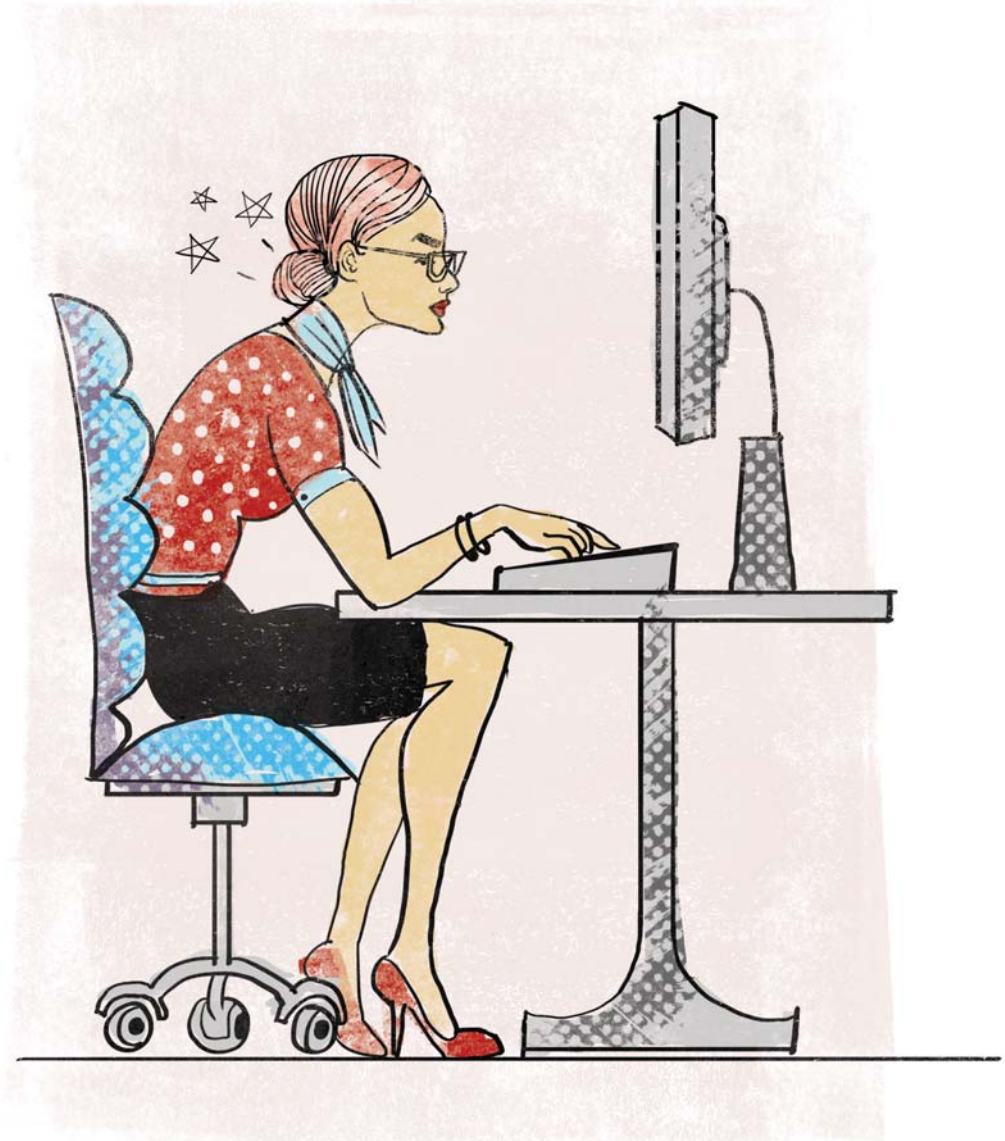
OFFICE ERGONOMICS

and its impact on health and productivity
with focus on musculoskeletal symptoms



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About the authors

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Foreword

Musculoskeletal pain problems are common among office workers and have been an important issue over the years. Whether these are caused or just aggravated from poor postures and inappropriately adjusted work-stations, the issue continues to be a challenge to staff, employers and ergonomists. In this brief review and overview of some important aspects of these problems, the authors give hands-on suggestions on how to organize, monitor and address some of the aggravating factors.

It is our sincere hope that this article will provide arguments based on scientific evidence for our many field ergonomists that struggle to convince managers to buy ergonomically-adequate equipment, and to make sure the equipment is well adjusted for each individual worker. The role of the ergonomist is continuously changing with our technological advances, but to be effective this has to include direct worker participation.

1. A brief historical review

In the 1970s, in the global office environments, computers were virtually non-existent, and musculoskeletal pain was misunderstood or dismissed.
In the 1980s, punch cards were introduced followed by the big framed data entry computers. Large groups of secretarial staff worked 8-10 hr days in fixed body positions with limited breaks, inadequate lighting, poor office ergonomics, and "Taylor trained*" managers (Taylor, 1911). Many workers started to complain of aches and pains. In search to find the causes, and to alleviate these problems, safety engineers and physiotherapists were entering the field of office ergonomics. They used whatever common sense they had, and brought with them poorly validated methods such as bio-feed-back, posture angle measurements, electromyography, and repetition observations to address the believed causes of these problems. Back pain was increasingly reported as an "occupational illness" with reference to research of higher intradiscal pressures in certain seated, rather than standing positions (Nachemson, 1960, Wilke et al, 1999).

Carpal tunnel syndrome was identified as a typical problem believed to be caused by repetitive strain (Armstrong et al, 1979). Tennis elbow was another favorite occupational diagnosis attributed to typing, (figure 1).

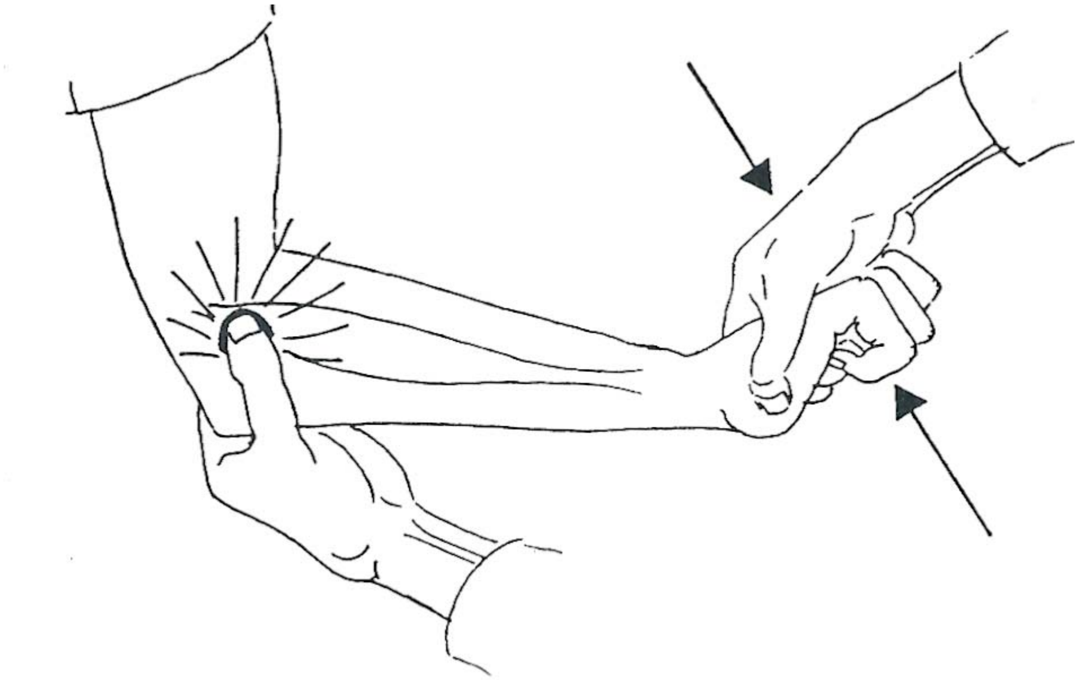
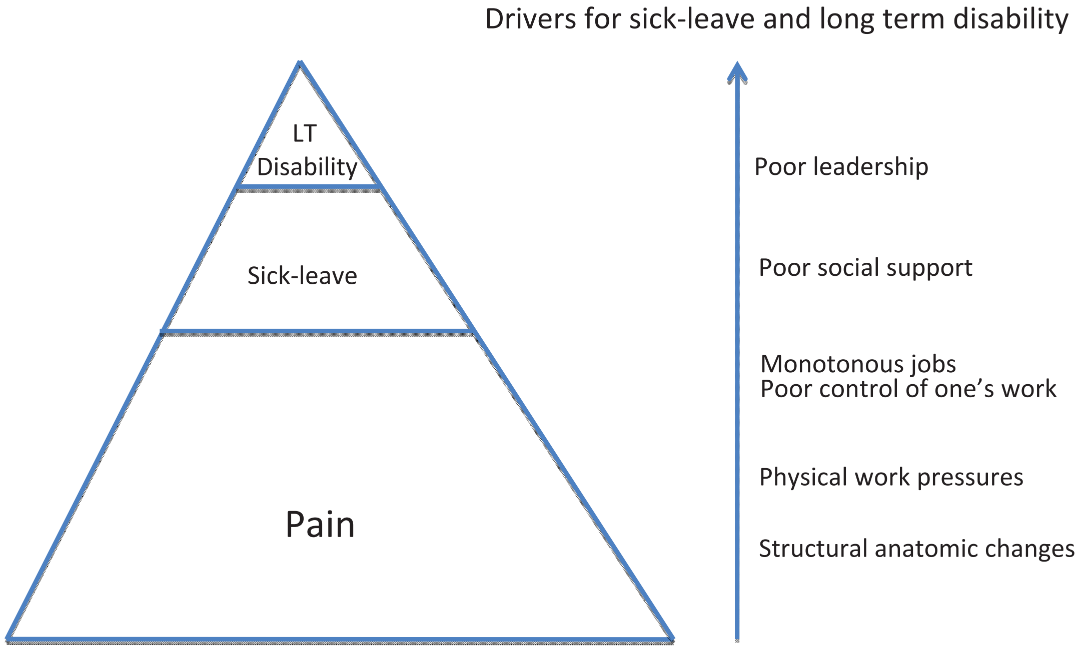


Figure 1
Tennis elbow

** Frederic Taylor (1856-1915) was lead developer of scientific management, whose work lead to mean time measurement (MTM) of work tasks and pay per piece to increase productivity.*



<u>Additional risk factors:</u>
Female gender, smoking,
alcohol and drugs, poor attitude to work
language difficulties, cultural traditions,
generous wellfare, poor physical conditions

Figure 2
Suggested relationship between pain, sick-leave and long term disability and some important associated risk factors in MSD (Dimberg, 1991)

Soon, studies were performed at the Volvo Corporation in Sweden to show that sick leave and bed rest were not a cure, but a curse. It was well known in athletic and aerospace medicine, muscle atrophy occurred when appropriate training was not sustained. It was convincingly shown in randomized controlled studies, that a quick return to work, and appropriate training, together with engineering controls, were much more effective to reduce pain and prevent long term illness (Lindstrom et al, 1992). An elucidating study on tennis elbow in workers (Dimberg et al, 1987) showed in a survey these conditions were equally common in categories involving light, medium and heavy work loads**.** Those who worked with heavy labor, reported having more pain, and saw a doctor for their condition, contrary to those with the light labor. Therefore, due to the falsely based statistics of patients visits recorded, the occupational doctors were convinced that these conditions were caused from their type work, instead of being aggravated by it.

Pain in the neck, shoulder, arm and back among office workers is ubiquitous. Over a period of 6 months, in the 2009 survey of 3348 office workers at the World Bank offices in Washington DC, 73% of the respondents reported having had such symptoms (Laestadius et al, 2009). Daily pain was reported from the neck/shoulders (21%), hand/wrist (10%), elbow (3%), and low back pain (13%). However, only 12% of the World Bank staff reported having taken sick leave because of it. Research at the Volvo company in Sweden has identified the prevalence of pain, sick leave, long-term disability, and risk factors (Dimberg, 1991).

The evidence based wisdom of treating musculoskeletal pain problems aggravated by work, is to optimize the ergonomic conditions rather than to stay at home and rest (Lindstrom et al, 1992; Quaseem et al, 2007). It must, however, be emphasized that all chronic pain conditions must always be medically investigated. Treatable conditions such as rheumatic arthritis, peritendinitis crepitans, tendinitis nodosa, and cancer, may loom behind perceived work related pain as illustrated by the example of a cigarette smoker with a long-standing shoulder pain condition, which was accepted as a work injury, but later turned out to be a lung cancer that has spread to the spine and nerve-roots.

2. Basic office ergonomics principles

2.1 Modern ergonomics

Modern ergonomics builds on functional biomechanics as defined by Frankel and Nordin (1980)*:* Functional biomechanics uses laws of physics and engineering concepts to describe motion undergone by the various body segments, and the forces acting on these body parts during normal activities. In principle, neutral body positions (neither flexion nor extension) and less effort are the goals. It is however important to understand that our bodies are designed for movement, and sitting in a single body position for a long time, however neutral, is likely not physiologically recommendable. We need constantly to vary our positions, but from a basic neutral baseline.

While it is reasonable to use a heuristic method (common sense), the link between exposure and illness (the pathological process) is often less clearly understood (Dimberg, 1996). Quite clearly there are anthropometrical differences between individuals, such as height and weight (figure 3).

Figure 3
Anthropometric differences

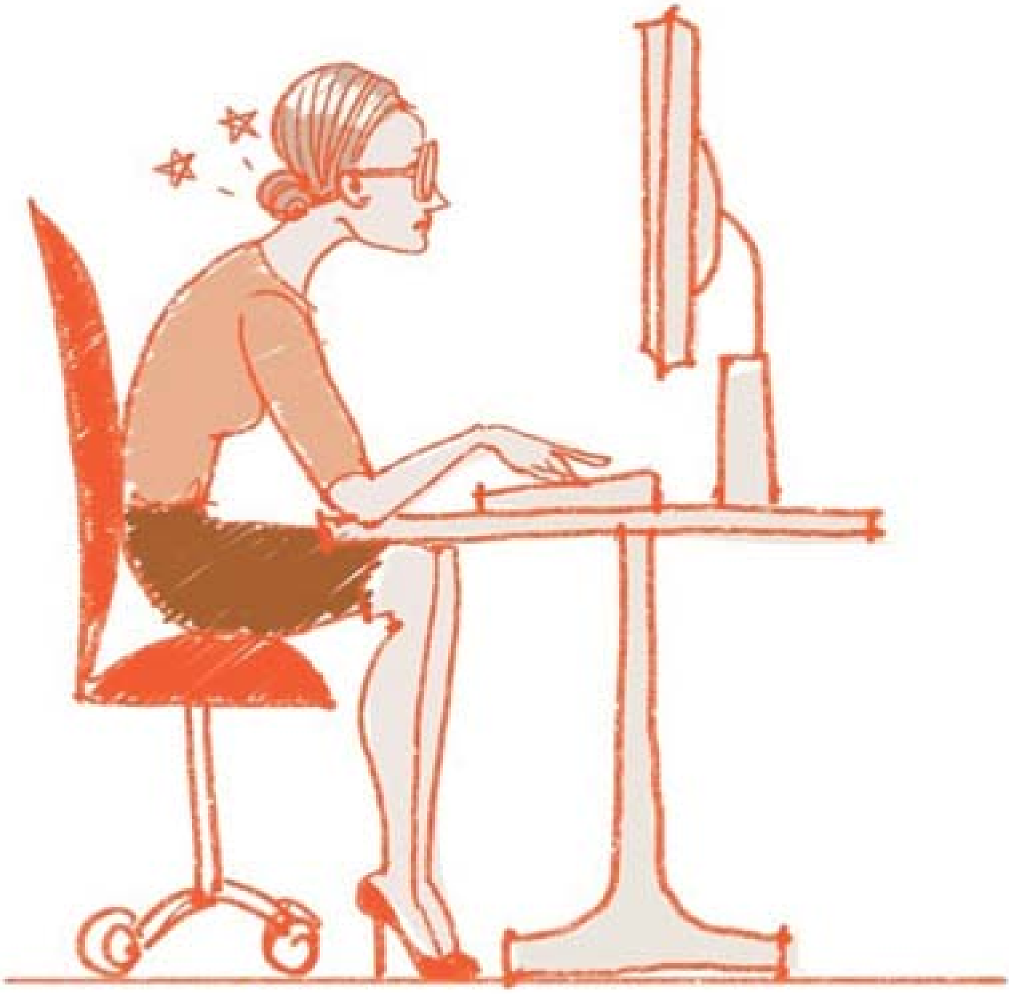


Figure 4
Discomfort at the work-station

It is important to understand that most office furniture and chairs in general are acceptable for 90-95% of the normal variation in terms of weight and size. This means however that at least 1 staff in 20 are either too tall or too small, and will need special accommodations! The excellent Herman-Miller Aeron chair comes for instance in 3 different sizes to allow for all body sizes. Neurological illnesses such as cerebral paresis, vision and hearing impairments may affect some already from birth. Illnesses and injuries make some of us more vulnerable for exposures that a healthy individual would not notice. Gender and left handedness (about 12% of a population) may also make us more sensitive to tools and other various types of equipment designed for right-handed healthy males, along with age, which affects us all. An older individual might need glasses (typically at age 40), and more light. Most people with age develop stiffness in the eye lenses with accompanying focus problems.

A multitude of factors affect the office environment and below follows an account of some of the most important elements (figure 5).

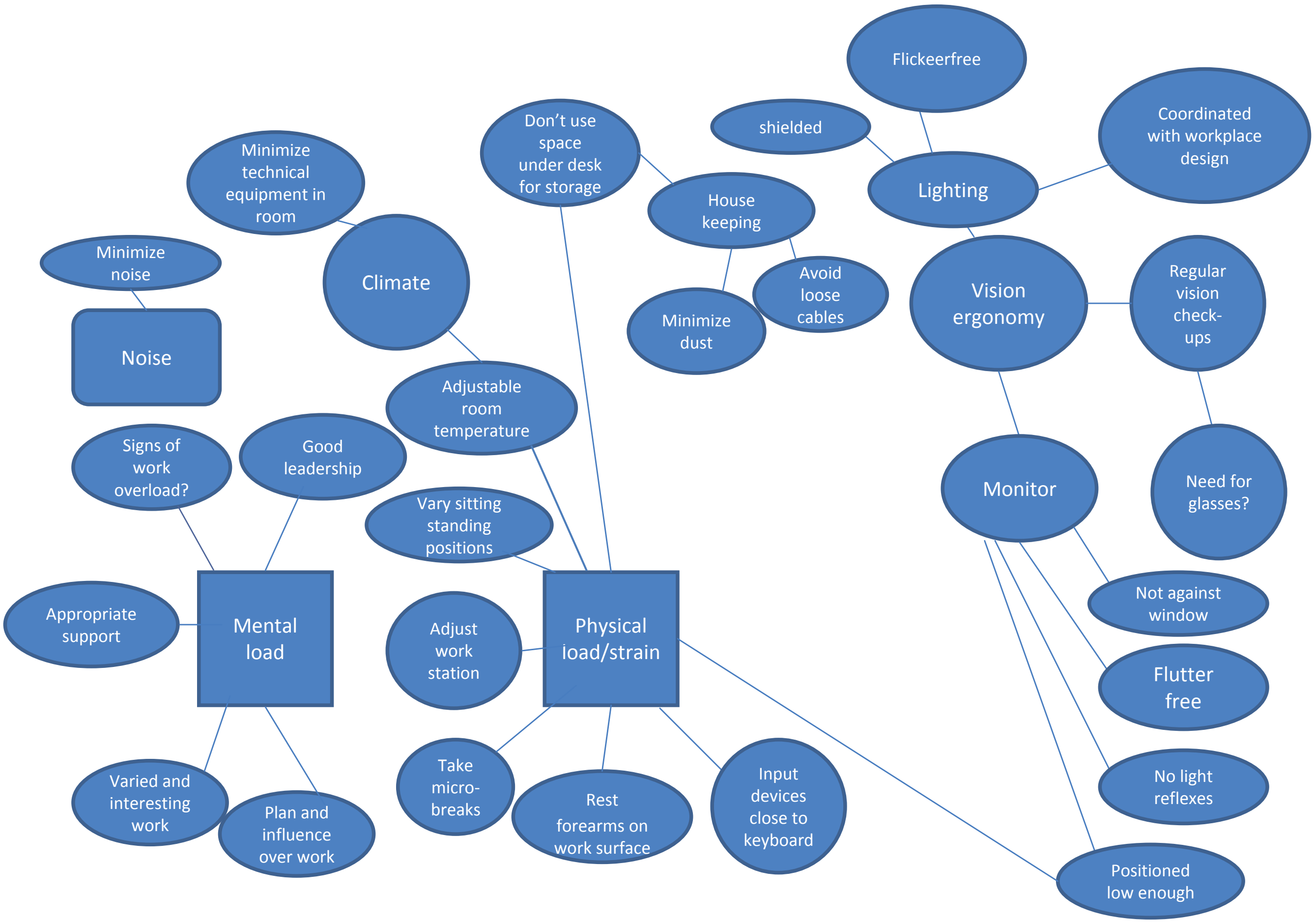


Figure 5
Guide to a good work environment (Swedish Work Environment Authority, 2011)

2.2 Biomechanical risk factors

These add to the strain of muscles, tendons and other soft tissues. These factors have been analyzed by Professor Thomas Armstrong and colleagues of the Center for Ergonomics, University of Michigan (Armstrong, 1991) and are listed in Table 1.

Table 1
Risk factors for cumulative trauma disorders (Armstrong 1991)

Repetition	Repetitive work without adequate alternative activity to allow for physiological recovery
Sustained or awkward posture	Prolonged and/or non-neutral position of any joint
Forceful exertion	Any activity requiring excessive strength or accelerated motion
Contact stress	Pressure on soft tissues caused by external surfaces
Psychosocial stress	Organizational or intrapersonal factors resulting in increased actual or perceived stress

2.3 Pathophysiological mechanisms of muscular strain disorders

In an excellent review article, Hagberg summarizes injury mechanism (Hagberg, 1984). The following paragraphs draw strongly on that article.

Degenerative joint disease-osteoarthrosis or osteoahrtritis-may be caused by increased stress on cartilage, such as repetitive impulse loading. According to some authors, this is sometimes preceded by trabecular microfractures in the subchondral bone caused by trauma. Other authors point to clinical evidence of polyarticular disease and suggest a metabolic abnormality of the articular cartilage. It is claimed that insertion disorders in tendons, ligaments, and articular capsules are caused by local ischemia leading to degeneration and producing inflammation and pain. In particular, the tendons of the supraspinous, the biceps brachii, and the upper part of infraspinous muscles have a zone of avascularity . This has been found to be the site of microruptures and degeneration that may be accelerated by aging. Impairment of the venous circulation may occur when the humeral head compresses the tendons (elevated arm) but also when there is increased tension in the tendon. Tendon inflammation has been provoked by repetitive contractions in rabbits. Degenerative tendinitis in the shoulder girdle aroused by exertion, for example, may trigger a foreign body response inflammation. Tenosynovitis is an inflammation of the tendon sheath and it's synovial. In the long biceps tendon, this may be caused by the tendon and its sheath rubbing against the lesser tuberosity during overhead movements. Post infective arthritis as well as tendonitis may presumably dispose a person exposed to shoulder stress to a more severe reaction. Muscle tenderness, myofascial pain syndrome, trapezius myalgia (figure 6), and related disorders are obscure conditions because pain does not originate from the contractile muscle fibers themselves.

Figure 6
Trapeziusmyalgia

It may possibly derive from pain fibers within blood vessels or the connective tissue. Hagberg points to three pathophysiological routes. The first is mechanical failure with ruptures of z-disks probably caused by temporary high local stress.

The second is local ischemia due to the impairment of the circulation by continuous muscular performance, which may already occur at 10-20% of the maximum voluntary contraction. This leads to a fall in pH and reversible enzyme inhibition. It is postulated that the tissue irritation causes extravasation of blood, edema, and fibrositis in some individuals. Highly repetitive work may then possibly cause cumulative trauma to the muscle cell (thence cumulative trauma disorders CTDs) affecting both morphology and energy metabolism.

The third pathophysiological route would be energy metabolism disturbance. Energy depletion in the muscle cell has been suggested as one factor in muscle pain. Defects in the energy metabolism are often associated with painful disorders in the muscle. Laboratory experiments involving repetitive shoulder flexions have produced energy depletion as indicated by an increasing serum

creatine kinase and accompanying pain. It is hypothesized that this may also be important for static loads. The possibility of certain primary metabolic disturbances in certain individuals has also been proposed.
The carpal tunnel syndrome is a textbook example where the injury mechanism is clearly understood. Friction caused synovitis of the tendon sheaths in the carpal tunnel causes pressure on the median nerve (Lundborg, 1988) figure 7.

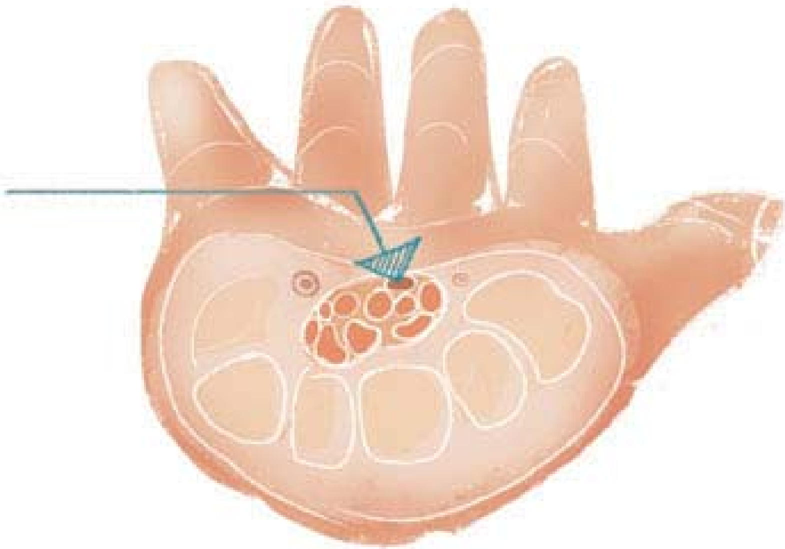


Figure 7
The arrow points to the median nerve surrounded by the flexor tendons.

Another example is supraspinous tendonitis, where the supraspinous tendon is pressed against the acromion in a space that has been limited by inflammation (Herberts et al, 1984).
Fibrosistis/fibromyalgia and generalized muscular pain are common conditions but with a poorly understood pathogenetic mechanism. The theory that static muscular load causes ischemia in the muscle, creating morphological changes in the muscle fibers, has been suggested but remains to be proven (Henriksson, 1983). It is easy to prove muscular fatigue and pain after minor static load, but the pathogenetic link from chronic muscular fatigue to permanent damage, and chronic pain, remains to be shown.

Microfractures have been suggested by Hansson et al (1988) to be a reason for lumbar pain in certain individuals, but no-one knows how common this is. The lumbar disc and its degeneration have been connected to low back pain, and the intradiscal pressure as measured by Nachemson and Elfstrom (1970) was for a long time the theoretical mechanism for ergonomic advice, but has since been abandoned by Nachemson (1991).

Spinal shrinkage as measured from height before and after loading provides a method for measuring mechanical load on the spine (Ericson et al 1980). The shrinking is dependent on the elasticity of the intervertebral disks. However, no-one knows if the shrinkage leads to a permanent disk problem or whether this may be the pathogenetic mechanism for back pain. It is well known that the openings for the nerves (foramina intervertebralis) between the cervical vertebrae decrease upon extension of the head (tilting backwards). For older people with age related formation of bone spurs, and for those with herniated discs, the nerves coming out of these holes may be pinged eliciting neck pain radiating in the arm (Windsor, 2009). This is the scientific basis for the monitor location.

From a terminology point of view, the old nomenclature of cumulative trauma disorders (CTDs), which implies a direct causative effect, will be replaced by the more modern term, musculoskeletal disorders (MSDs). Ideally a specific diagnosis such as lateral epicondylitis (tennis elbow), myalgia (muscular pain) and tendonitis should be used, and a thorough review of patients with these type of problems, allows for specific diagnosis or combinations of diagnoses to be made for most cases (Dimberg, 1986).

2.4 Psychological and social factors

They are probably the most important factors for the health of office workers. The principles outlined by Robert Karasek as psychological risk factors for myocardial infarctions which include job output demand, control over one's work program, and social support from fellow workers, are in our opinion equally important in reference to musculoskeletal tension and strain (Karasek et al, 1988). The role of the supervisor and his leadership is in this context crucial.   Documented in a survey, unexceptable work environments, leading to frequent sick leave periods, have been totally changed when the manager has been replaced with a good leader (Dimberg et al, 1991). A few years ago, this caused a "shut down" at a major car company plant, where annual staff surveys showed serious discontent. Because this particular plant showed financial increases due to a Tayloristic and bullying plant manager, the company decided to discontinue their staff surveys. Shortly thereafter, the whole plant went on strike and staff would not return until the manager had been replaced, a very costly lesson for the car company.

Recently published evaluation of work related psychosocial factors and regional musculoskeletal pain emphasized the importance of developing standardized methods for conducting evaluations of existing evidence, and the importance of new longitudinal studies for clarifying the temporal relationship between psychosocial factors and musculoskeletal pain in the workplace (Macfarlane et al, 2008).

2.5 Indoor air quality (IAQ)

The indoor air quality is another factor of importance for the well-being in work environment. The American Society of Heating Refrigerating and Air-conditioning Engineers (ASHRAE) publishes regularly updated standards on ventilation for acceptable indoor air quality (Standard 62.2, ASHRAE, 2011) Table 2.

Table 2.
Summary of Indoor Air Quality standards (ASHRAE)

PARAMETER	IDPH	ASHRAE
Humidity	20% - 60%	30% - 60%
Temperature	20° – 24° C; 68° - 75°F (winter)	20° – 24° C; 68° - 75° F (winter)
	23° – 26° C; 73° – 79°F (summer)	23° – 26° C 73° - 79°F (summer)
Carbon Dioxide	1,000 ppm	1,000 ppm
	(<800 ppm preferred)	
Carbon Monoxide	9 ppm	9 ppm
Hydrogen Sulfide	0.01 ppm	N/A
Ozone	0.08 ppm	N/A
Particulates	0.15 mg/m^3 (PM 10) (150 µg/m^3) 24-hr 0.065 mg/m^3 (PM 2.5) (65 µg/m^3) 24-hr	N/A
Formaldehyde	0.1 ppm (office)	N/A
	0.03 ppm (home)	
Nitrogen Dioxide	0.05 ppm	N/A
Radon	4.0 pCi/L	N/A

In an interesting study at Volvo in the mid 80s, Jorulf and colleagues demonstrated that 22 degrees C (71.6F) was perceived as the temperature where most people were comfortable in a mixed gender office environment when mainly sitting. The individual variation was however considerable with an overweight person preferring a colder temperature to a leaner person preferring a warmer temperature (Lars Jorulf, Volvo Truck Corporation, personal com.)

Air conditioning is another factor that may affect staff's well being. Lower humidity can increase the susceptible to respiratory tract infections, and humidity levels below 20% can increases the annoying effect of an electric spark upon touching metal surfaces (Maneghetti et al, 2011). Also, cold air coming down from an over head vent, can lead to annoying pain and muscle tensions.

Various smells may also cause distress in workers. We have encountered smelly conditions that were caused from a dead rat, leftover food in office cabinets, and water leaks causing mold. There is no doubt that inadequate air quality (IAQ) problems will lead to distress, which may increase muscular tension, and also aggravate musculoskeletal pain disorders.

2.6 Vision ergonomics

Working at the monitor can be stressful to the eyes, and lead to discomfort such as light sensitivity, dry and itchy eyes. The distance from the monitor and its height are important to avoid eye strain. The monitor should be placed at an arm length distance from the body, and the first line of the text on the monitor should be viewed without moving the head up or down. Particularly for those who use bifocals, looking at the monitor from the bottom of their lenses, annoying neck strain can arise when keeping their head backwards.

Over the age of 40, most people develop a stiffness in their eye lenses and accompanying focus problems. It is important to see an ophthalmologist regularly, especially if having persisting eye symptoms. Painful and red eyes can be a sign of a serious problem such as glaucoma (elevated eye pressure) or allergies.

The question about whether direct or indirect background lighting is preferable from an ergonomic standpoint is related to whether glare and contrast issues can be addressed. The monitor should be free of flickering and light reflexes, and not placed against a very light background such as a window. For data entry type of jobs, usually an additional task light for documents is recommended, as well as a document stand. Table 3.

Table 3.

Work station protocol for eye strain

Monitor
* Adjust the adjustable monitor brightness to 50%
* Adjust the location of the monitor (contrast)
* Suggest font size increase
Lighting
* Adjust the overhead lighting
* Suggest the need for task lighting (desk lamp)
* Use of filter screens (suggest to remove)

2.7 Computer work in the open office landscape

The design of the office is an important factor for general well being, and may occasionally be the source of audiovisual stress, significantly increasing muscular tension that may lead to decreasing postural adjustment and be a cause of muscular discomfort (Evans et al, 2000).

Historically, a totally open landscape of the past now tends to be replaced by various wall heights around individual workstations. Building a partially or totally enclosed room/cubicle in this type of environment is often brightened up with decorations, plants and harmonic colors.

Studies show that noise generated by human talk, even whispering, is more disruptive than “gray” sound from ventilation fans, computers and printers, or traffic. Perhaps our attention to the voice is a reflex drawn by instinct of survival (Kjellberg et al 1994). The removal of carpets and other sound absorbing materials will lead to higher sound levels.

Also visual disturbance, where eyes are quickly drawn to anybody passing by may be disruptive to concentration and focus (Kjellberg , 1990). Dealing with confidential information and the need for privacy may limit usability of the office landscape for certain professionals.

Figure 8
Office landscape

There are several variants of open office landscapes, such as for instance, flex offices. The open office landscape's design is especially important for the perception of comfort and discomfort (figure 8). It is strongly recommended to mix open group locations with adjoining silent rooms. There are different examples of silent rooms, some small just to allow you to speak on the phone in private, like phone booths, but inside the landscape. A fair number of small closed meeting rooms should be recommended depending on the size of the open landscape. Common rules of communication must be discussed and adhered to such as when do you have to move away from your location to speak on your phone? Which volume should the ring-signal of your cell phone be? How do you communicate with each other? How should visitors be entertained? Do you go directly to the meeting room or do you stay and chat first? It is also important to design open meeting areas in the landscape, but at significant distance from the other staff locations. Common is these days to make glass cubicles in the landscape, where meetings can be held to maintain the visual contact with other staff.

In order to minimize disturbing noise a number of absorbing structures such as textile fabrics, and ceiling absorbents can be introduced. You can also define certain parts of an open landscape to be silent areas.

Table 4 summarizes some important aspects recognized in current research (Chigot P, O'Neill M et al, Kjellberg, 1990). Table 4

Table 4

Some pros and cons of the open office landscape

Factor	Pro	Con
Cost	Cheaper to design, and less cost to maintain per person seated	
Human interaction	Promotes teamwork	Can be a distraction/disturbance
Confidentiality		Difficult to maintain
Cognitive process		Difficult to focus
Infections		Promotes spread of respiratory viruses
Light		Ceiling lights may create disturbing reflexes
Mobility		Staff tend to avoid moving around
Noise		Louder environment
Ventilation/temperature		Difficult to individualize temperature
Personality	Extroverted staff adapt easier	Introverted staff prefer closed rooms

2.8 The workstation

2.8.1 The monitor

The old type of monitors used a cathode ray for projection. They were big, bulky and heavy with low luminance and a tendency to flicker. They have now mostly been replaced with those based on the principles of liquid crystal, plasma or light emitting diodes. These are thinner, lighter and with much better luminance. The resolution is also becoming much better. Some screens use interactive software, so you can elicit commands by pointing directly on the screen. This technique increases the need to regularly wipe the monitor to avoid dirt and fingerprints. The font size can easily be changed to provide better readability.

2.8.2 The computer

The Lap-top, note book, iPad and smartphone are all easier to move around than the traditional desk top computers. Ergonomic principles may however be a challenge to adhere to.

2.8.3 Special software

Hands-free computing through speech recognition software is quickly gaining market and has the advantage of letting the computer do the typing. It is however problematic to use for making tables, designing and drawing.

2.8.4 The keyboard

Alternative keyboard designs are offered such as the split keyboards, to allow for better neutral hand alignment, and the raised keyboards to avoid pronation of the hands. These may provide relief for individuals suffering from various ligament and osteoarthritis problems of the hands, but have not been widely accepted by the general users.

2.8.5 The chair

The chair is a very important component of the workstation. Ideally you would like to have a chair that provides for individual positioning (Table **5**).

Table 5

Requirements for an ergonomic chair

Feature	Specifications	Description
Seat Height adjustability	16-21 inches 41-54 cm	Should be height adjustable to accomadate individual needs
Back lumbar support	1.2-2 inches 3-5.1 cm	Adjustable up and down to coincide with the lumbar region of the spine
Back rest height (measured from the base of the seat)	23-25 inches 58-64 cm	Back rest should provide support to lower and upper back (shoulder blade area)
Back rest Tilt/recline	Adjustable 0-15 degrees	Should lock in place for firm support
Back rest width	Minimum 12 inches 30.5 cm	Material for the back rest should be firm, breathable, and resilient
Arm rest	Up and down 7-11 inches 18-28 cm In and out (arm separation range) 18-22 inches 46-56 cm	Should be soft and padded
Seat pan	15-17 inches 38-43 cm	Waterfall sloping edges. Padded and contoured for support
Base	Adjustable length 5 castors minimum	Rolls easily over floor or carpet

During a 2009 0ffice chair selection process for an international institution with 15000 staff, 4 chairs were selected as the workers preference (figure 9).

Figure 9 *
Four good chairs: top left: Aeron (Herman Miller), top right: #19 (All Steel), down left: Leap (Steelcase) and down right: Mirra (Herman Miller)

Based on the findings of the ergonomics study in the World Bank (Laestadius Goldoni et al, 2009) a very important finding was in spite of the electronic information, and pamphlets were for many staff useless for appropriate adjustment of their chair. A personal visit by an ergonomist, or someone trained to properly adjust the chair, and all other elements of the workstation (furniture and IT equipment), was necessary for good ergonomic posture.

2.8.6 The desk

Particularly when several staff of various heights use the same desk, easily adjustable desks through a lever or electrical engine are preferable to avoid inappropriate sitting positions. Particularly for staff with back ailments having trouble sitting, an adjustable desk that can be raised to standing position may be a good option (figure 10).

** While there are plenty good office chairs, these are the chairs evaluated in the procurement process of the World Bank. The authors have no financial involvement with the manufactures.*

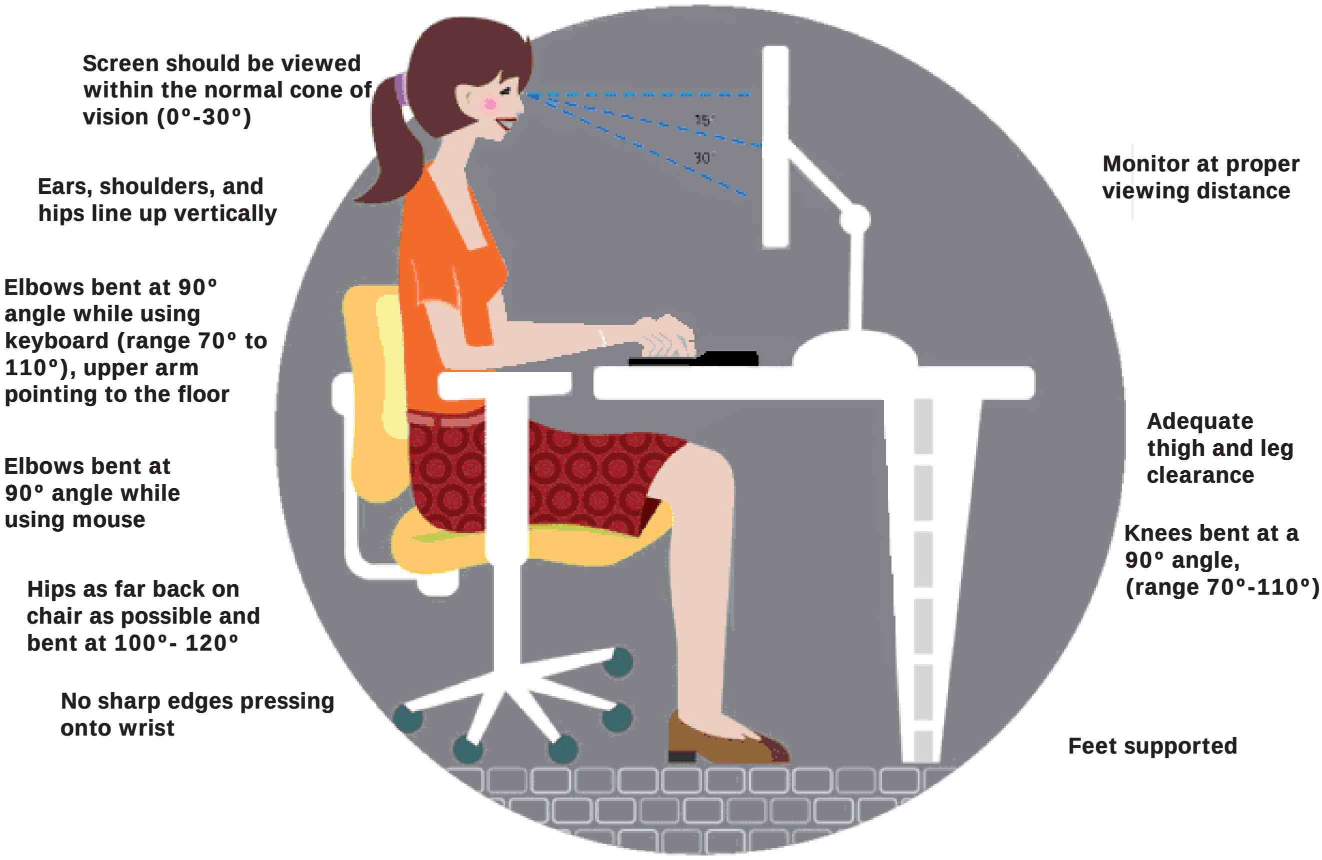


Figure 10
A proper work-station set up

2.8.7 The mouse

Being an important input device, the mouse has been extensively studied and improved to fit various hand-sizes and disabilities like the Ullman pen-mouse and the various types of contour mouses now available. With various types of hand disabilities, it will almost always be possible to find an appropriate mouse to accommodate the user.

2.8.8 Additional resources

There are a number of web-based ergonomic programs in the cyberspace. Some are pay per service, and others are free. Most give adequate advice on office ergonomics with helpful hints, but our research has shown that just pushing ergonomic information via emails, pamphlets and other types of venues has a limited value. Many staff will not read what comes their way, and for many that do there is a major difference between reading and doing. A person trained to assess and adjust the workstation is the key to a successful program! Below are links to some useful websites:

http://www.safetyonline.com/doc/Ergo-Clinic-0001
http://www.osha.gov/SLTC/ergonomics/
http://en.wikipedia.org/wiki/Ergonomics
http://sitemaker.umich.edu/center-for-ergonomics/home
http://office-ergo.com/
http://ergonomics.about.com/od/ergonomicbasics/a/ergo101.htm

Desk working area. Black area is the primary working area and gray is the secondary area. Adapted from the Ergonomics Standard by the Swedish Board of Work Environment AFS 1998:1. Distances in cm (figure 11).

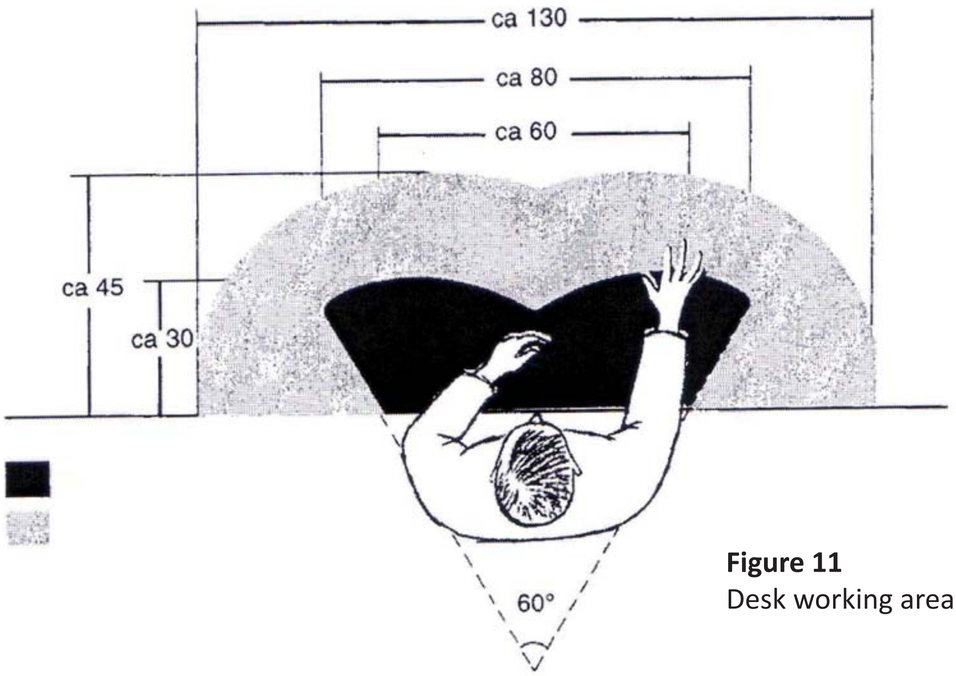


Figure 11
Desk working area

Table 6
Checklist for desk

Feature	Specifications	Description/Notes
Height Adjustable desk	20 -27 inches 50 - 70 mm	A height adjustable desk is ideal but may be cost prohibitive.
Height Fixed desk	26-28 inches 66-71 cm	A footrest must be used if, after adjusting the height of the chair, feet do not rest flat on the floor.
Depth	At least 30 inches or 76 cm	Desk surface should allow you to place the monitor directly in front of you at least 20 inches away.
Width	At least 47 inches or 120 cm if desk is used for keyboard only. At least 60 inches or 150 cm if used for keyboard and paperwork.	Desk space should be able to accommodate a variey of working postures and tasks.
Desktop edge	Maximum of 3 inches or 7.5 cm	Rounded desktop edges to minimize contact stress on the wrist.
Leg space Clearance space under desk	20 inches or 52 wide 17 inches or 44 cm deep at knee level 24 inches or 60 cm deep at foot level 4 inches 10 cm high at the foot	Should allow for users to change working postures. Should be clear of items such as computer, files, books, storage of other personal items.

AVOID CORNER STATION:

Back not supported, monitor too low and too far away

Keyboard in the corner

Curved wrists and straight elbows

CORRECT STRAIGHT POSITION:

Top of monitor at eye level

Monitor distance corrected

Back supported

Straight wrists and elbows at 90 degrees

Figure 12
Bad and good ergonomics

Table 7
Checklist - How to self-evaluate and organize your work-station.

Work posture	Head and neck are upright, or in-line with the torso (not bent down/back) Shoulders and upper arms are in-line with the torso, relaxed, not elevated or stretched forward. Upper arms and elbows are close to the body (not extended outward) Trunk is perpendicular to floor, supported by the back of the chair Thighs are parallel to the floor and the lower legs are perpendicular to the floor (thighs may be slightly elevated above knees) Feet rest flat on the floor, or are supported by a stable footrest Legs and feet have sufficient clearance space under the work surface so you are able to get close to the keyboard/mouse Mouse or trackball is located next to your keyboard so it can be operated without reaching Mouse is easy to activate and the shape/size fits your hand (not too big/small) Wrist and hands do not rest on sharp or hard edges Wrist/palm rest is provided (optional)
Monitor	Top of the screen is at or below eye level so you can read without bending your head or neck down/back Monitor distance allows you to read the screen without leaning your head, neck or trunk (typically arm-length)
Desk	Desk height is adjustable
Chair	Backrest provides support for your lower back (lumbar area) Backrest height is adjustable Seat front does not press against the back of your knees and lower legs (seat pan not too long) Seat height is adjustable Armrests support the forearms without resulting in hunched shoulders (armrests too high) or leaning to one side (arms too low) Armrest height is adjustable

Figure 13
Estimation of correct monitor distance
20”-28” (51-71 cm) from eyes to monitor -
about armlength

3. Disability accommondations

A growing output of assistive devices both in terms of hardware and software make disability accommodations increasingly possible.

Vision impaired people may take advantage of zoom-ware for text magnification and easier reading, and reading text out loud from a screen with software such as JAWS (Job access with speech).
An overview of available resources can be found at the website of the American Foundation for the Blind (http://www.afb.org/section.aspx?FolderID=2&SectionID=4).

Hearing disabled people may use hearing assistive technology systems including FM Systems , infrared Systems, Induction Loop Systems and One-to-One Communicators, and individual hearing aids. Direct conversion of speech to text can also be found for instance Dragon point and speak. Updated available resources can be found at the American Speech Language Hearing Association (http://www.asha.org/public/hearing/treatment/assist_tech.htm).

Mobility impaired people may be assisted by scooters, and for instance software allowing a person without movable fingers to use a stick for preprogrammed keys and voice commands. More available resources can be found at the International Center for Disability Resources on the Internet website (http://www.icdri.org/Mobility/index.htm)

It is most likely that voice commands and intelligent voice recognition systems in the future will replace much of the traditional keying for entering data.

Some major corporations have equipped special Assistive Technology Centers, where various equipment, chairs, desks and software are at display and can be tested by the disabled persons prior to being procured.

4. Ergonomics and productivity

Few controlled studies exist on ergonomics and productivity, although anecdotal evidence, and before and after scenarios have been published (Oxenburgh, 1985). The implementation of innovative office concepts and ergonomic programs on health and productivity among office workers was evaluated in several studies (Smith and Bayeh, 2003; De Croon et al, 2005; Meijer at al, 2009). Limited effects were noticed on work related fatigue, health changes, and productivity in the long term. Levels of evidence for specific ergonomic interventions ranged from insufficient to moderate. Generally, outcomes were focused mostly on the improved comfort of workers (Leyshon et al, 2010).

The assessment of the effectiveness of a group based interactive work style intervention in improving work style behavior was conducted by Bernaards et al in 2008. The work style intervention was effective in improving the stage of change with regard to body posture, workstation adjustment, and the use of sufficient breaks during computer work. These findings were confirmed by higher self reported use through breaks, exercise software reminders and working less hours without breaks. However, self reported changes in body posture and workstation adjustment, were less consistent. The work style intervention was ineffective in changing stress outcomes.

There is evidence that workstation adjustments are beneficial when combined with ergonomics training (Kennedy et al, 2010). Also, a recent Finish study demonstrated that an early ergonomic intervention reduces sickness absence due to upper extremity or other musculoskeletal disorders (Shiri et al, 2011).

In connection with the move of 1500 office staff to another building with improved ergonomics in Washington DC, Laestadius et al (2009) evaluated the association between work station features, working postures, and musculoskeletal pain symptoms. The prevalence of pain symptoms, working while ill, and absenteeism, was evaluated before, and 18 months after the proactive ergonomic program. A comparison was made with a similar reference group of another financial institution. Associations between improvement of postures and less musculoskeletal pain and eye strain were confirmed. A cross association between several features and postures and improved symptoms was noted, along with improved productivity. The study suggests that a proactive program adhering to the OSHA recommendations needs to include an individual workstation assessment to be effective in reducing symptoms and increasing productivity. Figure 14 shows the elements of an ergonomic management system which was proven successful in a large corporate environment:

ERGONOMIC MANAGEMENT SYSTEM

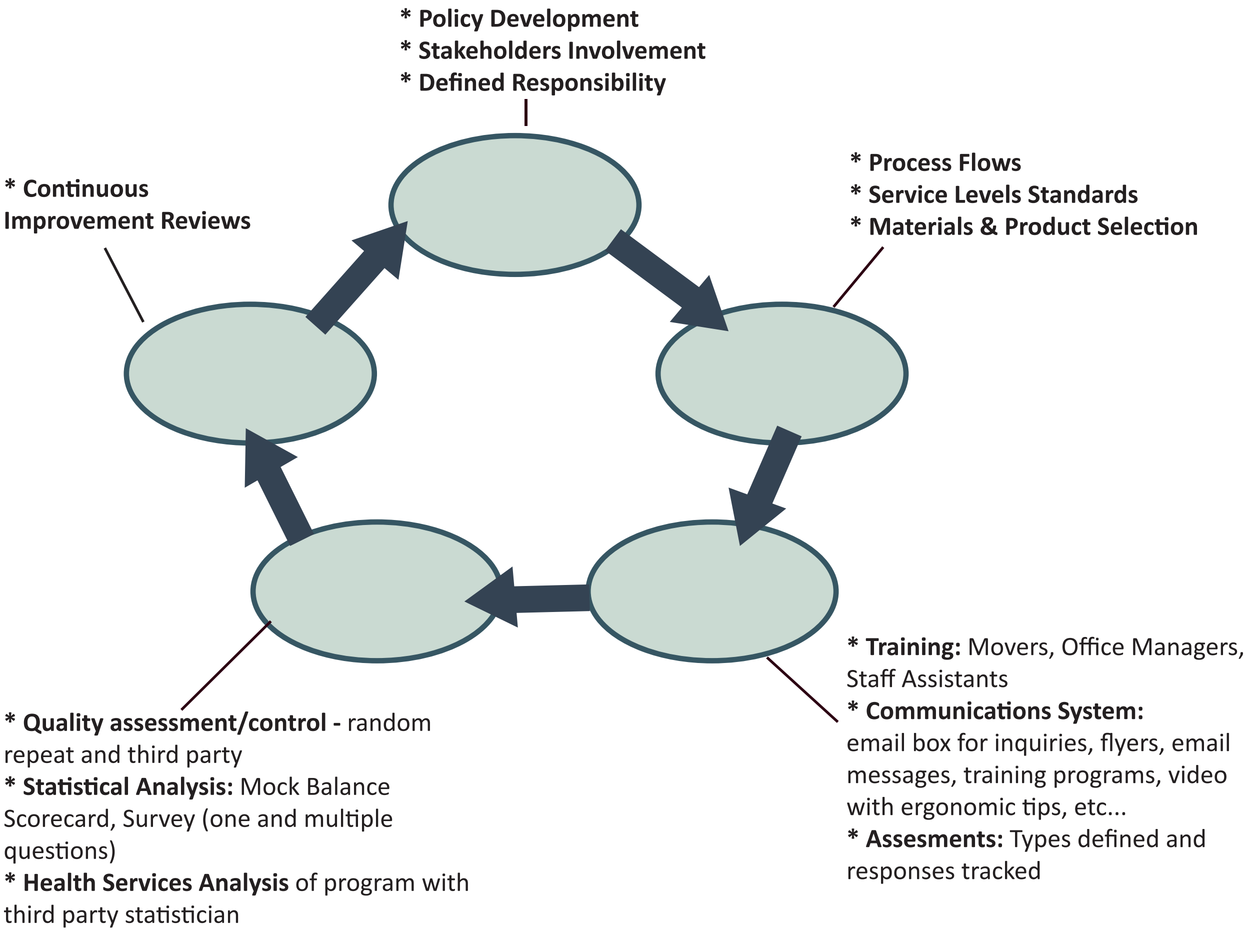


Figure 14
Ergonomic Management System

As new technologies continue to computerize the way professionals do their work, it is important for organizations to identify and measure the risks and the health and wellbeing associated with these changes. Further research with professional groups is needed to support effective risk management decisions and evidence based ergonomics intervention.

Strategies should be developed and implemented to protect workforce from the effects of ergonomic related musculoskeletal disorders. They should focus specifically on the diagnoses of musculoskeletal disorders to help track and analyze trends, and to integrate ergonomics into training not only for professionals, but into education programs from early ages on.

Table 8. Example of an ergonomic protocol

Ergonomic Self- Assessment Check List

Location:

1. Date of assessment:
__ __/ __ __/

2. Office room number
____

3. Last name/ First name:
____

4. Office telephone number:
____

5. Were there any changes made in this workstation setting after completing the surveys?
no
yes, please specify:
____
____

Assessment of the Ergonomic Features of the Current Workstation

Please check one of the offered answers: True (T), False (F) or Not applicable (NA)

	T	F	NA
Chair:			
6. Backrest provides support for your lower back (lumbar area)	☐	☐	☐
7. Backrest height Adjustable 	☐	☐	☐
8. Seat front does not press against the back of your knees and lower legs (seat pan not too long)	☐	☐	☐

	T	F	NA
9. Seat height Adjustable	☐	☐	☐

20

	T	F	NA
10. Armrests support the forearms without resulting in hunched shoulders (armrests too high) or leaning to one side (armrests too low	☐	☐	☐
11. Armrest height Adjustable	☐	☐	☐

22

	T	F	NA
12. Legs and **feet** have sufficient clearance space under the work surface so you are able to get close enough to the keyboard/mouse	☐	☐	☐
13. **Desk:** Adjustable	☐	☐	☐

Monitor:

	T	F	NA
14. Top of the screen is at or below eye level so you can read it without bending your head or neck down/back	☐	☐	☐
15. Monitor distance allows you to read the screen without leaning your head, neck or trunk forward/backward	☐	☐	☐
16. Monitor position directly in front of you so you don't have to twist your head or neck	☐	☐	☐

Keyboard and mouse:

	T	F	NA
17. Keyboard/mouse tray, if provided, is large enough to hold a keyboard and a mouse	☐	☐	☐
18. Mouse or trackball located next to your keyboard so it can be operated without reaching	☐	☐	☐

	T	F	NA
19. Mouse is easy to activate and the shape/size fits your hand (not too big/small	☐	☐	☐
20. Wrists and **hands** do not rest on sharp or hard edges	☐	☐	☐
21. Wrist/palm rest is provided	☐	☐	☐

Working Posture:

What is your typical working posture?

22. Head and **neck** are upright, or in-line with the torso (not bent down/back)	☐	☐	☐
23. Head, neck, and **trunk** face forward (are not twisted)	☐	☐	☐
24. Trunk is perpendicular to floor, supported by the back of the chair	☐	☐	☐
25. Shoulders and **upper arms** are in-line with the torso, relaxed, not elevated or stretched forward	☐	☐	☐
26. Upper arms and **elbows** are close to the body (not extended outward)	☐	☐	☐
27. Forearms, wrists, and **hands** are straight and in-line (forearm at about 90 degrees to the upper arm)	☐	☐	☐
28. Wrists and **hands** are straight (not bent up/down or sideways toward the little finger)	☐	☐	☐
29. Thighs are parallel to the floor and the lower legs are perpendicular to floor (thighs may be slightly elevated above knees)	☐	☐	☐
30. Feet rest flat on the floor, or are supported by a stable footrest	☐	☐	☐

5. Changing face of ergonomics- future challenges

5.1 The factors

There are numerous factors, which are rapidly changing and challenging our classic concepts and knowledge of office ergonomics:

- Increasingly widespread use of computers, especially by people who are outside the computing profession and are of all ages, including young children;
- Miniaturization of hardware leading to portability (Figure 15);
- Rapid development of technology introducing computational devices in new forms;
- Decreasing hardware costs leading to larger memory, faster systems and smaller devices;
- Increased development of network communication and distributed computing;
- Increasing innovation in development of input techniques (voice recognition systems, pens, gestures) improving access to computers and social networking by disabled people who were previously left out from the computer use.

The changes in computer technology are so rapid that there is no possibility for follow up on their long term health/performance impact on billions of users. Computer devices are getting smaller, they are mostly portable and no ergonomic recommendations on how to properly use them even exist. People are carrying around laptops, notebooks, iPads, iPhones, and are functioning in and out of the offices at all times. We cannot find any recent study addressing all technical, ergonomic, psychological and social aspects of current and possible future transformation of office work.

5.2 A mixed bag of new ideas and gadgets

Figure 15
Shrinking size of computer devices compared to a match-stick (far right).

In terms of keyboards, the commercial trend is that those with quicker keys, and preprogrammed functionality of single keys, are taking market shares when compared to ergonomic designs such as split keyboards, and raised keys (Woods, 2005; Rempel at al, 2007 and 2009; Juul-Kristensen et al,

2004). The computer game industry seem to lead this development (personal com. sales manager SIBA, Sweden).
Little concern about potential long term health aspects and no scientific monitoring in this regard seem to be part of that trend.

Notebook computer mouse designs of varying sizes have not been formally evaluated but may affect biomechanical risk factors and are having a potential impact on the prevention of work-related musculoskeletal disorders (Oude Hengel et al, 2008). Asundi et al (2010) quantified postures of users working on a notebook computer placed on a desk, the lap and commercially available lapdesk. All arrangements resulted in high values of wrist extension, wrist deviation and downwards head tilt.

A configuration of computers which allows hand-free computing (without interfacing with the mouse or keyboard) is initially developed for computer users with disabilities, but is being implemented more broadly today. Factors that influence performance of speech recognition users and the effect of such systems on working postures, productivity and perception of user friendliness are extensively studied (Koester 2004 and 2006). The tongue control systems developed to allow a quadriplegic person interaction with a computer or control of an assistive device, could also find their application as future computer input units (Lontis and Struijk, 2010).

Already on the market are now 3D viewing devices, with additional visual challenges, particularly for those suffering from vision problems/disorders.

Workstations allowing computer users to walk or cycle while performing computer tasks have been shown to demand sufficient energy expenditure to result in significant health benefits, focused not only to musculoskeletal disorder prevention but also decreasing health risks due to inactivity. However, observed performance decrements maybe related to both biomechanical and cognitive processes. Active workstations may be less suitable for mouse intensive work, and susceptible users (Straker et al, 2009).

6. Ergonomics as an essential part of education in the computer age

Having in mind rapid development of technology, and also the process of shifting traditional individual workspaces from offices into homes (telecommuting) or air planes and hotel rooms (business travelers), it seems to us that ergonomic management can no longer be the employer's responsibility only.

The importance and impact of teaching basic ergonomic principles throughout the educational process is still neither recognized nor addressed. It is already noted that college age students are reporting numerous musculoskeletal disorders due to their extensive and ergonomically incorrect usage of computers and other electronic devices (Jacobs et al, 2009 and 2011). Without some form of ergonomic intervention, these students are likely to enter the workforce with poor ergonomic habits, which places them on the road to future MSDS related pain problems as technology continues to play a dominant role in their lives.

By the age of five years, 75% of the children in the USA are using computers, and at this age they are only one half to two thirds the size of, and about one fifth as strong as, their adult counterparts. Compared to their adult counterparts, children have to apply twice the relative force, as a percentage of their maximum capacity, to activate the buttons and keys on the input devices. These measured differences may have application in the design of computer input devices for children (Blackstone et al, 2008). Although being trained in using computers since kindergarten, no attention is paid to teaching children about ergonomically correct postures. Ergonomics is a crucial point for good learning performance in the computerized world. There is an urgent need to focus on raising a healthy future workforce which is educated in ergonomics from an early age on.

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