable chairs that facilitate safe and comfortable work should be provided to staff. Each employee should adjust his or her chair to preferred settings, recognizing that the chosen position will affect or determine many seemingly unrelated variables, i.e., hand and wrist posture or line-of-sight angle. Chairs lacking adjustability can induce working postures that increase the likelihood of discomfort or CTD. Lack of adjustability almost guarantees some degree of static muscle loading, a major cause of fatigue, pain and discomfort. One of the most important aspects of a desk chair is that it should allow frequent and easy changes in posture and adjustments.

Chairs: Important Aspects

The features of chair design that are most vital are seat pan height adjustability, lumbar support from the backrest, backrest adjustability forward and backward, and seat pan tilt. Also important for comfort is that seat pans not be too soft or compressible as they can be restrictive to frequent postural changes.



Chairs: Seat Adjustment

The minimum range of adjustability for seat height is from 16 to 20.5 inches from the floor.¹ However, most height recommendation ranges, including the BSR/HFES 100 standard, are based on the assumption that seat pan heights should match or never be greater than the popliteal height, the distance from the floor to the back side of the knee, of the operator. Yet, there remains no epidemiological information to suggest that sitting at heights greater than popliteal height is uncomfortable to operators or increases injury risks. In fact, many operators complain more often of low sitting in chairs than of sitting too high. Additionally, the BSR/HFES 100 standard's recommended range is based on the arbitrary convention of accommodating the 5th percentile to 95th percentile range of heights, which fails to accommodate 10 percent of the workforce. Consequently, a range wider than 16 to 20.5 inches is appropriate. A range of 15 to 22 inches or wider is recommended.

Chairs: Seat Size and Type

Seat depth should be between 15 and 17 inches. If a seat depth is greater than 16 inches, the design should provide relief to the back of the knee, usually with a "waterfall" front edge. The minimum seat width should be 18 inches.¹ The seat pan should not be too soft or compressive, since such cushioning tends to restrict easy movement that produces static muscle loading and discomfort.

Chairs: Seat Pan Tilt

Seat pan tilt should be in the range of zero to 10 degrees forward or backward. A forward slope may create a mild sensation of sliding out of the chair. Sufficient friction should be supplied by seat material to prevent any actual sliding.

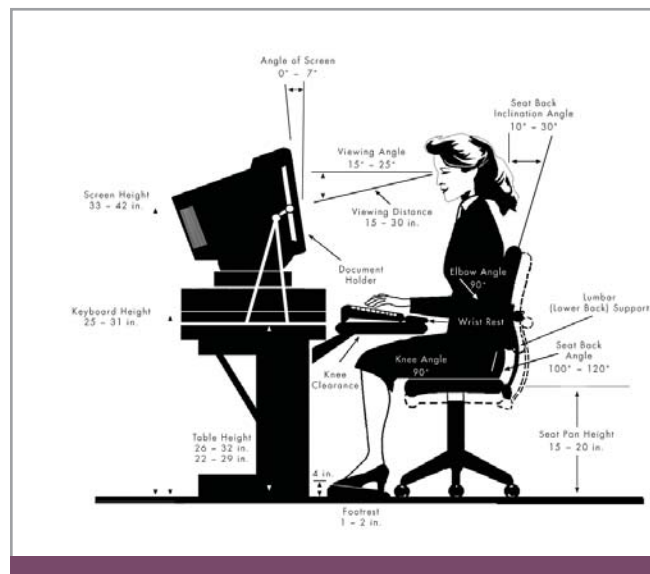
Chairs: Backrest

Lumbar support should be provided by the backrest for the lower back or lumbar region. The exact vertical location of the backrest may not be critical as long as the backrest makes contact with the lumbar region and induces the lordosis curvature, the natural inward curve of the spine at the lower back. However, backrest height adjustability is beneficial for individual preference and comfort. If the backrest does not make contact with the lower back, the operator will not receive lower back support.

Chair backrests should allow the worker to adjust from upright to reclining postures. Studies show that increasing the backrest angle from 90 degrees to 120 degrees reduces the load on spinal discs and also reduces muscle strain. Most computer operators instinctively know that reclining positions are more comfortable and wisely ignore the admonition to sit up straight in your chair.

In a broader sense, computer users will be most comfortable if they assume postures that roughly emulate those that are assumed when driving an automobile, comfortably reclining in the driver's seat. This posture demonstrates that the feet are not flat on the floor and the trunk is somewhat reclined. One difference is that the arms should be somewhat lower at the keyboard than they would normally be positioned on a steering wheel.

Computer Workstation Principles



Chairs: Easy Adjustability

Chair adjustability features are effectively useless if they are not apparent to the user. Adjustable features requiring use of tools, hidden knobs, levers or controls, or forcing the user to invert the chair or having to consult an owner's manual seriously restrict the user and are not recommended. Chairs that can only be height adjusted by rotating the chair do not offer easy adjustability since the adjustment feature is not visible to the user. In addition, such chairs gradually change settings during normal use. The best adjustable chair is one that is obviously and easily adjustable. Chairs should swivel so operators do not twist the trunk or spine when turning or reaching.

Chairs: Arm Supports

Chairs may or may not offer arm supports. Arm supports can be useful to prevent static muscle loading of the shoulders, neck and back and may be recommendable for some workers depending on other components and the type of job. For many chairs, these can be added or removed as an option. Arm supports attached to chairs often interfere with the ability to pull the chair sufficiently close to the worktable to allow contact with the backrest during work. This situation should be avoided. Supports, if needed, can be attached to the worktable rather than the chair. However, a need for arm supports attached to the table should not arise if other workstation elements meet the general guidelines provided.

Wrist and Palm Rests

Wrist rests or supports have been shown to be beneficial for reduction of spinal disc pressure in the lumbar spine and for reducing muscle tension in the shoulders. However, only 50 to 60 percent of operators prefer wrist rests. Many incorrectly consider wrist rests an item to aid the wrists rather than the low back or shoulders. However, for some users, wrist rests are thought to reduce the probability of wrist extension during typing and mouse use, thereby decreasing risks of cumulative trauma. This may be true for only a small portion of operators who are working with excessive wrist extension. When properly positioned, it should provide support to the base of the palms and not contact the wrists. It is a rest only and should not be used when performing data entry. Wrist rests or supports are low cost items that can easily be added to most workstations. Most are simply placed on the keyboard platform or tabletop in front of the keyboard and mouse and can be held in place by slip resistant friction strips that are attached underneath. Due to the low cost and ease of implementation, wrist rests should be available to operators who prefer them.

Footrests

Footrests should be provided to any worker whose feet do not reach the floor when the chair is adjusted to a comfortable position in relation to other workstation components. If the BSR/HFES 100 standard for chair height adjustment range is met, only five percent of female workers will encounter this situation when chairs are set to their lowest point. For smaller workers who prefer their chairs adjusted to higher than its lowest setting, footrests may also be necessary.

Lighting

Rarely are lighting conditions in office environments planned for avoidance of direct or reflected glare on computer monitor screens, especially in older buildings. The tilt feature on many monitors allows operators to adjust the screen to reduce the most annoying reflected glare. Positioning monitors at 90 degrees from light sources, including windows, can substantially reduce reflected glare. The workstation should not be oriented so that a worker directly faces toward a light source, such as a window, since the resulting direct glare can cause serious discomfort or can even prevent the employer from being able to work.

Excessive illumination levels should be avoided in order to reduce the likelihood of direct and reflected glare. Illumination levels for offices with computer monitors should be lower than those for offices without computer monitors. In general, for offices using computer monitors for which there are well-printed source documents and conversational tasks, the measure of illumination 300 lux is appropriate. For poor source documents and conversational tasks, 400 to 500 lux is appropriate. For data entry tasks, 500 to 700 lux is acceptable.

However, the Illuminating Engineering Society (IES) specifies 50 to 100 lux for general illumination for areas with computer monitors, with localized lighting providing as much as 500 to 1500 lux on the task itself. Such local lighting should be chosen carefully so that large luminance contrasts between the screen and the source documents or other nearby surfaces is avoided. If reflected glare is a concern, the IES method is preferred.

Use of Telephone Headsets

To reduce the employee's risk of sustaining a CTD-associated injury from repetitive flexing or extending one's neck and upper-extremity parts over a period of time from cradling the receiver, use of wired or wireless telephone headsets should be considered for offices where there is significant telephone usage. Many models are on the market that address and effectively control the numerous employee objections that initially surfaced relative to headset weight and limitations presented by a headset connection cord. Use of clamp-on devices to the headset only reduces the degree of neck deviation and shoulder extensions. It does not eliminate that posture.

Document Holders

Conventional recommendations for document holders have been based on two assumptions: 1) that visual strain and discomfort is increased when the viewing distances to screen and document are different, and 2) that physical or muscular discomfort of the neck and shoulders is increased if operators must repeatedly tilt the head up and down from screen to document. Document holders are intended to prevent such circumstances. A document holder that will allow source documents to be placed on the same plane as the monitor, either next to or below, should be acquired for workstations where source documents are used during data entry. This orientation will reduce the number of head and neck movements when viewing the source document, reducing stress to the muscles of the neck and shoulders. This will also reduce eyestrain and eye muscle fatigue by minimizing the frequency of pupil refocusing that is performed. There are a variety of types available to accommodate different document sizes and thickness.



Employee Breaks

Studies have shown that muscular fatigue, visual fatigue and mental fatigue can result from individuals working in an office environment performing computer-based data entry. Taking frequent, short breaks can provide stress relief, enhance circulation and relieve the buildup of static muscle fatigue that accumulates during prolonged computer use. In addition to any normally scheduled breaks, it is good practice to take a mini-break of approximately five minutes following intensive computer use exceeding one hour. Additionally, it is recommended that short micro-breaks of 15 seconds should be taken frequently, at least every 10-15 minutes. During this time, a few seconds should be used to close and cover the eyes or to focus on distant objects. The normal blink rate is reduced dramatically when prolonged computer work is performed. Frequent, short breaks can reduce eyestrain and moisturize the eyes.

Workplace Stretching

Stretch breaks throughout the day provide the opportunity for stress relief and time to recover from the accumulation of static muscle fatigue. Stretching also enhances blood flow to the extremities of the body. No employee should remain in a fixed position for any duration of time; periodic rest breaks should be taken throughout the workday by just getting up and walking around the employee's immediate work area on an hourly basis. Employees should be encouraged to do simple stretches during work breaks.

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