

**COMPUTER ERGONOMICS:
WORKSTATION LAYOUT AND LIGHTING**

Ministry of Labour Area Offices

Central Regional Office – Peel North

1290 Central Parkway West, 4th Flr
Mississauga ON L5C 4R3
(905) 273-7800
Toll-free: 1-800-268-2966

Central Regional Office – Toronto North

1201 Wilson Ave., 2nd Flr Bldg E
Downsview ON M3M 1J8
(416) 235-5330

Western Regional Office - Hamilton

1 Jarvis Street, Main Floor
Hamilton ON L8R 3J2
(905) 577-6221
Toll-free: 1-800-263-6906

Western Regional Office - London

217 York Street, 5th Floor
London ON N6A 5R2
(519) 439-2210
Toll-free: 1-800-265-1676

Northern Area Office

159 Cedar Street, 3rd Floor
Sudbury ON P3E 6A5
(705) 564-7400
Toll-free: 1-800-461-6325

For more copies of this document please contact your nearest Ministry of Labour office or:

Publications
Ministry of Labour
655 Bay Street, 14th Floor
Toronto ON M7A 1T7

Phone: (416) 326-7731
Toll-free: 1-800-268-8013
Fax: (416) 326-7745
E-Mail: mol.publications@mol.gov.on.ca

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INTRODUCTION

This document discusses worker health and safety issues relating to work performed using a computer at a workstation. The document contains useful information for workplace parties and may be referred to by inspectors with the Ministry of Labour in performing their duties in enforcing the Occupational Health and Safety Act.

GENERAL

Extended work with computers can lead to muscular fatigue and discomfort, usually in the back, arms, shoulders and neck. As well, if the computer is used for prolonged periods in awkward postures, there is a risk of musculoskeletal injury (MSI). This risk increases as the intensity of computer work increases. Frequently, the source of muscular fatigue and discomfort is the operator's posture while working at the terminal, and this posture is due in turn to the layout of the computer workstation and the furniture provided. The specific tasks and the intensity of the work are also factors.

Computer operators may experience visual as well as muscular fatigue and discomfort. Symptoms include eyestrain, burning eyes, blurred vision and headaches. The layout of the computer workstation can increase the visual demands on operators, as can lighting levels and glare.

This guideline discusses the factors affecting both the physical and the visual demands on people who work with computers. It addresses the layout of workstations, covering the relevant parts of the computer (keyboard, monitor, mouse, etc.) and related furniture and aids (chairs, desks, document holders, etc.). It also addresses lighting in the work environment and task design for computer work. There is also a section regarding portable computers, or laptop computers. The checklist provided at the end will allow the reader to make a point-by-point review of each computer workstation in a workplace.

The Canadian Standards Association (CSA) Guideline on Office Ergonomics (CSA-Z412-00) was referenced in the preparation of this document. Readers requiring more detail should consult the CSA guideline.

1) WORKSTATION LAYOUT

This section describes postures that seek to minimize postural demands. However, it should be noted that any one posture becomes fatiguing after a while, and that changes in posture are important. Thus the posture described and illustrated in Figure 1, is a guideline as to general suitability of posture, and is not the only recommended posture.

As noted in the CSA guideline movement is important to minimize postural fatigue and discomfort. Movement may include slightly adjusting the positioning of the head, shoulders, arms, back, hips, and legs. For example, hip angle changes as a person reclines in their chair. Leg and hip angles change as a person stretches their legs out in front. Shoulder and arm angles can be changed by moving the chair forward or back slightly.

KEYBOARD POSITION

When working at a keyboard, the operator should be sitting with the upper arms hanging naturally from the shoulders. The elbows should be bent at roughly a 90-degree angle when the fingers are in typing position on the home row of the keyboard. This posture allows the arms and wrists to be held in a natural and relaxed position that puts the least amount of physical stress on muscles and joints.

If work surfaces are too high, users must raise their arms and shoulders. This requires continuous muscular effort, called "static effort" or "static loading". This static effort in the arms and shoulders may be fatiguing, and it may also hinder blood flow, adding to discomfort and even to the risk of injury. In addition, the wrist may be flexed (bent forward) to reach the keys, placing stress on forearm muscles and wrist tissues.

If the work surfaces are too low, the worker must lean forward, placing stresses on the arms and back. As well, the wrists will tend to be bent back, also stressing the muscles and tissues.

A desk height that is too high or too low for writing can result in the same kinds of problems.

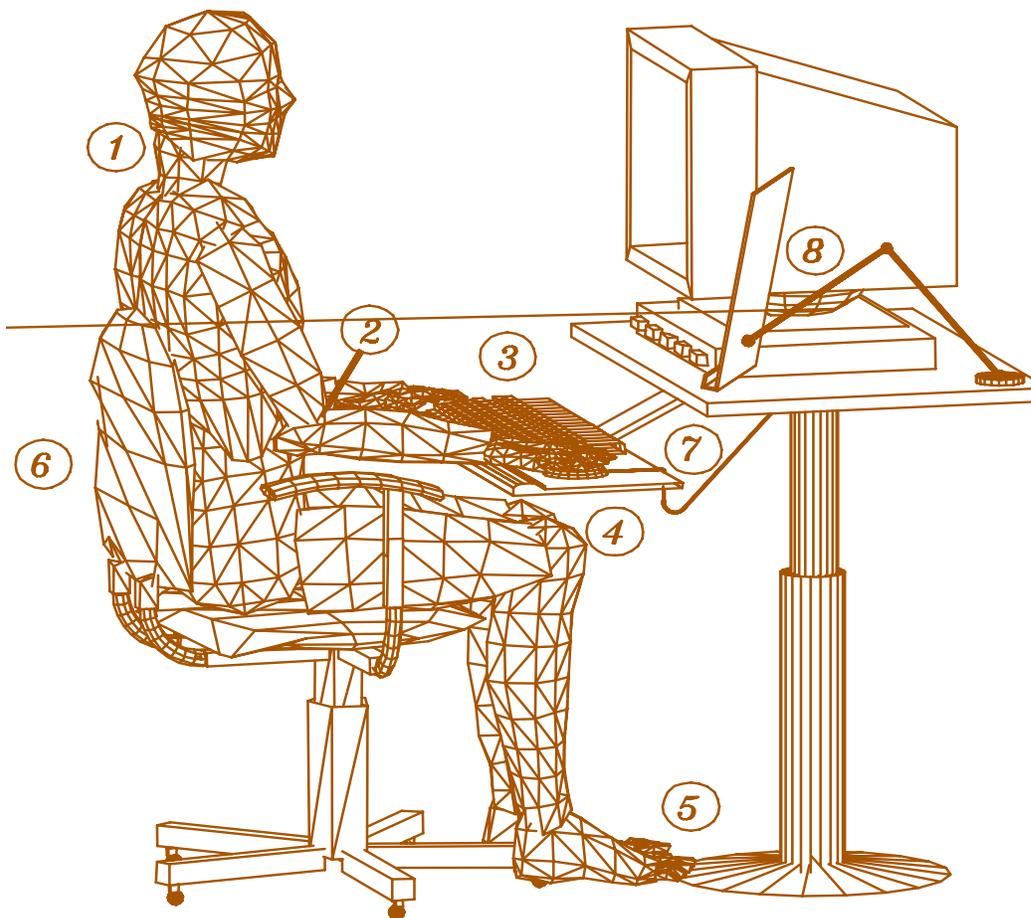


Figure 1: Adjusting Your Computer Workstation

Note: This diagram is just an example. Workstation set ups will vary according to the particular desk style, monitor, tray mount or other accessories used.

- 1) The monitor should be set at a height so that your neck will be straight.
- 2) Your elbow joints should be at about 90 degrees, with the arms hanging naturally at the sides.
- 3) Keep your hands in line with the forearms, so the wrists are straight, not bending up, down or to either side.
- 4) Thighs should be roughly parallel to the floor, with your feet flat on the floor or footrest.
- 5) If necessary, use a footrest to support your feet.
- 6) Your chair should be fully adjustable (i.e. for seat height, backrest height and seat pan tilt, and, preferably, armrests). It should have a well-formed lumbar (lower back) support to help maintain the lumbar curve.
- 7) There should be enough space to use the mouse. Use a wrist rest or armrest so that your wrist is straight and your arm muscles are not overworked (see Figure 2).
- 8) Use an adjustable document holder to hold source documents at the same height, angle and distance as the monitor.

THE MOUSE AND OTHER INPUT DEVICES

Input devices such as computer mice, trackballs and digitizing tablets are used to perform a variety of types of computer work ranging from word processing to computer aided design (CAD). There are a number of types and styles of devices. For example, some mice now have scroll buttons. Mouse settings can also be adjusted for left handed users and to change the speed and distance of mouse travel and clicking actions required. It is important that users, and purchasers of computers are aware of the range of devices and settings available, to determine which are most appropriate for their application and use.

Even with the appropriate device, poor positioning can lead to problems. Users may hold the arm they use to control the device in a fixed, raised or outstretched position. This results in static loading of the shoulder and in bent wrist postures that contribute to discomfort and risk of injury.

A mouse or a tablet should be placed as close to the worker's side as possible at a height that allows the upper arm to hang relaxed from the shoulder with a "neutral" wrist position, with the hand in line with forearm. This position causes the least physical stress. The mouse should be also placed so the cord and items on the desk do not limit movement.

If a keyboard/mouse platform is used, take care that it allows the mouse to be placed as close to the keyboard as possible (at the same height and in the same plane), and that it provides a stable surface of sufficient size.

At CAD and other workstations where work is done with one arm for long periods, the forearm should be supported by a desk surface to the side of the operator or by adjustable armrests on the desk or the chair (see Figure 2). This support is necessary to reduce static loading.

The mouse or other hand-held input device should not contribute to cramped hand postures. This may require consideration of different-sized devices for different hand sizes. The device should be shaped so as to minimize bent wrist postures, or, failing that, the forearm should be supported on a raised smooth surface to allow a comfortable wrist posture.

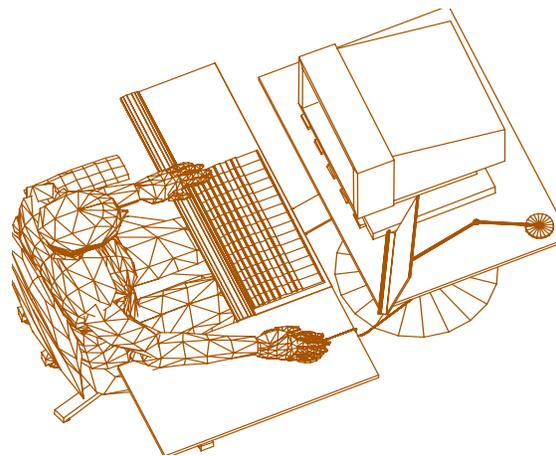
The mouse buttons should be located so as to avoid awkward finger and hand postures. The activation force (the force needed to make a button click) should not be so great as to cause fatigue. But it should not be so little that buttons can be clicked inadvertently since users will then tend to hold their fingers up away from the buttons, causing static loading of the muscles.

Users should be encouraged to hold the mouse in a relaxed way, not to grip it tightly, and to move it from the shoulder rather than just the wrist. This better distributes muscular demands and reduces wrist movements and static loading.

As noted in the CSA guideline, keyboards are usually the main input device, and they should be properly designed and placed. Placement of the keyboard has already been discussed.

The keyboard selected should be suitable to the task and user. There are alternative keyboards available, which vary from the standard design. These should be tested prior to implementation to ensure that they are suitable for the individual and task. The CSA guideline provides more detail in this regard.

Figure 2: Surface beside keyboard for mouse use.



Note: This diagram is just an example. Workstation set ups will vary according to the particular desk style, monitor, tray mount or other accessories used

MONITOR POSITION

Monitors should be placed so that the top of the screen is at the operator's eye level, though there are exceptions as noted in the next section on bifocals. The viewing distance between the operator's eyes and the screen should be in the range of 40 to 74 centimetres. The size of the monitor often dictates viewing distance. If the monitor is large the workstation should be large enough to accommodate it. The increasing use of flat screen monitors is allowing for better space use and more flexibility in screen position.

If the screen is too low or too high, the muscles of the neck must work continuously to hold the head in a viewing position, which may result in fatigue and discomfort. If the screen is viewed continuously or frequently it should be directly in front of the worker to avoid having to keep the head turned to one side. Improper viewing distances or positions may result in fatiguing head positions and in visual fatigue caused by the effort needed to focus.

BIFOCALS, TRIFOCALS AND SINGLE-FOCUS GLASSES

A computer operator who wears bifocals may tilt the head back to view the monitor through the bottom, close-vision, part of the glasses. If bifocals cause discomfort or awkward head positions, several approaches can be taken. The screen should be lowered such that the head is in a neutral position when viewing the top line of text or other material.

Alternatively, one could wear single-focus glasses designed specifically for computer work, with the focal distance chosen for the viewing distance between the worker and the screen. In this case, it is important that a document holder is also used, to position documents at the same viewing distance.

Other options are graduated bifocals, which have no sharp line between the two parts of the lens, trifocals, or the use of reverse bifocal lenses, where the computer screen prescription is in the upper part of the lens.

Computer users should have their eyes checked regularly and discuss their computer use with their optometrists.

SEATING

A height-adjustable chair can help in placing the operator at a proper height for typing and viewing the monitor, especially when height-adjustable tables are not available. The height of the chair should allow the feet to rest flat on the floor with the thighs roughly parallel to the floor. To place some shorter workers at a comfortable typing height, the chair must be raised. If a worker's feet then cannot reach the floor, the front edge of the chair may press into the underside of the worker's thighs, which may impair circulation and cause discomfort. These problems can be avoided by using a footrest.

The size of the worker is an important consideration in buying a chair. Many newer models of chairs come in different sizes to accommodate the variation in user sizes

An office chair should have:

- 1) a five-prong base, with its feet set in a circle at least as big as the seat itself,
- 2) seat height adjustable from 42 cm to 51 cm (standard), 38 cm to 45 cm (low height),
- 3) a covering made with a breathable material and a dense foam that gives way no more than 2.5 centimetres,

-
- 4) a seat pan that:
- ▶ is large enough to provide support for thighs and buttocks but not so long that the front edge presses into the backs of the operator's lower legs,
 - ◆ small: 38-42 cm
 - ◆ medium: 42-46 cm
 - ◆ large: > 46 cm
 - ▶ has a "waterfall" front edge (i.e. rounded, downward-curving) to reduce pressure on the underside of the thighs,
 - ▶ is adjustable, so that it can tilt from 3° forward (i.e., with the front edge 3° down from the horizontal) to 4° back, and
 - ▶ has a width of ≥ 45 cm
- 5) a backrest that:
- ▶ with lumbar support adjustable to 15-25 cm. above the seat. If the backrest is fixed (a less desirable option) the lumbar support should be within this range.
 - ▶ with the upper edge at a height of 45-55 cm above the seat pan for a standard back. A high back should be ≥ 7.5 cm higher than a standard back.
 - ▶ adjustable angle within a range of 93°-13°. A fixed backrest should be in the range of 93°-103°.
- 6) armrests:
- ▶ that are height adjustable to 19-24 cm or fixed within same range,
 - ▶ of length ≥ 18 cm but set back at least 15 cm from the edge of the seat,
 - ▶ should not impede computer work, or positioning of chair, and
 - ▶ with a distance between armrests of at least 45 cm (or adjustable).

Footrests, where they are necessary, should have a stable surface and be large enough to accommodate both feet easily. The footrest angle could be adjustable, though a fixed footrest is suitable if it allows for comfortable ankle angles (roughly 90° between foot and leg). Generally fixed footrest angles are in the range of 0 - 30°.

Make sure that workers are aware of the importance of adjusting their chairs correctly and know how to make adjustments themselves. Chairs should be readjusted when workers change the height they will be working at for any length of time: for example, from keyboarding to writing.

DESKS

The best way to provide the proper screen and keyboard heights for all operators is to use split-level tables or desks that allow each height to be adjusted independently. This allows for proper work postures for a range of user sizes. However, a fixed desk of suitable

height, the correct use of an adjustable chair, and a footrest and/ or monitor stand where necessary, will also allow for suitable postures.

The CSA guideline promotes adjustable worksurfaces but also gives a recommendation for a fixed desk height of 73 cm +/- 2.5 cm.

Any table, desk or stand used for computer work must be deep enough for both the keyboard and the monitor to be in front of the worker. The CSA guideline recommends a minimum of 76 centimetres. In cases where space is limited, the use of flat screens is one option for freeing up space.

There should be sufficient leg-room. The CSA guideline calls for 43 centimetres of horizontal knee space and 60 centimetres of "toe space", the total horizontal space for leg and foot. The vertical clearance at the front edge of the work surface should be at least 68 cm. The width of the leg space should be at least 50 cm.

DOCUMENT HOLDERS

Computer work often involves entering information from source documents. These should be located beside the screen and in the same plane. This reduces the size and amount of head and eye movements between the document and the screen and decreases the likelihood of muscular and visual fatigue. The best way to position documents correctly is to use an adjustable document holder. These are usually mounted on a flexible arm that is fixed to a base or clamps to the edge of the desk. The clamping type is preferable if desk space is limited. Before purchasing a holder, consider the size and thickness of the documents to be used and choose a holder that will accommodate them. A slant board is one option for supporting larger document.

TELEPHONE WORK

Increasingly, workers are required to use a keyboard while on the telephone. This often results in awkward head, neck and back postures with the receiver cradled between the shoulder and head to leave both hands free. Workers required to use a computer while on the telephone for long periods tend to experience discomfort, particularly in the head and back. In such cases, headsets should be used. Hands-free phones are also an option, where the office space and task are appropriate. A spacer or cradle that mounts to the handset is not a preferred option. Although it improves the head position, a static effort is still needed to hold the handset in place.

2) LIGHTING

When computer work environments are being planned, both overall lighting levels and the positioning of lights and windows must be considered.

Area lighting (overhead fixture) levels from 300 to 500 lux are generally considered to be the most appropriate for computer work. However, paper-based work often requires more light, particularly for poor quality or handwritten text. Older workers may also require more light. In these cases task lighting (small lamps for a specific area) can be used.

Excessive light levels may "mask" (or partly hide) characters or whatever is shown on the screen and create more and brighter sources of glare.

Glare is caused by large differences in light levels within the visual field. The eyes try to adapt to these large differences and visual fatigue and discomfort may result. In addition, the computer operator may adopt a poor posture while trying to reduce the glare by changing his or her orientation to the screen. This may result in neck and back pain.

There are three types of glare: direct, indirect and masking. Direct glare occurs when there are bright light sources directly in the operator's field of view. Windows are often a source of direct glare. Indirect glare occurs when light from windows or overhead lighting is reflected off shiny surfaces in the field of view, such as terminal screens, desks and other office equipment. Light from sources directly overhead causes masking glare on the screen, partly obscuring what the operator is trying to focus on.

Ways of reducing both direct and indirect glare include the use of light-absorbing blinds or curtains.

Methods used to control light from windows should allow for user control. Roller, vertical or venetian blinds, or thick curtains can be used. However, care should be taken in the selection and sizing of coverings to ensure that the light is fully blocked.

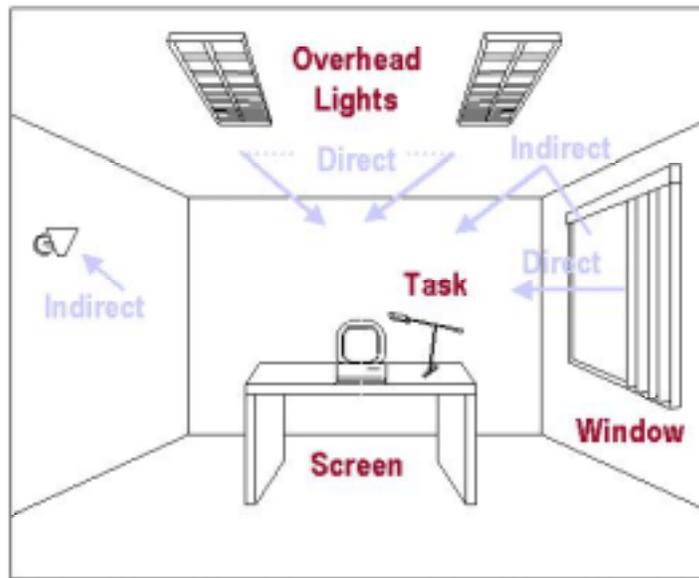


Figure 3: Types of glare and positioning to reduce glare

Where possible, terminals should be positioned such that the operator's line of sight is parallel to windows and overhead fluorescent lights (see Figure 3). Workstations should be located between rows of overhead lights

Direct and indirect glare from overhead lights can also be controlled by parabolic filters. These are light-fixture covers that allow light to travel only straight down and not to disperse at an angle, providing sufficient light while minimizing reflection on computer screens. Another option is an indirect lighting system designed such that the light from fixtures does not shine into the work area directly but only after being reflected off ceilings and walls. The lighting system should allow for uniform light levels.

Anti-glare screens should be used only after other methods have proved unsuccessful. Although these reduce indirect glare from the screen, the mesh types also tend to attract dust, and some glass models create more reflections. This may increase visual demands on the operator.

3) TASK DESIGN

Extended periods of time spent working at computer workstations may contribute to muscular and visual fatigue and discomfort. Maintaining any posture over time is fatiguing, no matter how well the workstation is set up. Also, the work actions in tasks such as continual data entry or word processing are highly repetitive, further contributing to discomfort and, possibly, to risk of injury.

Breaks from computer work are most effective in reducing discomfort when short breaks are taken frequently. They are more effective than working for long periods of time and taking longer breaks. Scheduling five minutes of non-computer work per hour provides relief from many of the postural and visual demands. In addition, for computer intensive tasks, attempts should be made to design jobs to include other duties. There is a related Ontario Ministry of Labour Health and Safety Guideline on rest breaks:

(http://www.gov.on.ca/LAB/english/hs/guidelines/vdt/gl_vdt_breaks.html)

4) PORTABLE COMPUTERS

Since the keyboard and screen on a portable computer (also called a laptop computer) are attached, it is often difficult to position the computer to get a comfortable posture for both keyboarding and viewing. Either the keyboard is too high or the screen is too low. The importance of optimum posture increases as the duration and frequency of computer use increases. Awkward postures can be tolerated for short periods of time. Laptops are not ideal for extended periods of use; however, they are increasingly used in this manner. Below are some good practices:

GENERAL

- a) For general use, place the laptop on a flat surface with the screen tilted back 110-150°.
- b) If desk use is extended some additional equipment should be used. As the keyboard and screen are attached it makes it difficult to optimally position the computer for suitable typing and viewing conditions. Ideally, a docking station or port replicator with a separate monitor, keyboard and mouse should be used. However, another option is to use a separate keyboard and mouse, then raise the laptop such that the screen is in an optimal position for viewing to avoid excessive neck bend (viewing angle of not more than 15 ° down). Bifocal users should take extra care to position the screen to allow viewing without awkward head positions.
- c) Take short "micro-breaks" frequently. Focus on a distant object for a few seconds.
- d) Avoid prolonged periods of use. (See MOL Guideline on Rest Breaks for VDT Operators.)
- e) Optimize viewing conditions:
 - i. Maintain a comfortable viewing distance (in the range of 40-74 cm). Font size can be adjusted to allow the laptop to be placed for both good viewing and a comfortable body position.
 - ii. Place laptop to minimize glare from lights and windows
 - iii. Adjust brightness and contrast to suit lighting conditions.

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- iv. Keep screen clean.
 - v. Have regular eye examinations and inform your eye care provider of your computer use.
- f) The Health and Safety Guide provided with the computer should be referenced.

HOTEL/HOME

- a) Some larger hotels provide rooms that accommodate computer use (i.e. suitable desks, chairs and connections). Inquire about these when travelling.
- b) If the desk provided at a hotel is not suitable, ask if an adjustable ironing board is available. It makes a useable adjustable worksurface. Yes, you can try this at home.
- c) Carry an extension cord and extra long phone cable, in case the outlets are across the room.
- d) Use a chair with good back support. A pillow or rolled up towel can be used to improve support.
- e) Sit on a pillow to raise yourself if necessary. Use a briefcase or other solid item as a footrest.

VEHICLES

- a) Store the computer in a manner that avoids long reaches. Long reaches (particularly behind the body into the back seat) and twisting at the waist during lifting increase the risk of injury. For example, this can occur if the computer is stored in the back of a two door vehicle. If a strap or other item catches while lifting sudden, high forces are placed on the muscles and joints involved, greatly increasing the possibility of injury.
- b) Laptop computers should not be used by the operator/driver of the vehicle, while the vehicle is in use. The vehicle should be safely parked while the operator/driver is using the laptop computer.
- c) When using the laptop in the vehicle, it should be positioned directly in front of you rather than off to one side. Move the seat as far back as possible, or move to the passenger seat, if necessary. Place the laptop on a briefcase or other flat object to allow for a level typing surface.
- d) There are a number of computer stands on the market. The best type of stand, or whether a stand is even required, will depend on type and extent of use, the type of vehicle and other considerations such as passengers in the vehicle.
- e) Position your vehicle so as to minimize glare, if possible. Use the visors and possibly a roll down blind that attaches to the window.

CARRYING

- a) When carrying the laptop over any distance, shift the load from side to side and between hands and shoulders.
- b) Batteries add weight. Avoid carrying an extra battery if you know you will have access to AC power.
- c) Avoid putting a lot of extra materials into your laptop case. Use another brief case if needed. This will reduce the load on one side and better balance the overall load.
- d) Avoid carrying a lot of hard copies of documents in the computer case. Work from electronic copies where possible.
- e) If carrying more than one item, try to balance the load on both sides of your body.
- f) Consider using a cart to reduce the amount of carrying.
- g) Backpacks are a good alternative when carrying over uneven terrain or in snowy conditions.

5) A CHECKLIST FOR COMPUTER WORKSTATIONS

A checklist covering the points made in this guideline is found on the next page. Please photocopy the checklist and the guideline.

References

A Guideline on Office Ergonomics (CAN/CSA-Z412-M00), Canadian Standards Association. Toronto, 2000.

Rest Breaks for Video Display Terminal (VDT) Operators, Health and Safety Guidelines. Professional and Specialized Services, Occupational Health and Safety Branch, Ministry of Labour, 1993.

A Checklist for Computer Workstations

Review one workstation at a time, answering each question for each workstation. Whenever the answer is no, see the relevant section of the Ministry of Labour's Health and Safety Guideline "Computer Workstations: Layout and Lighting" for recommended action. If you have any questions please call the Ergonomics Consultant at the Ministry of Labour Regional Office nearest you (see the inside front cover for telephone numbers).

Keyboard Position

- | | | |
|--|-----|----|
| 1) Upper arms hang relaxed at side during computer use..... | Yes | No |
| 2) Elbow joints are at about 90 degrees..... | Yes | No |
| 3) Hands are in line with forearms when using keyboard and/or mouse..... | Yes | No |
| 4) Forearm is supported when using a mouse or other hand-held device | Yes | No |
| 5) Both keyboard and mouse height allow appropriate arm postures..... | Yes | No |

Monitor Position

- | | | |
|---|-----|----|
| 6) The top of the screen is at eye height (bifocal and trifocal wearers excepted) | Yes | No |
| 7) Viewing distance (eyes to screen) is 40 to 74 cm..... | Yes | No |
| 8) Monitor is centred in front of user during continuous computer use | Yes | No |

Seating

- | | | |
|--|-----|----|
| 9) The seat pan height is adjustable 42 to 51 cm (standard seat)..... | Yes | No |
| 10) The seat pan tilt is adjustable +3 to -4 degrees | Yes | No |
| 11) The lumbar support height is adjustable 15 to 25 cm above seat | Yes | No |
| 12) The angle of the backrest to seat is adjustable 93°-113° | Yes | No |
| 13) Upper edge of backrest is 45-55 cm above the seat pan (standard back)..... | Yes | No |
| 14) The worker knows how to adjust chair for maximum comfort..... | Yes | No |
| 15) The thighs are roughly parallel to the floor..... | Yes | No |
| 16) Feet are flat on the floor or a footrest is provided where necessary | Yes | No |

Desks

- | | | |
|--|-----|----|
| 17) Horizontal knee space is greater than 43 cm..... | Yes | No |
| 18) Horizontal toe space is greater than 60 cm | Yes | No |

Document Holders

- | | | |
|---|-----|----|
| 19) An adjustable document holder is present | Yes | No |
| 20) The holder is large enough for documents being used | Yes | No |

Lighting

- | | | |
|---|-----|----|
| 21) Lighting levels appear to fall between 300 and 500 lux..... | Yes | No |
| 22) The computer screen is free of glare spots..... | Yes | No |
| 23) The worker is shielded from sources of direct glare..... | Yes | No |
| 24) The worker's line of sight is parallel to the plane of windows | Yes | No |
| 25) The office area is illuminated with indirect light fixtures..... | Yes | No |
| 26) Overhead light fixtures are fitted with parabolic filters if appropriate..... | Yes | No |
| 27) The workstation is located between rows of overhead lights..... | Yes | No |
| 28) The worker is provided with an adjustable task light (if required) | Yes | No |

Task Design

- | | | |
|---|-----|----|
| 29) The worker is encouraged to take frequent breaks (e.g., 5 minutes every hour) away from keyboarding during prolonged computer use | Yes | No |
|---|-----|----|