# MIRTH Risk Reduction Approaches

This document contains a general framework for reducing risks associated with musculoskeletal problems in industry with emphasis on task typically perform in manufacturing and assembly work. This is not an exhaustive set of risk reduction approaches and conformance to these principles does not guarantee full legislative compliance.

This work was performed on the EC supported MIRTH project (Musculoskeletal Injuries Reduction Tool for Health and Safety (GIRTH-2001-00574)

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# 1. Initial Analysis: Identifying Areas for Effort

## 1.1 Number of Occurrences

Reduction effort must be concentrated where it will be most effective. One way to do this is to use Pareto Analysis. The basic idea is that 80% of the problems are caused by 20% of the activities or work areas or body sites. For this purpose data must be collected on the number of injuries (or other relevant measure) per each activity or work area or body site. Cumulative totals are then plotted against the individual sources of injury, such as body sites, set in decreasing order of their frequency of occurrence. The causes that give rise to 80% of the cumulative total are then the first to receive the reduction effort.

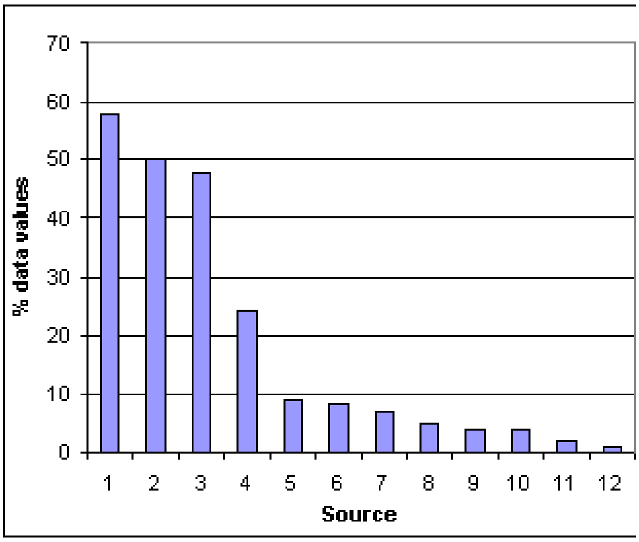



Figure 1 Histogram of values

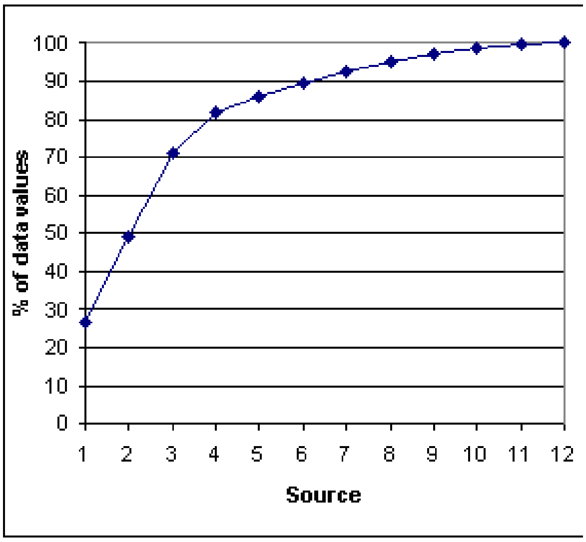



Figure 2 Cumulative totals

## 1.2 Risk Rating

Actual risk levels in terms of real probability of occurrence are very difficult to estimate, especially as the specific details of each person and situation differ widely. Instead a more qualitative approach is possible and is recommended for use with Display Screen Equipment (European Agency for Safety and Health at Work) as given in Table 1. Precise, exact values are not strictly necessary, as the purpose is to set the priorities. Similarly, in every application it should be possible to adapt this approach to the particular situation(s) in a given organisation e.g. different terms, fewer or more categories. Once this has been done the corrective actions can commence.

Whatever approach is used to assess risk, a two-pronged approach to reduction is required. Simple problems should receive simple remedies, and the more complex problems will require receive more complex remedies which usually require detailed investigation. These two categories cannot be seen as sharply separated from each other but are rather degrees of difference. In practice many situations will need a mix of both simple and complex treatment. Which to use where must be largely up to the judgement and experience of the investigator.

Table 1 Risk rating matrix

| | | Likelihood | | |
|---|---|---|---|---|
| | | Low 1 | Medium 2 | High 3 |
| Hazard | Low 1 | 1 | 2 | 3 |
| | Medium 2 | 4 | 5 | 6 |
| | High 3 | 7 | 8 | 9 |

## 1.3 Initial Rectification of the Workplace

In many cases it becomes apparent very quickly that there are a number of fairly simple and obvious changes that need to be made. Before carrying out a detailed analysis and improvement programme as described below, it makes sense to rectify these obvious deficiencies first. The process may render later detailed study less necessary. Alternatively, the problem(s) may be eliminated or reduced substantially by changes in the organisation of the work. A variety of suggestions is set out below.

1. Consult the Workers

It is the workers who experience the discomfort and inconvenience involved in doing the job, and these are difficult if not impossible for an observer to detect. The worker can tell the investigator what these are, where the pain/discomfort is felt, and what difficulties are experienced in doing the job. From long continued experience of a limited range of activities the worker can often also make useful suggestions for improvement of the workplace design.

2. Repeat the observation/improvement cycle

Often, once the first set of improvements has been made, it is found that still more changes are needed. Similarly, one set of initial changes may themselves cause some other, new deficiencies. In either case further investigation is needed, and several cycles of this process might result.

3. Consider Job Rotation or Job Sharing

In some cases it may be very difficult or even impossible to rectify completely some problem aspects. In such cases rotating the job between two or more workers can relieve exposure of any one individual. Such a reduction in exposure also reduces the time required for recovery from the pain or discomfort and so productivity will be increased.

4. Re-allocate some of the tasks

Rather than have one worker perform several adverse tasks it may be possible to spread these among several workers instead, in other words “spread the pain around”. In this way recovery from one or two adverse tasks may take place while performing several other "easy" tasks. Konz has described this as making use of "working rest" which makes the point rather clearly. Another version of this strategy is to allocate one or more of the adverse tasks to a machine or other piece of equipment, provided the expense is manageable.

5. Institute controls

Engineering controls: will be used to reduce or eliminate the hazards by technical manoeuvres like design of the workplace, design of the tools and working methods, design of the product, and provision of aids such as lifting equipment.

Administrative controls: are manoeuvres that effect the organisation of the work or on the ways the work is done. They include e.g. allocating the workers to different tasks, working schedules, rotation of workers between different tasks, rules for performing the work, and training of working techniques.

Ergonomics Controls: which include appropriate requirements in the design of tools and workplaces, systems and procedures, training regimes, physical and social environments, materials handling, work times and shift work, human reliability and the risks of accidents and injury, and user interfaces. These need more elaboration below.

These countermeasures are unlikely to remove all of the significant deficiencies and so more detailed investigation is needed. Suggestions for doing this are set out below.

## 2. General Ergonomics Requirements

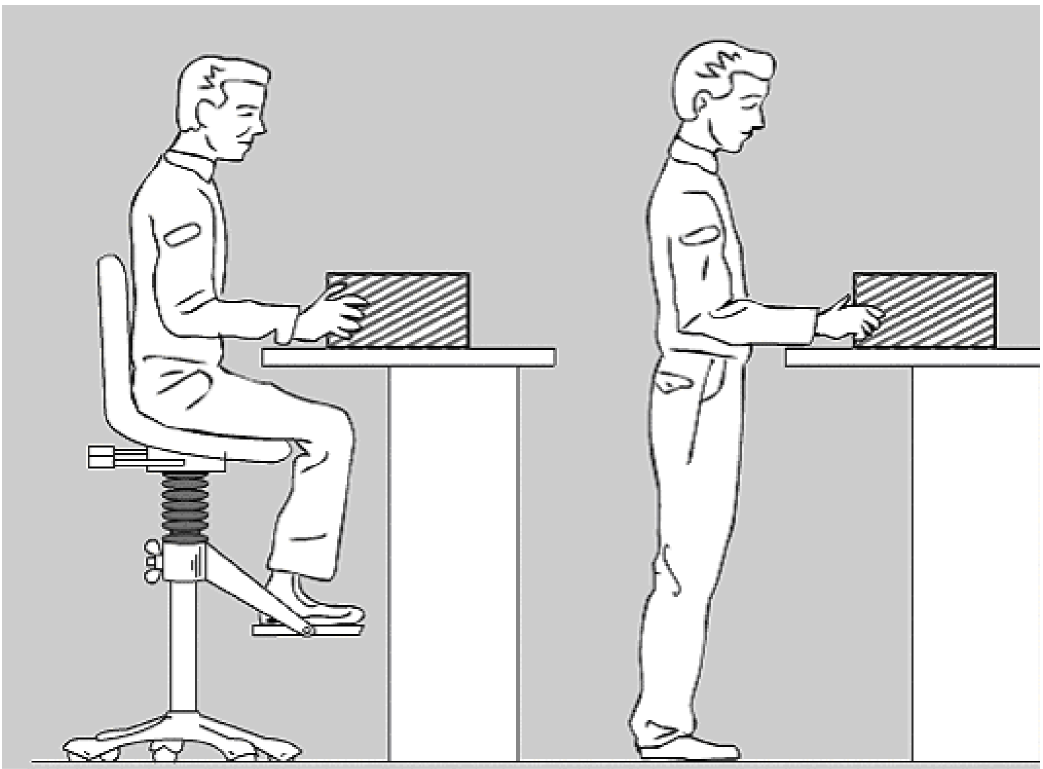
The basic rule is that the job activities, workplace design, and equipment design must be arranged to suit the person doing the job. This means that the worker should perform the tasks that make up the job in ways that are as close as possible to being "natural". All other parts of the work must be changed to fit human capabilities. As a general guide to fulfil these aims Corlett (1978) enunciated a set of principles.

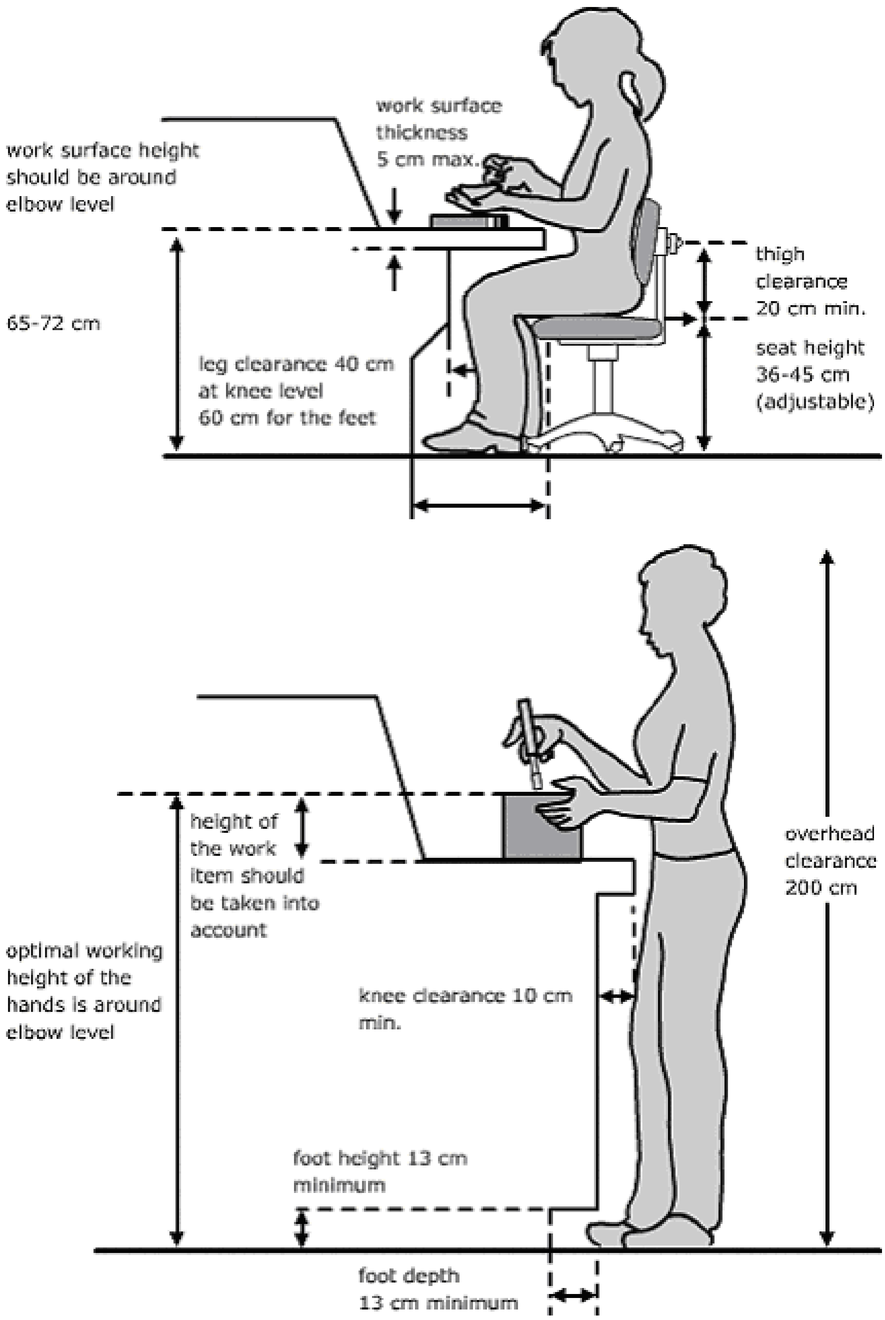
### 2.1 Corlett's Principles (Corlett, 1978)

As the list is worked through from top to bottom each level incorporates more of the items in the level above, thus becoming more complex and making it increasingly likely that an adequate design decision will be a compromise. At the same time, principles attached to any items are subject to the overriding effect of principles attached to items at a higher level. By this arrangement each decision in designing a work situation should take account, to some extent, of the complexity of people and avoid the sub-optimisation which sometimes arises.

Postures and Space

The worker should be able to maintain an upright and forward facing posture during work

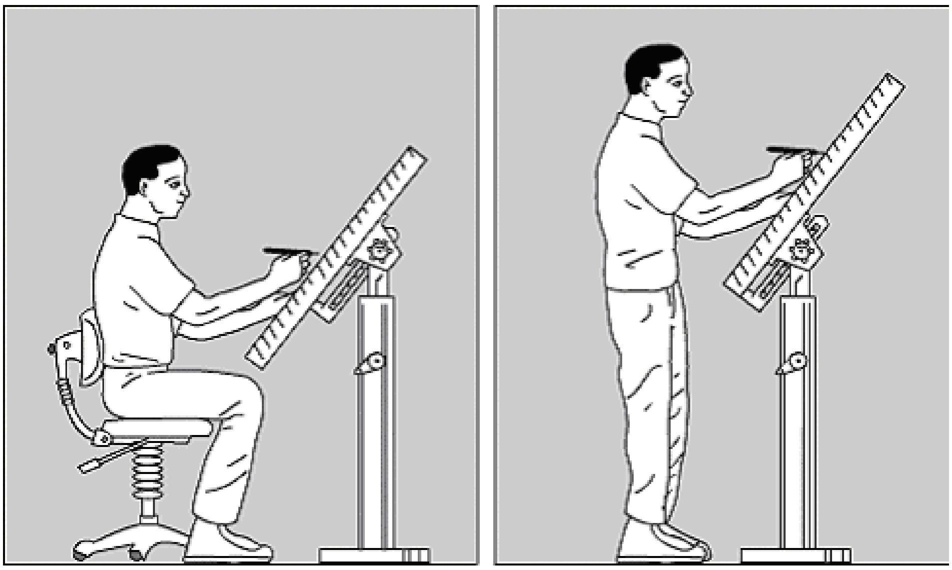




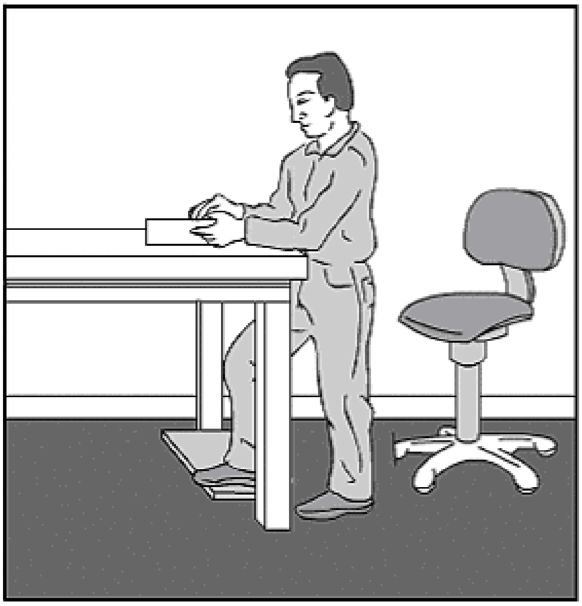

2. Where vision is a requirement of the task, the necessary work points must be adequately visible with the head and trunk upright or with just the head inclined slightly forward.

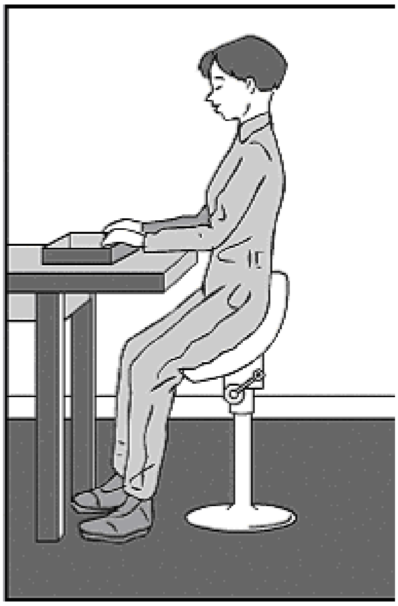
3. All work activities should permit the worker to adopt several different, but equally healthy and safe, postures without reducing capability to do the work.

4. Work should be arranged so that it may be done, at the worker's choice, in either a seated or standing position. When seated the worker should be able to use the back rest of the chair, at will, without necessitating a change of movements.

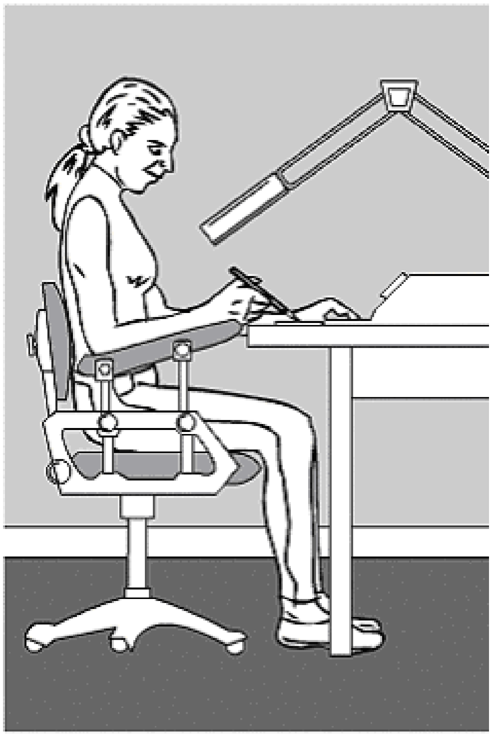


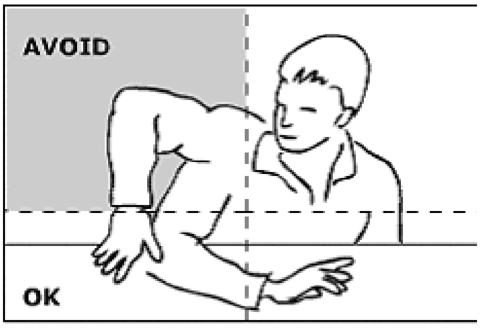
5. The weight of the body when standing should be carried equally on both feet, and foot pedals designed accordingly.

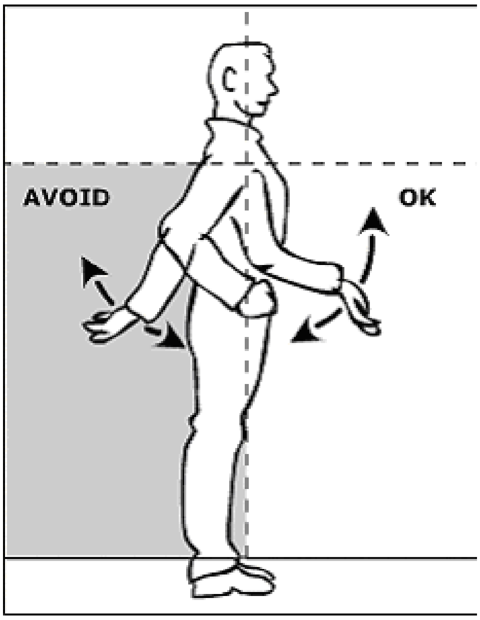




Work should not be performed consistently at or above the level of the heart; even the occasional performance when force is exerted above heart level should be avoided. Where light hand work must be performed above heart level, rests for the upper arms are a requirement.

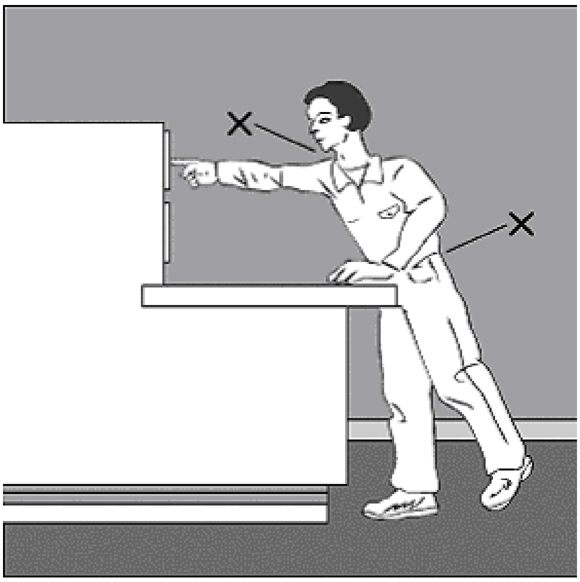





Movements

Work activities should be performed with the joints at about the mid-point of their range of movement. This applies particularly to the head, trunk and upper limbs.



Where muscular force has to be exerted it should be by the largest appropriate muscle groups and in a direction co-linear with the limbs concerned.

Where a force has to be exerted repeatedly it should be possible to exert it with either of the arms, or either of the legs, without adjustment to the equipment.

Momentum should be employed to assist the worker wherever possible, and it should be reduced to a minimum if it must be overcome by muscular effort.

Continuous curved motions are preferable to straight-line motions involving sudden and sharp changes in direction.

Ballistic movements are faster, easier and more accurate than restricted (fixation) or 'controlled' movements.

Movements in repetitive tasks

Both hands should preferably begin their therbligs simultaneously and finish at the same instant.

Both hands should not be idle at the same instant except during rest periods.

Motion of arms should be in opposite and symmetrical directions instead of in the same direction and should be made instantaneously.

To reduce fatigue, motions should be confined to the lowest possible classification as listed below, the least tiring and most economical being shown first.

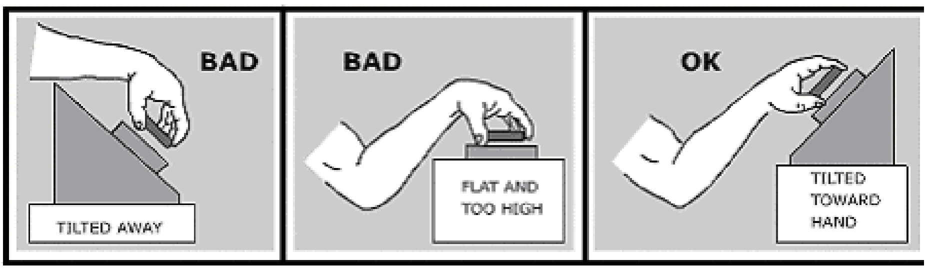
1st finger motions

2nd finger and wrist motions

3rd finger, wrist and lower arm motions

4th finger, wrist lower and upper arm motions

5th wrist, lower and upper arm and body motions




Rest pauses should allow for all loads experienced at work, including environmental and information loads, and the time interval between successive rest periods.

Equipment and Arrangements

Two or more tools should be combined wherever possible.

Tools and equipment used in highly repetitive situations

Gravity feed containers should be used to deliver the material as close to the point of assembly or use as possible. This delivery point should be near the height of the point of use to eliminate any lifting or change in direction when carrying the parts.

Ejectors should be used to remove the finished part.

Use ‘drop delivery’ whereby the operator may deliver the finished article, by releasing it in the position in which it was completed, without moving to dispose of it.

All materials and tools should be located within the normal group area.

Combinations and Sequences

Consideration should always be given to the transfer of work from the hands to the feet or other parts of the body.

Tools and materials should be so located as to permit a proper sequence of therbligs*. The part required at the beginning of the cycle should be next (to) the point of release of the finished piece from the former cycle.

Sequence of motions should be arranged to build rhythm and automaticity into the operation.

* see Glossary for an explanation

## 3. Typical Disorders and Things to Avoid (adapted from Kroemer, 1989)

Kroemer noted that most of these deficiencies are easily observable as follows: rapid and frequently repeated actions; exertion of finger or arm forces; contorted body joints; blurred outlines of the body owing to vibration; and the feeling of cold and the hissing sound of fast flowing air. Training of operators in physiologically correct activities, and the provision of alternating work (to allow ‘breaks’ in otherwise repetitive or maintained activities) are also essential.

According to Kroemer seven conditions specifically need to be avoided as follows:

Job activities with many repetitions: Use Silverstein's (1995) definition of repetitive activity as work in which each cycle lasts less than 30 seconds, or as work in which one basic activity element is present during more than 50% of the total cycle time.

Work that requires prolonged or repetitive exertion of more than 30% of the operator’s muscle strength available for that activity.

Putting body segments into an extreme position, such as severe bending of the wrist.

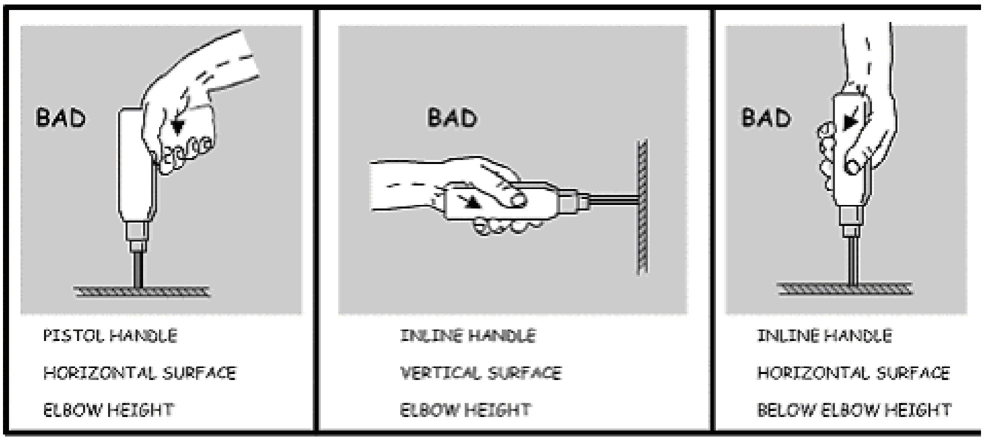
Work that makes a person maintain the same body posture for long periods of time.

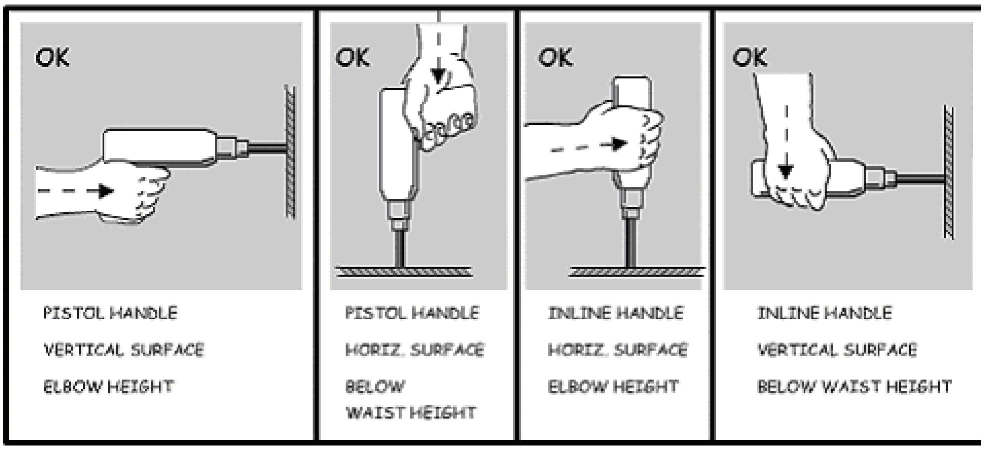
Work in which a tool vibrates the body or part of the body.

Exposure of working body segments to cold (including the escape of compressed air).

Combinations of these conditions.

Most ergonomics problems result from work situations so any programme must start there. The Tables below have been adapted from Kroemer (1989) and integrate two of his tables.  It utilises many technical terms that will be unfamiliar to investigators or planners who are not experts in Ergonomics and for such people explanations are given in the glossary.

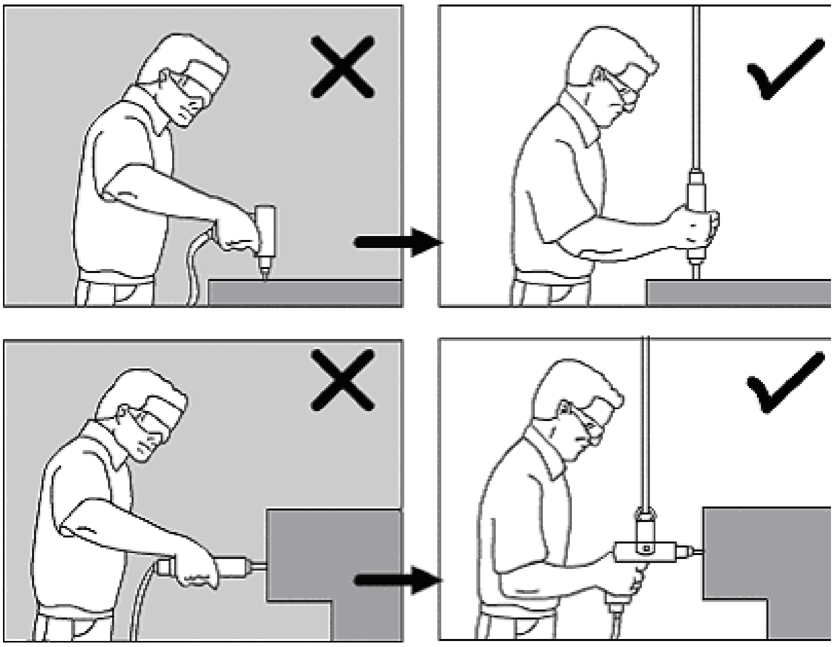



Some other suggestions are shown here:


Faulty wrist posture


Example of a jig that corrects for faulty wrist postur



Allow the shoulder and upper arm to be relaxed

Use rounded corners and edges, and padding.

DO NOT: Allow the forearms to be elevated above horizontal.

| Typical Job Activities that Cause Problems | Body Activities Induced by the Job Activities | Disorder caused | Avoid in General | Avoid in Particular |
|---|---|---|---|---|
| Buffing, grinding, polishing, sanding, assembly work, typing, keying, cashiering, playing musical instruments, surgery, packing, house-keeping, cooking, carpentry, brick laying, butchery, hammering, hand washing or scrubbing | Repeated wrist flexion or extension, rapid wrist rotation, radial or ulnar deviation, forceful wrist motions and deviation, pressure with the palm<br>Pinching | Carpal tunnel syndrome | Wrist deviation, finger pinch | |
| Turning screws, small parts assembly, hammering, meat cutting, playing musical instruments, playing tennis, bowling | Radial wrist pronation with extension, forceful wrist exertion, repeated supination and pronation, jerky throwing or impacting motions, forceful wrist extension with forearm pronation | Epicondylitis, tennis elbow | ‘Bad backhand’ | |
| Belt conveyor assembly, typing, keying, small parts assembly, packing, load carrying in hand or on shoulder | Prolonged static posture of neck/ shoulder/arm, prolonged carrying of load on shoulder or in hand | Tension neck | Static head posture | |
| Soldering, buffing, grinding, polishing, sanding | Rapid pronation of the forearm, forceful pronation, pronation with wrist flexion | Pronator teres syndrome | Forearm pronation | |
| Use of hand tools | Repetitive wrist flexion with pronation, or extension with supination of the forearm | Radial tunnel syndrome | Wrist flexion with pronation, OR extension with supination | |
| Punch press operations, overhead assembly, overhead welding, overhead painting, overhead auto repair, belt conveyor assembly work, packing, storing, construction work, postal ‘letter carrying’, reaching, lifting | Shoulder abduction and flexion, arm extended, abducted, or flexed in the elbow more than 60 deg, continuous elbow elevation, work with hand above shoulder, load carrying on shoulder, throwing object | Shoulder tendonitis, rotator cuff syndrome | Arm elevation | |

| Typical Job Activities that Cause | Body Activities that they Induce | Disorders caused | Avoid in | Avoid in |
|---|---|---|---|---|

| Problems | | | General | Particular |
|---|---|---|---|---|
| Punch press operation, assembly work, wiring work, packing, core making, use of pliers | Forceful wrist extension and flexion, forceful ulnar deviation | Tendonitis in the wrist | Often repeated movements, particularly with force exertion, hard surface in contact with skin, vibrations | |
| Buffing, grinding, sanding, polishing, punch press operation, sawing, cutting, surgery, butchering, use of pliers, 'turning control' as on a motorcycle, inserting screws in holes, forceful hand wringing | Wrist motions, forceful wrist extension, and ulnar deviation while pushing or with supination, wrist flexion and extension with pressure at the palmar base, rapid rotation of the wrist | Tenosynovitis, De Quervain's syndrome, ganglion | Finger flexion, wrist deviation | |
| Buffing, grinding, polishing, sanding, overhead assembly, overhead welding, overhead painting, overhead auto repair, typing, keying, cashiering, wiring, playing musical instruments, surgery, truck driving, stacking, materials handling, postal 'letter carrying', carrying heavy loads with arms extended | Carrying heavy load in the hand, carrying load by shoulder strap, hyperextension of arm, shoulder flexion, prolonged restricted posture of upper body and arm, reaching overhead | Thoracic outlet syndrome | Arm elevation, carrying | |
| Operating trigger finger, using hand tools where the handle opening is too large for the hand | Repetitive finger flexion, sustained bending of the distal finger phalanx while more proximal phalanges are straight | Trigger finger | Finger flexion | |
| Playing musical instruments, carpentry, brick laying, use of pliers, soldering, hammering | Prolonged flexion and extension of the wrist, pressure on the hypothenar eminence, sustained elbow flexion with pressure on the ulnar groove | Ulnar nerve entrapment, Guyon tunnel syndrome | Wrist flexion and extension, pressure on hypothenar eminence | |

| Typical Job Activities that Cause Problems | Body Activities that they Induce | Disorders caused | Avoid in General | Avoid in Particular |
|---|---|---|---|---|
| Chain sawing, jack hammering, use of vibrating tool, sanding, paint scraping, using tool too small for the hand, often in a cold environment | Gripping of vibrating tool, using hand tool that hinders blood circulation | White finger (or dead finger) syndrome, Raynaud's syndrome | Vibrations, tight grip, cold working | |

For Tension Neck: Design the work so that head and/or neck postures alternate.

## 4. Examine the Design of the Work

1. Do a task analysis

Often there are features of the work design that can be changed to reduce the ergonomics deficiencies and thereby reduce or eliminate the postural problems at source. The process requires a highly detailed examination of all elements of the tasks that make up the job. It should be broken down into the set of tasks involved, a task being defined as "the smallest part of the work that can be allocated to a separate operator". This is task analysis. See Drury (1983) for appropriate information on one way to do it.

The tasks themselves are often divided into the following four groups:

| | |
|---|---|
| Operation: | an action is performed on something |
| Movement: | the location of something is changed |
| Hold: | the operator maintains a grip on something |
| Delay: | the start of a following activity is prevented |

Once the breakdown of tasks has been completed and they have been classified into the groups designated above they must be examined in detail to see if improvements can be achieved. Not only can this examination reduce the ergonomics problems but it can also achieve a marked increase in productivity. In other words "Good Ergonomics is Good Economics".

2. Examine the tasks critically

Task analysis also raises questions as to whether some tasks presently performed by a person should instead be allocated to a machine (including a computer) or the reverse. Changing these allocations offers further opportunities to reduce or eliminate ergonomics problems and/or improve productivity. It requires answers to the following questions. What is done? Where is it done? When is it done? Who or what does it? How is it done? Once these have been answered, a further set of questions arises as follows. Why is it done, why is it done there, why is it done then, why is it done by that person or thing, and why is it done by that method? Each of these raises further questions: what happens if it is not done, or not done there, or then, or by that person or thing, or using that method? Finally for each of these questions we must ask: what alternatives are available, and which one should be used? A convenient way to set these out is by means of a Critical Questioning Matrix as recommended by Konz and Johnson **(2008)** and presented on the next page.

Critical Questioning Matrix
(modified from Konz and Johnson (2008))

| | Why this_______? | What happens to the system if not this_______? | What alternative is there to this__________? | What should be the ___________? |
|---|---|---|---|---|
| What is done? | ACTION | ACTION | ACTION | ACTION |
| Where in the system is it done? | PLACE | PLACE | PLACE | PLACE |
| When in the sequence is it done? | POINT | POINT | POINT | POINT |
| Who or what does it? | PERSON OR THING | PERSON OR THING | PERSON OR THING | PERSON OR THING |

| | | | | |
|---|---|---|---|---|
| How is it done? | METHOD | METHOD | METHOD | METHOD |

3. Apply this Work Design Check-sheet

| With regard to the following aspects of the work: | To improve the design what can be: (clearly some cells below are not feasible) | | | |
|---|---|---|---|---|
| | Eliminated? | Combined? | Simplified? | Changed? |
| Sequence of operations/movements | | | | |
| Equipment design | | | | |
| Tools | | | | |
| Material(s) | | | | |
| Product design | | | | |
| Limb(s) used | | | | |
| Muscle(s) loaded | | | | |
| Vision needs | | | | |
| Positions of equipment/controls | | | | |
| Height of equipment controls or bench | | | | |
| Duration of operation or hold | | | | |
| HO Posture and variety | | | | |
| Directions of actions | | | | |
| Distances of reaches | | | | |

OR can it be improved by adding:

Drop delivery?

Quick-action clamps?

Sliding grasp action?

Double-action effect e.g. with the clamps?

A fixture or jig to hold the parts?

Continuous motion instead of jerky?

Air or hydraulically operated vise

Help of momentum?

Simultaneous work?

Gravity feed?

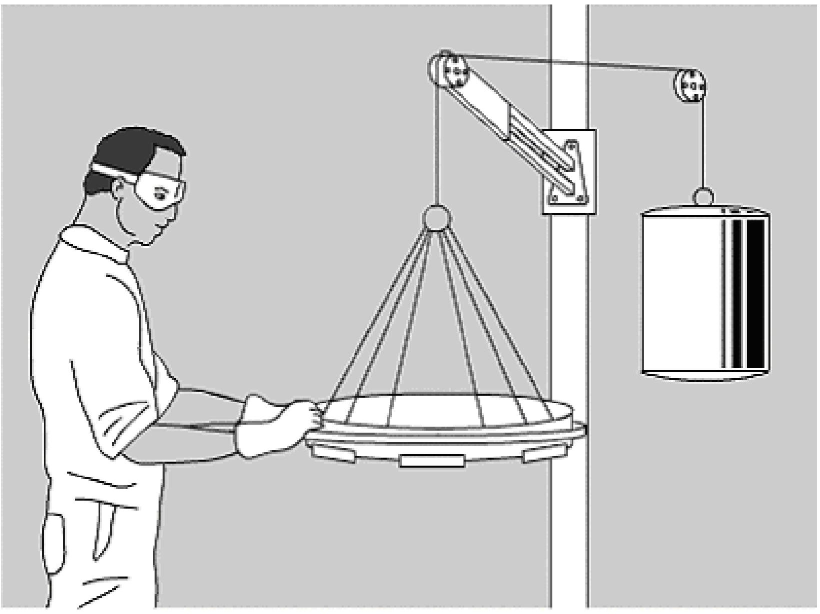
Sit or stand option?

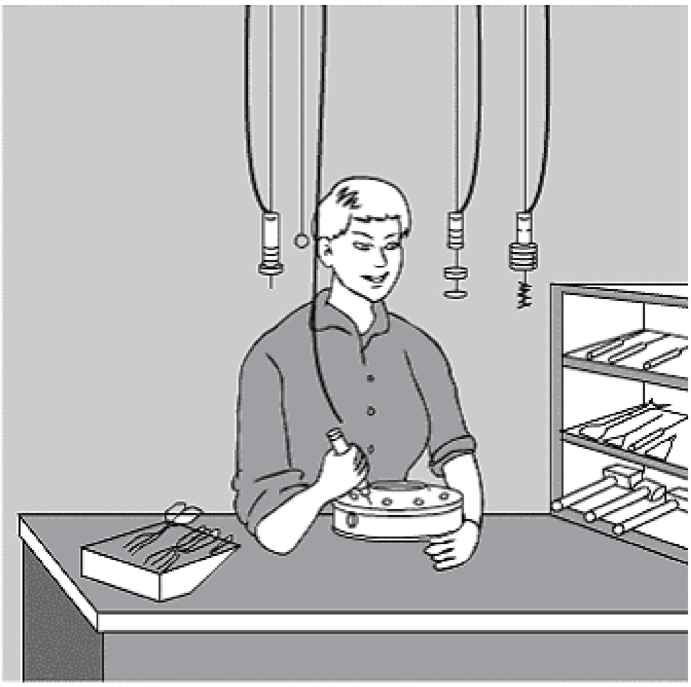
Ejectors?

These last questions raise the question of what other aids could be used to help improve the design. That is the next section.

5. Organise Hardware to Assist the Work

1. Counterbalance the load





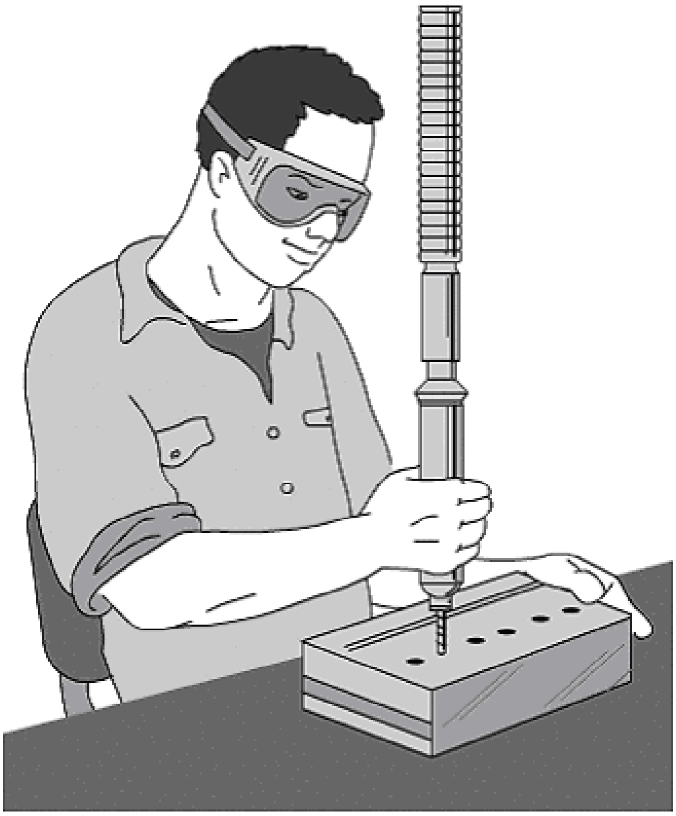
2. Use Jigs and fixtures

In many manufacturing jobs the designer provides them to obtain accuracy in machining or assembly. Sometimes, opening and closing them or positioning the work piece, calls for more movements on the part of the operator than are strictly necessary. For example, a tool may have to be used to tighten a nut when a wing nut would be more suitable; or the top of the jig may have to be lifted off to insert a part when the part might be slid into it instead. But the terms need to be defined first:

JIG: holds parts in an exact position and guides the tool that works on them.

FIXTURE: a less accurate device for holding parts which would otherwise have to be held in one hand while the other worked on them.

The holes in this jig position the drill in the correct locations for the holes:



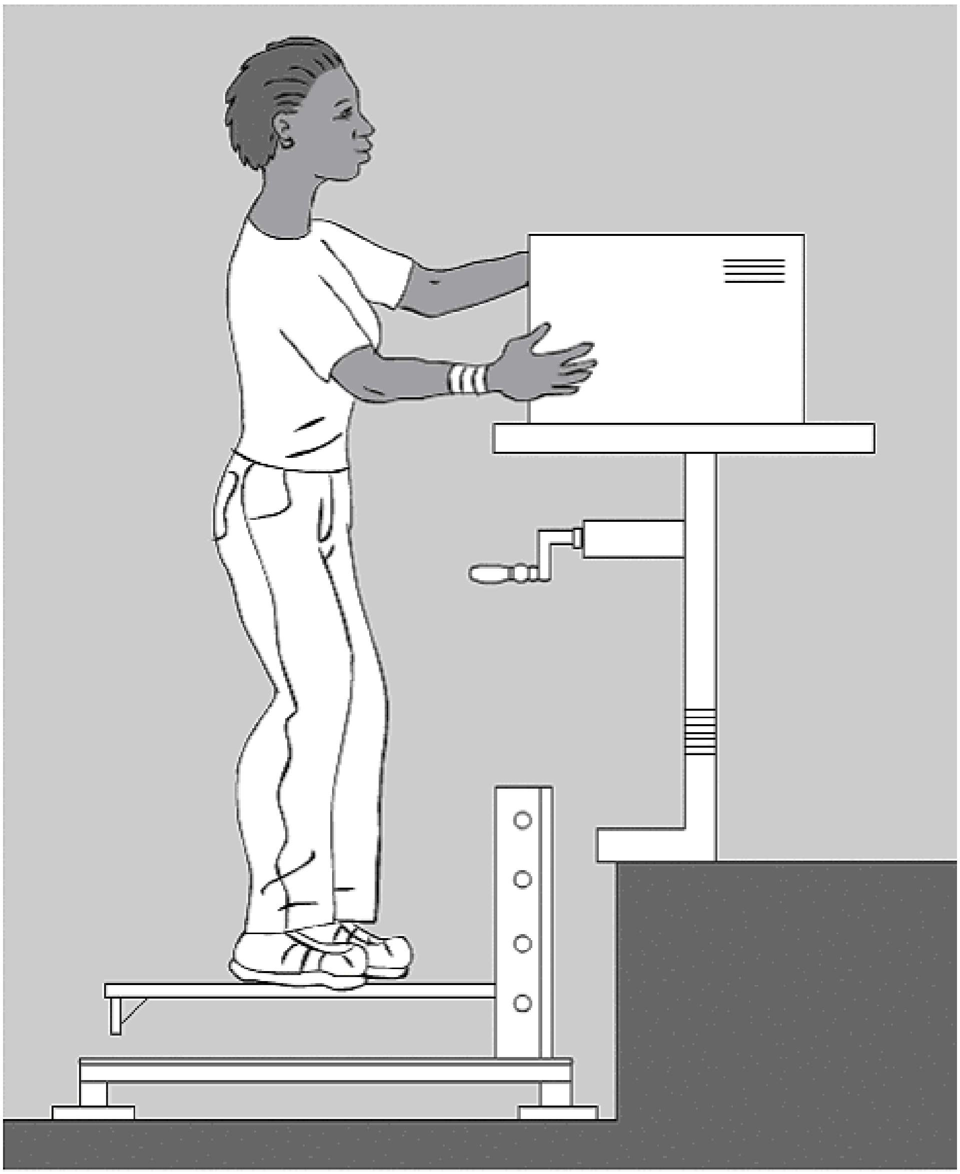
3. Raise the height of the operator to match that of the equipment: see next page

4. Particular equipment points worth noting are:

Clamps should be as simple as possible to operate and should not have to be screwed unless this is essential for accuracy of positioning. If two clamps are required, they should be designed for use by the right and left hands at the same time.

Both hands load parts into the jig or fixture with a minimum of obstruction between the point of entry and the point from which the material is obtained.

Unclamping a jig should at the same time eject the part, so that additional movements are not required to take the part out of the jig.



Make fixtures to take two parts: on small assembly work it may be possible, if it does not require both hands to work at once; then provide sufficient space between them to allow both hands to work easily.

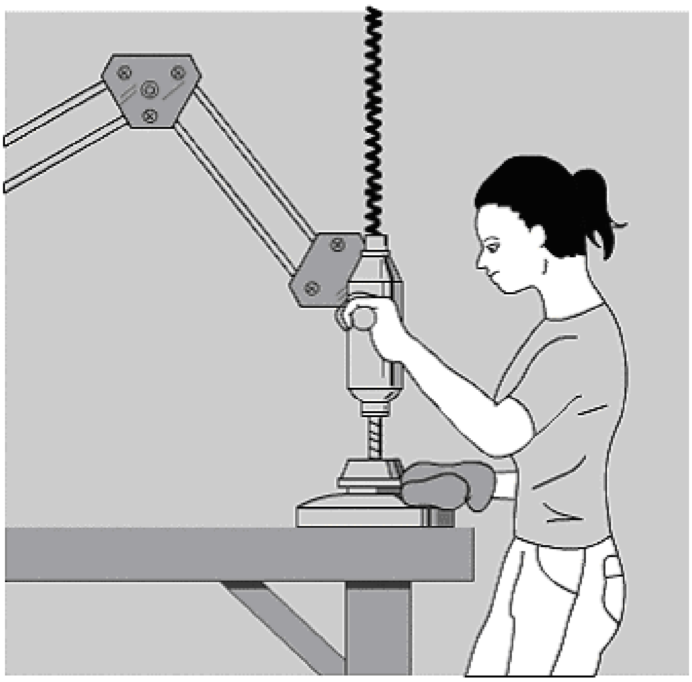
Where jigs take several small parts: save loading time by clamping several parts in position as quickly as one.

Mill or assemble two or more at once: wherever this is feasible.

Use spring-loaded disappearing pins to position components: they can save a lot of machining or assembly time, but ensure that their strength of construction is robust enough to minimise the need for repair.

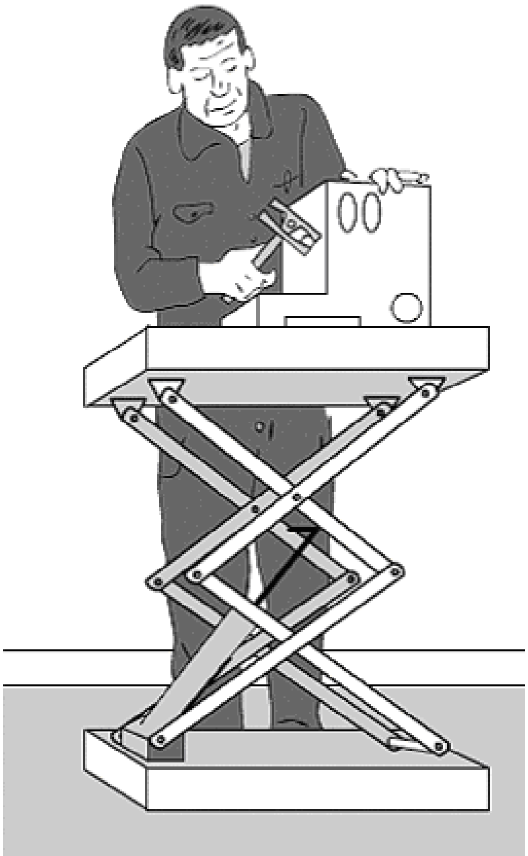
Ensure that the operator can see what is going on at all stages, especially during insertion into, or removal from, the jig or fixture; check this before any design is accepted.

This example shows a combination of counterbalancing and use of a fixture, with the whole positioned at a reasonable height for the operator. But the hands may have been put a little high relative to the heart:



5. Use a variable height work surface

Sometimes these are spring loaded so that they automatically rise up as parts are removed and the load lightens. Alternatively they are adjusted up and down by a hydraulic or electric motor, possibly activated by a foot control. Se the parallelogram system illustrated below:



(Adapted from: Introduction to Work Study (3rd Ed.), 1987, I.L.O., Geneva) pp 159-160.

## 6. Eliminate Static Load

This maintains a static contraction of a muscle often from a Hold or from maintaining a particular posture. The effect is to impede the flow of blood to and from the muscle in question thus starving it of nutrients and creating a build–up of waste products. But when work is dynamic and rhythmic the alternating contracting and relaxing of the muscle assists both processes. Kroemer and Grandjean (1997) say that the detrimental effects are particularly noticeable when:

A high effort is maintained for 10 seconds or more.
A moderate effort is maintained for 1 minute or more.
A slight effort is maintained for 5 minutes or more.

Examples of situations where these conditions arise are: holding the arms out ahead or above one's body, leaning forward over a machine, leaning sideways while performing an operation, standing on one leg while the other operates a pedal, holding something while an operation is performed on it.

These can be alleviated or eliminated by using arm rests for the operator, or spring balances to support the load of a tool such as a nut runner or mechanical screwdriver, or using spring balances to support the operator's arms, as illustrated already above.

7. Give all workers an adjustable chair or stool.

Caution: sitting causes a 40% to 90% increase in pressure on the discs of the lower back compared to standing upright, and is a major contributor to many "low back" problems. Better is to provide a sit/stand option where the operator can rest the rump on the front edge of the seat with the legs and torso almost straight, for some of the time, and sit fully on the seat at other times. This also helps to alternate between the support muscles and vary the areas of the body compressed by its own weight. For details of chair dimensions see the first part of this document where it addresses Office Ergonomics.

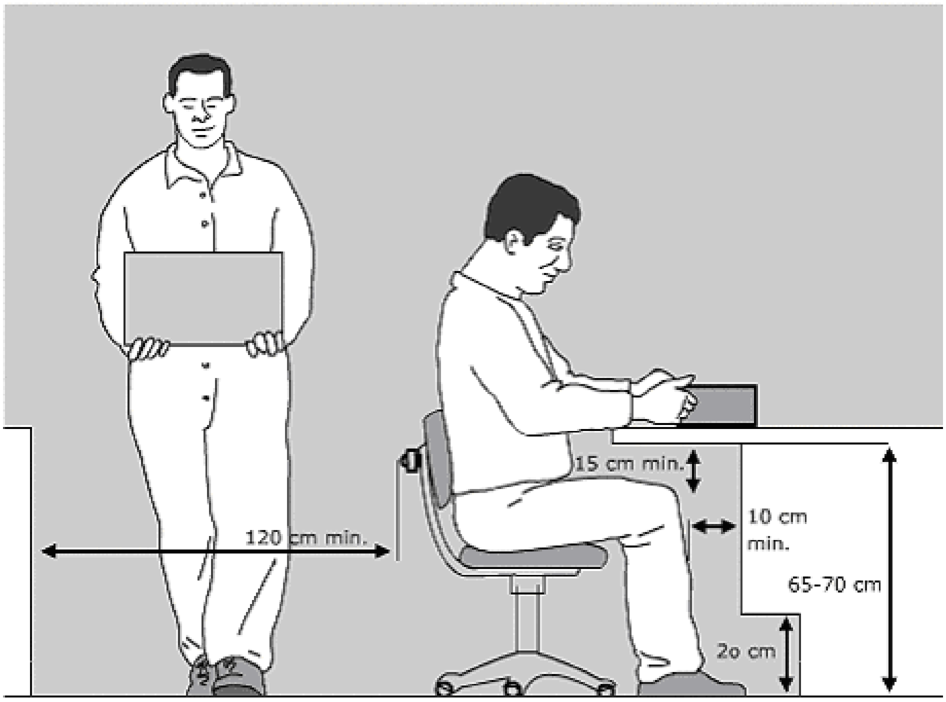
8. Ensure that the workplace is well laid out.

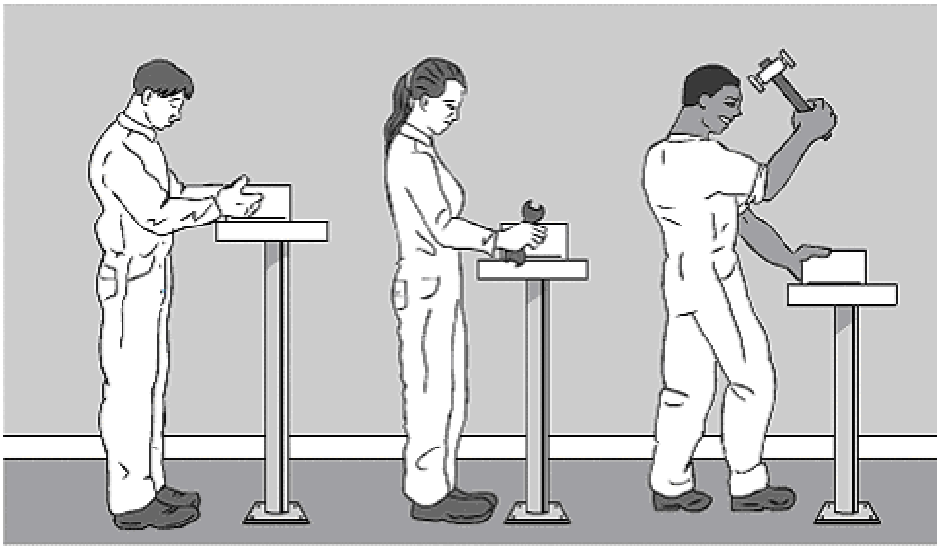
This means a few simple rules such as:
Arrange the work surface height to be 50mm below the elbow.
Place parts bins directly in front of the operator's upper arms
Use the operator's preferred hand
Keep arm motions in the "normal" area: this is the area that can be reached by the operator without bending the torso away from the vertical in any plane.
Let the small woman reach, let the large man fit

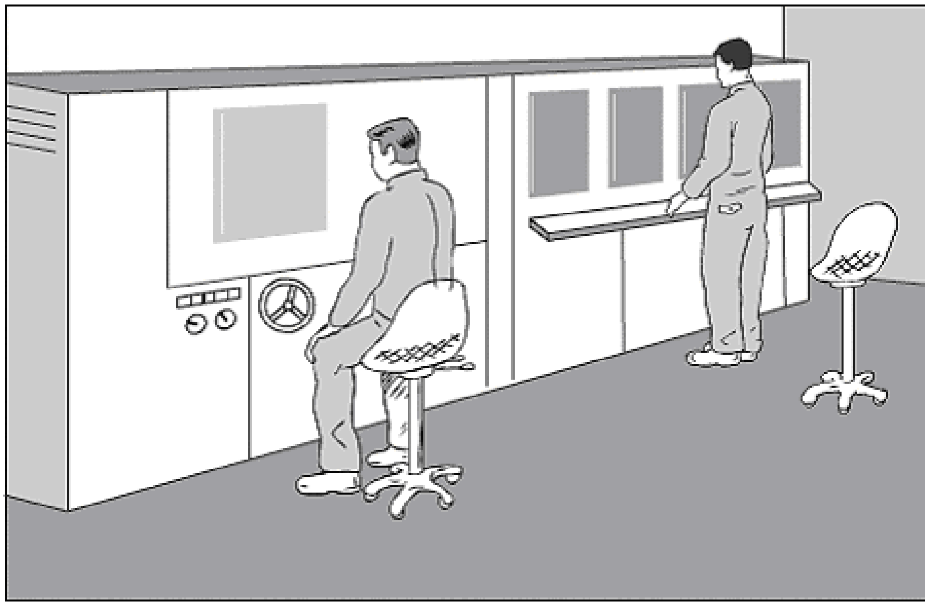
The best approach is to incorporate adjustability into the height and spacing of things in the workplace. A good example is provided by the driver's seat of a modern automobile. In workplaces one way that this can be achieved is to provide a series of boards which can be placed on top of one another to raise the surface on which shorter operators stand.

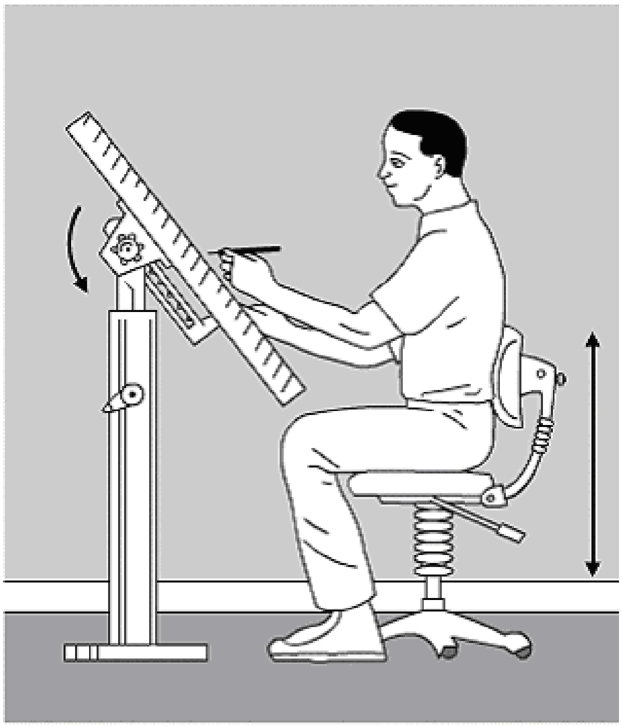
## 5. Illustrations of Good Postures

Just a few examples to show the end result that we are aiming for are shown below:







## Appendix I. Anatomical Terms

Abduction/Adduction

Abduction: movement sideways away from the central axis of the body e.g. away movement of an arm in the same plane as the shoulders

Adduction: movement across the body towards the central axis e.g. movement of an arm from hanging vertical at the side towards the opposite side of the body

Wrist Deviation

Radial Deviation: sideways bending of the hand at the wrist towards the thumb

Ulnar Deviation: sideways bending of the hand at the wrist towards the little finger

Pronation/Supination

Pronation: rotation of the forearm to bring the palm to face down e.g. clockwise for the right arm

Supination: rotation of the forearm to bring the palm to face up e.g. anti-clockwise for the right arm

Flexion/Extension in General

Flexion: movement that reduces the angle between two bones

Extension: movement that increases the angle between two bones

Flexion/Extension at the Wrist

Flexion: when using a keyboard, bending the wrist up and away from the keys

Extension: when using a keyboard, bending the wrist down towards the keys

Body Planes

Sagittal Plane: a vertical fore and aft plane that divides the body into left and right parts, and planes parallel to it

Coronal Plane: a vertical plane across the body through the shoulders that divides the body into front and back segments

Transverse Plane: a horizontal plane at right angles to the above two planes that divides the body into upper and lower portions

## Appendix II. Musculo-skeletal Ailments and Injuries

Carpal Tunnel Syndrome
Tenosynovitis
Epicondilytis
Bursitis
Rotator Cuff Syndrome
Tension Neck
Radial Nerve Syndrome
Tendonitis

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