The Changing Face of Office Ergonomics

Lennart Dimberg[*,1], Jasminka Goldoni Laestadius[2], Sandra Ross[2] and Ida Dimberg[3]

[1]*Department of Primary Health Care, Institute of Medicine, Gothenburg University, Sweden*

[2]*The World Bank Group, Washington, DC, USA*

[3]*Sahlgrenska University Hospital, Gothenburg, Sweden*

Abstract: Musculoskeletal pain has been an important issue over the decades among office workers. Whether caused or just aggravated from poor posture, or inappropriately adjusted workstations, the issue continues to be a challenge to staff, employers and ergonomists. In this brief 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 who 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 and awareness.

Keywords: Leadership, musculoskeletal disorders, occupational diseases/prevention and control, office ergonomics, pain/etiology, posture, psychological, risk factors, stress, work-related disorders, workspace design.

1. A BRIEF HISTORICAL REVIEW

In the 1970s, in the global office environments, computers were rare, and musculoskeletal pain was misunderstood or dismissed.

In the 1980s, punch cards were introduced followed by the massive framed data entry computers. Large groups of secretarial staff worked 8-10 hour days in fixed body positions with limited breaks, inadequate lighting, poor office arrangement, and "Taylor trained" managers[1] [1]. 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, adapting the workstations to task the workers. They used whatever knowledge they had, which consisted of 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" referring to research of higher intradiscal pressures in certain seated, rather than standing positions [2, 3].

Carpal tunnel syndrome was identified as a typical problem believed to be caused by repetitive strain [4]. Tennis elbow was another favorite occupational diagnosis attributed to typing (Fig. **1**).

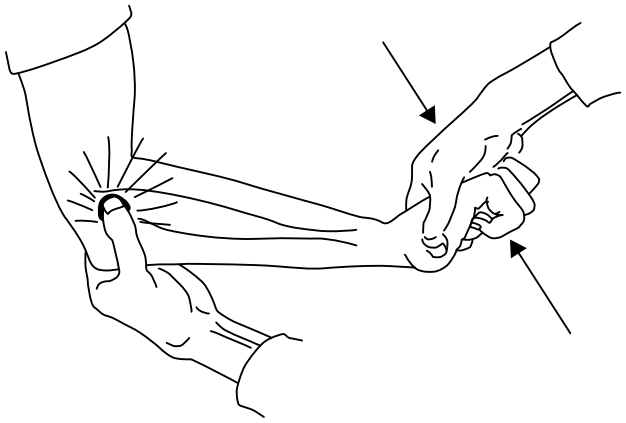

Fig. (1). Tennis elbow.

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 physical training was not sustained. It was convincingly shown in randomized controlled studies, that a quick return to work, together with appropriate training and engineering controls, was much more effective in reducing pain, and in prevention of long term illness [8]. An elucidating study on tennis elbow in workers showed in a survey these conditions were equally common in categories involving light, medium, and heavy workloads. From the physically demanding jobs, workers reported having more pain, and consulted physicians regarding their condition, contrary to those who worked in less demanding jobs. Therefore, due to the falsely based

*Address correspondence to this author at the Department of Primary Health Care, Institute of Medicine, Gothenburg University, Sweden;
Tel +46 31 7861000; Fax +46 31 7781704;
E-mail: Lennart.Dimberg@allmed.gu.se

[1]Frederic Taylor (1856-1915) introduced the principles, mechanisms, and philosophy into management to improve productivity through simplification and standardization of tasks.

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statistics of patients from visits recorded, occupational doctors were convinced that these conditions were caused by their type of work, instead of being aggravated by it [9].

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, D.C. 73% of the respondents reported having had such symptoms [10]. Daily pain was reported from the neck and shoulders (21%), hand and wrist (10%), elbow (3%), and low back pain (13%). However, only 12% of the World Bank staff reported having taken sick leave resulting from pain in the musculoskeletal system. Research from the Volvo company in Sweden identified the prevalence of pain, sick leave, long-term disability to be positively associated with age, sex (female), smoking, heavy labor, working with vibrating machines/tools, and poor leadership [5, 6] (Fig. **2**).

Recent studies suggested, high prevalence (50%) of musculoskeletal symptoms in the neck, arms, low back, and thumb pain (from intensive texting) within the younger population associated with frequent use of small computer devices (iPhones, iPads, laptops and notebooks) [11-13].

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 [8, 14]. It is important to emphasize that all chronic pain conditions must always be medically investigated. Treatable conditions such as rheumatic arthritis, peritendonitis crepitans, tendonitis 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 lung cancer that had 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 the 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 [15]. In principle, neutral body positions (neither flexion nor extension) and less effort are the goals. It is critical however, to understand that our bodies are designed for movement, and sitting in a single body position for long periods of time, however neutral, is most likely not physiologically recommended. 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 [16]. Quite clearly there are anthropometrical differences between individuals, such as height and weight (Fig. **3**).

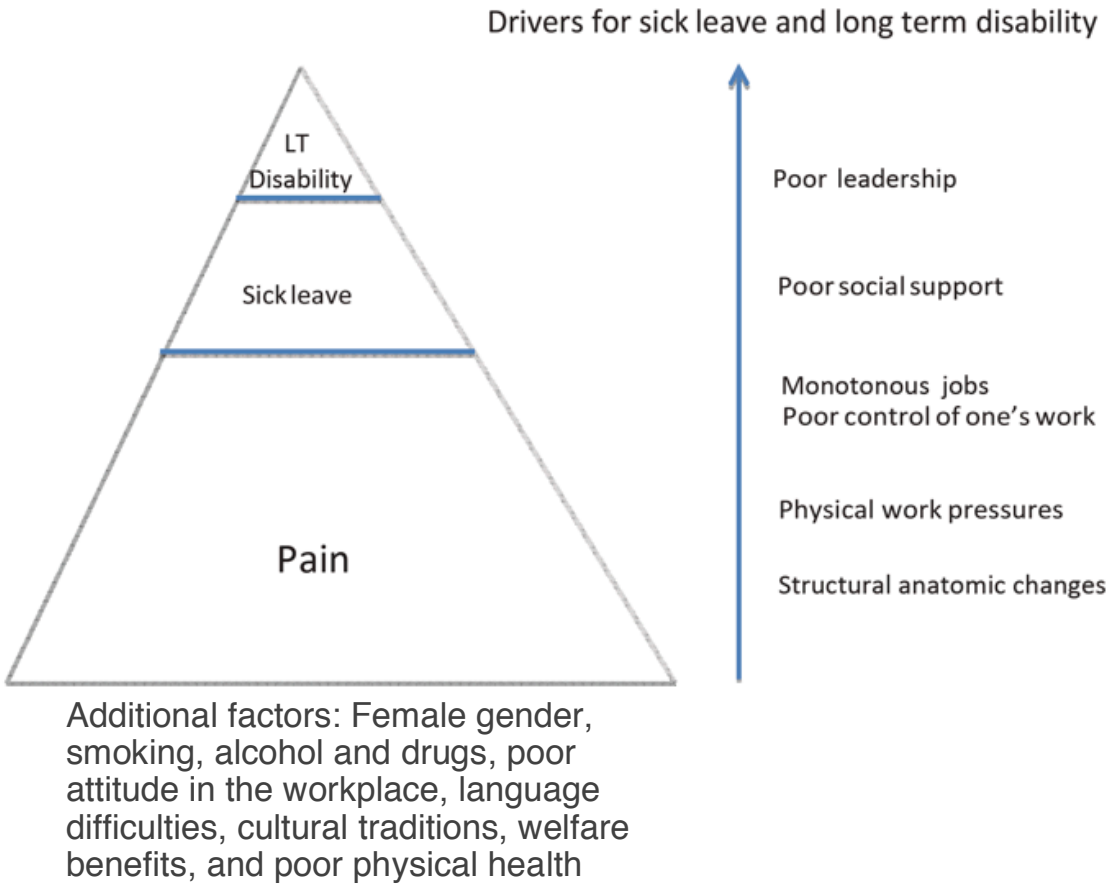

Fig. (2). Suggested relationship between pain, sick leave and long term disability and some important associated risk factors in MSD [5-7].

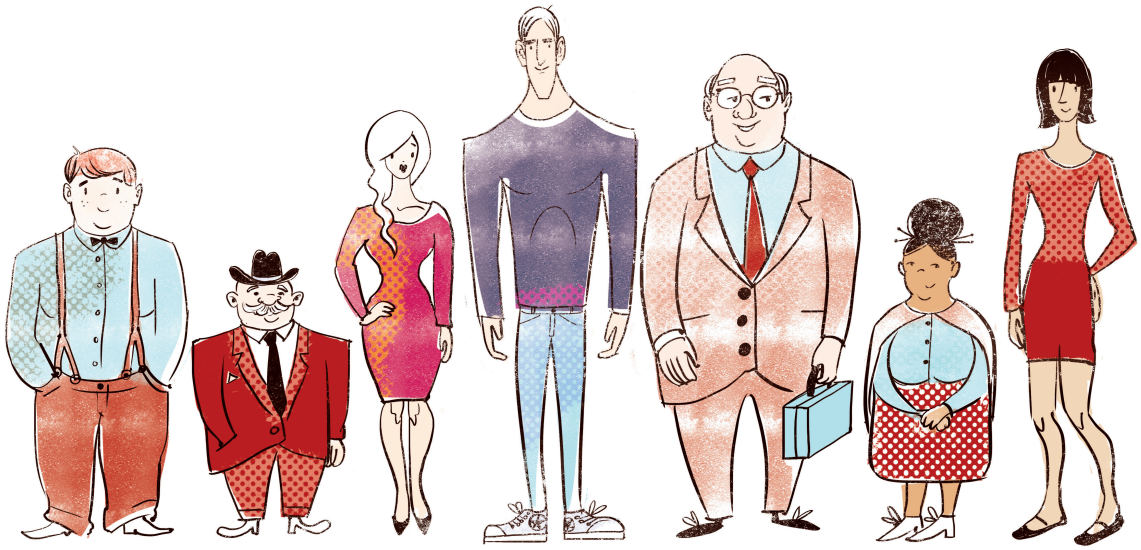

Fig. (3). Anthropometric differences.

Fig. (4). Discomfort at the workstation.

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.

A multitude of factors affect the office environment and below is an account of some of the most important elements (Figs. **4**, **5**).

2.2. Individual Risk Factors

In a systematic review of work-related musculoskeletal disorders, da Costa *et al.* (2010) found heavy physical load, smoking, high Body Mass Index (BMI), high psychosocial work demands, and the pressure of co-morbidities to be well documented [18]. 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 from age 40 and on), and more light. Most people with age develop stiffness in the eye lenses with accompanying focus problems.

2.3. Posture, Muscular Pain and Strain

Posture in the context of ergonomics according to Merriam-Webster dictionary ”is the way in which your body is positioned when you are sitting or standing” [19].

From an evolutionary perspective, man was originally a hunter/gatherer. This function puts strong emphasis on changing positions quickly, being flexible and calculating. A strong and well-trained body increases survival in a hostile environment. From an anatomical standpoint the upright, the postural muscles mainly support standing, and sitting body positions. These can be active for long time periods, need only moderate variation of body position changes that can carry your body the whole day. When the body is well balanced, fatigue takes a ling time to develop. However, if

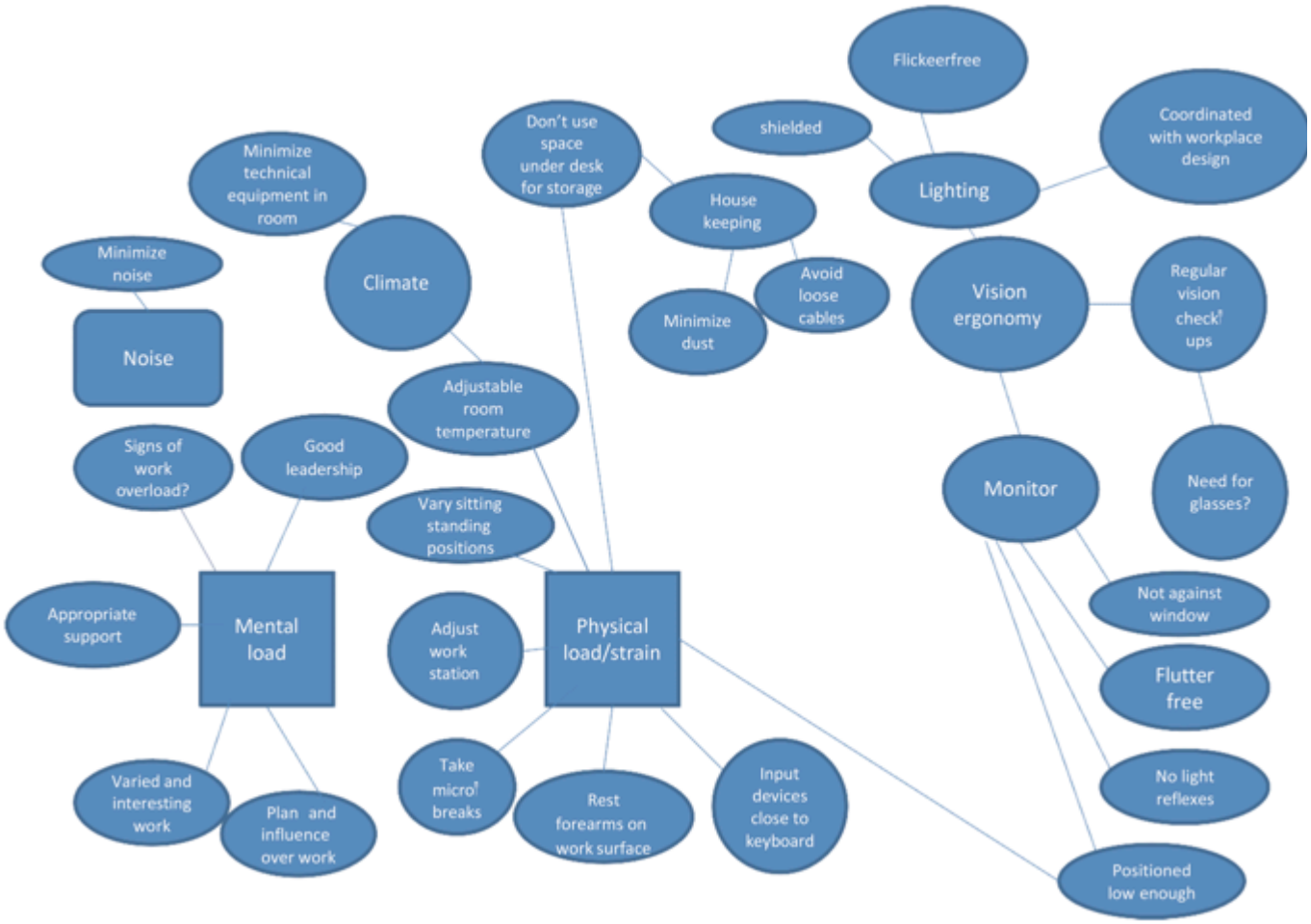

Fig. (5). Guide to a good work environment according to the Swedish Work Environment Authority [17].

you withdraw from the balanced position by lifting your arms up, stooping, or leaning to the side, you activate your phasic muscles, which are the shoulder girdle and the phasic neck muscles. These are muscles that fatigue easily, and accumulate lactic acid causing muscular pain and stiffness. Try to hold out your arms to the side for as long as you can. Few can manage for 5 minutes before your shoulders begin to feel stiff. This is what any static body position away from the balanced posture will do.

Dynamic and varied body positions will allow your muscles to adapt and give them the appropriate oxygenated blood-flow.

A head tilted forward or backward away from the resting position will create muscular tension and pain.

This is particularly evident these days when school students extensively use their small cellular phones *when* texting and watching movies in extremely awkward positions [20]. Another common effect *associated with frequent use from these devices*, is thumb pain [21].

According to the results of Gustafsson (2012) to avoid thumb pain, it is recommended to use both thumbs, avoid sitting in a forward position and text slowly when using phones, and only for a few minutes at the time [12].

2.4. Biomechanical Risk Factors

Biomechanical risk factors for work related musculoskeletal disorders add to the strain of muscles, tendons and other soft tissues. These factors have been analyzed by Professor Thomas Armstrong and colleagues from the Center for Ergonomics, University of Michigan and are listed in Table **1** [22].

2.5. Pathophysiology-Connecting the Dots Between Pain, Strain and Disease

Mats Hagberg sums up injury mechanisms in an exemplary review (Hagberg, 1984). The following paragraphs draw strongly from that article [23].

Osteoarthritis is a degenerative joint disease. This joint disease can be caused by increased stress and repetitious impacts. Some authors quoted claim that a traumatic injury to the subchondral bone may create micro fractures that precede this condition. Other researchers suggest a metabolic cartilage abnormality, since many joints often are affected even if they are not subjected to repetitious injuries. Localized ischemia in muscles and tendons may also cause pain, swelling and tissue damage. Certain tendons in the shoulders like those of the biceps brachia and the

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

suprapinous muscles are particularly prone to microscopic ruptures and degeneration from age. Elevating the arm when the humeral head pushes on the tendons can impair the venous blood flow. Inflammation of the tendons in rabbits has been shown upon highly repetitive activities. Ageing degeneration of the tendons in the shoulder may also create a "foreign body" inflammation. Swelling of the tendon sheath and its lining may be caused from the biceps-tendon grinding against the small tubercle of the humerus during movements over shoulder height.

A previous healed joint infection may predispose a person to a more serious reaction upon repetitive shoulder stress. Muscle tenderness such as trapezius myalgia (Fig. **6**), and generalized muscle pain are not caused by the contractile muscle fibers since they do not contain any pain receptors. Instead, pain may emerge from pain sensors in blood-vessels or connective tissue.

Hagberg mentions three alternative ways of muscle pain.

One is a tear of z-discs caused by high tension. Another is poor blood circulation due to continuous muscle contraction. This would occur already at 10-20% of maximal muscle power. It would lead to a drop of pH, which would inhibit certain enzymes, where swelling and the formation of fibrous tissue would follow.

The (in keeping with Hagberg's three ways) third way to cause muscle pain is disruption of the energy metabolism. Muscle metabolic defects are often associated with muscle pain. It is possible that certain persons have inherited metabolic pathways that make them more sensitive to injury and pain.

The carpal tunnel syndrome is a well known condition caused by frequent movements of fingers and wrist. These movements cause friction and swelling to the tendon sheaths which run in the narrow carpal tunnel of the wrist together with the median nerve that upon pressure causes pain.

Another well described mechanism of shoulder pain is the supraspinous tendonitis, where the tendon rubs against the acromion in the shoulder, a space that may be narrowed by inflammatory swelling [24]. Fibrosistis, fibromyalgia and muscular pain are frequently reported diagnoses, but the pathogenetic link is unclear. Henriksson (1988) suggested that static muscle contraction will reduce blood circulation and eventually cause structural changes in the muscle fibers [25]. This mechanism remains to be proven. Hansson (1988) suggested microscopic fractures to be the cause of low back pain, but its prevalence has not been ascertained [26]. Also, the role of the lumbar disc in low back pain was studied by Nachemson and Elfstrom (1970) by measuring intradiscal pressure in various positions [27, 28]. These findings were for many years the evidence basis for the ergonomic advice in low back pain patients. As a cause of back pain Nachemson later abandoned his theory [29].

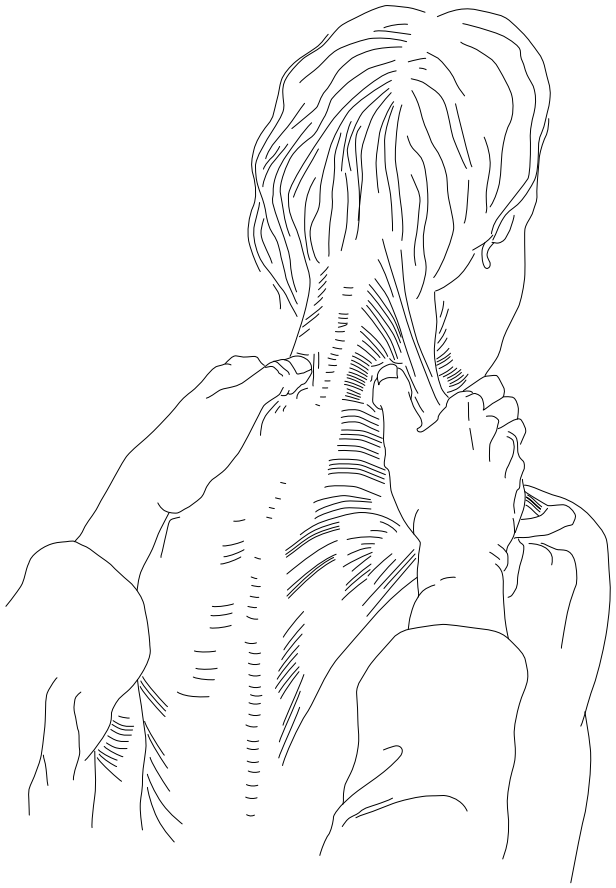

Fig. (6). Trapeziusmyalgia.

Also, adding extra weight and measuring the height of the spine measured spinal shrinkage. The shrinking is caused by the elasticity of the discs between the vertebrae [30]. Its role as a causative reason of low back pain is however unclear.

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 pinched eliciting neck pain radiating in the arm [31]. This is the scientific basis for 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), or work related musculoskeletal disorders when associated with work. 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 types of problems, allow for specific diagnosis or combinations of diagnoses to be made in most cases [5].

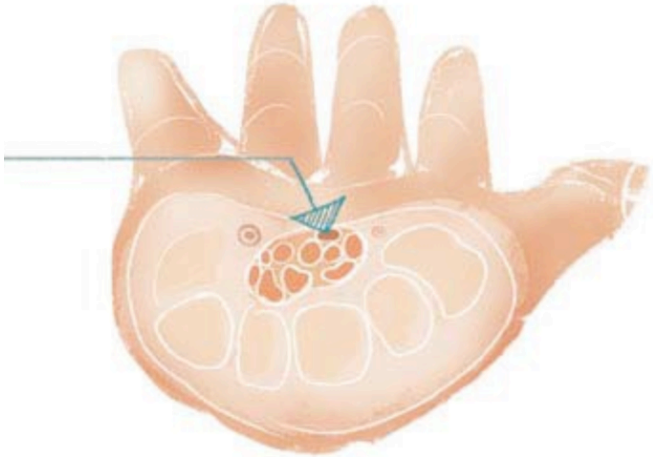

Fig. (7). The arrow points to the median nerve surrounded by the flexor tendons.

2.6. Psychological and Social Factors

Psychological and social interaction are probably the most important factors regarding the health of office workers [6].

The role of the supervisor regarding his or her leadership is crucial. At a major car company plant, annual staff surveys showed serious discontent. Because this particular plant was very profitable due to a Tayloristic and bullying management, the company decided to discontinue their surveys. Shortly thereafter, the whole plant went on strike until management had been replaced. A very costly lesson. In the MacFarlane *et al.* (2008) report on work related psychosocial factors and regional musculoskeletal pain, he points at the necessity to review existing evidence in prospective studies and observe the temporal relationship between psychosocial factors and musculoskeletal pain at the worksite [32].

2.7. Indoor Air Quality (IAQ)

Indoor air quality is another important factor to insure comfort in the work place. 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) in Table **2** [33].

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).

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

Parameter*	IDPH	ASHRAE	OSHA PEL	ACGIH TLV
Humidity	20% ₸ 60%	30% ₸ 60%	N/A	N/A
Temperature	68° ₸ 75° F (winter)	68° ₸ 75° F (winter)	N/A	N/A
	73° ₸ 79° F (summer)	73° ₸ 79° F (summer)		
Carbon Dioxide	1,000 ppm	1,000 ppm	5,000 ppm	5,000 ppm
	(<800 ppm preferred)			
Carbon Monoxide	9 ppm	9 ppm	50 ppm	25 ppm
Hydrogen Sulfide	0.01 ppm	N/A	20 ppm	10 ppm
Ozone	0.08 ppm	N/A	0.1 ppm	0.05 ppm
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	15 mg/m^3 (total)	10 mg/m^3 (total)
			5 mg/m^3 (resp.)	3 mg/m^3 (resp.)
Formaldehyde	0.1 ppm (office)	N/A	0.75 ppm	0.3 ppm
	0.03 ppm (home)			
Nitrogen Dioxide	0.05 ppm	N/A	5 ppm	3 ppm
Radon	4.0 pCi/L	N/A	100 pCi/L	4 WLM/yr (working level months/year)

*IDPH means standards according to the Illinois Department of Public Health; OSHA PEL means Permissible Exposure Limit in the United States and ACGIH TLV means Threshold Limit Values according to American Conference of Govermental Industrial Hygienists.

Air conditioning is another factor that may affect the employees' well-being. Lower humidity can increase those sensitive to respiratory tract infections, and humidity levels below 20% can increases the annoying effect of an electric spark when touching metal surfaces [34]. Also, cold air coming down from an overhead vent can lead to annoying pain and muscle tensions.

Various odors may also cause distress in workers. We have encountered strong smelling conditions that were caused by 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.

2.8. Vision Ergonomics

Working at the monitor can be stressful on the eyes, and lead to discomfort such as light sensitivity, dry and itchy eyes. Helpful suggestions to consider to correct these discomforts are need for reading glasses, increase font size, and adjust the monitor screen for brightness, glare, contrast, and any annoying flickers.

To avoid eyestrain, adjust the height and distance of the monitor.

The monitor should not be placed against a light background such as a window, and should be free from any light reflections or flickering. It should be placed 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. For those who use bifocals, it is important to look at the monitor through the bottom part of the eye lens. Annoying neck strain can arise when positioning the head back. When viewing the monitor through the lower portion of eye glasses, position the monitor accordingly so the head remains up right.

It is important to see an ophthalmologist regularly, especially if having persisting eye problems. Painful and red eyes can be a sign of a serious problem such as glaucoma (elevated eye pressure) or allergies. Dry eyes occur when there is insufficient fluid in the eyes. This may commonly be caused by illnesses such as allergies, and rosacea [35]. Contact lenses can also be a problem and cause red eyes. This condition may be aggravated by a dusty environment and air-flow from a misplaced fan.

The question 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**. For additional suggestions please see OSHA computer work-stations [36].

2.9. 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 cause muscular discomfort [37].

Historically, a totally open landscape from 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 made more appealing with* decorations, plants and harmonic colors.

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.
*	Add a document stand.
Lighting	
*	Adjust the overhead lighting.
*	Suggest the need for task lighting (desk lamp).
*	Use of filter screens (suggest to remove).

Studies show that noise generated from conversations, even whispering, is more disruptive than sounds generated from ventilation fans, computers, printers, and traffic. Perhaps these distractions are drawn out of our instinct for survival [38]. 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 [39]. Dealing with confidential information and the need for privacy may limit usability of the office landscape for certain professionals.

There are several variants of open office landscapes such as flex offices. The open office landscape's design is especially important for the perception of comfort and discomfort (Fig. **8**). It is strongly recommended to mix open group locations with adjoining sound proof rooms to accommodate staff needs.

Here are some important common rules for communication:

- Move away to a private room when engaging in long conversations.
- Turn down your cell phone ring volume or put on vibrate mode.
- Avoid shouting across a room.
- When necessary, take visitors for short walks away from the common area of the Landscape, and if possible, go directly to a meeting room without stopping to chat.

It is also important to design "open meeting areas" in the landscape, ideally a significant distance away from other staff locations.

Fig. (8). Office landscape.

It is common these days to make glass cubicles in the landscape where meetings can be held to maintain the visual contact with other staff.

A number of absorbing structures such as textile fabrics, and ceiling insulations can be used to minimize disturbing noises.

Table **4** summarizes some important aspects recognized in current research [40].

2.10. The Workstation

2.10.1. The Monitor

The old type of monitors used a cathode ray for projection. They were big, bulky and heavy with low luminance with a tendency to flicker. Today, most of these monitors have now been replaced with liquid crystal, plasma or light emitting diodes. These are thinner, lighter and more luminescent with better resolution.

Some screens use interactive software, so you can elicit commands by pointing directly on the screen and the font size can easily be changed to provide better acuity.

This technique increases the need to regularly wipe the monitor to avoid dirt and fingerprints.

When working on iPads and smartphones, the same principals of basic ergonomics apply: maintain a good posture by trying to read the text in front of you with a straight neck, and take frequent breaks.

2.10.2. The Computer

The laptop, notebook, iPad and smartphone are all easier to move around than traditional desktop computers. Complying with the ergonomic principles may however be a challenge. Keyboards and monitors of laptops are unavailable to adjust individually, so in order to maintain a neutral sitting position, a typical solution would be to place the laptop on a stand at eye level and connect a separate keyboard. Another solution may be to use a docking station with a separate monitor, and to use your laptop as a central processing unit (CPU). Since the keyboard and monitor of laptops are connected, they are not possible to adjust individually.

When using smartphones for playing games for long time periods, a horizontal position (laying in bed) may probably be recommended from an ergonomics standpoint.

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

Table 5. Requirements for an ergonomic chair.

The Chair Should
• Be easily adjustable.
• Have a sturdy five-legged base with good chair casters.
• The chair should swivel 360 degrees so it is easier to access items around your workstation without twisting.
• Have a minimum range for seat height of about 16 inches.
• Have a seat pan length should be 15 inches to 17 inches.
• Have a minimum width of about 18 inches.
• Have padded and contoured edges for support.
• Have a seat pan tilt with a minimum adjustable range of about 5 degrees forward and backward.
• Have an edge of the seat pan rounded.
• Have material for the seat pan and back firm, breathable, and resilient.
• Have a backrest at least 15 inches high and 12 inches wide and should provide lumbar support that matches the curve of your lower back.
• Have a backrest that allows you to recline at least 15 degrees and should lock into place for firm support.
• Have the backrest extend high enough to support your upper trunk and neck/shoulder area.
• Have adjustable armrests. They should be at least 16 inches apart.
• Have armrest height adjustable between 7 inches and 10.5 inches from the seat pan.
• Have armrests padded and large enough (in length and width) to support your forearm without interfering with the work surface.

2.10.3. 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, still problematic to use for creating tables, designing and drawing.

2.10.4. The Keyboard

Alternative keyboard designs include split keyboards and raised keyboards. The split keyboard is better designed for the wide shoulder population but may cause problems in a person with a smaller frame. The raised keyboard is designed to avoid pronation of the hands. These keyboards may provide relief for individuals suffering from various ligament and osteoarthritis problems of the hands, but have not been widely accepted for regular use.

2.10.5. The Chair

The chair is a very important component of the workstation. Ideally you would like to have a chair that allows for individual positioning.

While there are many good office chairs, these are the chairs that were evaluated in the procurement process at the World Bank. The guidelines in Table **5** were adapted from the Unites States Occupational Safety and Health Administration (OSHA) [41]. The authors have no financial involvement with the manufacturers.

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

Based on the findings from the 2009 study in the World Bank, electronic information, and pamphlets were found to be counterproductive regarding the adjustments of chairs [10]. 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.

2.10.6. The Desk

When several staff of various heights use the same desk, they found it easy to use adjustable desks through a lever or electrical engine to avoid inappropriate sitting positions (Table **6**, Figs. **10-12**).

2.10.7. The Mouse

Being an important input device, the mouse has been extensively studied and improved to fit various hand-sizes and disabilities. It will almost always be possible to find an appropriate mouse to accommodate the user.

2.10.8. Additional Resources

There are a number of web-based ergonomic programs available on the internet. Some are pay per service, and others are free. Most give adequate advice on office ergonomics with helpful hints, but our research has shown pushing ergonomic information *via* emails, pamphlets and other types of venues has limited value. Numerous 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 (Tables **7** and **8**, Fig. **13**). Below are links to some useful websites.

3. DISABILITY ACCOMMODATIONS

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 from 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).

Fig. (9). Four good chairs: top left: Aeron (Herman Miller), top right: #19 (All Steel), down left: Leap (Steelcase) and down right: Mirra (Herman Miller)[2].

A hearing disabled person may use the hearing assistive technology systems including FM Systems, infrared Systems, Induction Loop Systems and One-to-One Communicators and, individual hearing aids. Dragon point and speak, can directly convert speech to text.

Updated available resources can be found at the American Speech Language Hearing (http://www.asha.org/)

A mobile impaired person may be assisted with scooters, and software that provide the capacity to use a stick for programming keys and voice commands.

[2]*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.*

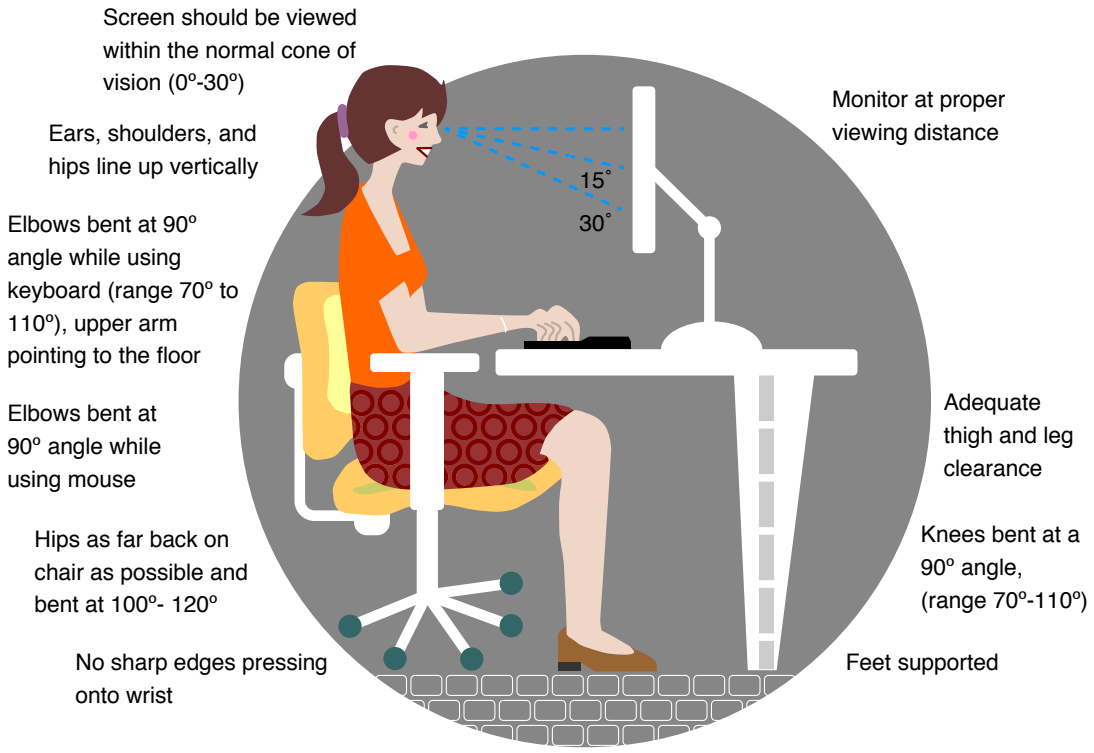

Fig. (10). A proper workstation set up.

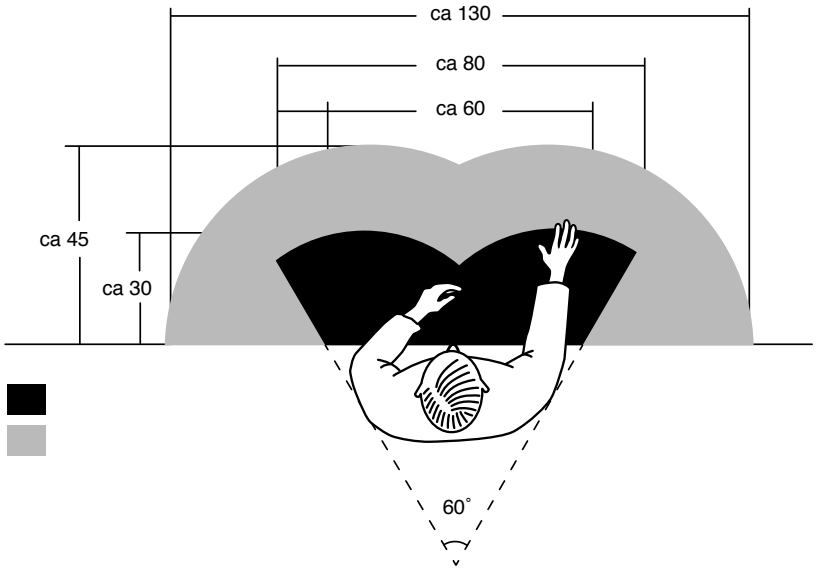

Fig. (11). Desk working area. Black area is the primary working area and gray is the secondary area. Adapted from the Ergonomics Standard by the Swedish Board of Work Environment AFS 1998:1 [42]. Distances in cm.

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.

The department of defense (USA) has established a computer accommodations program (CAP) to provide reasonable accommodations for disabled staff. Their website (http://www.cap.mil) provides much useful on assistive technology.

Some major corporations have equipped special Assistive Technology Centers, where various equipment, chairs, desks and software are on display for hands on testing prior to being procured.

4. ERGONOMICS AND PRODUCTIVITY

Few controlled studies exist on ergonomics and productivity. Anecdotal evidence using before and after

Table 6. Checklist for desk (Adapted from OSHA e-tools).

Feature	Specifications	Description/Notes
Height Adjustable desk	20 -28 inches 50 - 71 cm	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 variety 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 15 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.

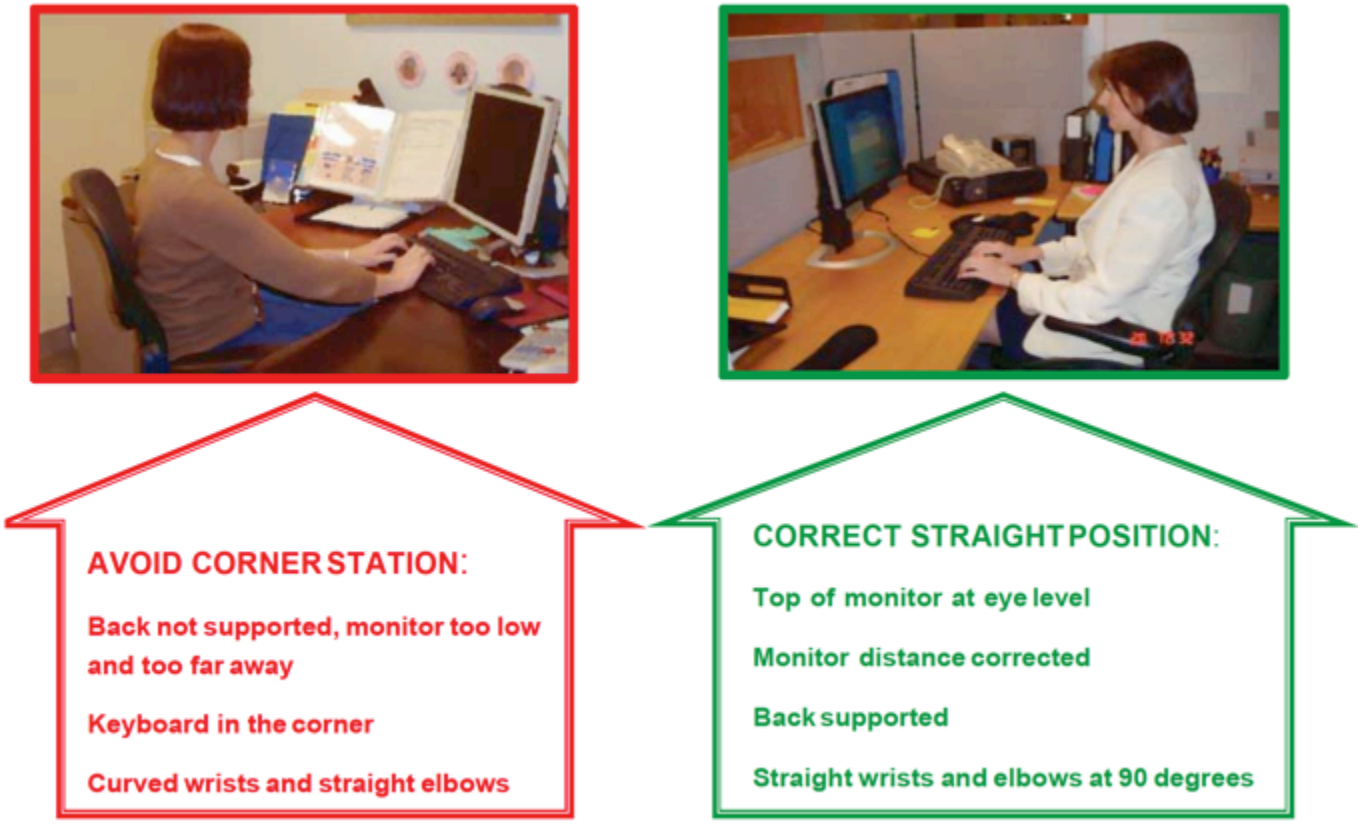

Fig. (12). Bad and good ergonomic solutions.

scenarios, have been published [43]. The implementation of innovative office concepts and ergonomic programs on health and productivity among office workers was evaluated in several studies [44-46]. Limited effects were noticed on work related fatigue, health changes, and productivity in the long term.

In a systematic review by Lyeshon *et al.* (2010), the evidence for specific ergonomic interventions ranged from insufficient to moderate when focused on the improved comfort of workers [47]. Bernard *et al.* (2008) looked at the effects of a group based work-style intervention [48]. They found that changing the work style through six behavioral training sessions after 6 and 12 months improved body posture and increased the frequency of taking breaks. The intervention, however, did not change the stress outcomes.

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

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.

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

Fig. (13). Estimation of correct monitor distance 20”-28” (51-71 cm) from eyes to monitor - about arm length.

There is evidence that workstation adjustments are beneficial when combined with ergonomics training [49]. Also a Finish study by Shiri *et al*. (2011) showed that sick leave for musculoskeletal disorders was reduced after early ergonomic intervention [13].

In connection with a move to a new building involving 1500 office staff in Washington, D.C., Laestadius *et al.* (2009) evaluated the association between work station features, working postures, and musculoskeletal pain symptoms [10]. 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.

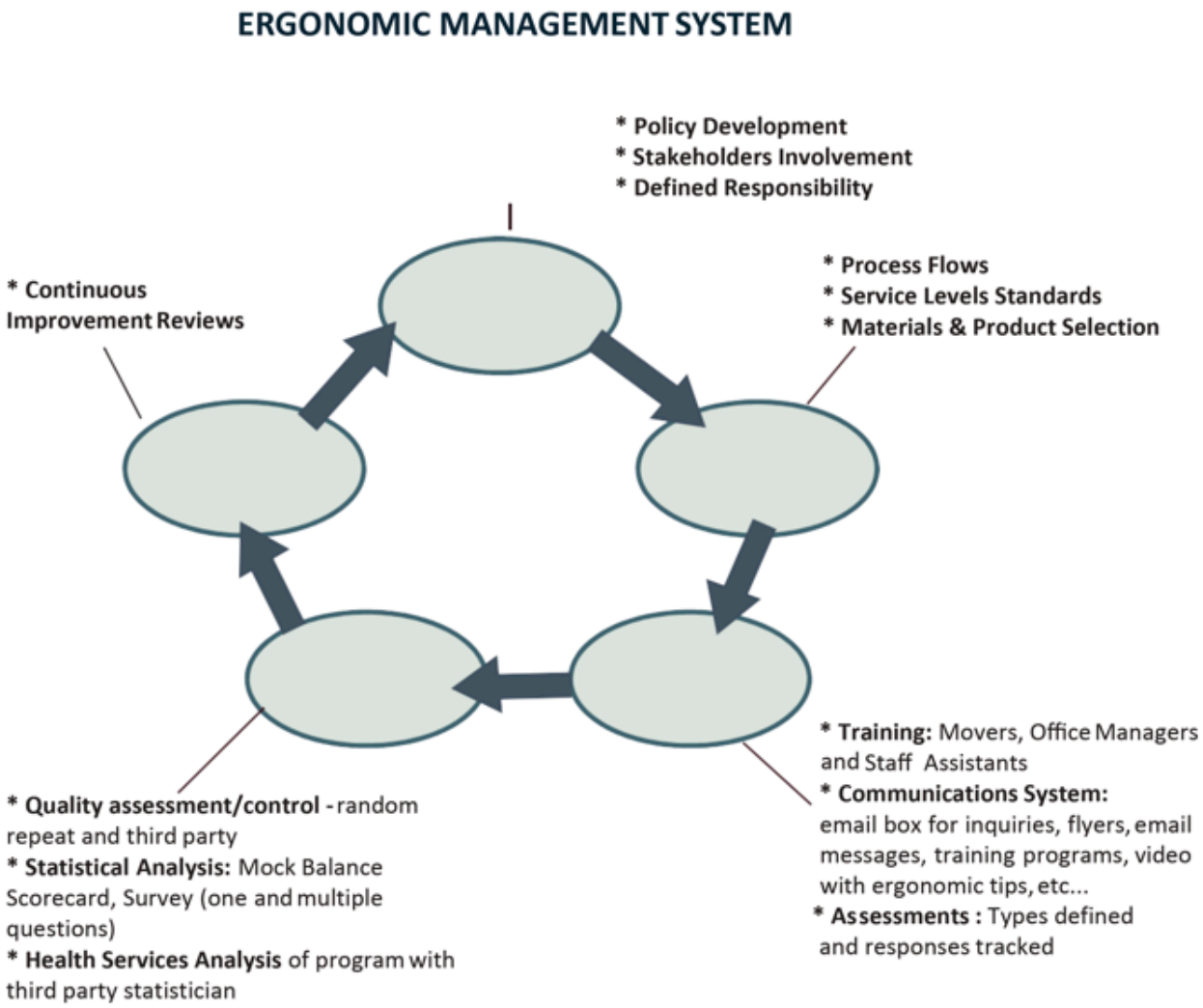

Fig. (14). Ergonomic Management System.

Significant associations were found regarding the improvement of posture, eye strain, a decrease in muscle pain, as well as improved productivity.

More importantly, the study suggests that a proactive prevention program in line with the OSHA protocol should include individual work station assessments by an ergonomist to be effective.

Fig. (**14**) shows the elements of an ergonomic management system which was proven successful in a large corporate environment:

As new technologies continue to computerize how all workers do their job, it is important for organizations to monitor and measure the risks affecting health and wellbeing that come with these changes. Further research into how new technology affects us all is needed to support effective risk management decisions and evidence based ergonomics intervention.

Strategies should be developed and implemented to protect the workforce from work 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, and educational programs for all ages, and professions.

5. CHANGING FACE OF ERGONOMICS, A FUTURE CHALLENGE

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, by people from all ages and professions
- Miniaturization of hardware leading to portability (Fig. **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;

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)

Chair:

6. Backrest

T F NA

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)

9. Seat height

Adjustable

(Table 8) contd…..

10. Armrests **T** **F** **NA**

support the forearms without resulting in hunched shoulders (armrests too high) or leaning to one side (armrests too low

11. Armrest height

Adjustable

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:

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:

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

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 inline (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

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

- Because of the rapid changes in the field of computer technology, it is becoming difficult to follow-up on the long-term health/performance that impact billions of computer users. Computer devices are becoming smaller, and portable (iphones, ipads, laptops and notebooks) without ergonomic recommendations and guidelines. There are few studies at present addressing these rapid technical, ergonomic, social, and psychological changes in an office work environment.

5.2. A Mixed Bag of New Ideas and Gadgets

In reference to the keyboards, the commercial trend, and their preprogrammed functionality, are capturing market shares when compared to the ergonomic designs of the split and raised keyboards [50-53].

The computer game industry appears to be leading this development (personal com. sales manager SIBA, Sweden).

Little concern regarding the potential long-term health aspects and the absence of scientific monitoring imply this 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 [54].

Asundi *et al.* (2010) quantified postures when computer users were working on a note-book computer that is placed on a desk, the laps, and commercially available lap desk.

Although the lap desk improved postures, these cases resulted in high numbers of wrist extension, wrist deviation and downwards head tilt [55].

A configuration of computers which allow 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 [56, 57]. The tongue control system was developed to accommodate a quadriplegic the capability to have interaction with his or her computer. Additional assistive devices, could also find their applications useful as future computer input units [58].

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

To walk or cycle at the work-station, while working on the computer has been shown to have significant fitness advantages in addition to muscle pain prevention, as compared to the usual inactivity of desk work.

However, these active workstations may be less suitable for susceptible users and mouse intensive work, resulting in significantly more errors [59]. Liability for employers in case of injuries is also an issue.

6. ERGONOMICS AS AN ESSENTIAL PART OF EDUCATION IN THE COMPUTER AGE

Keep in mind, due to the rapid development of technology, and the shifting traditional individual workspaces from offices into homes (telecommuting), air planes, and hotel rooms (business travelers), ergonomic management can no longer be the employer's only responsibility.

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 [60, 61]. 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 MSD 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 a valuable utilization towards a new design of computer devices for children [62]. At present there is not enough consideration paid to instruct children regarding the correct ergonomic posture techniques. Ergonomics plays a crucial part in our everyday work lives, and there is an urgent need to focus on raising a healthy future workforce, which is to become educated in ergonomics from an early age.

ABOUT THE AUTHORS

Lennart Dimberg, MD, PhD has been an occupational physician for the Volvo Company between 1978- 1998 and the lead occupational physician for the World Bank between 1998-2009. He has worked together with orthopedic surgeons to diagnose, treat and prevent ergonomically related musculoskeletal problems in industrial and office workers. He is currently associate professor at the Department of Public Health and Community Medicine, Gothenburg University, Sweden

Jasminka Goldoni Laestadius, MD, PhD is an occupational medicine physician with the Joint Bank Group/Fund Health Services Department, The World Bank Group, Washington, DC, USA. She has been the task leader of ergonomic research projects for the World Bank. She has also consulted the UN World Food Program and the International Monetary Fund on occupational health policy and productivity management.

Sandra Ross BSc was at the initiation of this report an ergonomist for the World Bank Health Services Department, Washington DC, USA.

Ida Dimberg MScArch is an architect with special interest in participatory design and works as a Planning leader of hospital development at Sahlgrenska University Hospital, Gothenburg, Sweden.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

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