Practical Ergonomics

Application of ergonomics principles in the workplace.

Human Factors at Work

PRACTICAL ERGONOMICS

Barbara McPhee

A Project funded by the
Coal Services Health and Safety Trust

ACKNOWLEDGMENTS

I am very grateful for the support of a number of people including Ken Cram and Sharon Buckley of the CS H&ST Secretariat and the Members of the Trust without whose patience and understanding this project would never have been finished.

I am particularly indebted to Rebecca Mitchell, Christine Aickin, Marcia Lusted and Cliff Carrasco who have contributed ideas and reviewed the text; to Rosemary Smith for professional editing; to Caroll Casey for indexing services; to Ollie Hetherington from Adgroup for his patience, ideas and the design of the Handbook; to Cara Gray for most of the illustrations; to Bronwen Otto and Ron Stothard for feedback on the text; and to Jim Knowles for putting it all through the 'Jim Test'.

Finally I would like to thank all those people from the Australian mining industry who have worked with me in the past and who never cease to amaze me with their persistence, knowledge of their work and their ingenuity.

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July 2005

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A Handbook by

Barbara McPhee

With contributions from
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Aim

There are many hundreds of textbooks and thousands of papers written on ergonomics and human factors in design. Most contain detailed information that is useful to the specialist or the professional when solving ergonomics problems. However, their technical nature may confuse the non-ergonomist and they may require specialist interpretation.

Ergonomics is often straightforward as much of it is commonsense. At the same time, its application may not be obvious or easy because it involves people and people are complicated. The difficulties in applying ergonomics lie in the differences between people and how these can be accommodated. The combination of sex, age, experience, education, fitness and health, inherent abilities and social values makes every person unique. Everybody can draw on his or her own experience, knowledge and skills to say what is reasonable to expect a person to do but we know that this works only part of the time.

Many jobs contain unnecessary and potentially damaging design faults and organisational obstacles that compound the intrinsic difficulties of the tasks. Normal job demands may then become hurdles increasing errors and reducing productivity and efficiency. These hurdles can also lead to risks to workers' health and safety. For many people it is often difficult to know where the reasonable cut-off point is between completing tasks and maintaining a safe and healthy work environment.

Unfortunately there are very few books available that cater for the needs of workers and their supervisors who have no formal education in ergonomics principles and application. Those that do exist tend to concentrate on the problems of office and industrial work and there are significant gaps when trying to identify and solve problems outside those areas. Nevertheless workers and their supervisors in all occupations in Australia are now actively involved in solving ergonomics problems at work. Usually these are primarily related to occupational health and safety issues but increasingly they also relate to productivity, efficiency, and job satisfaction.

Recognising and solving ergonomics problems requires some knowledge and teamwork. This handbook aims to provide some basic information on ergonomics principles and how workers and supervisors may apply these, particularly for the prevention of health and safety problems at work.

This Handbook is designed as a 'map' of ergonomics: its scope and application in the workplace rather than a complete summary of all issues. It provides introductory material in the form of general principles and guidance that might be of use to people working in heavy industry such as mining, construction, agriculture, forestry and the utilities. For the most part it steers away from recipe solutions and concentrates on the process of ergonomics problem solving. It does not attempt to repeat what is adequately covered in other publications. Key Principles for sections are included.

The reading list (Further Reading) is intended to provide access to further, more detailed or specialised information on different topics. However, it is suggested that when seeking solutions for groups of people, particularly at the beginning of the process, a professional ergonomist can assist in the interpretation of technical material.

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July 2005

Contents

Part C: Measuring the benefits of ergonomics 81

Part D: Additional information 91

Reference symbols

KEY PRINCIPLES • Look for these coloured boxes throughout the book for important key principles.

Introduction

What is ergonomics?

The word 'ergonomics' is derived from an Ancient Greek word meaning 'rules or study of work'. It is also referred to as 'human factors (in design)'. Ergonomics is concerned with appropriate design for people – the design of systems, processes, equipment and environments so that tasks and activities required of them are within their limitations but also make the best use of their capabilities. Therefore the focus of the design is on the person or a group of people.

Ergonomics is a science; it is a rigorous, user-centred approach to research and design. It is also a philosophy and a way of thinking. It is applied widely in areas such as aviation and other transport systems, sport, education, public facilities, the home, recreational equipment and facilities and in the workplace generally. In fact, the whole community benefits from ergonomics design.

Scope of ergonomics

Ergonomists and designers take into account a wide range of human factors and consider biological, physical and psychological characteristics as well as the needs of people – how they see, hear, understand, make decisions and take action. They also consider individual differences including those that occur due to age, fitness/health, or disability and how these may alter people's responses and behaviours.

Human characteristics considered in ergonomics

Anatomy	Anthropometry	Dimensions of the body (static and dynamic)
	Biomechanics	Application of forces by gravity and muscles
Physiology	Work physiology	Expenditure of energy
	Environmental physiology	Effects on humans of the physical environment
Psychology	Skill psychology	Information processing and decision making
	Occupational psychology	Training, motivation, individual differences, stress

From: Singleton WT (1972) Introduction to Ergonomics, WHO, Geneva

As there are many factors to be considered in ergonomics, a range of people are involved in its research and application. Specialist ergonomists usually have university qualifications in ergonomics and related fields and can come from a range of disciplines such as physiology, psychology, engineering, physiotherapy, occupational therapy, medicine, industrial design, architecture, occupational health and safety (OHS), industrial relations and management.

The word 'optimum' is often used in ergonomics and refers to the balancing of the needs of people with real-life limitations such as availability of solutions, their feasibility and costs. Successful solutions depend on solving the real rather than the apparent problem(s). This in turn requires careful observation and analysis.

In reality ergonomics problems and solutions may not transfer exactly from one country, region or industry to another – they have a social context. Although the basic human characteristics are the same they take on local differences for a range of reasons – geographical, social, economic or historical. It can be described as 'the way we do things around here' and relates to the culture of a country, region, industry and/or company. Therefore problems must be identified and addressed locally because each set of circumstances is different. Importing solutions without reference to local issues and resources may fail.

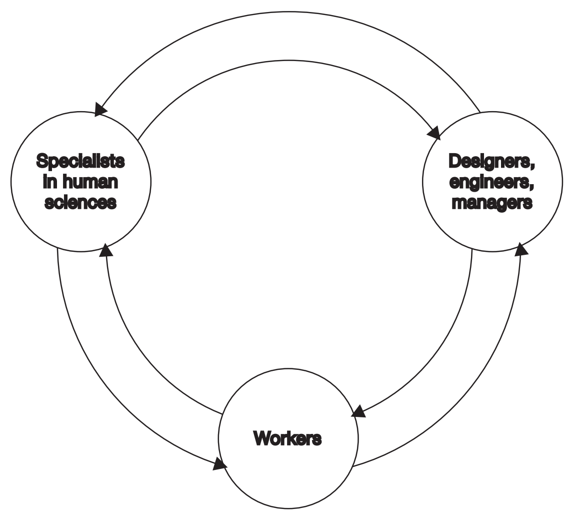


Figure 1.1: The relationship between different contributors to ergonomics

In terms of cost benefits the costs of solutions and the time needed to identify and quantify the problems need to be considered against the cost of making mistakes or having injuries. Unfortunately reduction of work-related disorders is often hard to prove statistically and there is likely to be a long delay before information is available to justify changes. Sometimes it is easier to justify the cost of ergonomics changes because they will make the job faster, easier and probably safer. Therefore the benefits of changes need to be assessed in different ways in the short and long term.

Ergonomics in Occupational Health and Safety

At work ergonomics is applied to the design of the workplace and tasks and to work organisation. It is often referred to as occupational ergonomics within the OHS community. As such it aims to promote health, efficiency and wellbeing in employees by designing for safe, satisfying and productive work.

Positive performance factors such as worker comfort, well being, efficiency and productivity are all considered in determining how to achieve an acceptable result. In this respect ergonomics is different from many other areas of OHS hazard management, where the primary aim is to reduce risks of injury or disease. Good ergonomics in the workplace should improve productivity and morale and decrease injuries, sick leave, staff turnover and absenteeism.

Elements in occupational ergonomics

When analysing work and how it can be improved from an ergonomics point of view there are five elements that need to be addressed:

1. **The worker –** the human element of the workplace. Employees have a range of characteristics that need to be considered including physical and mental capacities; experience and skills; education and training; age; sex; personality; health; residual disabilities. An individual's personal needs and aspirations are also considered.
2. **Job/task design –** what the employee is required to do and what they actually do. It includes job content; work demands; restrictions and time requirements such as deadlines; individual's control over workload including decision latitude; working with other employees; and responsibilities of the job.
3. **Work environment –** the buildings, work areas and spaces; lighting, noise, the thermal environment.
4. **Equipment design –** the hardware of the workplace. It is the part of ergonomics that everybody recognises and includes electronic and mobile equipment, protective clothing, furniture and tools.
5. **Work organisation –** the broader context of the organisation and the work and how this affects individuals. It includes patterns of work; peaks and troughs in workload, shiftwork; consultation; inefficiencies or organisational difficulties; rest and work breaks; teamwork; how the work is organised and why; the workplace culture; as well as the broader economic and social influences.

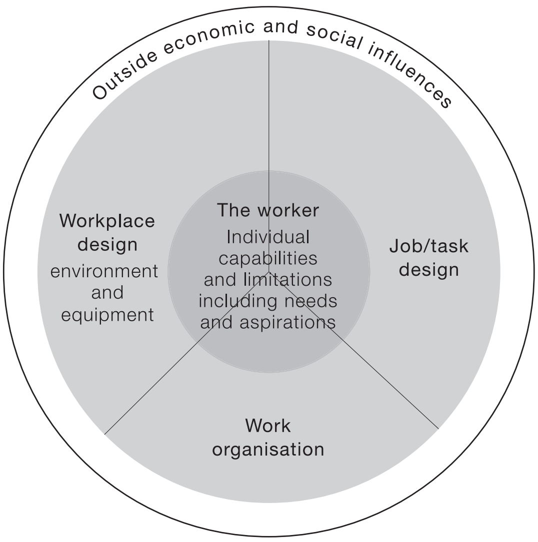


Figure 1.2: The relationship between different elements of ergonomics

To design better jobs we need to know about the work and how it will be done. We also need to know about the people who will do the work and their capabilities and limitations. Not only do we need to consider physical and mental aspects but we also need to take into account individual aspirations and needs –

the social component. As work changes over time reviews and modifications are constantly required if systems and people are to work harmoniously and efficiently. No matter how well the workplace is designed it can be undermined by poor job design and work organisation.

Seeing the whole picture

As most people realise disorders arising from work can have a number of causes and they are not always obvious. Organisations are complex and people are too. For instance we now know that physical disorders may not arise purely from physical stresses. Psychological and social factors can contribute to the development of symptoms in some individuals at particular times. In order to understand these issues we need to examine the work and its organisation more broadly and understand how various work factors may interact with each other and how personal factors might change the impact of work factors.

In occupational ergonomics, the physical design aspects of work or the ‘hardware’ may be only part of the problem and therefore part of the solution. In some cases it may be a small part. Other factors influence the development of a problem including work organisation and task design, job content, work demands and control over workload, support and training. Usually these aspects require ergonomics to be integrated into the broader work systems.

Therefore to determine if an optimum solution has been achieved the people who will perform the work (the ‘who’), the nature of the tasks (the ‘what’) and the context in which they are done (the ‘where’, ‘when’ and the ‘how’) need to be considered.

Human capacities and limitations

The sense organs

Humans make physical contact with their environment through their senses. Information is conveyed to the brain through sense organs such as the eyes, ears and nose.

The stimulus has to be strong enough for the senses to detect before a person can be aware of any stimulation from the environment. The 'absolute threshold' marks the difference between being aware and not being aware of a stimulus and this may vary at different times and under different conditions.

A second threshold, termed the 'difference threshold', refers to detectable differences between two stimuli that can be observed by an individual.

People's senses adapt to various stimuli in different situations. If the stimulus is constant and familiar the sense organs can become insensitive to it.

Eyes

The eye operates like a camera catching (through the pupil) and refracting light (lens) and converting it to a picture (retina to the optic nerve).

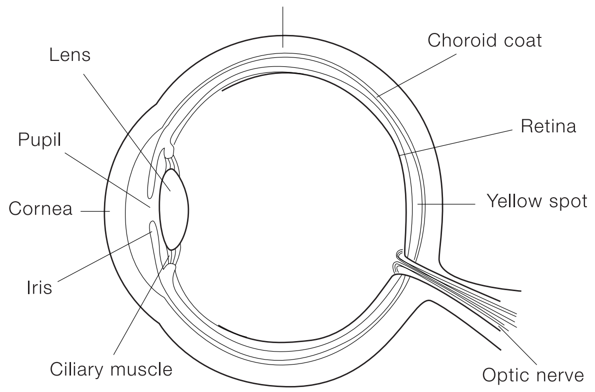


Figure 2.1: Anatomy of the human eye.

Eyes are susceptible to hazards such as flying particles and irritating dusts, chemical or radiation damage and, in cases of inadequate lighting, eyestrain. Protection for the eyes can be achieved either with physical barriers that protect against foreign objects eg safety glasses or by improving workplace and task design so that the eyes do not have to work too hard – reducing glare and reflections, optimising workplace lighting and viewing object qualities such as contrast, colour, size and shape. This includes the design of displays and printed material. (See also Illumination and lighting; Displayed and Oral Information).

A small percentage of the population is colour-blind. These people are usually men with varying degrees of red/green blindness. This can be critical for certain occupations and when viewing visual displays involving these colours.

Ears

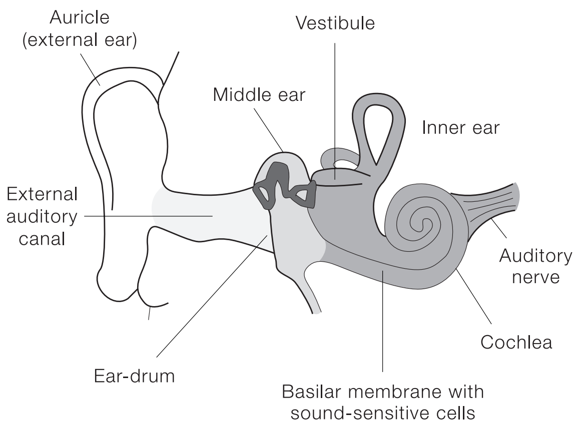


Figure 2.2: Anatomy of the human ear.

The ear and auditory system are more complicated than most people realise. It consists of the external ear, middle ear (separated from the external ear by the ear drum), inner ear and the central auditory pathways. Sound travels to the ear in waves. These are transmitted via the auricle (visible part) and external auditory canal through the eardrum to small bones in the middle ear that vibrate. From there the vibrations are transmitted to the inner ear and to the sensory cells of the cochlear that respond to particular frequencies or pitches. The cells transform the sound waves to nerve impulses that are transmitted to the brain. The cells and hairs can be damaged when exposed to loud noise.

Different kinds of noise affect hearing in different ways: the higher the pitch the worse the effects; the clearer the tone the greater the hazard; the higher the intensity the greater the damage. The greater the length of exposure to damaging noise on a daily basis the greater is the risk of hearing loss. (See also Noise).

The ears also contain the semicircular canals that are necessary for balance and body orientation.

Skin

The skin is the largest (1.4-2 square metres) visible part of an individual and is also the body's largest organ. It protects tissues underneath from physical and chemical damage as well as protecting the body from drying out and abrupt changes in temperature.

The skin contains:

- **sweat glands –** help maintain an even body temperature;
- **fine blood vessels –** assist in temperature control, nutrition and waste removal;
- **nerve endings –** act as sensory receptors for heat, cold, pain, pressure and touch;
- **sebaceous glands –** secrete substances to keep the skin supple and protect it from harmful bacteria.

Exposure of the skin to some substances and physical agents, such as the sun, may cause skin irritation, non-allergic contact eczema and burning. Protection of the skin is achieved best through elimination of or isolation from the substances and agents, and less effectively with PPE.

Nose

The nose both transmits sensations of smell and filters and alters the temperature of the air that an individual inhales. An individual's sense of smell adapts quickly to some smells. However, some of these may tell a worker that there is a problem.

Workers may need respiratory protection in environments where unpleasant or noxious smells cannot be eliminated. Dangerous, unnecessary and/or unpleasant smells will need to be controlled where the sense of smell is needed as an early detection monitor.

Taste

Taste buds are on the tongue and respond to the sensations of sweetness, salt, bitterness and sour tastes.

Posture and movement

Kinesiology is the science of human movement as it relates to the structure of the musculoskeletal system. It describes motions of the body segments and identifies the muscle actions responsible for those.

Posture provides the basis for movement and refers to the angular relationships of the body parts and the distribution of their masses. These elements influence the stability of postures, the loads on the muscles and joints, and how long different body positions can be maintained before fatigue sets in.

The interaction of human movement and posture is called biomechanics and this deals with the levers and arches of the skeleton, and the forces applied to them by the muscles and gravity.

Movement and posture is fundamental to human existence. People have evolved through the activity and postures imposed by their living conditions and their need to feed, clothe and look after themselves. As a result, human physical performance is optimum when postures and movements are dynamic and varied. (See also Problems Arising from Poor Task Design; Rest and Work Breaks).

In general the human body moves and works most efficiently when joints are in the neutral (mid) range and the muscles are around mid length pulling at right angles to the bone. However, movement of joints through their full range each day is necessary to keep the body supple and the joints and muscles working efficiently.

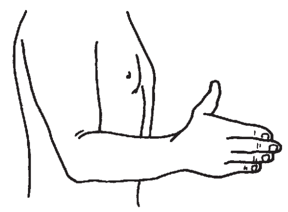


Figure 2.3: Mid position for the shoulder elbow and hand.

Balance and movement control

Balance is the ability to maintain equilibrium in different positions. This changes with the size of the base of support such as the feet, the buttocks in sitting or the whole body in lying and the height of the centre of gravity. Balance is maintained in standing and sitting by continually making minor corrections of position. In general we maintain stable postures by static balancing and unstable postures by dynamic balancing such as in walking.

As the position of a person's limbs changes sensors in the muscles, tendons and joints relay this information to the brain. This allows a person to know where different parts of their body are in space even when they cannot see them.

Both the muscle and joint sensors as well as those located in the ear (semicircular canals) are essential for balance and co-ordinated movement.

Muscle work

Muscle exerts its effects by contraction, which is the development of tension in a muscle. However when the muscle 'contracts' it does not always shorten. Contraction may be static (no movement) or active (movement). These states are further categorised as:

1. Isometric (static) – the muscle builds up tension but the length remains unchanged. Static muscle work is the most energy efficient but is also the most tiring. Compression of blood vessels and nerves stops nutrients and wastes from muscle activity from being dispersed eg when attempting to lift an immovable object or when an object is held stationary.

2. Concentric (active) – muscle fibres contract to shorten the muscle eg the biceps muscle bends the elbow and overcomes the resistance of the weight of the arm, the source of the resistance being inertia and the force of gravity.

3. Eccentric (active) – allows for controlled lengthening of the muscle(s) against gravity.

Static muscle work is common in postural muscles of the neck, shoulders, back and buttocks. These stabilise the trunk allowing for more accurate and efficient movement of the limbs. The positioning of the body for optimum movement occurs naturally where the environment allows.

Both types of active muscle work use more energy but are less tiring than static muscle work.

Levers in the body

A muscle seldom acts alone; most muscle action involves the complex integration of muscle activity to produce whole movements. Most movements employ lever action, the bones acting as levers and the muscles applying force about a fulcrum (joints).

Three types of lever action are employed:

1. First order lever – mechanical advantage is determined by the length of the lever on either side of the fulcrum eg the see-saw and nodding of the head.

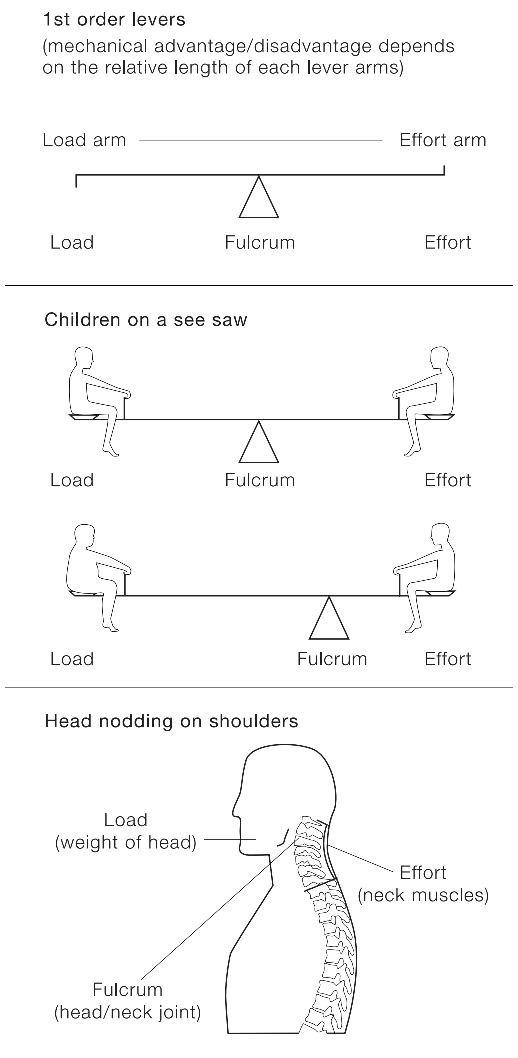


Figure 2.4: First Order Levers

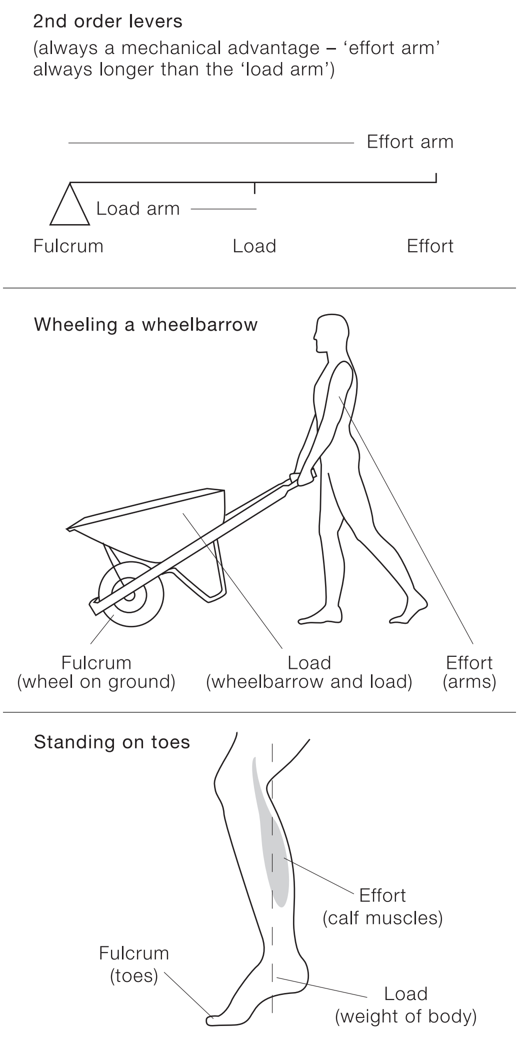


Figure 2.4: Second Order Levers

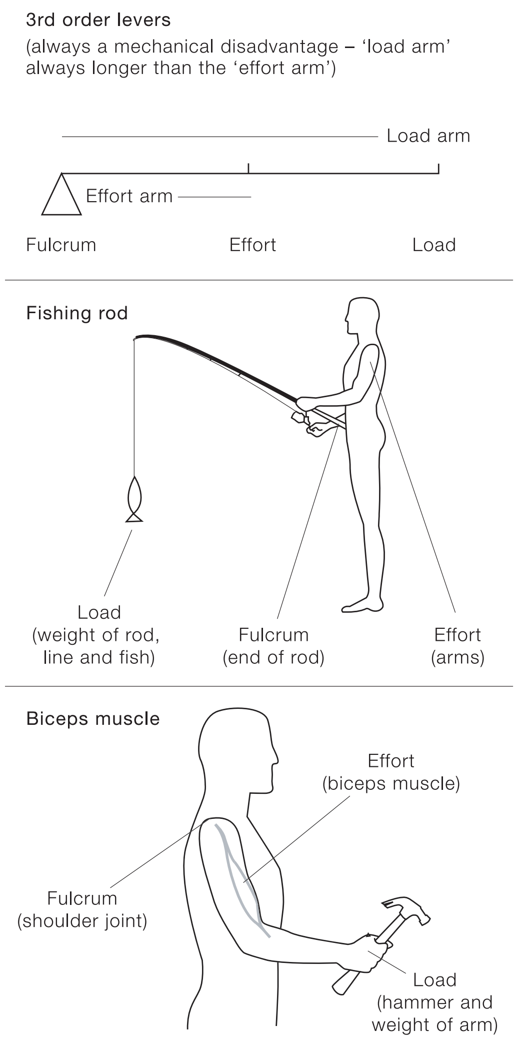


Figure 2.4: Third Order Levers

2. Second order lever – a relatively small force (the calf muscles pulling on heel) acting through a large distance lifts a large weight through a short distance. This always imparts a mechanical advantage eg a wheelbarrow or in tip toeing.

3. Third order lever – a relatively large force (in this case the muscles of the upper arm) acting through a short distance lifts a smaller weight through a large distance. This always leads to a mechanical disadvantage eg pulling up a fishing rod the lower end of which is supported against the body or in lifting an object by bending the elbow.

Most levers in the body are third order and as a result the body is very inefficient at generating force. The human body usually works at a large mechanical disadvantage and considerable energy is required to achieve modest output.

However, third order levers give humans some special advantages. These are speed, range and precision of movement.

As a rule of thumb in ergonomics work should never be designed so that it requires strength and precision at the same time. This can place intolerable stresses on muscles and joints especially if it is required for repeated or extended periods during the working day.

The upper limb

The upper limb comprises the hand, wrist, forearm, upper arm and shoulder. The hand is comprised of 19 bones with a further eight in the wrist. It is highly flexible but also delicate and has evolved to manipulate and feel small items with a great degree of sensitivity and skill. It does not have intrinsic strength or mechanical power as the muscles of the hand are very small and are adapted to fine movements and precision. Some mechanical power can be achieved through the larger forearm muscles acting on the fingers and through body leverage. Therefore the hand can perform two different types of grasp – the pinch or precision grip and the palmar or power grasps. (See Figures 2.5 and 2.6)

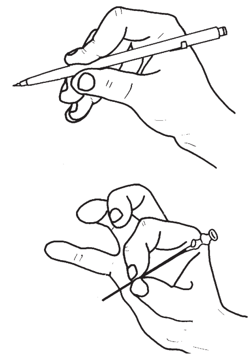


Figure 2.5: Pinch or precision grip

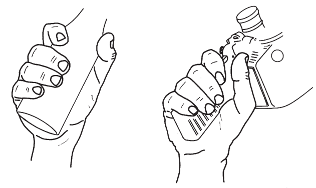


Figure 2.6: Power grasp

Both require the forearm and particularly the hand to be stabilised. This is achieved by forearm, upper arm, shoulder and trunk muscles which for the most part are working statically. The manipulative ability of the hand is improved by the full range mobility of the shoulder joint, the hinge action of the elbow and by the rotation of the forearm at the elbow and wrist.

Strain injuries in the upper limb

The hand is a delicate and highly complex machine at the end of a very flexible lever on a mobile body but its ability to perform depends to some extent on the rest of the body. Its optimum position (neutral position) is called the position of function. (See Figure 2.8). Where the shoulder or the trunk cannot be positioned for optimum movement of the hand all three areas may suffer strain. This possibility must be considered in relation to the physical layout of work or the demands of the task.

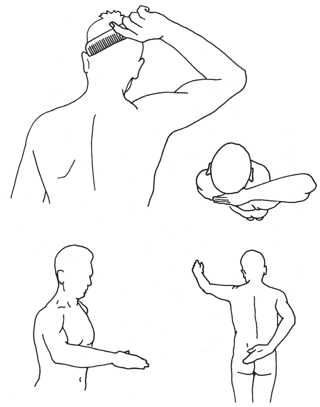


Figure 2.7: Shoulder flexibility.

Similarly where joints are in their outer or inner positions repeatedly or long periods, all structures – capsules (connective tissue around a joint), ligaments (strengthening tissue in a capsule), tendons (join muscles to bones) and muscles – may be stressed. For most people such positions are held for short periods and are desirable intermittently. They are not difficult or damaging unless maintained for long periods or repeated many times. Sitting reading or sewing with the neck bent is an extreme posture and may lead to considerable discomfort if continued over any length of time.

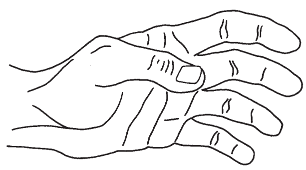


Figure 2.8: Position of function.

Work that requires the human body to adopt fixed postures and to repeat movements has become common over the last two to three hundred years. In such jobs the body must work in a way that it was never evolved to do. Repeated movements, be they light or forceful, and fixed work postures, such as at a computer terminal, a work bench or conveyor line put mechanical stress on the body. This cumulative loading on muscles, their capsules and ligaments sooner or later results in fatigue and perhaps strain, and eventually disorders such as Occupational Overuse Syndrome (OOS). (See also Problems Arising from Poor Design)

The spine

The spine is made up of a series of bones called vertebrae. Discs and a series of muscles, fine ligaments and capsules hold the 24 moveable vertebrae together. The discs act as shock absorbers and allow the spine a great range of movement and postures, which are controlled and activated by the muscles. Ligaments and capsules protect the smaller joints in the spine. There are four fixed vertebrae in the lower end of the tailbone known as the coccyx. (See Figure 2.9)

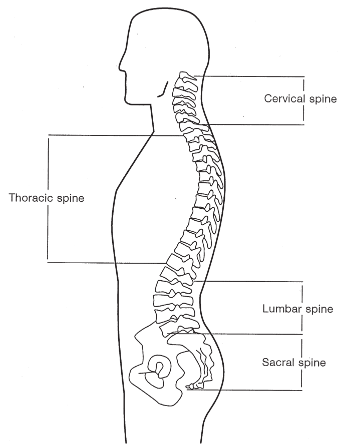


Figure 2.9: The human spine

How strong is the spine?

The spine is often considered a 'weak link' in humans because it is frequently subject to injury. The exact reverse is true. The spine is the axis of human movement and must meet two competing mechanical requirements: rigidity and plasticity. The muscles and ligaments act like the stays on a ship's mast to achieve this. The spine sits on the pelvis and extends to the head and neck. The shoulders are set transversely and act like a mainyard to stabilise the upper spine and this is linked in turn by muscles and ligaments to the pelvis. (See Figure 2.10). These multiple components superimposed on one another and interlinked with muscles and ligaments allow for movement and stability. It is therefore a remarkably adaptable and flexible structure.

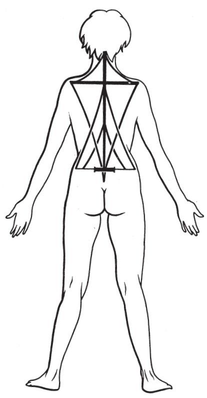


Figure 2.10: Supporting structures of the spine

Flexibility and adaptability come at a price and that is strength. The spine is not well designed for the heavy loads and the repeated abuses it suffers in modern life. It needs to remain reasonably flexible and strong to function correctly.

Overweight, lack of physical fitness and overuse lead to injuries and these are common in leisure and work. Most injuries, especially in the early stages, are simply muscle strains and small tears of the ligaments or other supporting soft tissues. However, over time more serious injuries can develop and may result in damage to the vertebrae and, more commonly, the intervertebral discs. Therefore back injuries are nearly always cumulative in nature and arise after months or years of excessive loads on the structures of the back.

KEY PRINCIPLES

- Human physical performance is optimum when postures and movements are dynamic and varied.
- In general the human body moves and works most efficiently when joints are in the neutral (mid) range and the muscles are around mid length.
- If joints are held in more extreme positions over extended periods strain can occur.
- Static muscle work tends to be more tiring than active muscle work even though the latter uses more energy. Most stabilising postures involve static muscle work.
- Most levers in the body are third order and therefore the body is most inefficient at generating force. However, third order levers give humans some special advantages. These are speed, range and precision of movement.
- Work should not require strength and precision at the same time.
- The upper limb (arm and shoulder) is capable of highly skilled and precise movements but is not strong and is subject to strain injuries. The shoulder is particularly flexible but can be unstable in certain positions.
- The spine can meet two competing physical requirements – rigidity and plasticity but this comes at a cost, which is strength. It is therefore subject to injury when it is strained.

Body size

Anthropometry refers to the dimensions of the human body and how these are measured. It covers the size of people; their height and circumference; their weight and percentage body fat; the length and range of movement of their limbs, head and trunk; and their muscle strength.

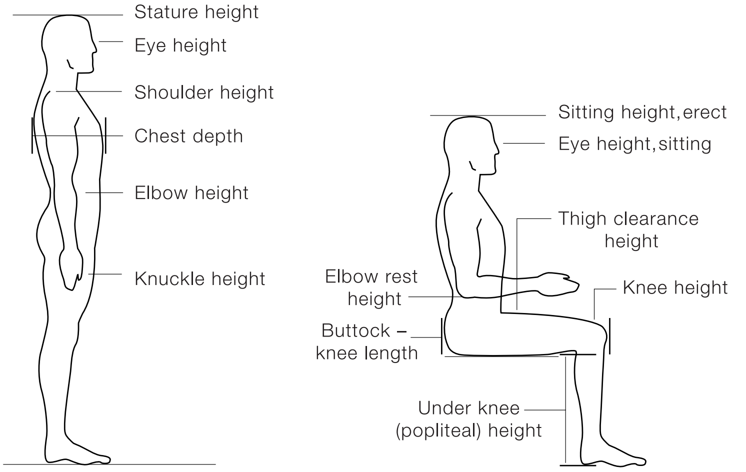


Figure 2.11: Static body measurements

Measurements of large numbers of people are needed in any given population to determine ranges, averages and percentiles. Children of different ages, male and female adults and older people all may be included in the population sample depending on how the data may be used.

Measurements are made in two different ways – referred to as static and dynamic anthropometry. The most common measurements are made with the body in rigid standardised positions and this is static anthropometry. Dimensions are linear and are made relative to the body surface eg standing height, length of leg, head circumference. Measurements are standardised using the same methods and postures on different individuals but they allow comparisons between individuals and between population groups. They provide information on the size differences of individuals but they are not functional measurements.

Dynamic or functional anthropometry, in which dimensions are measured with the body in various working positions, is more complex and difficult to perform but it has important applications in the workplace. Measurements are three-dimensional and describe such things as space envelopes in driving cabs, arcs and ranges of movements for the optimum use of controls, and safety clearances.

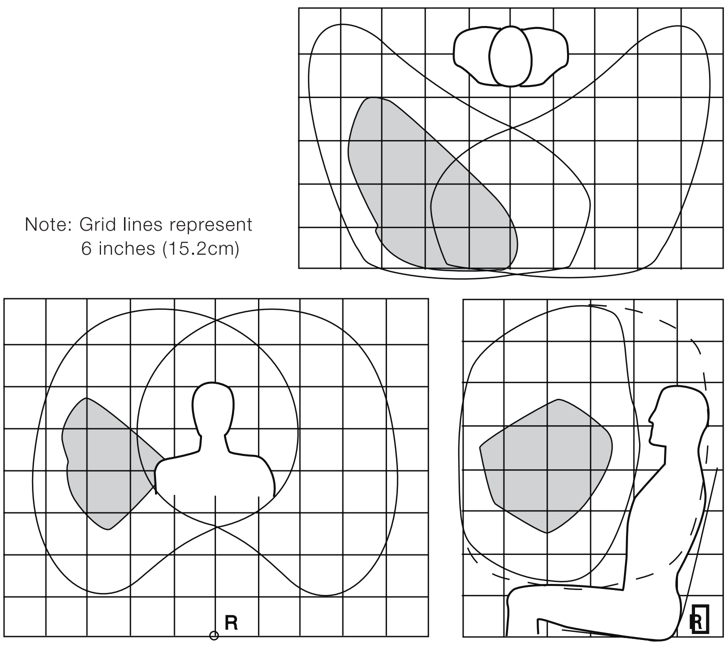


Figure 2.12: Space envelope – hand movements and hand grasps depicted in three-dimensional space showing the optimum for different manipulations

Using anthropometric information

In workplace and equipment design, ranges of dimensions are often specified to allow for the short and the tall, the fat and the thin and those who may be differently proportioned to the average. Ranges can include extremes at either end such the 5th percentile in height represents people who are in the shortest 5%, while the 95th percentile represents the tallest 5%.

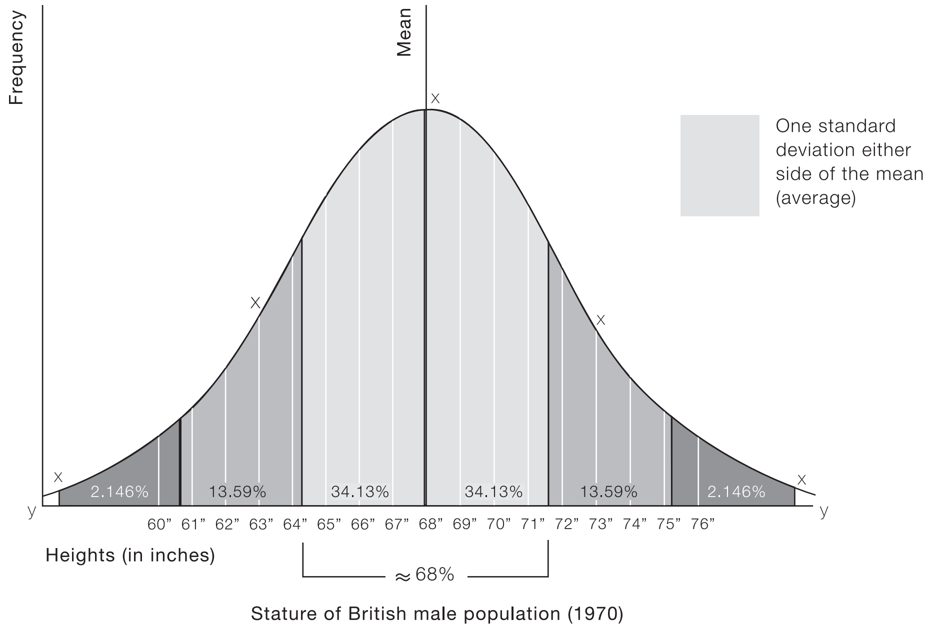


Figure 2.13: Curve of normal distribution showing range of height for British men. One Standard Deviation from the mean (average) represents nearly 68% of men with a range of about 7 inches (180mm).

Often a design needs to suit the majority of the population as far as possible while not accommodating everyone in the extremes of range eg seats in a bus or an aeroplane suit 90% of the population adequately but may be very uncomfortable for very short or tall or obese people. In these cases static dimensions are used as a guide e.g. average (mean) height of the travelling population.

In most dimensions the middle 68% of the population can be accommodated relatively easily with little or no adjustment required. Ninety-five percent of the population can be accommodated with some flexibility in design or by using adjustments eg desks and chairs. It may be very uncomfortable to achieve a fit for very tall/short or big/small people above 97.5 percentile or below 2.5 percentile.

If it is possible to use equipment lower/higher/wider/narrower than the optimum, variation is limited to one direction – it has a one-way tolerance eg the height of a door for a tall person, the height of shelf for a small person.

Some design is concerned with static dimensions such as body height (stature), leg length or shoulder width. For instance, thigh length governs the optimum depth of a seat for a particular person while lower leg length dictates the height of the seat.

Where dimensions may not be critical, one dimension, usually stature, may be used as an approximation of other dimensions such as leg length and shoulder width. Using commercially available data tables other static dimensions can be derived. However, this method must be used with care as there are many exceptions to the rule and all the data that are readily available in this form are from the USA or Europe.

Factors that effect body size

The following factors effect body size:

- **age –** there is an increase in dimensions from birth to age 20 in males and to age 17 in females with a decline after 60 years.
- **sex –** men generally are physically larger except in hip breadth and thigh circumference than women. Men's arms and legs are longer than women's absolutely and relatively in standing and sitting.
- **ethnicity –** statistical variations occur in size, proportions and body builds between people of Asian, Caucasian and African racial backgrounds as well as within each of these groups eg between nationality groups such as Scandinavian and Mediterranean people.
- **fitness and health –** the presence or absence of disease, nutrition and physical fitness can significantly effect height and size.
- **occupations –** workers in active jobs may tend to be physically larger than those in sedentary work. This may be due a self-selection process but is also related to age, diet, health and activity. However sedentary workers tend to have more body fat due to inactivity.
- **posture and body position –** differences in measurements occur between rigid and slumped postures, and dynamic and static measurements. The rigid, static measurements may provide a starting point for design but the dynamic or more functional postures are more likely to reflect the true situation.

KEY PRINCIPLES

- Consider differences in users' body size in the design of furniture, equipment and tools. Allow for different sized users by incorporating adjustments or other methods where the fit between the equipment and user is critical.
- When in doubt measure the standing height of your working population to determine roughly the range of sizes that you may need to consider.
- The middle two-thirds of the population can be accommodated relatively easily. However, designing for the other third (one sixth either side) may need more attention and time.
- Body size changes with age and different levels of fitness and health.
- Decide beforehand if you need to accommodate people in the extremes of body size range and make special provision for these people in the design of the workplace.
- Use static and dynamic body dimensions appropriately.
- Use the appropriate anthropometric tables for specific populations.
- Commercially available anthropometric tables are useful as a guide when designing work, workplaces and equipment but they should be interpreted with care.

Further reading: *• Book 2: Kroemer & Grandjean • Book 3: Sanders & McCormick • Book 4: Stevenson • Book 18: Pheasant*

Physical strength and work capacity

Strength

Differences between men and women

While some women are stronger than some men on average men are one third to one half stronger than women. This is due to body size, muscle mass (40 – 45% of body weight in men and 25 – 25% in women), the distribution and percentage of fat, and muscle bulk in the shoulders, abdomen, hips and legs.

Differences between younger and older workers

Muscle strength peaks are reached in men at about 20 years old and in women a few years earlier. Maximal oxygen uptake, heart rate, stroke volume, lung ventilation and muscle strength decrease significantly with age. In both sexes maximal aerobic power reaches a peak at the age of 18-20 years followed by a gradual decline. At the age of 65 the mean value of aerobic power is about 70% of what it is for a 25year-old. The mean value of aerobic power for a 65-year-old man is roughly the same as a 25-year-old woman.

The strength of a 65-year-old individual is, on average, 75-80% of that attained at the age of 20-30 years when medical conditions are not a limiting factor. The rate of decline in muscle strength with age is in both sexes greater in the leg and trunk muscles than in the strength of the arm muscles. The decline in muscle strength with age is due to a decline in muscle mass.

Work capacity

The capacity of an individual to undertake physical work can be measured directly by examining the individual's maximal oxygen uptake or indirectly by measuring heart rate. Heart rate is a reliable measure of workload and is easily measured in the workplace.

To maintain a work level all day for a fit, young and healthy person, 25-30% of the maximal aerobic power (oxygen uptake) is usually acceptable. Maximal aerobic power varies markedly between individuals and the important thing is that individuals are measured against their own basic cardio-vascular capacity. However for all people the heavier the work rate the shorter the work periods should be.

Maximal heart rate can be roughly estimated as 220 minus the individual's age. For instance for a 40 year old person the maximum heart rate could be expected to be about 180 beats per minute. In most people a heart rate of about 120-130 beats per minute corresponds to a workload of 50 per cent of the individual's maximal oxygen uptake. These figures would need to be modified for older, less fit or dehydrated workers.

An average heart rate of 110 beats/min for moderate levels of work is generally acceptable physiological limits for an 8-hr working day for a 20 to 30 year old person. Exceeding these limits, even slightly for some people, may lead to fatigue (tiredness) and general lack of coordination, which may result in errors and injuries.

Environmental factors such as temperature, humidity, air velocity, (see also Work in Hot and Cold Environments) noise, vibration and dust need to be considered carefully as these may effect the performance of individuals doing strenuous work. They may decrease the person's alertness, concentration or physical capacity for work thereby increasing the risks of errors and injuries.

Endurance and efficiency of muscles

Efficiency of muscular contraction is desirable at work. It may be promoted by:

- eliminating unnecessary movements;
- using muscles according to their correct function;
- making use of body weight and momentum and of gravity;
- maintaining balance;
- varying movements;
- varying position and posture;
- employing postures allowing maximum torque;
- using accessory supports for counterthrust or stability;
- training and practice.

Endurance of a given muscular performance varies with the nature and intensity of exertion, the size and structure of the muscles involved, and practice in the task. Static effort can be endured for much shorter periods than exertion involving movement. Endurance fails sooner when either rate of work or load is increased, or when degree of contraction of muscles approaches maximum levels. Postural muscles have greater endurance than faster moving muscles, which are designed more for speed of contraction; most muscles have variable amounts of red or pale fibres depending on their main function, movement or support of posture.

Practice increases power and endurance, due largely to better coordination and elimination of unnecessary contraction: the same end is achieved with less effort. Training enhances the speed, strength and stamina of muscle contraction. However, motivation is also of great importance in any activity requiring endurance of muscular effort.

In prolonged static or repetitive muscular exertion, the maintenance of constant speed and load requires a progressive increase in muscle activity ie more contraction for the same output, both in the muscle group mainly involved and in recruitment of other muscles. Movements become larger and longer, one running into another, and involuntary contractions of other muscles occur. Eventually, the manner of achieving the task may change and there may be a reversion to earlier established habits. These changes are related to the onset of muscular fatigue.

Physical fatigue

If particular movements are carried out continuously it is reasonable to expect all the muscles to tire, both those executing the movement and those stabilising or enhancing the movement. Stabilising (static muscle work) is more fatiguing than muscle contractions that cause movement (active muscle work). As fatigue can lead to strain the effect of unchanging postures and static muscle work can be equally as damaging as highly repetitive movements. Muscles may tire and become sore to touch and move. Points of weakness such as the muscle/tendon/bone junction at the knee, shoulder or elbow or the tendons over the ankle or the wrist suffer damage and lead to pain.

Dynamic physical work can also lead to problems if it is excessive for the particular individual. Movements in the outer range of the muscle or the joint, heavy lifting, pushing, or pulling (forces that are too high), movements that are prolonged (duration of activity) or repetitive can lead to strain and fatigue and eventually injury. In this respect younger and older, trained and untrained individuals, as well as men and women can vary widely in their capacities. Health and nutrition, previous injuries, lifestyles and natural abilities also play a part in contributing to a person's capabilities to undertake a specific task. (See also Problems Arising from Poor Task Design)

KEY PRINCIPLES

- Incorporate frequent short breaks in the work rather than a single long one.
- Limit duration of continuous muscular effort.
- Vary tasks, postures and movements as much as possible.
- Limit energy expenditure in a task to a reasonable level.
- Ensure appropriate frequency and length of rest breaks in all work but especially in heavy tasks, repetitive work and hot work.
  - Avoid:
    - ~ work in fixed or awkward postures
    - ~ sudden or jerky movements
    - ~ sudden peak forces
    - ~ prolonged repeated work with the same muscle groups
    - ~ working with the joints in the extremes of their range movements for more than a few minutes at a time
    - ~ prolonged periods of continuous muscular effort.

Further reading: *• Book 20: Rodahl*

Information processing and decision-making

Humans process incoming information and make appropriate decisions regarding this information in any work environment. When an individual receives a stimulus it progresses to a short-term sensory store. From there stimuli are moved to a perception stage where the incoming information is matched with prior knowledge or experience of a similar situation. A decision is then made regarding the appropriate action to be taken in a situation. A response may be selected immediately or additional information may be required for further processing.

Further processing will involve working memory and long-term memory. Working memory holds a limited amount of both verbal and spatial information, while long-term memory holds information that a person has retained during their lifetime and this information may be retrieved in order to aid in the decision-making process.

The level of attention of the individual varies with each stage of information processing and with the level of arousal of the individual. Difficulties regarding decision-making can occur at any stage of the model.

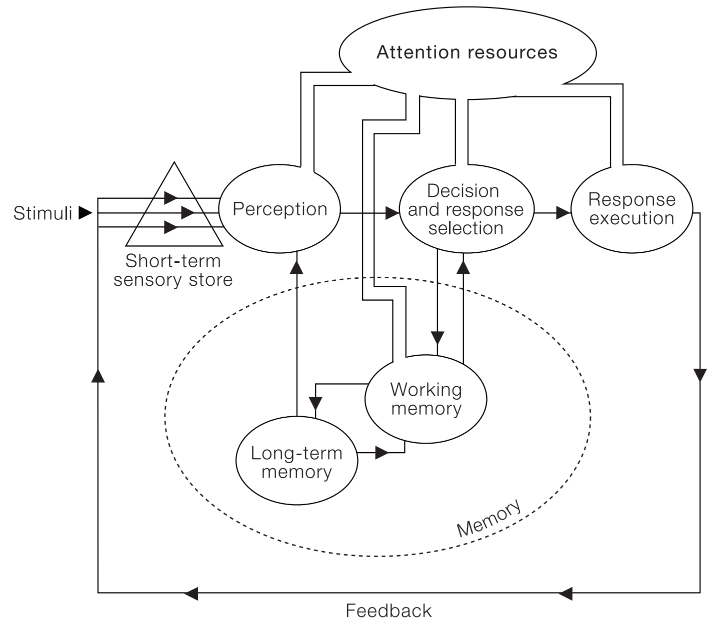


Figure 2.14: Wickens' model of human information processing.

If numerous events occur at the same time an individual might have trouble processing a lot of information at once and critical information may be missed, or the correct information might not be able to be retrieved from long term memory (forgetting) or incorrect information may be retrieved. (See also Human Error).

Controlled and automatic processing

People can attend to multiple sources of information from their surrounding environment at the same time. As an example, it is possible for an experienced driver to drive a vehicle safely and listen to the radio. Individuals can process two types of information simultaneously. This is called parallel or dual processing and can be divided into two main types:

- **controlled processing –** requires intentional effort;
- **automatic processing –** occurs without an individual's conscious awareness when a particular event or procedure is well known and is repeated often eg a person's ability to ride a bicycle usually improves with practice and the movements become automatic.

Individual variation

Individual factors such as the level of fatigue, boredom/ arousal, stress and skill level and environmental conditions such as the physical environment, job/ task design and organisational features can influence a person's information processing and decision making ability.

Both personal and environmental factors need to be addressed to ensure an optimal environment for decision-making. For example, people can be rotated through different monotonous tasks to decrease boredom. If necessary, specific tasks or jobs should be re-designed. (See also Task Design)

KEY PRINCIPLES

- Incorporate appropriate rest breaks and variation of tasks.
- Limit the difficulty level of tasks.
- Ensure the worker's skills and ability matches work demands.
- Ensure the work environment is optimal for the tasks to be completed.
- Avoid:
  - ~ Environmental hazards, such as poor lighting, glare, excessive noise or temperature
  - ~ Prolonged work on monotonous tasks
  - ~ Confusing or complex displays of information.

Human error

A human error has been defined an inappropriate or undesirable human decision or behaviour that reduces, or has the potential for reducing effectiveness, safety, or system performance.

Several systems have been developed in order to classify the types of errors that people can make. Two frequently used methods are based on information processing or on actions. Rasmussen distinguished between three levels of human performance:

1. Skill based performance;
2. Rule based performance;
3. Knowledge based performance.

Reason adopted this approach and extended it. He maintained that each type of performance produced different types of errors, with different causes and solutions.

Information processing errors

Skill based performance – Failures in the execution of the planned action – either performing an action that was not part of the original plan (slip) or missing out a part of a sequence of the original plan (lapse). The cause is inappropriate checks on performance (attentional failures). These are operational errors made by the individual; they are almost subconscious actions and make up the majority of errors.

Rule based performance – Failures are in the selection of the correct plan of action – either applying a rule that was not appropriate in this situation, or applying a 'bad' rule. These are tactical errors; they are informal and common and arise from inadequate rules governing performance.

Knowledge based performance – Failure in active problem solving arising from normal decision making biases; poor 'knowledge' or an incomplete mental model of a situation. These errors in decision-making are strategic, formal, planned and rarer.

Each type of performance produces different types of errors with different causes and solutions. For instance, knowledge-based errors can be occurring for months at a high decision making level of the organisation. These can lead to catastrophic outcomes. On the other hand a skill -based error may happen quickly and affect just one person.

A fourth level is referred to as a violation. This is where a person knows that they are performing an incorrect (inappropriate) action, but chooses to do so anyway and his/her actions are carried out as intended. There are a number of 'causes' of violations. The motivation to act according to the rules is not present; positive consequences of breaking the rule outweigh negative consequences; there was no choice but to break the rule (conflicting rules); or there was a personal 'need' to break the rule (perception of societal norm, sensation seeking).

Actions-based errors

Using this system individuals can make two types of errors – an error of omission, where part of a task or the entire task is omitted and an error of commission, where a task is performed, but performed incorrectly.

There are several types of commission errors:

- **improper selection –** involves making the incorrect selection eg hitting the start button instead of hitting the stop button on a piece of machinery;
- **sequential errors –** occurs when actions are performed in the wrong order, eg a forklift operator raises the tines, selects a container from a stack and transfers it to another location without lowering the tines. The container falls;
- **timing errors –** occur when actions are performed at the wrong time eg while operating a pressing machine the operator takes too long to remove his hand from the press and his hand is crushed;
- **qualitative errors –** involve actions where the poor quality of the information constitutes an error eg the wrong date is put on a permit-to-work and an electrician is electrocuted because he commences work on the incorrect day when the electrical supply is still connected.

What causes errors?

An individual may be susceptible to making an error due to the influence of numerous organisational and individual factors.

Organisational factors include:

- inadequate or inappropriate work layout;
- poor physical environment eg noise, heat, humidity, poor lighting or visual distractions;
- inadequate design of equipment including poor ergonomics;
- poor supervision.

Individual factors include:

- inadequate training;
- inexperience on a task;
- poor knowledge of a task;
- inadequate skill level;
- low motivation;
- attitude and emotional state;
- perceptual disabilities;
- stress levels;
- poor physical condition;
- social factors.

Avoiding errors

There are three basic ways to decrease human errors:

1. Improve the training received by an individual on a particular task so errors are minimised;
2. Reduce the likelihood of a human error;
   - ~ improve the work design and work layout – make improvements that will accommodate human limitations and reduce error provocative situations;
   - ~ ensure early detection of errors and early remedial action eg installing safeguards and early feedback devices that will alert the individual that an error has occurred and ensure that remedial action is well practiced;
3. Reduce the impact of a human error by ensuring that the impact is minimised when things do go wrong.

KEY PRINCIPLES

- All humans make errors.
- Understanding human error is important when designing work so that the frequency of errors is reduced and/or the consequences of making errors is minimised.
- Two frequently used methods of classifying the types of errors that people can make are based on information processing or on actions.
- Training and design are two approaches to decreasing the impact of human error at work.
- Employ early detection systems to ensure errors are identified early so remedial action can be taken.

Motivation

Motivation in the workplace refers to as an individual's intention or willingness to perform a task to achieve a goal or reward that will satisfy them. Each individual experiences differing amounts and types of motivation and considers different rewards or incentives as being attractive.

Some individuals are intrinsically motivated ie performing and completing a task and the resulting feeling of accomplishment is its own reward. Others are extrinsically motivated and prefer their rewards to come from external sources in the form of bonuses, promotions and/or praise.

Improvement strategies

Devising goals to be met by employees and rewarding them for meeting these goals are one way in which employers can motivate employees. In order for motivational strategies to succeed in the workplace employers must recognise that each employee will have different individual needs and goals. Thus types of organisational rewards that motivate one employee to perform well may not necessarily motivate all employees eg monetary, or time off in-lieu. Employees must be included in the decision-making process regarding goal setting and have the ability to provide comment on the types of rewards that are proposed by management.

The organisation needs to ensure that:

- goals to be achieved contain an element of challenge for the employee;
- goals are attainable;
- feedback mechanisms are in place so that employees are provided with information regarding their performance;
- any organisational rewards offered are linked to objective employee performance achievements and that these rewards are individualised;
- group goals do not have unwanted outcomes such as peer pressure that leads to overloading of slower or physically weaker workers.

Incentives

An incentive is an anticipation of reward. Some organisations use incentive-based schemes to enhance motivational levels among staff while others try to motivate by building incentives into an individual's job eg performance-related pay systems and rewards of 'free-time' away from work.

However these incentives will often increase the risks taken by the individual and ultimately produce poorer performances. Quality of work can also suffer if the emphasis is placed on speed and quantity.

Incentive payment schemes

Bonus schemes, piece rates, premium systems, payment by results, and measured day work are terms given to methods of production involving incentive payment schemes. These are designed to encourage and reward higher individual and group performance and/or productivity in a range of occupations.

While it is acknowledged that many incentive schemes operate in order to maintain production at a viable and predictable level, they have disadvantages, which, given the different circumstances of their application, may have considerable hidden costs. Many of these are in the area of occupational health and safety and include cumulative disorders (OOS and low back pain), mental stress and accidents.

While these schemes are a means of sustaining productivity, they should not operate where the sole criterion for their operation is speed of production. Within any group of employees, a variation in working rates will occur due to factors such as natural skills, arousal and fatigue. Incentive payments should not be used to encourage employees to work beyond their personal limits.

Appropriate methods of reward that do not compromise safety and health need to be determined in consultation with all key stakeholders.

Low morale

When individuals are de-motivated, low morale may develop. Indicators of low morale include:

- increased absenteeism;
- higher than usual turnover of employees;
- a decrease in individual performances and productivity;
- higher than expected accident or incident rates.

Low morale in an organisation can be addressed by:

- encouraging individuals to become interested in their work. This may include having a variety of tasks and responsibilities, building up knowledge about the purpose of the task, and experiencing task completion;
- improving job satisfaction by being given some degree of autonomy and responsibility for the outcomes of work;
- being given feedback on the results of work activities.

KEY PRINCIPLES

- Different people are motivated in different ways.
- Workers should be consulted regarding any improvement strategies.
- Improvement strategies should not compromise health and safety.
- Quality of work can suffer if undue emphasis is placed on speed and quantity.
- Vary tasks and responsibilities, increase autonomy and provide feedback to counter low morale.

Occupational stress

Individuals can experience stress when demands exceed an individual's ability to cope. These demands can be personal or work-related or both. Stress can have negative effects on an individual's work performance, health and wellbeing. It can occur in the workplace when individuals experience:

- a lack of control over workloads or overly demanding workloads and schedules;
- a lack of social support in the workplace, either through supervisors or peers;
- a lack of clear direction from supervisors or management;
- a lack of information regarding the individual's role in the organisation;
- a lack of career opportunities or job security;
- conflict with other individuals within or external to the organisation;
- physical work environment problems with extremes in temperature, noise, vibration or exposure to hazardous substances;
- violence or aggression from fellow employees or clients or as the result of events such as armed hold-ups.

The signs of stress

Individuals who are experiencing stress may have psychological symptoms such as increased feelings of anxiety, depression, aggression or confusion. They may have physical symptoms such increased blood pressure, heart rate and muscle tension and headaches. They may also be prone to habits such as smoking or drinking alcohol, show signs of irritability, perform poorly at work and have a high rate of absenteeism.

Overcoming occupational stress

Identifying the real causes of stress amongst individuals may take time and may need mediation skills to resolve. In some cases discussions and a general willingness to listen will be all that is required. In general solutions to the problem of occupational stress can involve both alterations to the work environment itself and/or attempts to improve an individual's ability to manage stressful situations. Stress management training can be beneficial and may include development of coping techniques to deal with stress such as muscle relaxation, meditation and time management skills.

Organisations should try to identify why individuals may be feeling stressed. They should then structure an appropriate response that will address the stressor or stressors – stress related problems could have several causes. All interventions should be developed in consultation with the individual involved, trialled and then evaluated. (See also Task Design; Ergonomics Risk Management; Employee Participation in Problems Solving)

KEY PRINCIPLES

- Stress can have a negative effect on work performance, health and wellbeing.
- Symptoms of stress may be both psychological and physical.
- Interventions to decrease stress may involve changing the work environment or work organisation and/or improving a worker's ability to manage stressors.

Further reading: *• Other material 8.11: Devereux • NOHSC 1.20: Stress & Burnout at Work • Other material: 8.6: Stress*

Fatigue

Fatigue, (weariness from effort) has no characteristic pattern and occurs in various forms depending on the part of the body exerted. It may manifest itself in one or more of three ways – as a subjective sensation of weariness and discomfort, as objective physiological change, or as a decrement in performance. The onset of the manifestations may occur in any order.

Fatigue is a normal feature of most work, yet it cannot be easily measured. It can be assessed roughly in terms of impairment or decreased performance, although one can occur without the other. The detrimental effect on work of continued work while an individual is fatigued includes effects such as diminished quality and quantity of output.

Transient fatigue is normal in day-to-day activity and is removed by appropriate rest. Cumulative fatigue builds up from period to period of activity, and is not relieved by apparently reasonable rest. It indicates that the activity is beyond current capacity and a person may feel general lethargy or that they are 'going stale'.

Tired people need increasingly more effort to achieve the same output and they may accept lower standards of performance. However, with high external or internal motivation a tired person may continue to perform as before but will require proportionally longer and longer periods of rest in order to recover.

Although awareness of fatigue may be sudden, a time of onset and the point at which performance starts to deteriorate is hard to determine for most people doing routine tasks.

Physical fatigue

The nature and effects of repeated muscle activity may not be obvious to the untrained observer. It will be obvious to the person undertaking the activity and may be discerned by the skilled observer. Effects can be measured but this can be difficult in a work situation.

Heavy physical or repetitive work can cause general physical and/or local muscle fatigue. These are usually indicated by a decreased ability and desire to undertake the work with increasing energy required to maintain the level of output. Errors and accidents can increase with physical fatigue so appropriate rest breaks should be taken. (See also Physical Strength and Work Capacity; Rest and Work Breaks)

Mental fatigue

Mental fatigue can be described as the experience of deterioration in perception usually as a result of prior mental effort or physical activity. Mental fatigue is complex and cannot be measured easily by a single indicator.

Mental fatigue can occur:

- after complicated tasks requiring extensive mental effort;
- when monotonous tasks are performed over long periods of time;
- when individuals are getting inadequate sleep.

A number of factors can also influence an individual's feelings of fatigue including:

- **personal factors –** age, gender, health/ physical fitness, sleep patterns, training, task experience, job satisfaction;
- **organisational factors –** organisational culture, morale, motivational schemes, shift schedules, task demands, operating procedures;
- **environmental conditions –** temperature, noise, vibration, light;
- **design of equipment –** hand tools, the relationship between displays and controls, machinery and workstation design.

The signs of fatigue

Individuals who are fatigued will feel tired and lethargic, experience reduced alertness and vigilance, an unwillingness to work and generally experience a decline in both mental and physical performance. Evidence of this decline will include poor decision-making ability, which may include increased risk taking to make savings in the effort required to perform a task. There also is an increased risk of a tired person making errors. (See also Human Error; Shiftwork and Extended Hours).

Reducing fatigue

For ways to minimise effects of fatigue and boredom see also Task Design.

KEY PRINCIPLES

- Fatigue is a normal part of most work.
- Tired people need to lift their levels of effort to perform the same amount of work. They are more likely to be slower and make more errors.
- Personal, organisational, and environmental factors, and design of equipment can influence feelings of fatigue.
- Rest breaks are necessary to delay the onset of fatigue and allow people to recover from mental and/or physical effort.

Further reading: *• Book 20: Rodahl*

Older workers

Older workers tend to be more consistent, careful and conscientious. They have no more work absences than other workers, they have fewer accidents and are less inclined leave their jobs. They usually have extensive work and life experience which can be used to advantage in most jobs.

However, increasing age brings some limitations including some reduced physical and mental capacity. The main limitations include:

- vision and hearing acuity which decrease with increasing age;
- decreased ability to concentrate for long periods on difficult tasks especially in noisy or difficult work environments;
- lowered ability to focus and divide attention and to suppress irrelevant information;
- slower rates of information processing, recalling from memory, speech processing and language production;
- cumulative musculoskeletal wear and tear (sprains and strains) and decreasing physiological capacities leading to a decreased work ability (this appears to be greater in those who have worked in physically demanding jobs);
- other health problems such as cardiovascular disease, diabetes and digestive disorders.

The design of tasks and work organisation need to take these factors into account. Strategies to accommodate older workers might include:

~ the reduction of physically heavy work as age increases;

~ the use of corrective spectacles especially where the tasks are computer based;

~ allowing time to learn new tasks and understand new technology;

~ designing training programs to assist older workers adapt to new methods and systems. The programs should be based on what older workers already know, 'learn by doing' methods. Using older trainers may help overcome difficulties.

Generally older workers have considerable knowledge and experience to contribute that is important in decision-making. They are usually keen to give information and offer suggestions and opinions and they respond well to consultative and participatory processes. These factors need to be considered systematically during job reviews and in long-term planning.

Shiftwork

Evidence concerning the influence of age on the shift working population is not conclusive but it is generally accepted that the ability to tolerate shiftwork declines after 45 years. (See also Shiftwork and Extended Hours).

Accidents

A review of the literature regarding occupational accidents showed that:

1. Older workers do not have more accidents at work than younger workers;
2. In an Australian study, the greatest number of traumatic work-related deaths occurred in the age range 20–54 years (about three-quarters); a smaller number of deaths occurred in individuals aged less than 20 years (6%) and those over 65 years (5%);
3. Older workers generally require longer periods of recuperation from injury due to age-associated physiological changes;
4. Factors that can influence recovery time from injury include the type of workplace hazard exposure, socio-economic factors and possible changes in reporting of minor workplace accidents (older workers may tend not to report minor injuries);
5. Older workers may be at risk of particular types of accidents, specifically sprains and strains of joints such as the shoulder, knee, ankle or back. However, information on exposure to work hazards, taking age into account, is not available.

KEY PRINCIPLES

- A lifetime's acquisition of knowledge, knowledge of procedures and expert skills often compensate for physiological and physical limitations in older workers.
- Older workers may not work as quickly as younger workers in stressful working conditions such as those induced by noise and sleep deprivation particularly if they are taking medication.
- Design of tasks and organisation of work can be structured to accommodate any limitations older workers may have.
- Older workers need and appreciate consultation and specific and careful training in new tasks especially those related to computer-based systems.

Further reading: *• Book 27: Langford and McDonagh • Book 28: Kumashiro*

People in systems

Systems are the structures that underlie complex situations. A system can be considered to be a set of interrelated and interdependent parts arranged so that it appears to be a unified whole. Organisations are systems and they are made up of sub-systems acting together to meet the objectives of the organisation. Organisations themselves are sub-systems within society. The design and management of organisations has a very powerful effect on the safety and health of people at work.

The size and complexity of an organisation is often baffling and intimidating for individuals within it. Understanding what constitutes a system, how it works and how and why decisions are made can help individuals become more active in the process of change and development.

Systems ergonomics

Solving ergonomics problems involves improvements at various levels within a system. Local ergonomics solutions (microergonomics) often cannot be properly implemented because of wider issues. To be effective today's systems require people to be involved in implementing changes including ergonomics solutions if they are to be really effective. This is also required by some occupational health and safety (OHS) legislation.

Systems ergonomics is also referred to as organisational design and management (ODAM) or macro ergonomics. It tries to examine the whole picture. It attempts to look at problems and issues in the perspective of the overall system so that it achieves effective and lasting change.

Managing change

In the developed world change is a feature of most workplaces. As a result 'change management' is a term commonly used to denote a special approach to the way changes are handled in an organisation. Change is difficult to manage because normal human responses are subject to personal and emotional influences as well as rational, logical ones. No matter how good the technology, how wide the debate, how clear the arguments, individuals will not always agree with the experts about the benefits of change – whatever form they take. Responses will vary depending on the age, sex, education level of the person and a range of other personal and social factors. What works well in one location for one group may not work in another. These issues need to be recognised as a barrier to change and managed. Therefore designers and decision-makers must take care not to impose change without adequate consultation or to transfer technology and systems from one workplace to another without a proper analysis of local requirements and limitations.

It is unreasonable and counter-productive to be too prescriptive in an approach to solutions for recognised and foreseeable problems. This tends to blunt imagination and discourage local, more appropriate solutions over the long-term. If general principles of good task and workplace design are understood and applied, and peoples' local needs are given adequate consideration when planning the system, the basic mismatches and obvious problems can be avoided. More specialist ergonomics input becomes necessary as the complexities of the systems increase and as the need to contain costs and to reduce errors and wastage becomes more critical. System reviews are essential to ensure that changes are working and to rectify outstanding problems.

Essential elements to successful change management are:

- Change must be justified;
- Careful and iterative planning moving from generalised goals to more specific and concrete objectives;
- Commitment to the change by the most senior managers;
- Involvement of and participation by stakeholders (individuals or groups who will be affected by the change);
- Knowledge and communication including adequate feedback;
- Incentives for individuals to change;
- Support by managers and fellow workers.

KEY PRINCIPLES

- Ergonomics problems need to be addressed within the context of the wider work system.
- Successful change requires vision, careful planning and firm and on-going commitment by senior and middle managers, workers and other stakeholders. Without this the change process will be less successful or may fail totally.
- Commitment can be gained through the active involvement and participation of stakeholders. Imposing changes without this can be counterproductive.
- Local problems need local solutions. These may or may not be solutions that have been applied elsewhere. Imported solutions need evaluation with respect to their suitability for a particular workplace.

Further reading: *• Book 23: Kuorinka & Forcier • AS 5.19: AS/NZS 4804:2001• AS 5.20: AS/NZS 4801:2001*

Ergonomics risk management

The application of the risk management approach for all types of risks is becoming increasingly important to reduce the probability that corporate objectives will be jeopardised by unforeseen events. The focus is one of positive and directed due diligence rather than negative compliance and for many organisations this is a significant change in direction.

Risk management involves hazard identification, risk assessment and control and the monitoring and evaluation of controls (solutions). Analysis of risk is at the heart of the risk management process. This is determined from the range of potential consequences and the likelihood (exposure and probability) of their occurrence. It can be as detailed and technically precise as is required by the process or equipment being assessed. However, for the most part, simple methods can achieve reasonable outcomes and the reduction of risks to an acceptable level for day-to-day ergonomics hazards. (See also Risk Management Techniques).

Changes to OHS laws in most Australian jurisdictions over the last few years require workers and supervisors to manage their own health and safety risks. Ignoring risks or imposing unsatisfactory solutions to problems is not morally or legally defensible. Problems should be identified and solved through a process of consultation and risk management. Both the process and the outcome are important.

OHS legislation in New South Wales now requires that risk management be practiced by all organisations and for all risks – from major to minor. This implies that workers and managers must be informed about ergonomics and be able to apply ergonomics principles on a daily basis.

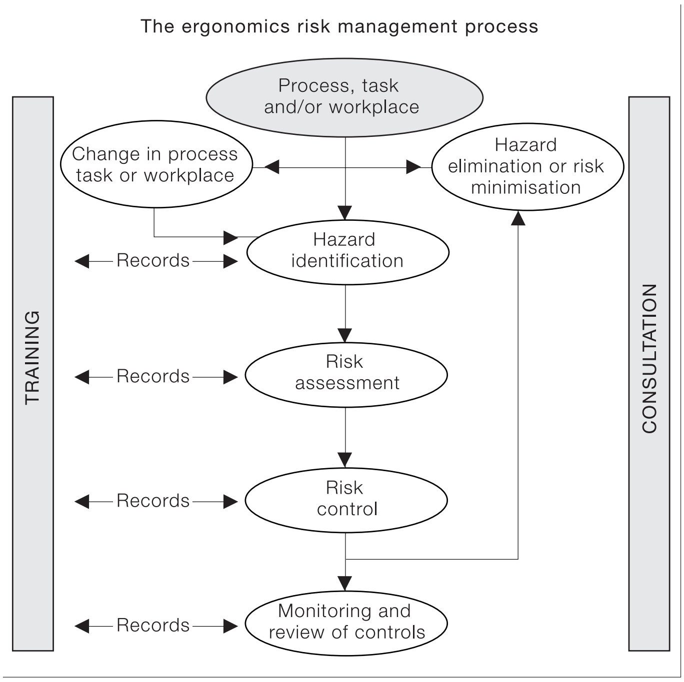


Figure 3.1: The ergonomics risk management process

Further reading: *• AS 5.17: AS/NZS 4360:2004 • AS 5.18: HB 436:2004 • AS 5.21: HB 205:2004 • Industry material 6.2: MDG 1010 • NSW WCA 2.1: Risk Management at Work*

Adapting risk management to ergonomics

Risk management techniques, commonly used in business and safety management systems, can be adapted easily to ergonomics. They have the added advantage that systems safety personnel understand the process and can integrate it into a company's OHS program.

A risk management strategy in ergonomics involves identifying ergonomics hazards in the workplace, assessing them to decide how important each one is and then controlling them by the best means possible ie finding an 'optimum' solution. It also involves monitoring to ensure that the process continues and is successful.

Ergonomics hazard identification

The first step in controlling a risk is to identify that a hazard exists either in your industry as a whole or at your workplace and which jobs might be affected. Which jobs or tasks are associated with difficulties, complaints, incidents or injuries? Where are those jobs?

In determining which tasks or activities may be hazardous and need to be assessed the following sources of information could be used:

- **statistics and injury records –** eg first aid records, records of accidents and near misses, workers compensation records and reports by supervisors/team leaders and employees. However, injury records from years past may provide a list of past problems and may not be a true indication of the hazards that currently exist;
- **consultation with employees –** eg formal supervisor/safety representative reporting, meetings, informal discussions, questionnaires;
- **direct observation of the workers, tasks and the workplace –** eg area inspections, walk through surveys, audits.

Teams of people do this process best. They may be from the areas being assessed or from different areas. The workplace should be surveyed systematically to ensure that no hazard is missed. Ergonomics hazard identification can be carried out on jobs/tasks, locations/areas, roles/duties or processes.

Ergonomics risk assessment

Risk assessment is necessary after possible sources of injury, loss or other problems have been identified. If all risks cannot be dealt with immediately it is important to deal with the most hazardous first. To do this it is necessary to determine the possible severity of the hazard and the likelihood of a problem occurring.

Risk assessment should highlight:

- **frequency of the risk –** is the risk common? how many people might be exposed to it? how many people might be effected if exposed?;
- **severity of the risk –** nature of the injuries and losses associated with the risk, cost of work and individual factors which might contribute to the risk --the nature of the task, the load, the work environment, work organisation, training, individual capability;

The risk assessment will indicate the areas requiring risk control measures and it should be carried out in consultation with those who do the job. The following is an example of a commonly used risk ranking method (WRAC) that can be modified for use in ergonomics.

Risk assessment is particularly important whenever:

- a work process and/or practice causes problems especially an injury; or
- a work process and/or practice is introduced or modified.

Probability:

A	Common	**B**	Has happened	**C**	Could happen
D	Not likely	**E**	Practically impossible		

Maximum reasonable consequence

	Descriptor	*People*	*Equipment/costs*	*Production delays*
1	Catastrophic	Fatality	Major > $500k	> 2 days
2	Major	Serious Injury/ Illness	$250 k – $500k	1 to 2 days
3	Moderate	Lost Time Injury or Illness (LTI)	$50 k – $250 k	6 to 24 hours
4	Minor	Injury/illness requiring medical treatment	$5 k – $50 k	1 to 6 hours
5	Insignificant	First aid or less	Minor < $5 k	< 1 hour

Risk Ranking Matrix

The identified risks are then ranked according to their likelihood of occurrence and consequence according to the Risk Matrix:

Consequence \ *Probability*	A	B	C	D	E
1	1	2	4	7	11
2	3	5	8	12	16
3	6	9	13	17	20
4	10	14	18	21	23
5	15	19	22	24	25

Figure 3.2: An example of a risk ranking method. A Risk Ranking of 1 to 6 indicates High Risk; 7 to 15 indicates Moderate Risk; and 16 to 25 indicates Low Risk.

Controlling ergonomics risks

In practice, finding solutions to some problems using control measures is often hard to achieve. Usually a problem is not solved with one solution because a range of control measures is required. Sometimes these are systems changes that can seem insignificant and unimpressive and certainly not as glamorous as the one-off solutions that are so often portrayed in solutions handbooks. However, achieving a solution should be the focus.

Sources of information on solutions can be found from:

- the workers who do the job including supervisors and managers;
- manufacturers and suppliers of equipment;
- specialists in particular areas of engineering, ergonomics, health and safety;
- other workplaces that perform the same or similar functions.

It is also important that appropriate controls are matched to the level of risk. This is referred to in safety as the hierarchy of controls and is required by law through OHS legislation in some states in Australia. The first three in the hierarchy are known as hard barriers; the last two are soft barriers. They are:

- **elimination –** ie elimination of the hazards;
- **substitution**;
- **engineering controls –** eg reduction through design;
- **administrative controls –** eg provision of policies and procedures, appropriate training, work breaks, job rotation and/or warning signs, training.
- **personal protective equipment (PPE)**.

Hard barriers are usually much more effective in reducing real risk and are required where the risks are high and there is the likelihood of a serious injury or fatality.

Soft barriers are generally less effective, as they rely on people's adherence to procedures or rules and are subject to error or violation. Compliance with rules and procedures is a major problem in any workplace and each individual must be highly motivated if they are to work effectively.

Training (awareness raising, procedures, skills) is a soft barrier but necessary at every stage to complement a well designed workplace and efficient systems. It is particularly important for the successful implementation of change. Sometimes training may be used as a substitute for hard controls, where there is the need for an immediate, temporary solution or where no other method of control is available. However it needs to be done very well in such circumstances. This training must always include information on why ergonomics is important and the general principles of risk reduction.

Education and training can modify peoples' perception of risk and sometimes their behaviour but there is much less evidence of success in training people to use a safe method. Therefore, while training is essential for all workers, used on its own, it is likely to be unsuccessful in reducing risks of injury. (See also Training, Experience and Skill Development)

Evaluating controls

When monitoring hazards it is important to regularly repeat the hazard identification and risk assessment process to ensure that the solutions are working and, where necessary, make appropriate changes. Improvement must be continually monitored and ongoing.

The solution(s) needs to be evaluated in terms of:

- effectiveness/impact on the problem;
- availability including long-term implications;
- cost benefit and or cost effectiveness.

A risk assessment should always include a review to evaluate the impact of the process and the implementation of the solutions. Unfortunately this rarely occurs. There is a great reluctance to revisit problems unless there is an obvious failure or lack of progress.

Sometimes people are so committed to their solutions they are reluctant to admit that they do not work. Others move on to the next problem and assume that the proposed solutions have been implemented and are working. This may not be the case. Some solutions may work well, while others may not have been implemented appropriately and others may have made no impact at all on the problem. There might be little indication of continuing or new problems as a result of the intervention until such a review is undertaken. An honest and timely examination of how well the intervention or solution has worked is important but it is not easy to achieve.

KEY PRINCIPLES

- The process of risk management (hazard identification, risk assessment and control) can be readily applied to ergonomics.
- It is essential that hazard identification and risk assessment be carefully carried out to ensure that the right problems are being solved.
- Finding solutions to ergonomics problems is often a process of combining a range of small and unimpressive changes to reduce risks. Seldom is there a spectacular one-off solution to routine problems.
- All solutions and interventions need to be evaluated for their effectiveness but this process is often ignored or forgotten.

Employee participation in problem solving

Employee participation in different forms can contribute substantially to the success of different work systems and workplaces. However, successful participation in decision-making and consultation takes time and skill, and there must be time in the planning process to allow for it. It must also start early as sometimes decisions are made at the outset that cannot be reversed by the people who ultimately have to make the system work.

Participative processes are an excellent way of involving workers and training them in the practical aspects or ergonomics application.

The participative approach may take longer and it may be more difficult but it is more likely to lead to the desired outcomes in the short- and long-term. Employee participation in the planning or redesign of their work and/or workplaces does not cost more than the cost of getting it wrong.

The following principles for participatory management have been proposed:

- There are many ways of achieving participatory management;
- Participatory management programs should start gradually and work towards higher-involvement management;
- Participatory management is easier to initiate in new operations, as there is inertia in existing organisational structures and procedures that must be overcome. This diverts resources;
- Pilot or experimental projects in participatory management often are too isolated to succeed. It is better to start with a broader base of involvement;
- Once an organisation moves towards greater involvement of the workforce it may be difficult and counter productive to unwind this process;
- Leadership and vision are critical to success. Everyone must share the vision of successful participation;
- Shared values such as self-worth, democracy, equality and fairness are important to success;
- Success breeds success. Start with small things that will succeed and work towards more complex issues;
- Things rarely go to plan so plan for the unexpected;
- Plan for the long-term as organisational change that lasts takes time.

Participatory ergonomics

Participative techniques have been used successfully by designers and in safety management systems for many years. They are now proving to be an interesting and productive method for systematically identifying workplace ergonomics problems and developing solutions.

The concept of participatory ergonomics has been promoted for about 20 years and refers to the co-operative interchange between expert and non-expert to find satisfactory solutions to a range of problems especially where there needs to be trade-offs and compromises. It arose from the need to involve workers, who did not have an expert working knowledge of ergonomics, in the process of change. It has proven useful in disseminating ergonomics information and helping organisations find real ergonomics solutions in the workplace. It is another application of macro ergonomics.

In the design of work the depth of employee experience should be used to plan, implement and refine the system and employees should be encouraged to become actively involved in the process of change and improvement. This information can then be harnessed by managers and designers to achieve more workable solutions for identified problems and, more importantly, to prevent problems occurring in new systems of work.

Participative ergonomics can provide:

- names, labels and models for ideas, principles and practices that workers are already using;
- ownership of ideas and responsibility for identifying the most appropriate solution that enhances the likelihood of implementing ergonomics successfully;

- a framework and model for further change – if workers are involved in the process of identifying the problems and solutions they will be able to use the same framework to solve future problems.

Participatory risk assessments

Participatory ergonomics takes many forms. One that is useful is the participative risk assessment workshop. This forum allows a focus group to devote uninterrupted time to a problem using a systematic approach with a view to identifying solutions to the problem. In particular it allows ergonomics issues to be aired with respect to the wider work system and therefore provides a perspective that may not be possible using other methods. It also gives the company a documented starting point for change.

Participatory risk assessments can be carried out on tasks, locations, roles or processes but using sub tasks (sometimes referred to as job steps), tasks or activities is the most common approach. They involve as many key stakeholders as is feasible because a crucial factor in their effectiveness is the availability of relevant knowledge and expertise of a cross-section of people who are familiar with a particular work situation. Outcomes are dependent on the team being representative and providing a balanced view at a level of expertise appropriate to the nature of the subject under review. The ergonomist as the facilitator is independent within the team but can also provide background information on ergonomics. This is different to most facilitators' functions. In some cases further expertise may be required to advise and/or supplement the core team.

The availability of relevant information and expertise is an essential factor in the effectiveness of the participative process. Technical knowledge is usually required at both the assessment level and for the development of suitable solutions (controls). Therefore the composition of the assessment group is critical to solving the problem. People who are not fully acquainted with the process and its limitations in assessing different types of risks need to take care and seek guidance from experienced personnel.

In addition this process can be used for training, disseminating information and successfully achieving change in complex areas such as ergonomics. It can also provide the opportunity for full and constructive consultation with all stakeholders, something that is difficult and time-consuming to achieve with other processes.

It is important to be realistic about identifying and selecting solutions and what may be achievable. The participative approach allows these issues to be aired and worked through by the group thereby gaining support for the process. Group members also can gain an appreciation of how continual small improvements can substantially reduce risks of illness and injury as well as improving the job.

Communication at work

Human communication is the two-way exchange of ideas and information between people and is one of the most important elements in the effective working of our society and our workplaces. Poor communications due to lack of language or reading skills, unresolved differences between individuals or an inability or unwillingness to seek and receive feedback are at the heart of many serious OHS issues at work. The use of jargon or technical language that needs to be learned may also be a barrier to communication for new or young workers. (See also Measuring the Benefits of Ergonomics)

Effective communication in the workplace it is one of the hardest things to achieve and maintain in practice. Women innately communicate differently to men and while this is recognised often different styles of communication are not accommodated especially in highly technical areas. Many training programs and textbooks are devoted to improving written, spoken and organisational communication.

There is an increasing focus on communication of danger and risk in the workplace. Effective signage and other written communication are important but these may not be as effective as they need to be if people are not literate in English. Symbols and pictorials may help but some training in recognising these may be required. (See also Displayed and Oral Information)

Written information on OHS and ergonomics may need to be conveyed to workers and it may be difficult to determine how much is read and understood. Training and worker participation in risk management are two ways in which misunderstandings or miscalculations about dangers, hazards and risks can be identified and overcome. This process must be ongoing.

KEY PRINCIPLES

- Participatory management is difficult but can fundamentally change an organisation for the better if undertaken with care and commitment.
- Participation by employees in problem solving at work can encourage ownership of changes and understanding of the process of change.
- Participatory techniques are an excellent method for training workers in the theory and application of ergonomics.
- Participatory workshops must have a suitable mix of skills and knowledge about different aspects of the work under review. This includes ergonomics and OHS expertise where necessary.
- Effective workplace communication is essential in all areas of OHS and ergonomics.

Further reading: *• Book 23: Kuorinka & Forcier • Book 26: Noro & Imada • Book 27: Langford & McDonagh*

Task design

The aim of job or task design is to provide interesting, worthwhile work that in turn improves productivity and efficiency though reduced injuries and ill health, absenteeism, employee turnover and social stress.

Job or task demands that exceed the individual's physical or mental capacity to meet them may result in errors, fatigue, stress and injuries. For instance manual handling research over the last 30 years indicates that heavier weights, repetition and force beyond an individual's capacity, and awkward or constrained postures lead to higher than expected rates of errors, discomfort, injuries and other disorders. Mental overload or underload can lead to errors and other inefficiencies. (See also Human Error; Physical Strength and Work Capacity; Rest and Work Breaks)

When trying to solve occupational health and safety (OHS) or productivity problems, task design and how the work is organised may be as important as hardware solutions such as better-designed furniture or job aids. There are a number of methods that can be used to improve the design of work including broadening and varying tasks, increasing responsibilities, allowing control over work and encouraging social contacts. Problems with computer work may be overcome by a more efficient arrangement of work and more appropriate software design as well as improved information displays and better designed furniture. Manual handling problems may be solved by either rearranging the job or eliminating the handling rather than installing a manual handling aid.

Fragmentation of work

Over the last few hundred years there has been a tendency to reduce the complexity and to increase the repetitiveness of some types of work. This is referred to as the fragmentation of work or Taylorism. It describes production methods devised by Frederick W Taylor who was an early methods study expert. Complex jobs are broken down into simpler components each of which requires relatively little training and which an individual worker repeats. This approach was considered more efficient by some and was adopted in the earlier part of the 20th century by large manufacturers for production lines eg Henry Ford. This has spilled over into jobs in white-collar industries such as banking, insurance, and finance and increasingly into industries such as mining.

However, while there were perceived benefits to this approach a downside became more evident as the protection of workers' health and safety was given greater emphasis. Physical health problems particularly emerged as efforts to increase efficiency further were unsuccessful. People have physical and mental limits at work. These limits vary enormously between individuals and workers' health and safety can be compromised where these limits are not understood and taken into account when work is designed.

Task variation

In contrast to the perceived benefits for production many OHS recommendations advise strongly against the fragmentation of work and are in favour of task variation or multi-skilling. This is desirable for the prevention of many occupationally related disorders because it reduces constant exposures a range of both physical and psychological hazards.

Task variation can be achieved in three ways: through job enlargement, job rotation or the use of self-directed work teams:

1. Job enlargement (enrichment) – increasing and varying the job content either by adding tasks or adding complexity to tasks. Broadening and enriching jobs in this way allows people to move through a succession of different jobs, each of which make different demands on the persons abilities. This encourages employees to reach their potential over time. It is a much more acceptable alternative for providing variety, but requires careful planning and longer training periods.

2. Job or task rotation – moving workers from one component task to another to bring variety to work although the job remains unchanged. It is a ready way of spreading the load of stressful jobs among a large group of employees, but it does have drawbacks. It is effective only where jobs are different enough to provide physical and mental variety. Many employees do not like rotating for a number of reasons, even when it is in their best interests to do so. It can be disruptive and time-consuming and workers may need to do tasks they do not like and are not good at. Also, job rotation can mask the real causes of the problems and may only extend the period before problems eventually arise. Employees have to learn more skills and thus require more training and supervision.

3. Self-directed work teams – more worker participation than the methods described previously. Workers are organised into groups and the planning and organisation of the work and responsibility for the end product may be delegated to them. Theoretically it gives people more control over the whole process rather than just over parts and encourages a much broader view of the job. This can be rewarding both for the company and the employees but it requires considerable time, training and investment in employees.

Workload

The individual's performance of a task can vary with the workload required. At extremely low levels of workload boredom may set in resulting in missed signals and a poor performance (See also Human Error). Medium levels of workload are optimal and performance remains high, however further increases in workload may result in overload and a marked decline in performance. (See also Physical Strength and Work Capacity.)

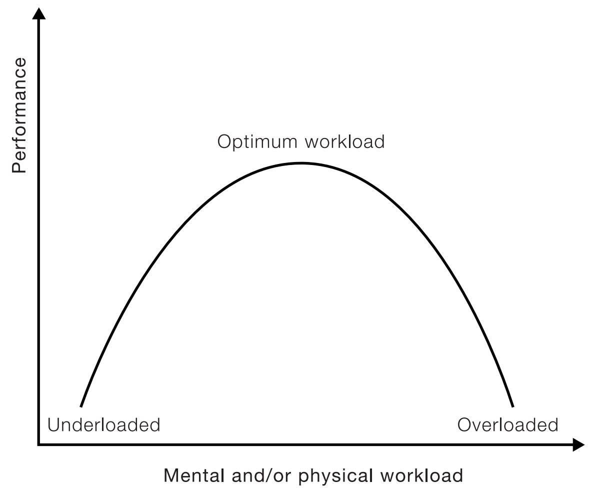


Figure 4.1: Workload and work performance

Workload can refer to both physical workload and mental workload. Mental workload is the amount of cognitive processing required by an individual during the performance of a task. (See also Information Processing and Decision-making).

Mental workload is affected by numerous individual and environmental factors that will affect an individual's ability to complete required tasks. These factors include:

- individual – level of fatigue, stress and boredom/ arousal, training, skill level, prior experience, motivation level, perceived difficulty of task and accuracy needed for the task, type of task and time constraints will all affect an individual's ability to perform a task;
- environmental – level of illumination and noise, temperature, design of the workstation and human-machine interface.

Under-load and overload

When designing tasks to avoid both under-load and overload worker consultation is required as no two people are the same. If individual workers are to achieve greater productivity intensive training and a high level of worker support may be required.

Further reading: • Book 21: Violante, Armstrong & Kilbom • Book 23: Kuorinka & Forcier

Job satisfaction

Job satisfaction refers to an individual's general attitude or feelings toward their work and work experiences. There can be major differences in job satisfaction between individuals and even between individuals performing the same job. An individual's level of job satisfaction is often interrelated with other aspects of the job, including work conditions. (See also Motivation)

There are three main areas that contribute towards an individual's experience of work satisfaction:

1. **Organisational aspects –** include incentives such as income; possibility of promotions; ability to be involved in decision-making; appropriate supervision; and the match between job expectations and reality;.

2. **General work aspects –** include workload; appropriate skill and task variety when performing work; significance of task performed to overall work outcome; autonomy or decision latitude in the job; appropriate feedback on work performance; and a suitable physical work environment;

3. **Personal characteristics –** including level of ability to perform work tasks; appropriate levels of experience; stress and coping abilities; general levels of self-esteem; personality; job expectations; and general life satisfaction.

Most people would like to believe that the work they do is of value and that when they work they are productive, efficient and produce high quality work (quality, quantity and time). Very few people achieve this consistently because they work in human designed (and therefore imperfect) systems. However, each person should be able to expect a safe and healthy job, with reasonable conditions of employment and reasonable remuneration or other reward.

Work demands and job control

Job demands need to be balanced with a degree of control by the worker over how the work will be done. Those employees who have high demands placed on them but who have little job control (decision latitude) are the most likely to be at risk of developing psychological or physical disorders. This is illustrated in the following diagram.

Demands

Learning motivation to develop new behaviour

Control	Low	High
High	Low demand High control (low strain)	High demand High control (active)
Low	Low demand Low control (passive)	High demand Low control (high strain)

Risk of psychological strain and physical illness

+ Support

Adapted from Karasek and Theorell, Healthy Work – Stress, Productivity and the Reconstruction of Working Life. Basic Books, New York, 1990, (page 32)

Figure 4.2: 'Karasek' model

Conversely those who have high demands and a high degree of control over how they meet those demands contribute to high levels of motivation, learning and new behaviours.

Support

A modifying influence in the demands versus control theory can be support. It is argued that support, or the lack of it, can either reduce or magnify the effects of problems at work.

Supporting people at work by developing their skills, minimising their weaknesses and helping them to cope with life stresses is part of good management. Managers need to understand the strengths and limitations of different types of technology and workplace design and how the limitations of some systems may lead to problems for users. This means full consultation with the people who will be doing the work from the start of the design phase through to the ongoing performance of the system.

People need consistent and adequate support throughout the design and implementation phases of new systems. Workers need to participate fully and provide feedback to designers and managers. Help desk services need to be appropriate and effective for the technology. People, especially older workers, need to learn by doing and to gain confidence with new systems. Managers need to keep a user focus and continually re-appraise and fine tune. Support must be kept going when the system is up and running especially for the crisis times – either at work or in individuals personal lives. (See also Occupational Stress)

KEY PRINCIPLES

- The key characteristics of jobs are task variety, task identity, task significance, autonomy and feedback.
- Redesign repetitive or boring jobs to make them more satisfying.
- Where there are high job demands ensure that there is adequate control (job latitude) by the individual over how the work is completed.
- Aim for task variation and autonomy through job enlargement, and/or autonomous work groups rather than job rotation.
- Consider how changes in technology in the workplace may lead to the need for job re-design.
- Appropriate, timely and ongoing training is an important element in the effective performance of a job or task.
- Employees need education in ergonomics to enable them to participate fully in the development of solutions to ergonomics problems.
- Consider the negative impact of environmental influences and design to minimise these.
- Provide appropriate and on-going support for employees particularly during the implementation of new systems.
- Understand the importance of effective worker consultation and work organisation.

Problems arising from poor task design

Sedentary work

Prolonged sedentary work is becoming more the norm in workplaces everywhere and occurs mainly in offices, transport and manufacturing. While sitting all day is preferable to standing a combination of sitting and standing is the most desirable as it provides the necessary postural and physiological variation normal for human beings.

Design of work must allow for these postural variations and should improve levels of alertness and wellbeing. Many work places have introduced task rotation and exercise programs to overcome the possible harmful effects of sedentary work that include back pain, occupational overuse syndrome (OOS), problems for the digestion and circulation in the legs. However, these strategies are less effective than work with inbuilt variation.

KEY PRINCIPLES

- Build variety into tasks wherever possible.
- Allow for freedom of postures and movements in tasks where workers are seated for more than an hour at a time.
- Encourage seated workers to exercise and undertake activities other than sitting during breaks.
- Encourage regular, frequent breaks from the seated workstation.

Computer work

More and more jobs involve work with computers and input devices such as keyboards and the mouse. Most people find the computer is an invaluable tool when used intermittently throughout the day. Problems arise for some people however when computer work becomes the total job as it may be physically repetitive and undemanding mentally. In some cases computer work requires long hours of absorbing and intensive mental work so that the user is oblivious to time and physical and mental fatigue. Both these types of jobs can lead to physical problems such as OOS, eye fatigue and headaches.

It cannot be predicted accurately who will develop symptoms in high demand/low control jobs but theoretically all who do this sort of work are at risk. Given this, the two most important strategies for preventing problems lie in task design:

1. Keyboard output and skill levels are attainable by all keyboard operators within each job;
2. Deadlines are realistic for everyone and allow adequate breaks.

Some peaks and troughs can be expected but prolonged periods of either high intensity work or underload (more than a day or so) can precipitate problems in some more vulnerable people. If job demands continually outstrip the capacity of all or some groups to meet them, then some urgent reassessing will need to be done.

Computer training needs to match the needs of individuals, and the demands of and skills required by the job and the technology. It must be timed to match the introduction of the equipment and allow people time to learn. Appropriate support for people while they are learning is essential.

Ultimately work groups should be able to reassess their situation regularly to see if changes need to be made. The ability to control work demands at a manageable level for the individual and the group and problem identification and solving by a work group is very important.

Further reading: • NOHSC 1.7: Prevention of OOS in Keyboard Employment • ACTU 7.1: Screen Based Work • Other material 8.3: Display screen equipment • Other material 8.3: Understanding ergonomics • Other material 8.5: Office work • Other material 8.12: Ergonomics

Repetitive work

Repetitive work may require repeated muscle activity involving the use of the same muscles in a range of apparently different movements or using different muscles in repeated movements that look similar. Sometimes this can lead to injuries. An injury may mean that the same activity is done completely differently after the injury and this is referred to as favouring the injured part , which could lead to further injuries.

Repetitive work processes are often described as monotonous and boring, with individuals performing this type of work often experiencing dissatisfaction. Such occupations may involve responding to intermittent signals eg console operation or require simple, repetitive movements eg factory process work.

Research has found that individuals who perform short repetitive tasks tend to make more errors than employees performing varied tasks, largely because the nature of repetitive work has the effect of decreasing an individual's level of cognitive arousal (see also Information Processing and Decision Making). Different individuals will experience different responses to repetitive work. A few will enjoy the routine nature of repetitive work and find this type of work relaxing, straightforward and free from responsibility. Others will seek greater mental stimulation.

Very simple and repetitive jobs can be automated and performed by machines, although certain repetitive jobs may still require the flexibility of human workers to perform them.

When repetitive work cannot be automated, it is important that job or task rotation or job enlargement be used to diversify the workers' activities, limit physical overuse symptoms and avoid boredom by incorporating more variety into the work.

Injuries

The term occupational overuse syndrome (OOS) refers to a range of conditions marked by discomfort or persistent pain and/or other dysfunction in muscles, tendons or other soft tissues of the hand, arm or shoulder and sometimes occurs in the foot and ankle. Other terms used to describe these conditions are repetition strain injury (RSI), cumulative trauma disorder (CTD) and work-related musculoskeletal disorders (WMSD). For simplicity they are referred to in this handbook as OOS.

OOS is usually caused or aggravated by work associated with repetitive movements, sustained or constrained postures and/or forceful movements.

Factors such as posture, training, fatigue, a person's size and age, and their muscle strength and fitness also need to be considered. The relationship between workload, its effects on work capacity and on the development and severity of sprains and strains appear to be modified by factors, such as length of working day, periods worked without breaks, and the percentage of the working day spent doing repetitive activities in fixed postures.

As well personal factors such as personality, mood, the perception of load, work pressures, job satisfaction and non-work related factors might alter the individual's response to early signs of fatigue and discomfort. (See also Fatigue)

Psychosocial factors such as stress at work may contribute to the development of these disorders. Often multiple factors acting together over time lead to symptoms. Two important factors that are often overlooked are excessive time pressures and job demands over which the workers have no control.

It appears that increased risk of strain occurs when individuals:

- have new demands placed on them;
- habitually work beyond their capacity;
- personal, social or environmental factors reduce their tolerance to physical stress.

Preventive strategies

The following strategies can be used to prevent the development of OOS:

- **task variation or multi-skilling –** highly desirable; achieved through job enlargement which may enable a number of different types of activities to be incorporated into a job description; or less effectively through job rotation;
- **exercise programs –** increasing strength, endurance and increased blood flow. However, results are mixed when only exercise intervention is used to control these disorders. Some programs may slightly increase musculoskeletal discomfort in some workers. Professional advice on exercise programs is advisable;
- **adjusting work rates –** human performance varies between individuals and over time. Therefore work rates should aim to accommodate the physical and psychological capacities of all workers selected for the job including the slowest and least capable. This is particularly important in machine-paced work. Capacities can be increased with training and experience but even the fastest and most capable have off days and this needs to be taken into account;
- **minimising aggravating factors –** mechanical and technical breakdowns and inefficiencies can have a disruptive effect on employees and usually involve periods of extra load to make up production or output. Poor quality control may require reworking for no additional productivity. Therefore adequate machine and equipment adjustment and maintenance is essential in the smooth and efficient operation of any system. Other organisational factors such as overtime, shift work, peak loading, and bonus and other incentive schemes often require higher outputs than the employees can safely manage and should be avoided.

KEY PRINCIPLES

- Ensure that working postures are not awkward, prolonged or extreme.
- Ensure that work movements are not excessively repetitive, forceful, fast, jarring or associated with vibration.
- Design tasks that are balanced in content and demands.
- Design work with a variety of movements and postures, sitting and standing, gross and fine movements.
- Consult employees about any problems that they might have with their work and ensure that they are rectified.
- Watch for employees who may be struggling with work and try to support them in solving their problems.
- Allow employees adequate control over their pace of work and the demands that are placed upon them.
- Ensure that all workers are adequately trained for their work especially in work techniques that reduce the risk of strain.

KEY PRINCIPLES

- Do not place excessive demands on employees who have little or no control over their work and the way it is done.
- Ensure that chairs, desks and other furniture and equipment meets the individual employee's particular work requirements.
- Ensure that the work environment eg temperature, airflow, light, noise is designed to optimise work performance.

Further reading: *• NOHSC 1.5: National Code of Practice for the Prevention of OOS • NOHSC 1.7: Prevention of OOS in Keyboard Employment • NOHSC 1.8: Prevention of OOS in the Manufacturing Industry • NOHSC 1.18: Overuse injuries • Victorian WCA 3.4: Code of Practice for Manual Handling • Other material 8.12: Ergonomics • Book 25: Stevenson*

Manual handling

Manual handling has been defined as:

'any activity requiring the use of force exerted by a person to lift, lower, push, pull, carry, or otherwise move, hold or restrain any animate or inanimate object. Manual handling also describes repetitive actions with or without force, sustained work postures, exposure to whole-body or hand-arm vibration, bending, twisting and reaching'.

Manual handling occurs intermittently in most jobs. In some codes and guides repetitive tasks such as packing, keyboard work and using hand held tools are included in the definition. This avoids a rather artificial separation of heavy and lighter work, which may be confusing and complicate the process of prevention.

Any manual handling activity constitutes a hazard and a potential for injury unless demonstrated otherwise. It may be light or heavy, repetitive or intermittent. Where manual handling is a substantial or significant part of a job it is essential that all risks are identified and minimised. These jobs occur in a range of industries and organisations such as construction, manufacturing, health care, food processing, farming, printing, hospitality and mining.

Some work involves continuous manual handling for most of the day. Warehousing, the removals industry and delivery are examples of such jobs. Great care is needed in these situations to reduce the impact of handling during a work day by correctly pacing work, reducing unnecessary handling and through the use of lifting aids, job and workplace redesign and training.

Generally human handling of materials and people is expensive and inefficient, as well as posing significant risks to health to those who do it. This is especially true where the workload takes people to the limits of their work capacity.

Teaching people specific lifting techniques to overcome lifting problems has mixed success in reducing the risks of injury. Sometimes techniques can be helpful in specific situations but some techniques place extra demands on the muscles and joints eg squat lifting (bent knees and straight back), which is slower and physiologically more demanding. It may also increase the risk of further injury for people with damaged hips, knees or ankles.

Associated injuries

The majority of problems arising from manual handling are associated with sprains and strains mainly of the back and neck. However, other parts of the body are also affected most notably the shoulders, knees and ankles. Injuries in these areas occur from different aspects of manual handling tasks such as overhead work (neck and shoulders), walking on rough ground or areas with difficult access (knees and ankles). Most manual handling injuries are cumulative, developing over many months or years of overload.

Back disorders are the commonest causes of workers' compensation claims, sick leave and early retirement in the developed world. They are usually painful and no truly effective medical or surgical treatment exists for a large number of cases. They are believed to arise from damage to the spine and surrounding structures brought about by an accumulation of strains placed on the back over time.

These disorders emerge most commonly in middle aged and older people although it is not unusual for symptoms to be reported by teenagers and young adults subjected to high levels of physical stress. In some cases acute injuries, resulting from severe trauma, such as car accidents, precipitate symptoms in young people with little evidence of prior damage. Nevertheless, in most people symptoms and signs develop over many years and the precipitating event is unlikely to be the cause of the disorder – it is simply the last straw.

Different work-related and individual factors are considered to be risk factors for these disorders but there is no clear understanding of their relative contribution. As well there is no general explanation of how back disorders occur, that is, what actually goes wrong in the back which gives rise to symptoms.

Risk factors

The following work factors are believed to increase the risk of problems when manual handling:

Weight and load

Load should not be confused with weight. Load is force. The weight of an item may be considerable but with appropriate lifting aids the force required to move it might be minimal. The load experienced by an individual can be influenced not just by the nature of the object to be lifted, but also by task design, organisational and personal factors.

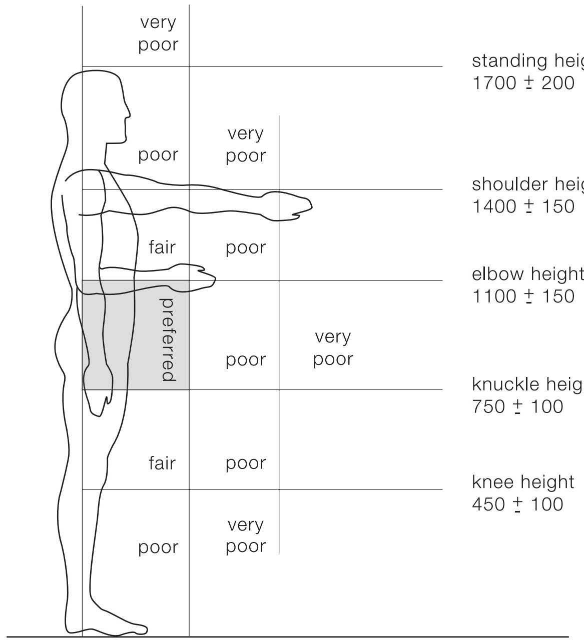


Figure 4.3: Height ranges for lifting

In physical work weight is just one aspect of load on the body. In most recent guides and Codes a maximum weight is not specified for this reason. In the National Code of Practice it is mentioned that risk reduction strategies may be required when weights exceed 16 kg for an individual, unaided lift. These must be in place for weights above 55 kg. These limits were set many years ago by international labour groups to limit loads carried by women and children and were embodied in legislation in many countries. When equal employment opportunity legislation was introduced it was these limits that were applied to the whole workforce. They are of little help in reducing manual handling injuries where other factors are not taken into account.

Important aspects other than weight in manual handling include:

- distance of load from the body (moment);
- range through which weight is lifted;
- origin and destination of lifts;
- postures assumed in order to lift (bent, and bent and twisted postures are the ones to which most risk is attached);
- speed of movement;
- characteristics of the load.

For repetitive lifting there is the added factors of:

- frequency of lifts;
- duration of lift, and
- cumulative loading (leading to fatigue).

Handling away from the body, bent twisted postures and speed of movement are now considered to be the factors that create the greatest risks for injury.

Frequency of lifts

Frequency of lifts between jobs may vary a great deal. The question is: how frequent is 'frequent'? In some regulations in Australia lifting more than twice a minute or a movement sustained for more than 30 seconds at a time is classified as frequent. This is a good guide for practical purposes but each situation needs to be considered in relation to other factors that contribute to load and worker fatigue.

Matching job demands with worker capabilities

Human beings are not well adapted to heavy physical work, their physical skills lying more in the areas of speed, flexibility, adaptability and range of movement. Therefore there are considerable limitations in designing heavy work for the average person. (See also Body Size; Physical Strength and Work Capacity)

Determining and matching job demands with the capacities of individual workers is particularly important in physically stressful work such as manual handling.

There is a range of task and individual factors that need to be considered in job design where manual handling is involved. These include:

- **physical demands (physiological, biomechanical, anthropometric) –** the workplace and job design features eg work height, reaches, workplace layout, design of loads, how far a load is carried and doubling handling;
- **psychological demands (cognitive and organisational) –** the way the work is done, mental work demands including meeting work targets, control over work, support in the workplace, training and the organisation of work;
- **individual or personal characteristics –** age, physical capabilities (age, sex, stature, ethnicity), fitness for the job including return to work after holidays, health including previous injuries and past exposure to heavy lifting; training for the job skills and experience.

Research carried out over the last 25 years indicates that heavier weights, repetition and force beyond an individual's capacity, and work and workplace design which force workers into awkward or constrained postures lead to problems. In the short term individual workers may cope with demands that exceed their capabilities in one or more of the following ways:

- short cuts in work procedures leading to unsafe practices;
- consistently working at a higher pace than is healthy with an increased risk of chronic or accumulated fatigue and injury especially as they age;
- change of job by those who are unable to meet work demands imposed.

Problems may arise gradually over time in people who adapt in the short-term. They then become evident years after the origins of the disorder have been forgotten. Drawing any kind of cause-effect relationship between the disorders and the initial causes is difficult if not impossible.

Risk factors and the National Standard

The National Standard and Code of Practice for Manual Handling (1990)* lists the following risk factors to be taken into account in the process of risk assessment and control. These are:

- actions and movements;
- workplace and workstation layout;
- working posture and position;
- duration and frequency of manual handling;
- location of loads and distances moves;
- weights and forces;
- characteristics of loads and equipment;
- work organisation;
- work environment;
- skills and experience;
- age;
- clothing;
- special needs (temporary and permanent) – this is taken to include an individual's health status, fitness for the specific job, training for the job;
- any other factors considered relevant by the employer, the employees or their representative(s) on health and safety issues.

To assess and control risks arising from manual handling it is essential to involve workers in the process of manual handling hazard identification, and risk assessment and control (See also Ergonomics Risk Management)

KEY PRINCIPLES

- Any manual handling is costly and inefficient so the workplace should be redesigned to minimise it wherever feasible.
- Correctly estimate individuals' capabilities in terms of handling weights, cumulative loads, and work rates and design for these. Design handling jobs to accommodate the weakest, the smallest and the slowest workers.
- Consider the cumulative effects of weights handled and the different planes of motion.
- Consider the combined effect of task variables (such as height of lift, size of the load) and worker variables (such as age, sex, body weight, anthropometric dimensions).
- Avoid work postures that are awkward, prolonged or outside preferred range.
- Avoid work movements that are repetitive, require excessive strength and endurance, require excessive speed, are jerky, restricted, inefficient or obstructed.
- The time for one basic element of a task to be completed is affected by the preceding and succeeding elements.
- The effect of pacing is exponential so that linear standardising of times gives incorrect estimations of effort.
- Provide well-designed manual handling aids where appropriate.
- Provide specific training in handling techniques where necessary but consider the extra demands that these place on employees eg squat lifting (ie bent knees and straight back), which is slower and physiologically more demanding. Generally this type of training is not particularly successful in reducing risks of injury.
- Optimise environmental variables such as temperature, humidity and air velocity for handling tasks.
- Minimise noise, vibration and dust exposure for people when handling.

Further reading: *• NOHSC 1.2: Code of Practice for Manual Handling (*Note: A new Australian National Code of Practice for the Prevention of Musculoskeletal Disorders from Manual Handling at Work is being prepared. Notice of its publication will be made on the NOHSC website.) • NOHSC 1.15: Managing Back Pain • NOHSC 1.16: Manual Handling • Book 24: McPhee • Victorian WCA 3.4: Code of Practice for Manual Handling • Victorian WCA 3.2: Managing Manual Handling Risks in a Small Organisation • Victorian WCA 3.3: Managing Manual Handling Risks in a Large Organisation • Queensland DWHS 4.2: Advisory Standard: Manual Tasks • Queensland DWHS 4.3: Advisory Standard: Manual Tasks Involving the Handling of People • Other Material 8.4: HSE Manual Handling Assessment Tool • Other Material 8.8: HSE Manual Handling. Guidance on Regulations • Other material 8.10: NIOSH. Work Practices Guide for Manual Lifting • Other material 8.11: Work-related Stress and Musculoskeletal Disorders • Other Material 8.12: Ergonomics*

Driving vehicles and operating machines

A significant percentage of jobs involve driving or operating vehicles or machines from cabs. In many cases safety and efficiency are critical and both the nature of the work and the design of the cab need to be optimised.

Often driving and operating involves extended work hours and night work. Therefore fatigue, arousal and wakefulness can be problems. Prolonged sitting, awkward postures, poor visibility, vibration and poor cab design can add to the driver's difficulties. (See also Vehicle Cabs; Noise; Vibration; Shiftwork and Extended Hours; Rest and Work Breaks.)

There is a range of additional components in many operators' jobs that can lead to reduced performance or attention to critical functions. For instance in driving buses the safety and welfare of passengers is usually an overriding consideration and can be the source of distractions and interruptions. School buses have the additional demands of children who are prone to unpredictable behaviour either within or outside the bus.

Delivery drivers have a mix of driving, loading and walking as well as dispatch responsibilities but usually have increased time pressures and the stress of heavy traffic. If the loads are heavy, there may be insufficient time for the body to adapt from the seated posture to upright active lifting and injuries can occur.

Dump truck, bulldozer and crane operators can be subject to long hours of sitting, routine (even boring) work and vibration. Ways in which these tasks can be varied need to be implemented.

Design of cabs and the alertness of the driver or operator involve far more complexity than many other workplaces. However, there is considerable information now available to help address task and workplace design issues. (See also Vehicle Cabs)

KEY PRINCIPLES

- All tasks undertaken by the driver/operator need to be assessed in terms of job demands and driver capabilities. Fatigue, overload and underload need to be managed to reduce the risk of errors.
- The design of the cab must accommodate driver needs including vision, noise, dust control, seating and task demands.
- Where vehicle operation involves extended work hours and shiftwork there must be adequate provision for rest and work breaks in the work schedule.

Training, experience and skill development

Few individuals start a job without needing further training or development of skills to perform the job. Continuing technological changes, differences between workplaces, promotional opportunities and multiskilling mean that employees are constantly required to learn new skills and understand different processes and procedures in order to perform optimally at work.

Training can be provided to employees in order to increase their knowledge and skills. It can be on-the-job, in a classroom at the workplace or off-site and can involve individuals learning different types of skills, such as technical (computer software), interpersonal (mentoring or different management techniques) or problem solving.

Adults learn best from their own experience and then move from this into new areas of knowledge and skill. It may be best to train adult learners in practical situations if they are not comfortable in a classroom. Some people like to see, others to hear and others to do. The best training provides a combination of these opportunities.

There is a wide range of skills that users may bring to a job. No two users of the same equipment will operate it in the same way. If it is important that equipment is used in a systematic and standardised way then much more training or relearning will be required.

In complex and highly specific systems much time and money may be needed for training, evaluation of the work system and retraining. Airline pilots are a good example of how training can help people to use complex systems competently. However, pilots are also very carefully selected and well paid. Asking for the same amount of effort and accuracy from workers with little training and paid one quarter of the salary may mean that employers or managers may be disappointed in the workers' performance.

Acquisition of physical skills

Physically skilled work involves quick and accurate muscular contraction, co-ordination of the different muscle groups involved, precision, concentration and visual control. Usually skilled work involves use of the hand(s) and in particular the fingers.

When a skill is being learned there are two phases: learning the movements and then adapting the body tissues involved. At first movements are done consciously and as training progresses the conscious part gradually reduces and the actions begin to become automatic. As the skill develops the movements change from jerky and unco-ordinated to smooth and flowing. In the first stages of skill acquisition extra muscle work occurs. Less energy is required for a skilled person doing exactly the same job as an unskilled person. As time progresses the body tissues adapt to the work by increasing muscle size or cardiovascular fitness.

Short training sessions, breaking the job up into parts and providing strict controls and good examples can improve skill acquisition. Short training sessions are necessary because a high degree of concentration is required and people tire quickly under these circumstances. Breaking the job into parts allows more difficult or critical parts to get more attention during the training and allows the practice of parts before putting the whole together. It is important that the best technique is developed. This is facilitated if accurate feedback and supervision are provided during the learning process.

Skill development and individual differences

Differences between individuals should be taken into account when any type of training scheme is developed or offered to employees.

Employees differ in the following areas:

- knowledge they posses before training begins;
- the way that they learn new skills;
- the speed with which they learn new skills;
- confidence in dealing with unfamiliar situations.

Thus the type of training methods employed should be adapted to the learning needs of each individual. The main aim of skill acquisitions is that individuals achieve a satisfactory level of competence.

Identifying training needs

The first stage of the training process is a review of training needs. This analysis should be performed on three levels:

1. **Organisational –** what training should be performed in the organisation and where is it needed?;
2. **Task/ job (usually called a task or job analysis) –** what skills or abilities are required to perform a specific task or job?;
3. **Personal –** what are the training needs of each individual?

Types of training

There are several types of training that can be conducted:

- **Knowledge teaching –** the provision of knowledge to employees regarding a specific operation or system. This aids in teaching individuals the reasoning behind safe operating procedures or other safety measures;
- **On-the-job training –** job rotation and the use of mentoring relationships or apprenticeships where new employees learn the skills required to perform their job from more experienced workers;
- **Simulator training –** workers practise their skills on a simulated situation eg aircraft pilots, military personnel and medical staff;
- **Part-task –** workers are taught part of a task that often can require special practice or can be a particular skill that should be developed before comprehensive training is begun eg medical training;
- **Team-based training –** training is provided to groups of individuals who often work in teams. As a member of a team individuals are required to perform their respective jobs successfully and to co-ordinate their efforts to meet team goals;
- **Refresher training –** involves workers re-learning skills and can involve on-the-job drills eg evacuation drills or simulated exercises eg first aid training. Refresher training is essential for workers to sustain skills that are used infrequently but are necessary especially in emergencies;

Whichever training method is used, it should be evaluated. This is can be done in a number of ways but must test the skills and knowledge acquired with regard to what is required by the task.

Training aids

Training aids are helpful for individuals who have acquired new skills to enhance their performance. They can include:

- reference or procedural manuals;
- checklists;
- charts, notices or labels;
- decision trees or decision charts;
- an in-house expert or outsourced technical support who can provide support when needed.

Education and training in ergonomics

Education of stakeholders is important for a successful ergonomics program. By definition ergonomics requires that the people doing the work must be involved in the design of that work if solutions are to be successful. As well, if money, time, and expertise are used to produce an ergonomically sound workplace, then employees should understand why it has been so designed and how it can best be used. Training should encompass both of these elements.

Ergonomics training can be formal or it may be incorporated into participative activities such as design reviews, risk assessments, focus groups and quality circles. It may also be learned on-the-job through using checklists and tools developed to identify hazards and solve problems.

KEY PRINCIPLES

- All workers require regular training either to update their skills or to learn new ones.
- Different training methods are used for different types of work and workers as well as for the skills and knowledge required to be learned.
- The application of ergonomics requires worker involvement and training in order for workers to understand why changes are necessary and how best to use them.

Further reading: *• Book 23: Kuorinka & Forcier*

The work environment

Workplaces

Workplace layout design must take into consideration multiple users and the movement of people and materials. It covers more than the individual workspaces and looks at access between workspaces and other functional areas of the organisation eg stores, maintenance, plant room. A workplace can be within a building, a construction site or a mine site; the cab of a vehicle or quite literally 'out in the field' in the case of geologists, farmers, surveyors or environmental officers.

The layout of any workplace should consider traffic flow with the view to reducing slips, trips and falls; manual handling risks; traffic accidents involving vehicles eg forklifts; emergency and fire escapes.

Layout of workspaces

Workstations and workspaces are the immediate physical surroundings of the worker. They can serve a range of different purposes from being the area in which a person works all day to an area that is used by a variety of people for different purposes intermittently. They can be discrete areas such as a computer workstation or part of a larger work area such as a workshop or production line area. No matter what they are workplaces must conform to basic ergonomics principles to accommodate users.

Workspace size

The workspace itself must be of a suitable size. Often this is dictated by external factors that have nothing to do with the people working in the area, the equipment they are using or the activities they are performing.

Within buildings limitations in space and location may be related to the cost of rent, building availability or a lack of planning. Sometimes functions outgrow spaces: more and more people and/or equipment are fitted into the same space and arrangements become increasingly ad hoc. Redundant or infrequently used equipment may not be removed or relocated and may be left to clutter the work area. Lighting, temperature control and ventilation may be inappropriate for changed functions and arrangements. In these cases review is needed urgently. However, no matter how adequate they may seem all workspaces need regular reviews to ensure that they are satisfactory and provide a safe and healthy work area.

In mining and similar industries such as construction and agriculture a person's workspace may change constantly or may be mobile such as the cabin of a piece of plant or machinery. These may be difficult to control fully due to the requirements of the building, farming or mining process. In these cases the same rules apply – the workspace must be adequate for the workers and the functions that they need to perform. The longer the worker is in the workspace during a work shift the more critical the design becomes.

One area of concern when considering workspace size is access by maintenance personnel to machinery in a breakdown situation. Environmental conditions in the field may be difficult and these are compounded by difficult and even dangerous access to components and parts of the machine. Heat, cold, excessive moisture, mud, dust, fumes, restricted spaces and difficult access may add to the problems normally experienced in a workshop where mechanical aids and some protection from the elements are available. Under these conditions each task needs to be assessed for ergonomics risks in conjunction with accident and production risks.

Workspace arrangements

The arrangement of the individual workspace is important especially when the work is stationary and performed in either the sitting or standing position. It depends largely on the type of work being done and the equipment being used. The physical arrangements must permit correct and appropriately supported work posture and unimpeded movements by each worker. The workspace arrangements may have to be modified by for each individual if the work is critical.

A number of competing demands may make it impossible to have a perfectly arranged workplace or to meet all recommendations simultaneously so the aim is to achieve an optimum overall. In any workspace there needs to be sufficient space for the use and storage of a range of equipment including tools and appliances, lifting aids, components and spare parts, computer- related equipment and supplies, manuals and reference material, personal protective equipment (PPE) and fixed items.

The location and storage of tools, fixtures, equipment and material used at the any workstation should be within the reach of the worker and not cause awkward postures during use. In some cases where items are used intermittently it may be preferable to store them away from the workstation. This has two benefits: it allows the employee more space and encourages them to get and move about from time to time. (See also Posture and Movement; Task Design)

In order to accommodate the user the following requirements need to be taken into account:

- horizontal work area;
- work height (the height at which the hands are working);
- adequate viewing distances and angles;
- sufficient leg space for seated or standing work;
- sufficient head space for adequate clearance for the tallest person when standing straight;
- reach distances should not exceed those of the smallest people;
- seat – area needs to be sufficient for easy access and correct adjustment;
- hand tools – both use and storage;
- all loads including tools should be stored so that they can be handled close to the body and at about waist height. Avoid deep storage bins; low, deep or high shelves for heavy or awkward items, and ensure that walkways are kept clear;
- fixed and moveable equipment – proximity to the work area, access, use and storage;
- the flow of product or components;
- size, shape, location and surface of steps. On vehicles and machinery they need to be a minimum of 200 mm deep, the lowest step should be a maximum of 400 mm off the ground and at least two boot widths wide;
- design and location of handrails. These need to be within reach of the smallest person and must comply with the relevant Australian Standards.

Workshops and other industrial work areas

In designing workshops and other industrial work areas, the following factors should be considered:

- **access –** hatches, steps/stairs and walkways need to be adequate for the biggest person wearing PPE and carrying equipment such as tools and testing devices;
- **size of the work area –** the largest workers should be able to adopt comfortable work postures in the work area and it should also accommodate all the equipment that is required to do the work safely;
- **the design and selection of tools and job aids –** particularly where access and workspaces are limited may need special attention;
- **temperature and other environmental conditions –** humidity, heat, cold, fumes, oils and dusts need to be measured and any unwanted effects on the worker must be controlled;
- **visual requirements of the task –** need to be assessed and any special requirements must be met especially where workers need to wear protective or prescription eyewear;
- **noise levels –** currently must be below 85dbA or suitable hearing protection must be provided. Environmental conditions such as heat and humidity may need to be reassessed if hearing protectors are worn;
- **wearing of PPE –** needs consideration in task and workplace design eg hearing and eye protectors, hard hats, cap lamps and batteries, self-rescuers, and gloves.

Designing for maintenance tasks

There are a number of considerations for maintenance personnel when working on machinery either in a workshop or in the field. Most of these relate to poor access, restricted work spaces especially when large tools need to be used or PPE must be worn, inadequate tool selection and/or design, heat and cold, poor visibility, noise and environmental pollutants.

In the last few years manufacturers have made significant design changes to plant to reduce both the time required to undertake routine maintenance and the health and safety risks for maintenance personnel.

Ergonomics design and risk assessments are now required for the design, manufacture and registration of plant in some Australian states through the respective OHS legislation. There is a lot of information on body size and strength and this should be used to ensure that workspaces for maintenance personnel are adequate. (See also Posture and Movement; Body Size; Physical Strength and Work Capacity)

The following design issues need to be considered in any workplace but especially in workshops, industrial and construction areas and for maintenance tasks:

Design issues

- Free, even and uncluttered walkways on and around the machinery and equipment wide enough to be able to walk forward are provided.
- Changes in levels of walking surfaces are minimised.
- Slip and trips hazards are eliminated (this includes maintaining temporary floors and uneven ground which may be a work area or walkway).
- All holes or depressions where a foot could get stuck or which may pose a trip or a fall hazard are covered or otherwise eliminated.
- Well-designed steps, footholds and ladders for access to the machinery and equipment are provided.
- Sharp edges and protruding obstructions are minimised or eliminated.
- Slip-resistant surfaces on all walkways and steps are provided.
- Work areas are lit adequately.
- Loud noise is controlled at source.
- Work areas are designed to minimise the use of PPE.
- Work areas can accommodate the number of people required to do the job without posing a hazard.
- Height and space restrictions are minimised.
- Pinch points and moving parts that could crush hands, feet, or the body are eliminated.
- Designated storage areas for supplies and equipment with adequate, safe access are provided.
- Reach distances are minimised or reduced especially for moving and handling loads.
- The need for bending especially bending with twisting is minimised.
- There is adequate access and visibility for maintenance and routine checks.
- Minimal work is carried out above the shoulders or below the knees.
- There is minimal manual handling of supplies and equipment, most particularly double or multiple handling.
- There is an optimum location for operators on or near machinery and equipment while working.
- All sized users are considered in the design of the work areas.

KEY PRINCIPLES

- Workspaces must accommodate all users, their equipment and the tasks to be carried out.
- Special consideration needs to be given to access and conditions for maintenance tasks. This may involve specifying or modifying machinery design to meet the requirements of OHS legislation.
- Review workspaces regularly for their suitability for current tasks and users.

Further reading: *• Book 4: Stevenson • Book 5: Clark & Corlett • Book 7 Woodson, Tillman & Tillman • Book 11: Officewise • Book 16: Diffrient, Tilley, Bardagjy • Books 17: Diffrient, Tilley, Harman • NOHSC 1.10: Plant in the Workplace (Employers and Employees) • NOHSC 1.11: Plant in the Workplace • NOHSC 1.22: Workplace Layout & Design*

Illumination and lighting

Whenever visual tasks are undertaken the light intensity (the amount of light which falls on the work surface), must be sufficiently high to allow them to be carried out rapidly and with precision and ease. Apart from light intensity, differences in luminance (contrast) in the visual field are also important. Luminance is the amount of light reflected back to the eyes from the surface of objects in the visual field.

Light intensity is expressed in lux, and luminance (brightness) in candela per square metre (cd m2).

In determining the amount of light that must fall from the surroundings onto a work surface, it is necessary to distinguish between orientation lighting, normal working lighting and special lighting.

Orientation lighting

Select a light intensity of 10-200 lux for orientation tasks. The minimum required intensity to detect obstacles is 10 lux. A light intensity of 10-200 lux is sufficient where the visual aspect is not critical, such as in corridors of public buildings, or for general activities in storerooms, provided no reading is required. A higher light intensity may be necessary for reading or to prevent excessive differences in brightness between adjoining areas. Where eyes need to adjust rapidly when moving between the areas, such as when driving into tunnels, reduce the differences in brightness.

Normal working lighting

Select a light intensity of 200-800 lux for normal visual tasks such as reading normal print, operating machines and carrying out assembly tasks. Where the details are small or hard to read, the person is older or has visual difficulties or where there are great contrasts of light such as near windows, more light will be needed.

Special lighting

Select a light intensity of 800 – 3000 lux for special applications. It is sometimes necessary to use desk lighting to compensate for shadows or reflection on the work surface. Intensive activities requiring precision such as visual inspection tasks require much higher illumination levels to distinguish fine detail.

Avoid excessive differences in brightness within the visual field. Reflections, dazzling light and shadows can all cause difficulty in seeing.

Use a combination of ambient (general) and localised or task lighting for localised tasks. In underground mining situations lighting may be provided by individual miners' cap lamps and machinery lights. In these situations problems can arise from the disabling glare of lamps shining in workers' eyes; shadows and perception difficulties presented by directional lighting; and inadequate light for a task. As well neck, shoulder and back strain can arise where there is a need to tilt the head backwards in order to see a task above the head. Poor lighting arrangements in mining need to be recognised and addressed on a case-by-case basis.

As well miners underground, use cap lamps for all sorts of signalling purposes. There can be problems however when there are misunderstandings or when new employees or visitors do not understand the protocols. Therefore these need to be formally recognised and communicated.

KEY PRINCIPLES

- Quality of light including source, direction, hue and intensity is often just as important as the quantity of light.
- Poor or inappropriate lighting can affect workers' health and safety as well as their efficiency.
- Poor lighting arrangements need to be recognised and addressed on a case-by-case basis.

Further reading: *• Book 1: Dul & Weerdmeester • AS 5.3: AS 1680.2.1:1993) • AS 5.4: AS 1680.2.2:1994 • AS 5.5: AS 1680.2.3:1994 • AS 5.6: AS 1680.2.4:1997 • AS 5.7: AS 1680.2.5:1997 • Other material 8.12: Ergonomics*

Noise

Most noise control programs concentrate on reducing the total amount of noise that a person receives each day in order to conserve his or her hearing. However noise can also be a nuisance without effecting hearing. Nuisance noise can be distracting, affect concentration and reduce productivity. It may also lead to early and unnecessary fatigue.

Noise can also be annoying or distracting and this can be tiring or even dangerous where critical tasks are being performed. In environments that are too quiet i.e. <30dB(A) any noise may become distracting or irritating. Usually a balance needs to be struck.

People react differently to noise but subjective responses should not be ignored, as they may be a warning that noise is excessive.

Noisy conditions can make conversation difficult. The following conditions can act as a guide if people are unsure if noise levels are unacceptable.

When noise levels are:

- above 80 decibels (dB) people have to speak very loudly to be heard;
- between 85 and 90 decibels people have to shout to be heard;
- greater than 90 decibels people have to move very close together and shout to be heard.

Apart from hearing loss and other direct health effects noise can be detrimental to communication and performance.

There are certain steps in identifying and assessing workplace noise problems and deciding what needs to be done. Precise measuring and analysis equipment is used to identify or confirm which people in any workplace are at risk of hearing loss due to noise exposure.

Controlling exposure

There are five basic steps:

- Identify areas of high noise levels;
- Identify those workers who are at risk, and measure their daily exposure;
- Conduct an education program, especially for those at risk, ensuring that supervisors and managers also attend.
- Prepare a noise control program under the headings:
  - engineering solutions (most preferred option);
  - administrative solutions;
  - personal hearing protectors (least preferred option).
- Determine the most effective program in terms of protection and cost.

Isolating the person from the noise through appropriate engineering controls can protect hearing (eg enclosing the workspace from surrounding machinery) or the noise from the person (eg enclosing the source of the noise). Personal protective equipment (PPE) such as earplugs or muffs is less effective but more easily implemented. This equipment may interfere with communication and can cause ear problems in hot, damp environments.

Engineering solutions

The following general guidelines to control damaging and nuisance noise at source apply to all workplaces:

- to preserve hearing keep the noise exposure for each person below 80 decibels on average per day;
- minimise nuisance noise such as high pitch, unexpected or distracting noises for everybody;
- make sure that the general noise level is not too quiet eg <30 dB (A);
- In order to achieve this the following strategies may be employed:
  - use a quiet working method or isolate noisy stages of the process;
  - use quiet machines and make sure they are well maintained;
  - enclose or isolate noisy equipment;
  - separate noisy and quiet work;
  - use sound absorbing materials in the workplace such as the ceiling and screening.

Administrative solutions

Sometimes it is possible to reduce exposures to noise by simply limiting the numbers of people in the area or restricting the times that noisy activities are carried out.

Use of personal hearing protectors

Hearing protectors are the least desirable method of controlling damaging noise. People have difficulty in wearing them in certain environments and where communication is important. However, sometimes they are the only reasonable option.

When choosing hearing protectors the pitch (frequency) of the noise must be taken into account. Different types of protective equipment have maximum damping effects in certain frequency ranges. Data on the characteristics of hearing protectors can be obtained from the suppliers. In order to encourage the use of hearing protectors, personal preferences in comfort and case ease of use must be taken into account. Different types of ear protectors should therefore be available.

- It is always more effective to control noise at source.
- Noise can distract and fatigue as well as damage hearing.
- Hearing protectors must be carefully chosen to provide the right amount of hearing protection as well as comfort and ease of use.

Further reading: *• Book 1: Dul & Weerdmeester • Book 7: Woodson, Tillman & Tillman • NOHSC 1.4: National Code of Practice for Noise and Protection of Hearing at Work • NOHSC 1.6: Management of Noise at Work • NOHSC 1.17: Noise • Other material 8.13: Physical Agents.*

Vibration

The two main types of vibration exposure are hand-transmitted and whole-body (WBV) and. Much is known about the effects on humans of hand-arm vibration but there has been less research into the long-term effects of WBV.

Hand-arm vibration

Hand-arm vibration usually arises from the use of hand held motorised power tools commonly with a frequency between 25 and 150 hz eg chain saws. The consequences for some people are disorders of the circulation of the fingers aggravated by cold (vibration white finger); tingling, numbness and/or reduced sensitivity and dexterity of the fingers; and muscle, joint and bone disorders. Once the conditions have become established they are not reversible so prevention through reduction of exposure duration and intensity is extremely important.

Vibration exposure

Vibration sources:

- Rough roads
- Vehicle activity
- Engine vibration

Modifying factors:

- Condition of roads and work surfaces
- Vehicle activity
- Type and design of vehicle
- Vehicle age and condition, suspension and maintenance
- Seat design, suspension and maintenance
- Cab layout, design and orientation
- Vehicle/Machine speed, driver skills and awareness
- Lighting and visibility
- Task design and work organisation

Figure 5.1: Vibration exposure

Whole-body vibration

Whole-body vibration (WBV) can be transmitted through the feet in standing work or, more likely, through the seat in seated work especially when operating machinery or driving vehicles. It is now believed that it may be a significant risk factor for the development of low back pain and other illnesses.

There appears to be three different scenarios where symptoms arise. The first is prolonged sitting; the second is where injuries result from a one-off severe jolt in an otherwise reasonable ride; and the third situation is where the onset of pain occurs after an extended period of moderate to severe jolts and jars.

WBV exposure arises from rough work surfaces, vehicle activity and engine vibration and there are range of factors that can either accentuate or reduce the impact of these.(See Figure 5.1)

WBV exposure can be measured and current standards give dose limits in terms of exposure times. The new Australian Standard AS 2670.1-2001 uses a combination of methods to assess if vibration and, in particular, jolts and jars commonly experienced in off-road vehicles and which are considered a risks to health. The vibration dose value (VDV) is one way of analysing vibration exposure with jolts and jars and appears to be a good indicator of what drivers, operators and passengers consider to be a rough ride. It is believed that rides with a VDV of ≥17 are likely to cause injury if exposure is prolonged and/or repeated.

In mining many rides exceed time limits for the likely health risk zone using different methods of analysis. The type of vehicle, its speed and condition (particularly its age and suspension system), and the condition of roads strongly influence ride roughness.

Figure 5.2: Drivers' subjective road roughness rating versus measured Vibration Dose Value (VDV)

Ways of reducing the impact of WBV include regular monitoring of vibration levels; operator training; limiting speed; prompt communication and correction of road problems; effective road maintenance programs; appropriate design of vehicles including the isolation of the cab in vehicles where vibration can be excessive; effective maintenance of vehicles; task variation and regular breaks out of the seat.

KEY PRINCIPLES

- Vibration should not result in discomfort eg seats should not 'bottom out' during a rough ride; hands should not feel numb after using vibrating hand tools.
- The duration and intensity of daily exposures should be monitored carefully and limited especially if symptoms such as back pain, headaches, nausea or numbness in the fingers are reported.
- The effects of aggravating factors such as cold and humidity should be minimised when using hand tools.
- The design of equipment can significantly reduce vibration during operation. Reducing vibration at source through the careful selection of tools, seats and machinery saves time and money.
- Equipment must be fit-for-purpose and used appropriately eg speed, type of work, techniques.
- Regular and thorough maintenance of machinery, equipment and tools must be undertaken to minimise vibration.
- Transmission of vibration should be prevented by the use of damping materials and suspension.
- Speed of vehicles and machines should be reduced as an immediate control of harmful whole-body vibration.
- Drivers, operators and users of vehicles and equipment must be competent in specific operating and driving techniques and adequately supervised.

Further reading: *• AS 5.10: AS 2670.1 – 2001 • AS 5.11: AS 2763.1 – 1988 • Book 8: McPhee, Foster & Long) • Book 15: Wilson & Corlett • Book 21: Violante, Armstrong & Kilbom. • Other material 8.13: Physical Agents*

Work in hot or cold environments

Work in the outdoors exposes employees to the extremes of weather and in particular temperature and may be complicated by the lack of facilities such as toilets, protection from the sun and wind and the provision of clean drinking water. In Australia, where heat is usually the main problem, there is also considerable exposure to cold either in the outdoors during winter or in cold stores.

There are six fundamental factors that define human thermal environments. The first four are air temperature; radiant temperature; humidity; and air movement and these basic environmental variables affect human response to heat or cold. Human activity and clothing also change an individual's response to thermal environments. All six need to be taken into account when designing work especially in extreme conditions. Temperature is important but should not be used as the sole indicator for action.

Other factors may also need to be taken into account eg behavioural factors that include:

- **clothing –** people may take off or put on clothes as their comfort dictates;
- **work postures –** especially those dictated by restricted spaces;
- **acclimatisation –** may influence the effects of heat and cold on individuals.

Individual tolerance to heat and cold

The effects of hot and cold environments vary between individuals. Some research indicates that distraction and /or arousal from feeling too hot or cold at work may reduce work performance and productivity, and could also result in increased absenteeism. Accident rates and unsafe work behaviours may also be affected by thermal comfort especially if people feel too hot.

There are large variations in individual responses to heat and cold and these will vary with the type of work being performed. Assess tolerable climatic conditions by using employee's opinions as well as observing their physiological responses (flushing, sweating, body temperature, skin temperature and heart rate), and changes in work performance. Decreased urine output, changes in behaviour and flushed skin may indicate dehydration and heat stress. Mild heat or cold stress will affect a worker's responses and their ability to perform work. Serious heat or cold stress can lead to strain and possibly death.

Humidity and wind speed

In the heat, humidity can alter a person's perception of how hot it is and his or her ability to undertake strenuous work may be reduced. In high heat and low humidity conditions, fluid loss may be rapid. However, the thirst mechanism in humans is not very sensitive so people exposed to heat must be encouraged to drink more and frequently before they feel thirsty.

The main factor, other than temperature, that produces coldness is wind speed. Therefore workers should be protected from wind in cold environments.

Measuring the effect of heat and cold

Any exact measure of heat and cold and their effects on an employee must take into account air temperature, radiant temperature, air velocity, humidity and the intensity of the work being performed. While there is no entirely satisfactory single measure of heat and cold stress various predetermined measures are available for different ambient and working conditions.

In neutral and cold climates the average resting body will lose about one litre of fluid per day while in warm environments about two litres.

Heat

Physical work raises the body's temperature and the increased heat is transferred to the atmosphere. If conditions impede transfer of this heat the body's temperature will start to rise. Such conditions occur with higher air temperatures (>30° C) especially in combination with higher humidity (>50%) and little airflow. If the worker is wearing heavy protective clothing and there is radiant heat from the sun the heat load on the body can be even greater.

The body cools itself mainly through evaporation of sweat. However, this fluid needs to be replaced by higher levels of water intake otherwise dehydration will occur. In high humidity the effectiveness of sweating is reduced. The body temperature may then start to rise and heat exhaustion and heat stroke can set in. Heat stroke can be fatal.

Heat disorders can occur for any of the following reasons:

- individual factors such as dehydration or lack of acclimatisation;
- inadequate appreciation of the dangers of heat by supervisors or individuals at risk;
- accidental or unforeseeable circumstances leading to very high heat stress.

Control of exposure to heat

As with most other areas of OHS, risks arising from exposure to heat can be controlled through engineering and administrative controls including training. The National Institute of Occupational Safety and Health (NIOSH) in the USA has devised the following control methods.

Engineering controls include:

- reducing the heat source by moving workers or reducing temperatures;
- convective heat control through cooling air and increasing air movement;
- radiant heat control by reducing surface temperatures, shielding etc;
- evaporative heat control through increasing air movement (fans), decreasing water vapour pressure (air conditioning), wet clothing.

Work practices include:

- limiting exposure time and/or temperature e.g. working at cooler times of the day, cool rest areas, extra personnel for job rotation and frequent breaks, increasing water intake;
- reducing metabolic heat through mechanisation, job redesign, reduced work times, increased personnel;
- enhancing tolerance times through heat acclimatisation; physical fitness; ensuring water and electrolyte losses are replaced;
- health and safety training including recognising the signs of heat illness; first aid and contingency plans; personal precautions; use of protective equipment; recognition of effects of non-occupational factors such as alcohol; and buddy system;
- screening for heat intolerance including previous illness and physical unfitness.

Additional programs include:

- Heat alert programs including planning for work in hot weather through timetabling and adequate information, facilities and personnel;
- Auxiliary body cooling and protective clothing including cooled garments and appropriate training;
- Understanding performance degradation when wearing all types of protective clothing including those that reduce heat loss or impair vision or hearing.

The mnemonic SHAFTS can be used to advise people how to increase tolerance to heat: the letters stand for sensible (ie appropriate) behaviour; hydrated; acclimatised; fit; thin; and sober (avoidance of alcohol and other drugs).

Working in the sun

Apart from the heat, the sun is now regarded as a major risk for skin cancer in outdoor workers especially those of European origin. The use of sun hats and other protective clothing, sun screens for the skin, sunglasses, the provision of clean drinking water and recognition of the need to take regular breaks from physical work in high temperatures should be mandatory in most outdoor jobs. These protective measures may alter the way the work is done and will need to be taken into account in the design of the work and the protective clothes, time schedules and payments for work done.

Cold

In air environments cold stress generally produces discomfort before any effect on health occurs. There is a strong behavioural reaction to cold and a person may avoid feeling cold with clothing, activity and/or shelter. Clothing helps reduce heat loss while activity raises the body's heat production. However if there are higher levels of activity sweating may occur and on rest heat loss and discomfort are made worse by damp clothing.

Cold can affect psychological responses including behavioural responses to increased discomfort. It can directly affect performance such as decreased arousal, reduced memory capacity, and perception. Changes can occur in mood and personality especially if the body's core temperature drops.

The effect of cold on the hands of individuals varies enormously under different conditions. These arise from a number of factors including size, structure and shape of the hand and fingers; contact force; surface temperature of the item being handled; material properties; surface mass; and the thermal condition of the whole body, the hands and fingers.

Control of exposure to cold

Workers in cool or cold climates, in cold storage facilities and in food preparation areas will need adequate protective clothing that takes into account the need to manipulate product, controls and tools safely and quickly. Therefore the wearing of bulky clothing, boots and gloves needs to be considered in the design of the job as well as for hand tools, access to and operation of machinery and the use of seating. Each job should be assessed for its particular requirements and reviewed on a regular basis.

The use of PPE such as gloves can minimise any harmful effects of handling cold items. Decreases in manual dexterity after contact with cold material may be offset by problems with dexterity when wearing gloves. However the design of gloves including thermal insulation and gripping qualities and their appropriate use needs to be carefully reviewed.

Issues that need to be addressed for workers in cold environments include:

- whether or not it is necessary for the workers to be in the cold environment in the first place. Are alternatives available such as the use of robotics or separating workers from the cold environments?;
- adequacy of clothing to protect from cold and the likelihood of sweating when workers are active;
- work practices encompassing appropriate behaviours e.g. wearing adequate protective clothing, length of exposure, activity, care when working with certain substances;
- monitoring air temperature, air velocity and equivalent chill temperature;
- screening workers who may have a reduced tolerance to cold.

KEY PRINCIPLES

- Ensure that there is accessible clean drinking water and encourage workers to drink adequate amounts of water in hot conditions. Drinking early and frequently is recommended.
- Protect workers from the sun, heat and cold winds.
- Provide workers with adequate, appropriately designed PPE for heat or cold.
- Provide workers with sun-screens, sunglasses, long sleeved shirts and long trousers when working in the sun.
- Provide equipment that can be used appropriately, safely and easily when wearing PPE.
- Ensure that work procedures are in place to reduce the risks of heat and cold stress. These include adequate work breaks, job rotation, extra personnel and job redesign.
- Train workers in the risks of working in hot and cold conditions and what they need to do to avoid problems including physical fitness, adequate fluids and limiting alcohol intake.
- Regularly monitor thermal conditions and workers responses to them.
- Consider alternatives to placing workers unnecessarily in hot or cold conditions.

Further reading: *• Book 15: Wilson & Corlett • Book 19: Parsons • Queensland DWHS 4.1: Heat Stress: Managing the Risk • Victorian WCA 3.1: Sun protection for Construction and Other Outdoor Workers • ACTU 7.2: Working in Seasonal Heat • Other material 8.13: Cold Environments – Working in the Cold • NOHSC 1.23: Comfort at Work – Too hot? Too Cold?*

Equipment design

Work stations, consoles, work benches

Considerations in designing workstations, consoles and work benches include:

- **horizontal work area –** these spaces need to include the use of materials, tools and equipment in the primary and secondary work areas and in the seldom-repeated activities in the tertiary work areas. The bench or desktop should be as thin as possible where people are seated usually no more than 50 mm. This allows the arms to hang by the side and manipulative tasks to be carried out at a comfortable height (about 500mm below elbow height);.

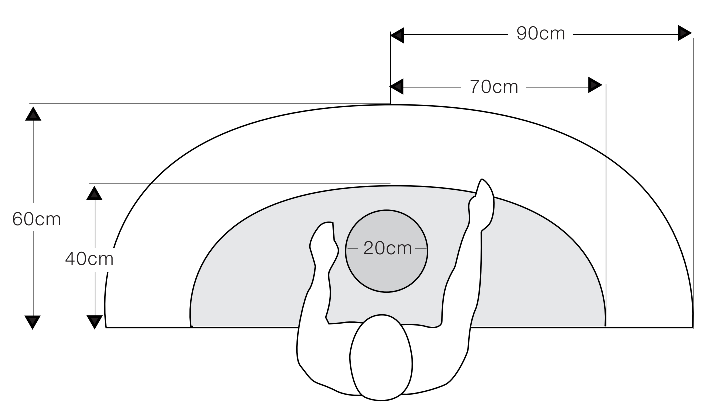


Figure 6.1: Horizontal work area

- **working position –** a sitting position is generally preferred for fine manipulation, and accurate control work; continuous light manual work; close inspection (visual) work; and where foot controls are regularly used. In sitting there should be enough space between the underside of the work surface and the seat for the legs and to allow movement. For standing work toe space should be at least 150mm in depth and height.

An operator should be seated for constant or repetitive use of foot controls. Where multiple functions are carried out the foot should be used for the grosser controls and the hand for the finer controls eg driving a vehicle.

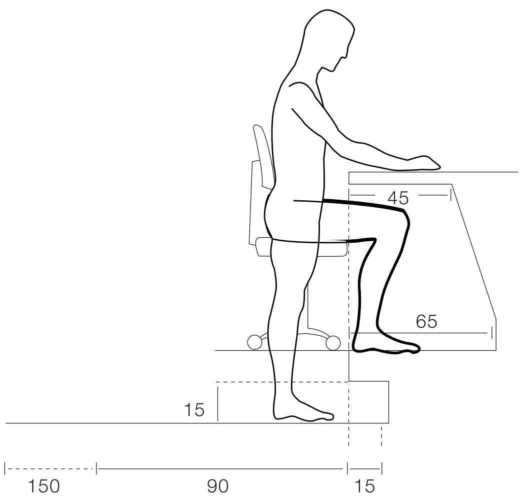


Figure 6.2: Leg space (cm)

A standing position is preferred where heavier manual handling work is performed; where there is no leg room under equipment; or where there are many controls and displays over a wide area that have to be monitored.

Standing work requires even, resilient floor surfaces such as rubber matting or carpet. This also reduces the risks of slipping.

Opportunities to sit or stand during the day, preferably as part of the job also should be included. Large and smaller users should be accommodated in these arrangements. This may be achieved with height adjustable seating, height adjustable work benches or an adjustable standing platform.

• **work height –** preferred work heights depend upon the nature of the task and the need for visual and manual precision as well as the handling of heavy components.

In most manual tasks the work height should be at a level just below the elbow with the upper arm held in a vertical position close to the body. For fine work involving close visual distances the work height should be raised to achieve this with minimal neck flexion and arm supports provided where appropriate.

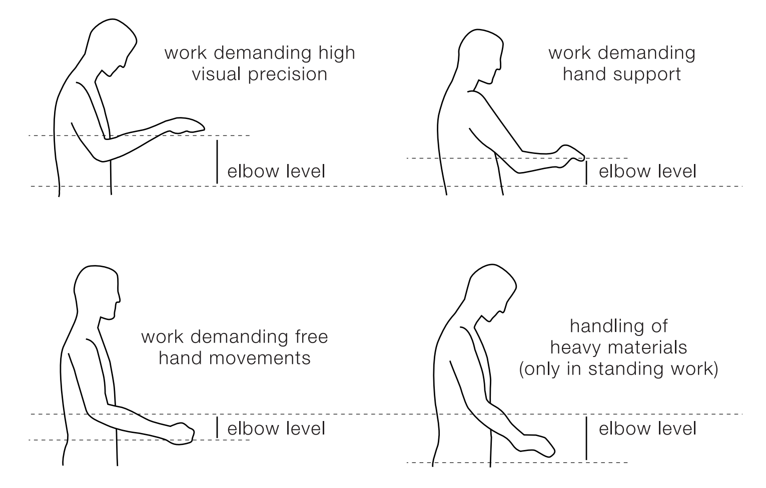


Figure 6.3: Working height

• **viewing distances and angles –** viewing distances for work should be proportional to the size of the work object. A small object requires a shorter viewing distance and a higher work surface. The most frequently viewed object should be centred in front of the worker. Recommended viewing angles vary depending on the work posture from 45° (forward leaning posture such as at a desk) to 15° (backward leaning such as in a control room) and how long a fixed gaze is required. Bent neck postures should not be maintained for more than a few minutes at a time without change. Distances should enable young and older workers to see properly without strain on the eyes or the muscles and joints

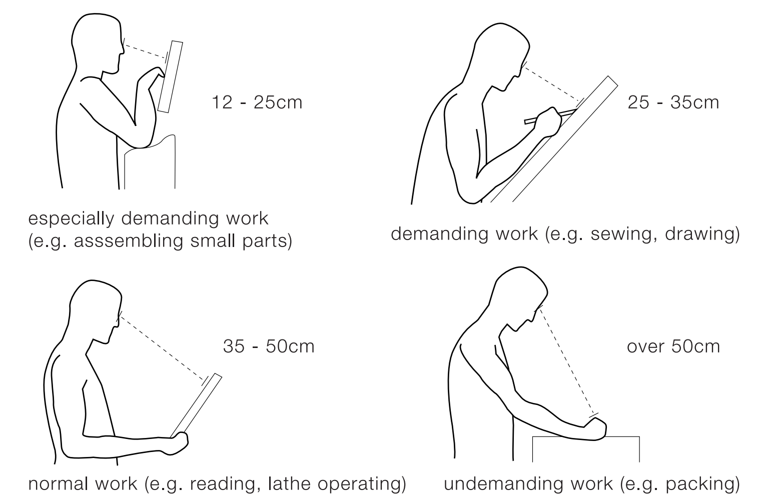
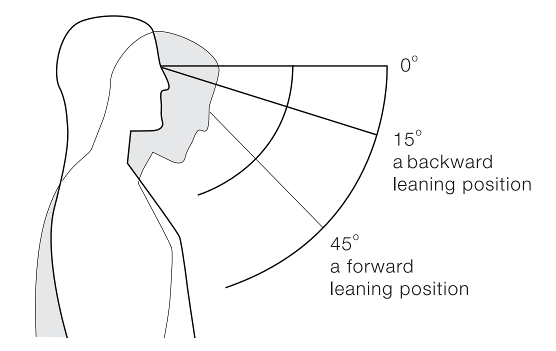


Figure 6.4: Viewing distances



6.5: Viewing angle

• **reach –** arm and leg reach should be based on the dimensions of the shortest user and take into consideration the postural, task requirements and working position (see Figure 6.1).

• **access and clearance –** space allowances for horizontal and vertical clearances and access to the workstation; access to machines and equipment used by operators and for maintenance personnel must be incorporated into the design of the work stations These allowances must be based on the dimensions of the largest user.

Tools

Tools are devices designed to extend human physical capabilities of reach, force application and precision movement thereby enhancing performance. Unfortunately they can also be a source of injury when inappropriately used or incorrectly designed. (See also Posture and Movement; Body Size; Physical Strength and Work Capacity).

Forces are generated from the human musculoskeletal system through the tool to the work piece and vice versa. Stresses arising from excessive forces and poor postures are frequently the result of poor tool design or inappropriate use. In some cases if a tool slips, breaks or looses purchase acute injuries can occur.

Tools are grasped in the hands and may be simple or may have controls. Generally mobile equipment is larger and is activated by controls eg handles, buttons, knobs, that have to be gripped, moved or turned by the application of manual or pedal force. These linkages become part of what is called the user interface. In some cases the status of the equipment can be transmitted to the operator through a display of some kind.

Handles

Gripping characteristics such as handle shape, palmar or pinch grips, output required eg power or precision work should be considered. Tools should have handles that have the proper shape, thickness and length to prevent pressure on the soft tissues of the hands and to allow a good firm grasp. They should be free of sharp edges and pinch points.

Insulate contact surfaces to prevent electric shock, burns or the transmission of unwanted vibration. Use low voltage electrical power and double insulation where possible.

Forces

The forces required to grip tools during use should be minimal and prevent slippage particularly where gloves are required eg hot, dirty or clean work. The grip surface should be compressible, non-conductive to vibration, heat, cold and electricity. Flanges can be used to stop the hand slipping down the tool or to keep a heavy tool slipping out of the hands when being carried.

If the tool is required to deliver power then it should have a power grip handle design ie the hand should be capable of gripping the tool with four fingers on one side of the handle and the thumb reaching around the other side locking on the index finger. (See Figure 5.6)

Where precision work is being required, the tool should have a handle that allows it to be gripped by the thumb and the first finger, or the thumb and the first and second fingers. (See Figure 2.5)

Design

All edges and corners of the tool and associated equipment should be rounded off and sharp, protruding elements avoided.

Tools should be designed so that they can be held and used with wrist and hand in the neutral position (See Figure 2.8) Where the task requires large forces or has to be performed over extended periods, the tool should permit the arms and shoulders to be used.

Align the tool's centre of gravity with the grasping hand so the operator does not have to overcome rotational movement or tool torque.

Ensure that the transmission of noise and vibration is minimised. Guard all moving parts.

Type of operation

Power operated tools should be used instead of muscle power where possible. Using a single finger to operate a power tool is not recommended especially where it is repetitive and/or is required for extended periods. While the majority of the population prefers to use the right hand tools should be designed so that they can be used with either hand.

Weight

Tool weight should be minimal. Where tools are heavy counterbalancing devices can reduce the weight. The tool should be easy to set down and pick up.

Controls

The control levers, buttons and knobs should be within the reach of the worker when operating the equipment. The forces required to engage the controls should be within the worker's capabilities but not so light as to be inadvertently activated or difficult to control speed or force. The direction of movement of the controls should be consistent with the expected outcome eg moving the control lever forward moves the equipment forward. Ensure that weight-holding is separate from the force, guidance and control functions.

KEY PRINCIPLES

- General work position, body and hand postures need to be comfortable and stable.
- Stabilising work materials is essential and may need a jig or other mechanical device.
- Handle characteristics such as shape, thickness, length and contact surfaces are important for grip.
- Controls should be suitable for the type of tool and its use and appropriately located.
- The balance and weight of the tool should enhance its operation and make it as easy as possible for the user to operate correctly and precisely.
- The tool and the work need to be clearly visible while setting up and operating.
- All necessary information on the operation and guidance of the tool needs to be available through training and/or manuals. Manuals need to be properly indexed and easy to use.
- Tool holders may be required between uses. The tool may also need secure storage.
- The electric cord position and the location and operation of controls should enhance operation.
- Guards should be used to protect users and others from moving parts. Debris and sparks need to be minimised.
- Adjustments should be easy to use and give the user feedback on the correct adjustment positions.
- Reduction of vibration, noise and heat may be required where these exceed accepted standards.
- Safety features such an emergency safety switch and prevention of electric shorts need to be incorporated in electrically powered tools. Refer to relevant Standards.
- Maintenance and repair schedules should include day-to-day checks and services, the prevention of parts loosening, as well as planned services after longer periods of operating. These procedures need to be clearly specified and documented.

Further reading: *• Book 3: Sanders & McCormick • Book 4: Stevenson • Book 6: Stevenson • Book 7 Woodson, Tillman & Tillman • Other material 8.12: Ergonomics*

Mechanical aids

Job aids need to be well designed for the purpose and readily accessible if they are to be used when they should. For instance lifting aids need to be compact, easy to move and use, stable and safe. Storage is often a problem and this needs to be considered when purchasing. In some cases moveable lifting aids such as cranes and hoists can be installed overhead thereby overcoming storage problems.

Height adjustable benches and jigs need to be sufficiently adjustable to accommodate all users and work tasks. Anthropometric tables (ranges of people sizes) are often used to guide designers in this. (see also Body Size) Adjustments should be easy and quick to make from the working position.

Wheels on mobile equipment should be of sufficient diameter to enable them to be rolled over rough or uneven surfaces without undue force and without the risk of sudden uncontrolled movements.

Maintenance programs must ensure that job aids meet legislative requirements and function as the manufacturer advises.

Further reading: *• Book 16: Diffrient, Tilley, Bardagjy • Books 17: Diffrient, Tilley, Harman • Book 4: Stevenson*

Displayed and oral information

Ergonomics is concerned with all aspects of communication but most importantly it has contributed substantially to our understanding of displayed and oral information (machines communicating to people). It has also developed some basic principles for communication systems.

In all jobs the communication of information is important. In some jobs it is critical. Depending on its nature and how essential it is to communicate precisely and quickly there are a range of methods that can be used. The objectives of a communication system are:

- **detectability –** the intended receiver can sense the signal;
- **recognisability –** the intended receiver can tell what the signal is;
- **intelligibility –** the intended receiver can tell what the signal means;
- **conspicuousness –** signal is attention-getting.

Consider:

- **Types of information –** Are they spoken messages, flow charts, task surveillance information, pictures?;
- **Time factor –** How rapidly must the information be transmitted?;
- **Number of intended recipients**;
- **Receiving environment –** Is there interference, noise?;
- **Reliability –** Can it be repeated if necessary?;
- **Quality –** Are there accents? What is the level of intelligibility? Is there use of jargon or specific terms?;
- **Language –** People whose first language is not English need to understand and be understood;
- **Personal factors –** Are recipients able to see facial expressions or hear voice inflections?;
- **Directionality –** Are they able to identify the source or the direction of information?;
- **Message capture –** Does there need to be a record of the transmission?;
- **Condition of the recipient(s) –** How busy are they? Are they using hands and eyes for other tasks? Is there physical stress such as vibration?;
- **Critical nature of the information –** What happens if the information is not transmitted or received correctly?

Further information on the design and use of auditory and visual communication can be found in ergonomics textbooks.

Visual displays

Increasingly people are using visual displays for the transfer of information. Simultaneous perception of a large amount of information by humans is best achieved through the eyes and the form in which it is presented must be suited to as many people as possible. Therefore information displays should be clear, concise and precise. There should be no doubt about what information is being communicated to the user. In order to achieve this a range of design rules applies.

Displayed characters may be illuminated such as on a computer screen or on a flat surface such as on the page of book. For legibility consider size, shape, spacing and contrast. In continuous text lower case letters are preferable to upper case. Capitals should be reserved for the first letter in a sentence, and for headings, titles, abbreviations and proper nouns. Use a familiar typeface, plain and without ornamentation. Use proportional spacing for letters and do not right align as the spaces become disproportionate to the words, making it harder to read.

KEY PRINCIPLES

- Use the simplest display concept appropriate for the information transfer needs of the operator.
- Use the simplest display format appropriate to the accuracy required.
- Use the most natural or expected display format for the type of information represented.
- Use the most effective display technique for the viewing environment and operator viewing conditions.
- Optimise the following display features:

  visibility – taking into account viewing distance, size, angle, contrast, glare and illumination and any visual problems in operators

  conspicuousness – ability to attract attention and to be distinguished from background interference and distraction

  legibility – pattern discrimination, colour and brightness, contrast, size, shape, distortion and illusory aspects

  interpretability – how well viewers understand the meaning and apply to their tasks.

Apart from the design of the display its location is critical. For information to be read and interpreted correctly it must be in the user's line of vision, it should not have reflective surfaces or be able to be degraded by high levels of light. The more critical the information the more it must be easily seen and interpreted.

If analogue displays are used (dials and pointers) to indicate levels or speed for instance be sure that increments are sufficient to be able to be detected and they are not subject to parallax error.

Displays should be readable from the user's position without them having to use awkward postures or movements. This is particularly important when information is critical. All information necessary to the normal functioning of the machine, equipment or system needs to be displayed in a readily interpretable form.

Instruments and other visual displays

The design of information displays and instruments should enhance the operator's capacity to determine the state of the machine accurately, easily and when it is needed. The aim is to minimise errors, operator fatigue and wear and tear on machinery.

KEY PRINCIPLES

- Location and layout of the displays need to comply with relevant standards and should be clear and readable from the operator's position.
- Displays should be grouped and/or located according to their function, the critical nature of the information and the frequency of usage. All principal displays need to be in the direct line of sight of the operator.
- Displays that are used infrequently may be out of the direct line of sight but information needs to be large and clear enough to be seen under sub-optimal conditions.
- Provide all the necessary information for operator's to make well-considered decisions.
- Do not provide unnecessary information that may clutter the visual field and/or confuse.
- The purpose and location of all displays needs to be clear.

Further reading: *• Book 3: Sanders & McCormick • Book 7: Woodson, Tillman & Tillman • Book 5: Clark & Corlett • AS 5.14: AS 2956.5: 1988 • AS 5.15: AS 2956.6: 1988*

Warnings

A warning is a message that is intended to provide information concerning a possible unpleasant or negative consequence of either an action or a non-action. Warnings can be provided in several ways:

- **verbal speech –** warnings given by co-workers or supervisors;
- **auditory non-verbal signals –** the timer on the stove sounding that food is cooked;
- **visual signals –** traffic lights;
- **signs, labels or symbols –** a traffic stop sign or a warning label on a hazardous substance or the non-smoking symbol.

The type of warnings given will depend largely upon the situation and for whom the warning is intended. For example, an auditory non-verbal signal would be lost in a noisy work environment.

Organisations should consider what type of warning would be suitable to use in a particular circumstance and ensure that the warning is appropriately designed. For example, when using written signs to convey a warning message, the type of language used in the message should be taken into account. Use short statements in plain language with symbols where appropriate. Colours of the sign, the typeface and the suitable placement of the sign in the workplace need also to be considered.

Where the operator might be in a fixed position the visibility or audibility of warning signals need careful attention.

Colour-blindness needs to be considered where red/green combinations might be used for danger and operational status.

KEY PRINCIPLES

- Warning lights alert the operator to a situation that makes the system inoperative (an error or failure) or may cause damage to the machine.
- Warning lights should be red.
- Yellow lights should alert the operator to a situation where caution, recheck or delay is necessary and if not attended to could lead to a dangerous situation.
- Green should indicate that equipment is operating satisfactorily or that the operator can proceed. It can also indicate the successful completion of steps within a process.
- White should indicate status, alternative functions, selection modes, a test in progress or similar items that imply neither success nor failure of system conditions.
- The use of flashing lights should be minimised and used to increase the conspicuousness of the signal and to alert the operator to a potentially dangerous situation.
- Flashing red lights should be used to indicate extreme danger.
- They should be located directly in front of the operator.
- Warning lights should be clearly visible.
- Redundancy (additional) indicators such as auditory signals should be provided where further information on the status of the system is required.
- Be aware of the need to check individual's ability to discriminate between colours e.g. colour-blindness especially red/green.

Note: Local or industry standards for displayed information may give contrary information to Australian Standards. The most appropriate Standard must then be followed.

- Additional, auditory alarms may be included to bring the operator's attention to a problem immediately.
- Auditory alarms should not be used simply to indicate the status of the system.
- Auditory alarms should be able to be heard and identified either through pitch or frequency or both.
- Very loud signals are not acceptable. They may startle listeners, may distract them in an emergency or a critical task and may cause temporary deafness.
- The audible alarms are often unnecessary if the colour coding conventions for visual alarms are followed.

Safety signs

The primary objective of safety signs is to warn or caution. The device should be noticeable, recognisable and understandable. They may fall into specific classifications of warning or caution signals or signs; or hazard advisory or instructional. They need to meet the following criteria:

- **conspicuousness –** the sign should stand out and be located where most people would look;.
- **emphasis –** words or symbols should imply danger. Words such as 'danger', 'hazard', 'caution' and 'warning' are suitable. Symbols should be standardised and immediately indicate the nature of the hazard;
- **legibility –** when words and messages are used the size and style of letters and contrast with them and the background need to be sufficient to be read. A border separates the message from the background;
- **simplicity –** use as few words as possible; keep information short and simple; tell the observer what to do or what not to do; avoid acronyms or abbreviations;
- **intelligibility –** say exactly what the hazard is and what might happen if the warning is ignored;
- **visibility –** make sure that the sign is visible under all expected viewing conditions;
- **permanence –** devices and sign materials need to be resistant to aging, wear, soil, vandalism and deterioration due to sunlight or cleaning;
- **standardisation –** use standard signs and symbols where they already exist. If local, long-term usage is likely to be better understood this might be acceptable. However, consider interpretation by visitors and newcomers. Wherever possible ergonomics principles should apply.

Further reading: *• Book 3: Sanders & McCormick • Book 7: Woodson, Tillman & Tillman • AS 5.8: AS 1319: 1994*

Controls

Layout

Specific considerations in the design of controls should include the following:

- Laid out and designed for easy and safe operation, and to prevent confusion over allocation of control functions or direction of operation. When operators are moving from machine to machine with similar functions controls should be standardised for position, function and operation as far as practicable;
- Organised into primary and secondary groups;
- Arranged so that similar functions are together (dissociate if confusion is likely) and position with sufficient space between controls to prevent unintentional operation;;
- Backlit with a dimmer switch for easier identification at night;

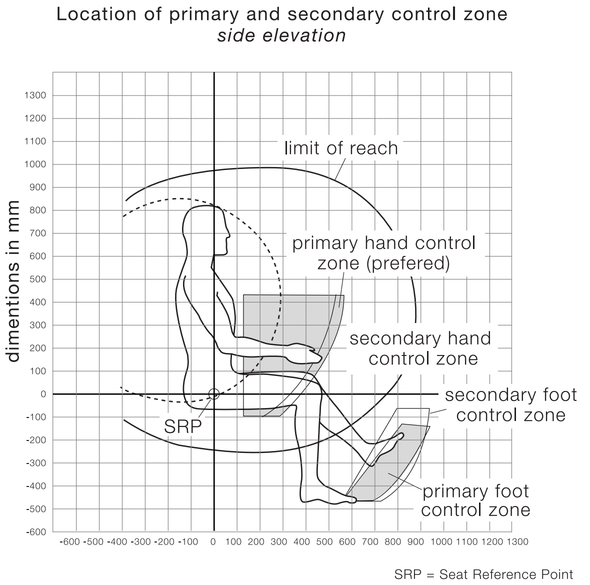


Figure 6.6 (A): SAE envelopes for cab design

- There are safeguards against accidental or inadvertent operation for critical controls eg locate out of easy reach; separate; or use guards, recessing, collars or an opening cover.

Shape and size

Each control should be readily distinguished by its location, type, shape, feel.

The size, shape, colour and location of knobs and switches and other controls must be matched to usage and their importance.

Size should accommodate large feet (pedals) or small/large hands and account for the need to wear protective clothing like gloves or safety shoes

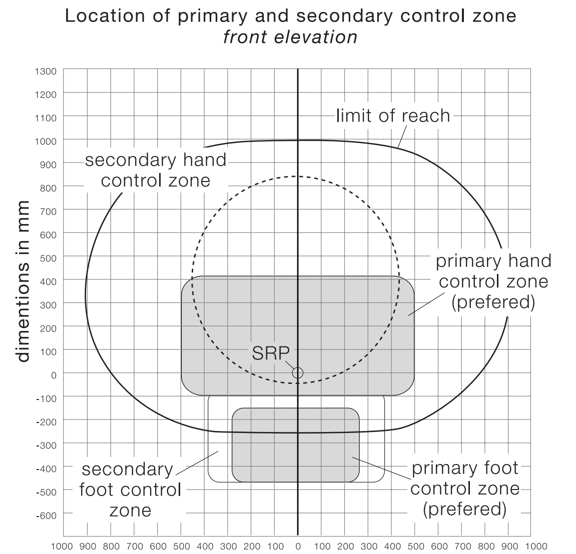
Movement, effort, resistance and feedback

Movement of controls should produce a consistent and expected effect.

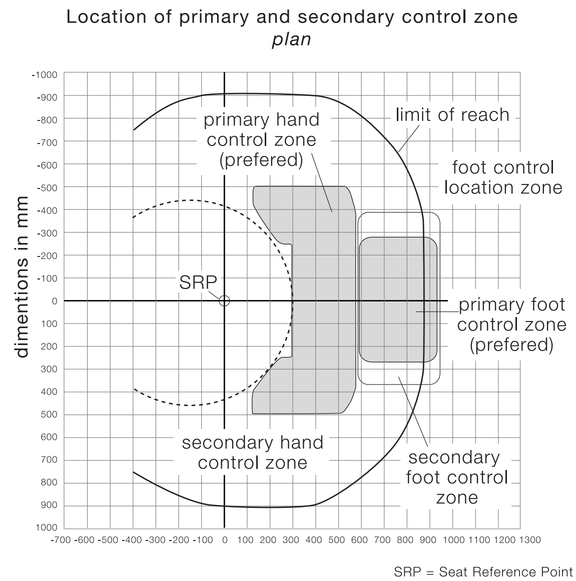
Control force and function need to comply with conventions. Recommended control motions should be observed

Optimum force should be required to activate control and movements should be consistent with the natural movements of the arms or legs. Angle of push or pull should be designed for optimum control and movement. Control type should be selected to provide the most appropriate movement or activation control eg levers for the application of force and speed, smaller controls for fine control and accuracy.

Controls should provide feedback so that operator knows at all times what his/her input is accomplishing. They should have distinct resistance gradients at critical control positions.



Diagrams 6.6 (B): SAE envelopes for cab design



Diagrams 6.6 (C): SAE envelopes for cab design

Function	Direction
On	Down (switches), right, forward, clockwise, pull (pull/push type switch)
Off	Up (switches), left, backward, anticlockwise, push
Right	Clockwise, right
Left	Anti-clockwise, left
Forward	Forward, down
Reverse	Backward, upward
Raise	Up, back, rearward
Lower	Down, forward
Retract	Up, backward, pull, anti-clockwise
Extend	Down, forward, push, clockwise
Increase	Forward, away, right, clockwise, out
Decrease	Backward, towards, left, anti-clockwise, in
Open valve	Anti-clockwise
Close valve	Clockwise
Emergency stop	Push button or pull cord
Remote shutdown	Left, backward, push (switch knobs), up switches

Table 6.1: Direction of movement for controls

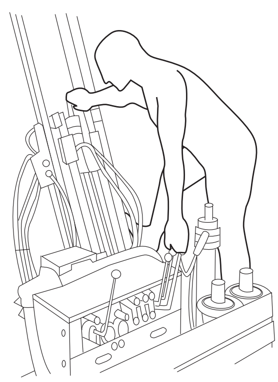


Figure 6.7: Reaching to poorly located and designed bolter controls

Static friction should be minimised (resistance to control movement initiation) as use of excessive force may cause overshoot and correction may be required.

Sensitivity of adjustment controls should be related to the degree of control required especially if they are heavy. Excessive force should not be required for small increases. For instance small movements should not produce large unwanted increases e.g. volume control.

Labelling and identification

The purpose and location of all controls must be clear. Controls should be marked with etched labels or permanent paint of contrasting colour ie white on black or black on white.

Lighted switches can provide quick identification and feedback on condition and function.

Remote control devices

Special attention needs to be paid to the design of remote control devices and there are many aspects where incorrect design could cause disastrous consequences. As a result an Australian and New Zealand Standard has been written to cover this area in mining.

KEY PRINCIPLES

- ***Type of control –*** consistent with the natural motions and postures of the operator's arm and hand or leg and foot.
- ***Feedback –*** the operator knows at all times what his or her input is accomplishing.
- ***Resistance –*** sufficient to dampen inadvertent inputs but not so much as to cause fatigue.
- ***Position of the control –*** the operator does not have to assume awkward postures or long reaches and the control can be manipulated through the entirety of its range. Postures adopted for continuous operation are comfortable eg accelerator pedals.
- ***Size and shape –*** should be compatible with the size of the operator's hands, fingers or feet. Consideration should be given to the wearing of protective clothing such as gloves with sufficient space between controls to prevent inadvertent contact or activation of other controls. The shape of the control should be compatible with the grip or motion required.
- ***Interface surface –*** should depend on the operation required. Surfaces should not be too slippery, sticky or abrasive or have prominent parts that cause injury.
- ***Undue pressure –*** smoothness may be required where changes of position are required. Knurling or serrations for fingers are not recommended in most situations because these can only suit one hand size.
- ***One-handed versus two-handed operation –*** two-handed controls may provide more precision but should not be used when an additional control is required to be operated simultaneously.
- ***Remote control devices*** need to conform to Australian Standards.

Further reading: *• Book 3: Sanders & McCormick • Book 7: Woodson, Tillman & Tillman • Book 5: Clark & Corlett • AS 5.14: AS 2956.5: 1988 • AS 5.15: AS 2956.6: 1988 • AS 5.9: AS/NZS 4240:1994*

Chairs and seating

Seated work and sitting postures

Standard work postures recommended in most guides and textbooks are a starting point for seat and work height adjustment. No posture, no matter how good, can be maintained for more than 15-20 minutes before small changes are required. No seat, no matter how comfortable, will allow the user to sit comfortably for more than about an hour at a time without having to move and make significant changes in posture.

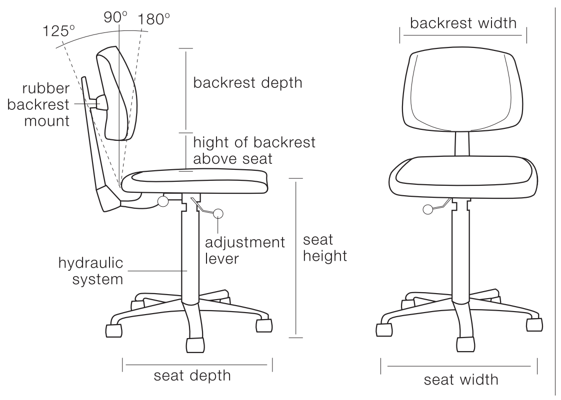


Figure 6.8: A basic office chair for computer, office and control room work

Therefore seated work should be mixed with standing and walking. The best way to guarantee that this happens is to design work with a mix of tasks that require employees to get up from a seat and stand and/or walk.

Work at desks and standard-height workbenches require a standard adjustable work chair.

Work at sit/stand workstations may require a higher chair. However, these can be unstable and are not recommended where alternative arrangements are possible. In some cases some work can be done in sitting in one part of the work area and in standing at another part. This may require more space as well as planning.

Work chairs

Designing optimum chairs is an ongoing process with much work still to be done. Nevertheless the basic requirements for a work chair do not change. It should provide adequate support for the user while working, should not place any unnecessary stress on any part on his or her body and should positively encourage optimum posture while allowing for comfort and efficiency and minimum muscle fatigue.

There are three major factors that have to be considered when sitting on a work chair.

1. The posture of the spine and in particular the position of and the pressure within the discs;
2. The type and amount of muscle work required to maintain work postures (static and active) and individual fatigue tolerance levels;
3. Compression of tissues (blood vessels and nerves) particularly at the back of the thighs and behind the knees.

Non-adjustable chairs are used in common areas such as tea or waiting rooms, where people are not required to sit for long periods in the same spot every day, or where chairs may need to be stored from time to time. These should suit most of the population (middle 90%) to a reasonable degree. The seat height should be in the range of 410–430 mm with a seat depth of no greater than about 360 mm. The seat should have a backrest which is from 80–130 mm above the seat and where practicable (indoors) should have sufficient padding to prevent ‘bottoming’.

Ergonomics considerations for work chair comfort

- as a starting position elbows should level with the work height, forearms horizontal and upper arms hanging freely.
- the head should be able to held erect with the backrest of the seat conforming with the curve of the lumbar spine.
- there should be room for the buttocks below the backrest.
- there should be adequate space forward for the legs stretched out and for knees and thighs under the bench top or desk.

- chair height should be sufficiently adjustable in relation to work height and lower leg length to accommodate tall and short people.
- feet should be placed flat on the floor to reduce pressure on the soft tissues at the back of the thighs. Very small users may need an adjustable footstool even when the seat height is adjustable.
- the backs of the knees should be free from the front edge of the seat so there is no pressure on the soft tissues.

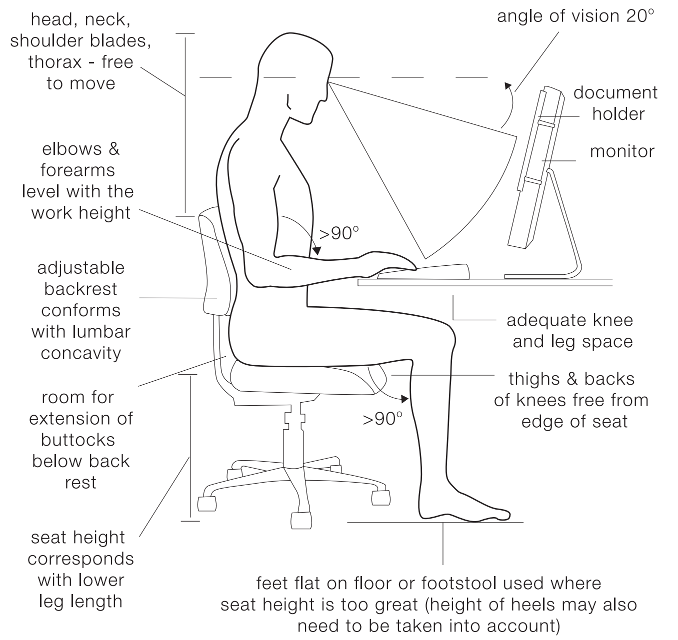


Figure 6.9: Optimum sitting position

These considerations provide a starting point for chair and desk/work bench adjustment. Individual requirements and certain jobs will mean that postures may vary from this but the principles will remain the same.

KEY PRINCIPLES

- No one posture is suitable all of the time or for all people. Regular changes in sitting posture are to reduce the effects of fatigue. Tasks should be organised so that people can take breaks from sitting periodically.
- No chair has been designed to seat people comfortably for more than about an hour at a time. Even the best designs become uncomfortable over time.
- If people are seated for the majority of the working day they need well designed seating including adjustments and padding.
- Work seating should be adjustable in seat height, backrest height and backrest angle. Other adjustments are desirable depending on individual needs.
- Adequate lumbar support (at the base of the spine) is important for comfort and back care.
- Where computers are used some adjustability in keyboard height, screen height, position and angle are important.
- Desk and chair height should allow users to sit with their feet flat on the floor and their thighs horizontal with minimum pressure on the lower parts of the thighs.
- Where a desk/chair is too high a footrest should be used.

Further reading: *• NOHSC 1.14: Selection of Office Furniture and Equipment • Book 11: Officewise • ACTU 7.1: Screen Based Work • Other guidelines 8.12: Ergonomics*

Vehicle cabs

There is a large body of ergonomics information available for designing cab spaces, and controls and displays in cabs. Much of it relates to control processes generally but is also applicable to cab controls. (See Driving Vehicles and Operating Machines)

Ingress/egress

Adequate hand holds to assist drivers' access to cab should comply with applicable standards. Hand holds must not be placed where driver's hand might be vulnerable to danger.

The Australian Standard AS 3868 – 1991 requires that if entry is more than 400 mm off the ground a step is necessary. The first step should be no more than 400 mm off the ground. However 500 mm is given as an acceptable height in some ergonomics literature.

Minimum width of each step for one foot should be 200 mm. The dimensions and materials suitable to access steps are specified in the Australian Standard.

Door size should allow easy, safe access to the cab without impediment. The minimum door width required by the standard is 450 mm. Optimum door width for transport vehicles is about 700 mm.

Operator's space

The design of the operator's space must be sufficient for comfort, visibility and operation of equipment such as communication devices. Operators should be able to reach controls and see displays comfortably and easily from the seated position.

Any manoeuvres necessary for the operation of the machine should be able to be performed safely and without unnecessary fatigue or discomfort. Controls should be within an 180° radius of the operator and within easy reach especially in free-steered vehicles (not on rails or tracks).

Good access to the seat and within the cab is dependent upon adequate space between the seat and other equipment and fixtures in the cab. Some seat adjustment fore and aft is usually necessary. Seat swivel will be necessary for some machines but there are limited applications for this (cranes, draglines, backhoes etc) and adequate space must be available in the cab.

Tripping or catching hazards and obstructions, both within the cab and while gaining access to it, should be eliminated or modified so as not to cause injury or accidental activation. Sharp corners should be rounded and protrusions padded or recessed or more space provided for access to the seat and equipment.

Line-of-sight requirements for vision outside the cab should be specified. Usually this assumes a control panel in front of the operator and at least 15° uninterrupted line of sight below the horizontal in front of and to the sides of the cab. Rear vision mirrors and other aids to vision should be designed so as not to distort angles, distances or perspective and should give clear and uninterrupted view of the area to be seen. Visibility should be sufficient to see people, obstacles and the state of the work area (the road, objects or materials being moved) that may be critical to the operation or to safety. Mapping the operator's sight lines can be undertaken for different vehicles and machines.

Noise and dust should be minimised through design and maintenance eg appropriate seals on doors and windows and air filtration systems that are well maintained.

There should be adequate, accessible storage space for manuals and other items kept in the cab.

Monitoring should be undertaken to ensure the adequacy of the design and maintenance of the operator's space.

Cab seats

Seat design and adjustments should be suitable for the type of work, the conditions, the vehicle and the operators. It should be robust and not have components that are easily broken, torn or damaged.

The specifications for a cab seat should take into account the range of sizes of operators, their job, the type of machine being operated, and opportunities to leave the seat. The seat should be able to accommodate about 97% of all operators. It should be designed for the job and the type of machine being operated.

The longer an operator is required to sit in the seat without a break the more closely the seat should meet the required specifications. Operators need to get up out of the seat and walk about at least 5-10 minutes in each hour depending on shift length and percentage of the shift spent in the seat.

Height adjustment of the seat is usually necessary to enable short and tall operators to see critical areas outside the cab. However height adjustment of seats in smaller vehicles such as cars and 4WDs are usually not possible due to low roof heights. Some fore/aft adjustment as well as height adjustment in the seat will be necessary to accommodate smaller and taller users. The detrimental effect of the excessive seat height can be reduced to a small degree by a seat tilt adjustment. However, operators may not be able to use the backrest as effectively with the seat tilted forward.

The backrest height needs to allow free shoulder and arm movement (usually below shoulder height) where there is no acceleration or deceleration fore and aft and no significant lateral movement (such as seats in cranes, drag lines and ship loaders).

A higher backrest is required for on-road and off-road vehicles to support the driver during acceleration and deceleration. The backrest should be firm and supportive, adjustable in height, slightly concave laterally with a lumbar support area that is convex vertically. If there is significant lateral movement within the cab the sides on the seat and the backrest should be slightly raised.

The seat cushion should effectively distribute pressure but not 'bottom out' with heavy users. Where there are significant jolts and jars or other types of whole-body vibration suitable seat suspension will be required.

Seat swivel may be required in machines such as cranes, draglines, bulldozers and ship loaders. If it is provided operators should be able to activate the seat swivel quickly and easily and should be encouraged to do so rather than twisting in their seats. As well, some mechanism for preventing swivel when it is not required should be incorporated.

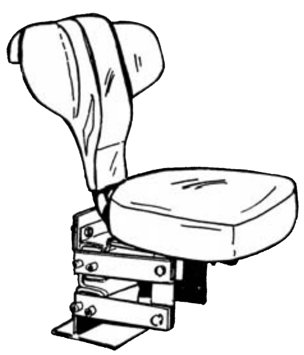


Figure 6.10: Seat for underground vehicle

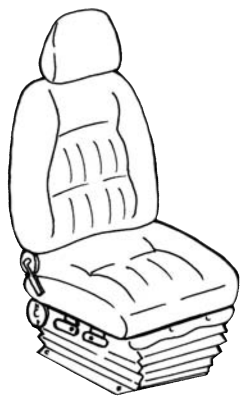


Figure 6.11: Truck seat

Seat	Seat depth – 380–480 mm, Seat width – 450 mm (min) Angle – 5-10° backwards The seat may be slightly dished (raised sides – max 25 mm transverse, 40 mm lengthways). Height adjustment in the seat (at least 130 mm, 200 mm preferred). Height adjustment range above floor level – 370-500 mm At least 150 mm of travel fore/aft adjustment of seat (AS 2956.5). Front edge and sides of the seat – well rounded to avoid pressure on the underside of the operators' thighs (approx. 60 mm radius).
Backrest including lumbar support	Height above seat – approx 200-250 mm (position of mid lumbar support above seat). Angle adjustment of backrest – 95-120° to horizontal.

All adjustments should be achieved easily and quickly from the seat position. Recommendations for adjustment should be provided, preferably attached to seat.

Armrests are usually not recommended in travelling vehicles. Where they are considered to be necessary their length and height need to be specified in keeping with current patterns of use and should not interfere with arm movements. They should be able to be stowed when not in use.

Seat belts should be provided where required.

Recommendations for adjustment and regular and timely maintenance should be provided, preferably permanently attached to the seat in some way or displayed in the cab eg transfers on wall. It should be easy to change or repair seat and backrest covers.

Vehicle displays

Display screens should have characters and graphics that can be read with ease at a specified distance. They need to be stable and adjustable in height, angle and distance from the operator's eyes. Graphics should be clear. Consider design and layout, size, colour, contrast, font and stability of the image.

Reduce specular reflections by matt and non-reflective surfaces and dark colours where appropriate. Consider surface treatments of the screen, careful placement and orientation of the unit and the use of glare-reducing blinds and window treatments. These must be easy to use and clean and there should be no decrease in visibility to the outside at night for the operator.

Primary displays should be in the direct line of sight of the operator. Displays that are used infrequently may be placed out of the direct line of sight of the operator. Information displayed needs to be large and clear enough to be seen under sub-optimal conditions.

The best viewing angle is at approximately 15°-35° below the horizontal line of sight. If operators use bi- or tri-focal spectacles consider height adjustment for screens that allows screens to be lower or spectacles prescribed for each operator for screen work.

Displays should be grouped and/or located according to their function, the critical nature of the information and the frequency of usage.

Illuminated displays should have a dimming feature for night use.

Vehicle controls

The shape, texture and angle of the handle, length of lever, separation, location, resistance and travel of controls need to be specified to optimise the operators' comfort and performance.

Optimum positioning of lever controls in relation to the operator is important. For continuous or repeated use the upper arm should be in a comfortable position and close to the operator's trunk.

The angle of handles should be considered carefully. The position of function is with the thumb up and the palm of the hand facing inwards. A handle that was slightly angled away from the body may be more comfortable than a straight alignment. (See also Posture and Movement)

A round grip provides more flexibility for changes of hand position, if that is required.

Finger convolutions are not recommended for the handle because they cannot suit all users. If friction or better grip is required consider higher friction surfaces. However, if the palm has to rotate around the handle this is inadvisable.

Lever, knob and button motion stereotypes should be observed (See Table 6.1). Where local recommendations or standards apply that are contrary to the general recommendations these need to be examined carefully for risks of incorrect operation and a clear guideline outlining reasons for choosing one or the other should be developed. Training times for inexperienced and new users need to be taken into account.

Levers are good where speed of operation is required but are poor for accuracy.

The size, shape, colour and location of knobs and switches and other controls must be matched to usage and their importance.

Layout of controls

Controls should be:

- laid out and designed to allow easy and safe operation and to prevent confusion over allocation of controls to functions or direction of operation;
- all primary controls including their displacement should be located with their neutral position and, if possible, all other positions in the zone of comfort;
- all secondary controls should be located within the zones of reach. (See Figures 6.6 A, B, C)

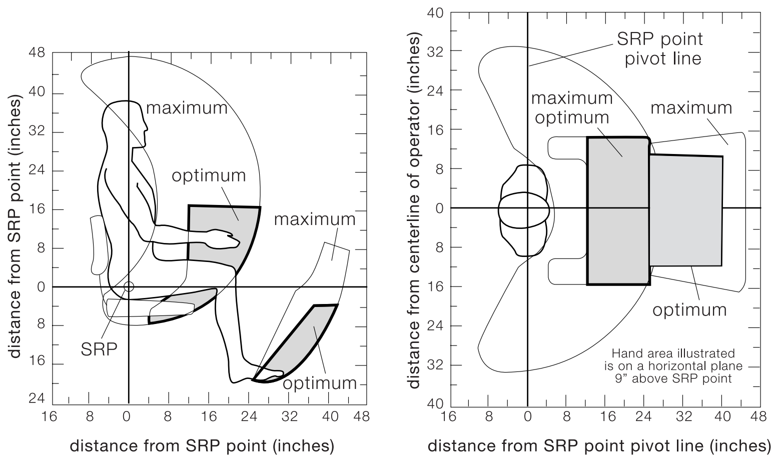


Figure 6.12: SAE space envelope for control locations in construction and industrial equipment

Controls, control linkages, hoses, tubes and connections should be located so they are not likely to be damaged by foreseeable external forces i.e. used as a step, requiring maximum hand or foot forces to be exerted. They should be easily accessible for inspection.

At least 180° of arc of a steering wheel should be located within the zone of comfort.

The distance between control levers, adjacent foot pedals, knobs, handles, operator's body and other machine parts need to be sufficient to allow unhindered operation without unintentional actuation of adjacent controls.

Design controls so that they can be actuated within the appropriate zones to eliminate potential interference between the body limbs when simultaneously operating the hand and foot controls.

Hand controls

In general for larger forces where the operating force is one hand, the arm is extended forward at 30° to the trunk. For high speed and accuracy the hand should be close to and in front of the body. Where switches are incorporated into the handle they should be far enough apart to prevent inadvertent actuation.

No more than six functions (preferably less) should be considered for a single controller. Resistance should be sufficient to dampen any inadvertent movement but not so great as to cause unnecessary operator fatigue.

Foot controls

The exact shape, separation, location, angle, resistance and travel of foot controls are critical for control and ease of use. Some adjustability in seat height may be required to accommodate taller and shorter operators.

Foot controls are quick to use and force can be applied easily. However, they do not give accurate control. Separation should be greater than 50 mm.

The final design should integrate the particular requirements of the operators including the prevention of accidental operation especially in emergencies and ergonomic design principles.

Simultaneous hand and foot control operation fixes the operator's posture and can be tiring for periods of greater than an hour. Therefore regular breaks will be required throughout the day.

Air conditioning controls

Controls for air conditioning should be located with primary or secondary controls. Function of each control should be identified in some way and should be easy and simple to use. Displays of information on the status of the air conditioning unit should be clear and unambiguous requiring minimum instruction to understand.

Noise from an air conditioning unit should be minimal and should be measured on maximum with the machine on full power with the doors closed. Airflow should be adjustable and able to be directed away from the operator. Outlets should be spread around the cab to ensure an even temperature in all areas. Temperature of and airflow into the cabin should be able to be controlled by the operator.

Other cab features

Sound levels in the cab

Noise generated by the vehicle or outside it should not expose the driver or passengers to levels that exceed 85 dB (A) for an eight-hour equivalent. Noise generated by the vehicle or outside it should not expose the driver to peak levels that exceed limits laid down in legislation.

Visibility

Ensuring that all surfaces are matt and non-reflective may reduce specular reflections. Avoid painting bonnets and parts in front of the driver/operator white or other light colours. Blind spots should be reduced to a minimum and where they remain they should be brought to the attention of the operator and others in the area. Line of sight must not blocked in any critical function by controls, displays or other parts of the cab

Mirrors

Mirrors or other devices are used to enhance visibility. They must be large enough and correctly positioned to enable the operator to see behind and to the sides of the vehicle.

Distortions created by curved mirrors should be brought to the attention of the operator and extra training may be required.

Extremities of the vehicle or machine should be visible at all times from the cab

Accessibility of various items

Ease of viewing of fluid level gauges/sight glasses enables regular checks to be made without difficulty or error. Misinterpretation of information should be minimised by the design of the sight glass/gauge, which should be easy to clean.

Ease of access to filling points and batteries for checking, filling or removal helps to reduce the risks of expensive errors, accidents or injury while filling and saves time.

Toolboxes (where they are required) should be easily accessible from either the cab or the ground and should be lockable.

Guidelines and standards

The Society of Automotive Engineers (SAE) in the USA produces standards that are applied widely in the design of vehicle and machinery cabs. They should be referred to for specific design standards. Australian Standards contain information on the minimum design standards for operating cabs generally some of which has been derived from the SAE.

KEY PRINCIPLES

- Optimise the design of the cab especially the displays and controls and the drivers seat.
- Optimise visibility within and outside the cab.
- Ensure regular breaks out of the seat and the vehicle wherever possible.
- Optimise shiftwork systems and be aware that extended hours of operation can lead to fatigue, reduced vigilance and operator error.
- Minimise distractions for the operator particularly in critical situations.

Further reading: *• Book 3: Sanders & McCormick • Book 4: Stevenson • Book 5: Clark & Corlett • Book 7: Woodson, Tillman & Tillman • Book 8: McPhee, Foster & Long • Industry material: 6.1: MDG 1 • AS 5.12: AS 2953.1:1988 • AS 5.13: AS 2953.2:1988 • AS 5.10: AS 2670.1:2001 • AS 5.16: AS 3868 – 1991*

Computers and work stations

Computer tasks

Computers are great tools and are used in most jobs these days. However, problems arise when they become a total job with little variation of tasks, postures or movement throughout the day. As with every sedentary job it is important for people's wellbeing and health to ensure that they undertake a variety of activities during a working day. Where possible, mix computer work with other tasks such as filing, telephoning, meetings etc. (See also Task Design)

Software design is also important. Flexibility and ease-of-use are often traded off for more features or a higher-powered system that are not utilised by the majority of users. Training and support facilities such as help functions and fully competent colleagues are essential for most users of computer systems. Flexibility and useability of software decrease the need for highly specialised and expensive training, which should be conducted on a need-to-know basis.

Younger people, especially those who may have studied computing or have used a computer at school will have far more confidence with and understanding of computer systems than older people. People over the age of 60 are less confident users of computers than younger people. Training will need to be organised differently and focussed for older and younger users.

Most users over 45-years-old will need reading spectacles or prescription task spectacles to read the screen as well as any source documents. The size and readability of both the font and display icons will be important for this age group.

Computer equipment

Screen image

Characters, figures and other aspects of the display should be easily read. A black-on-white image is easier to read than the reverse. The use of colours should not diminish the clarity of the image or the information. The information display should not be compromised by additional material on the screen which is not used regularly eg toolbars, rulers.

Larger screens may improve image clarity but need longer focal lengths than the average sized screen and therefore up to 50% more desk depth. Older users will have difficulty with smaller fonts and less contrast.

Keyboard

This should be:

- detached from the screen;
- matt finish;
- clear, etched figures on keys;
- thin (not > 30 mm at home row of keys (starting ASDF);;
- dished keys;
- firm travel and end-feel of keys.

Mouse

The mouse should:

- have adequate resistance to movement;
- be shaped appropriately;
- have firm travel and end-feel of keys;
- be large enough to be easily grasped by the hand but sufficiently sensitive for fine control;
- have adjustable resistance.

Screen

The screen should be adjustable in height, angle (vertical axis), tilt (horizontal axis) and distance from the operator (larger screens need up to 50% more space)

Workstations

These should be carefully designed to take account of:

- **users –** their age, physical characteristics such as height, their education and training, and their experience;
- **type of computer equipment used –** its age, special features, and general design;
- users' tasks (See also Task Design).

Chairs and desks

These should accommodate the range of height and sizes of users. Ideally the desk and chair should be height adjustable, with the chair having a properly shaped and padded adjustable back support.

Alternatively, if cost is a problem, different height chairs with an adjustable footstool or foot rail may be a solution. Most importantly, users should be given instruction on how to adjust the workstation for themselves and why it is important.

Document holders

These should be made available for source material. There are various designs for different types of work and documents. Some work better than others. If source documents are a standard shape and size a raised and tilted surface of any kind may be suitable. Books and special items may need particular designs that are available commercially.

The visual environment

The visual environment should be carefully designed. Lighting, either natural or artificial should create no glare, bright spots or annoying reflections in the visual field of the computer user. Reflections from the screen must be avoided. If possible computers should be positioned away from windows. If this is not possible the terminal should be at right angles to the window. Curtains and/or blinds are necessary to reduce glare from windows.

Generally speaking lighting levels should be lower than is normal for artificially lit rooms. Usually 300-500 lux is recommended as optimum if source documents or reference material are to be read easily.

Similarly, light fittings should be at right angles to the screen and to either side of the user. One-centimetre egg crate light filters reduce glare by shielding direct light from the side of lights. (See Illumination and lighting)

KEY PRINCIPLES

- The screen image must be clear and stable.
- The computer work station including chairs and desks must accommodate the full range of heights and sizes of users. The size of the desk must be appropriate to the size of the screen especially where bigger displays are used. The desk must also be big enough to accommodate all source material.
- There should be suitable storage space close by for all reference material for users.
- Design of the screen, keyboard and the mouse must be optimised for the task.
- A suitable document holder should be used for source or reference materials.
- The visual environment must be carefully designed.
- Computer work should be mixed with other tasks to allow a variety of movements and postures.
- Software used needs to be useable and flexible, and the type, amount and timing of training required must be appropriate.
- The age of the users, their need for training and reading glasses must be taken into account.

Further reading: *• NOHSC 1.14: Selection of Office Furniture and Equipment • Book 11: Officewise • ACTU 7.1: Screen Based Work • Other guidelines 8.12: Ergonomics*

Work organisation

Work organisation refers to the broader context in which the work is done – the culture and the way the workplace functions as a whole. It encompasses management styles, organisation of work groups, responsibilities and accountabilities. It is influenced by the type of industry or business in which it operates; its history and culture; peaks and troughs in demand for services or products; whether or not there is shiftwork, extended hours or flexitime; and profitability. The extent and type of trade union involvement and the need to meet externally determined standards also influence how a workplace is organised and managed.

Ultimately work organisation effects all parts of the workplace and probably has the greatest influence on ergonomics, occupational health and safety (OHS) practices and the development of high quality, satisfying work. Given this the application of ergonomics in the workplace needs to be understood in an organisational and social context.

Flexible work hours

The traditional 9am to 5pm eight-hour-day is no longer the primary work schedule available to many employees. With the introduction of flexible work schedules many individuals have the opportunity to use flexitime arrangements, time-in-lieu, 4-day weeks and other such arrangements.

There can be benefits for both the organisation and the individual in using flexible work schedules. These can be:

For the organisation: The opportunity to extend services and operating times; Increased attractiveness of working conditions for potential employees;

For the individual:The opportunity to balance the demands of private and working lives.

Any changes in the pattern of work in an organisation should be developed in consultation with employees. (See also Employee Participation in Problem Solving).

Peaks and troughs in workloads

One major source of excessive work demands on individuals is the seasonal or cyclical nature of some types of work. Mining, manufacturing and service industries all have problems balancing increased workloads and worker capacity from time to time. Where these peaks and troughs can be anticipated they can be planned for and adjustments can be made. Where they are unexpected careful scheduling is needed. Excessive overtime and unpaid extended work hours can be harmful to health, safety and productivity. These workloads need to be managed at an acceptable level.

Shiftwork and extended hours

Shiftwork involves working outside what are considered to be 'normal' working hours, generally between 7am and 6pm. As a rule of thumb the 40-hour week (comprising five 8-hour workdays with two days break) is the 'gold standard'. The more work hours deviate from this regular pattern the more strategies may be needed to overcome the effects of excessive fatigue and sleep disturbances are needed. An increasing number of workers are performing shiftwork and many suffer adverse effects from it.

Problems arising from shiftwork

Most of the health and safety problems associated with shiftwork arise from the working of irregular hours, often at times that are in conflict with the individual's internal biological rhythms. The body's circadian rhythm is normally set for activity during the daytime and for rest and relaxation at night. Disruptions to the body's circadian rhythm are most evident when an individual is required to work night shifts (between 11pm and 6am) and many people experience sleep problems during the day. During a night shift, an individual's circadian rhythm is at a low and, when combined with fatigue, performance is generally reduced. Poor performance can affect both safety and productivity on the job.

Health-related problems that have been associated with working irregular hours include gastrointestinal problems resulting from irregular diet and eating habits, an increased risk of stomach ulcers, cardiovascular problems and nervous complaints. Shiftwork also imposes restrictions on social and home life.

Individual differences can play a factor in a worker's adjustment to shiftwork and for a few individuals working irregular hours poses few if any problems.

Minimising OHS problems

It is important to minimise any OHS problems that are associated with shiftwork by:

- Reducing consecutive night shifts where possible, with a maximum of three 8-hour or two 12-hour night shifts a week;
- Rapidly rotating shift rosters, with shift changes every two to three days. These are preferable to slow rotating rosters;
- Forward rotating rosters (day-afternoon-night) are preferable to backward rotating rosters (night-afternoon-day) as they cause the least disruption to the body's circadian rhythm;
- The adoption of compressed work weeks. These have benefited shift workers in some workplaces;
- Identification of individual coping strategies. These lessen some of the adverse effects of shiftwork experienced by many workers.

Importance of uninterrupted sleep

A problem for many shiftworkers, especially those with young families, is getting enough uninterrupted sleep during the day after working a night shift.

Shiftworkers should try to ensure that:

- unwanted noise is controlled eg unplugging the telephone and restricting noisy activities in the home such as vacuuming;
- the bedroom is free from direct sunlight through the use of curtains or blinds;
- heavy foodstuffs and alcohol are avoided before sleep;
- a regular sleep routine is established.

Advantages of shiftwork

For some individuals there are advantages to performing shiftwork as workers do not need to commute to work during peak travel times. Commuting time to and from work can be reduced and shift workers are able to pursue hobbies and other interests and undertake family commitments during daylight hours, although this may be at the expense of sleep.

Compressed work weeks

One alternative to the traditional shiftwork pattern is the adoption of compressed work weeks. These involve the use of a set block of shifts of increased length, usually of 10-12 hours duration, offset by a reduced number of work days and with blocks of three to four days rest.

Compressed work weeks can be useful to the individual as they contain shorter blocks of shifts, fewer successive night shifts, and increased blocks of free time including weekends. Conversely, compressed work weeks involve additional working time per shift, possibly leading to fatigue that could affect performance. Extended work hours may also adversely affect an individual's health and recovery may be prolonged for a worker after completing a block of 10 or 12-hour shifts.

The adoption of compressed work weeks has benefited shiftworkers in some industries through increasing their recreation time, improving the quality and duration of sleep and through improving their physical health and wellbeing. However, this is not always the case. Each workplace and workforce is unique and will require shift rosters that suit their particular requirements.

KEY PRINCIPLES

- Individuals who perform heavy physical work or are exposed to a range of workplace hazards such as heat, noise, vibration or hazardous substances are advised not to work extended shifts. Exposure standards for the extended work days have not been developed for many hazards and therefore it is important to carefully assess daily work demands or exposures to ensure that they are acceptable.
- Workers who are involved in intensive mental work where the consequences of error or non-reaction may be serious are not recommended to adopt compressed work weeks.
- The number of consecutive 12-hour shifts should not exceed four, with no more than two consecutive 12-hour night shifts.
- Overtime is not recommended for individuals working 12-hour shifts.
- Suitable arrangements need to be made to cover workers who are absent from work due to illness.
- It is essential that shiftworkers are consulted and take an active role in determining changes to current shift rosters and how these changes are to be implemented in the workplace.
- Regular evaluation or assessment of the extended work days roster should be undertaken and if needed modification be made to the roster.
- Shiftwork is often inevitable but it can be damaging to health of workers if not managed correctly.
- Common problems with shiftwork include an increase in general fatigue due to disrupted sleep; disrupted biological rhythms leading to restrictions to personal, social and family life; reduced access to leisure and sporting activities; gastrointestinal, cardiovascular and nervous complaints.
- Extended work hours and compressed work weeks can lead to an increase in fatigue and may have other adverse effects. Strategies need to be in place to minimise these.
- Shift patterns need regular review and adjusting to suit changing needs and circumstances.

Further reading: *• Book 14: Monk & Folkard • ACTU 7.3: Shiftwork and Extended Working Hours • NOHSC 1.19: Shiftwork • NIOSH – CDC 8.9: Overtime and Extended Work Shifts • Other material 8.14: Workplace schedules*

Rest and work breaks

Rest and work

Everybody needs to rest for some part of any 24-hour period. How much rest is needed and what form it takes varies widely between individuals and will depend on the intensity of activity in the preceding hours.

Sixteen hours in a 24-hour cycle is the normal period of wakefulness for humans. Beyond this point the body's processes increasingly promote sleep. If work is continued beyond 16 hours substantial performance impairment is observed particularly with respect to attention lapses.

The following is a guide to the average amount of sleep required by individuals. However, some people can do with less, others may need more:

- No less than 5.5hrs sleep in each 24 hours;
- No less than 49hrs sleep in each week;
- No less than 210hrs sleep in each month i.e. No less than an average 7.5hrs sleep per day.

Work by its nature is tiring. During a work day most people need to take regular rest breaks in order to complete eight hours of work without excessive fatigue and the increased risk of injury or illness.

Work pauses

Work pauses are additional, spontaneous breaks not incorporated into the job structure but taken by all individuals in the course of a day. They are not the normal fixed breaks in a working day such as lunch but may be breaks between tasks or a change in routine. They are essential because they delay the onset of fatigue by allowing the body to recover from physical or mental work.

Work breaks

If intensive physical and/or mental work constitutes a significant part of a person's workload during the day it may be necessary to for them to take breaks in addition to the normal lunch and personal breaks.

There is no easy way to determine how long breaks should be to ward off the effects of fatigue at work, even for someone who is undertaking specific tasks. Therefore many work systems now incorporate set breaks to allow for mental and physical recovery. These are usually about 5-10 minutes within each hour for moderately demanding work. In general the length and type of break will depend on how hard the work is, the age and fitness of the worker and environmental conditions such as heat and humidity. Too short a break may lead to progressive or cumulative fatigue. (See also Fatigue)

Employees are usually best placed to determine for themselves when a break should be taken and how long it should be. However, workers often have to be encouraged to pause from work even when they are tired and they must be actively discouraged from accumulating breaks. As work demands sometimes do not allow this to happen, care must be taken not impose too demanding a work schedule with insufficient breaks. Consultation with employees who do the work should be undertaken before fixed work-rest schedules are finalised. Ongoing monitoring should be carried out to ensure that the breaks are appropriate. (See also Repetitive Work)

To estimate reasonable rest allowances in physical work it is necessary to examine the load and work rate against the number of hours the work is carried out during a work shift. There are guidelines on rest allowances for jobs such as heavy, physical work involving manual handling and work where safety is critical e.g. airline pilots. However, care is needed when using these guidelines as risks arising from fatigue may be underestimated. As a general rule, the number and duration of rest allowances must increase as the load and/or the intensity of work increases.

Exercises may be useful in reducing the damaging effects of repetitive or sedentary tasks or work in fixed or awkward postures. However they need careful planning and supervision. (See also Repetitive Work)

KEY PRINCIPLES

- Rest pauses and breaks during physically or mentally demanding work are necessary for recovery and to reduce the effects of fatigue.
- How long and how frequently rest pauses should be taken depends on a range of factors that need to be determined on a jobtask-by-taskjob basis.
- Exercises can be incorporated into work routines but they must be carefully planned and monitored. They can be helpful for some people; others will gain no benefit.

Further reading: *• Book 20: Rodahl • Book 21: Violante, Armstrong & Kilbom • ACTU 7.1: Screen Based Work*

Consultation and feedback

Consultation with workers is now considered a necessary part of the organisation of work and is encompassed in some OHS legislation in Australia. It can be defined as the sharing of information and the exchange of views between employers, employees and their representatives. It includes worker participation in identifying and solving problems, in decision-making and in obtaining feedback from workers on the success of programs and interventions. It is an active and inclusive process and needs to be systematically practiced in order to gain the benefits.

Feedback and communication are necessary for effective worker participation. The process takes time and can be difficult to establish if workers are not used to making decisions and solving problems. An essential component of a safety program is feedback to and from workers. Where there is a steady flow of information on progress, hurdles and developments workers respond better than when this information is absent.

Effective communication is central to all efficient management systems and in order to be effective it must be optimised. Too much information, particularly if it is of marginal value, bogs people down and they may opt out by ignoring all communications. Too little information and employees can feel left out and resentful. Information that comes down through an organisation's hierarchy should be matched by information that goes up. Its impact will be related to its need-to-know qualities. (see also Risk Management)

KEY PRINCIPLES

- Worker consultation and feedback is necessary for any ergonomics program.
- Effective communication is an important element of participation.

Further reading: *• NOHSC 1.21: Workplace Health and Safety Responsibilities • ACTU 7.1: Screen Based Work • NSW WCA 2.2: OHS Consultation*

Work teams

A work team is a collection of individuals who are required to work together to complete a goal or set of tasks. This type of teamwork can reduce worker alienation that can occur in some work places.

Work teams can either be:

- **Self-managed –** the team is given a goal to be achieved. It then determines how the work will be conducted to achieve the goal;
- **Integrated –** a supervisor oversees the work of the team in achieving the goal. This type of teamwork often occurs in mining where the supervisor oversees the work of a crew.

Types of teams

There are four main types of work teams:

- **Involved teams –** usually involved in providing recommendations or making decisions regarding a particular problem eg safety committees and quality circles;
- **Production teams –** usually involved in providing goods and services eg manufacturing or mining teams;
- **Project teams –** usually provide information in the form of reports and/or plans eg research teams or a panel of experts in a particular field;
- **Active teams –** can provide a variety of functions eg sporting teams scoring goals and medical groups performing a successful operation.

Benefits and drawbacks

Some benefits of teamwork include:

- increased problem solving skills;
- improved performance of employees;
- potential increase in lateral thinking and innovative ideas derived from multiple perspectives in brainstorming;
- increased output of the organisation;
- opportunities for managers to direct their attention to more long term strategic goals, rather than rudimentary supervisory functions.

Common drawbacks of working in teams include:

- some individuals may not pull their weight in the team;
- some individuals may have difficulty keeping up and may put themselves and others at risk of injury or overload;
- some team members may not agree on a particular course of action, creating a stalemate;
- conflict and competition may arise within the group.

If teamwork is to be effective team members must have the necessary skills to operate within the team, including both good communication and negotiating skills. The team must have clear goals to fulfil, be committed to completing these goals and have appropriate management support.

KEY PRINCIPLES

- Teamwork provides range of work options for individuals and if properly managed can be effective and efficient.
- There are advantages and disadvantages to team work. Its suitability must be determined taking into account individual and group factors as well as production needs and workplace issues.

Economic and social influences

Work provides a place for social interaction as well as being a source of income. Work behaviour is influenced by social interactions – workers are responsive to the expectations of people around them. Social isolation at work can be created by boring, monotonous tasks where individuals cannot communicate with other workers if they wish to do so. Opportunities for interaction with other workers regularly throughout a work shift needs to be incorporated into the job.

A number of recent changes in the wider community have changed the way people see their workplaces. These include:

- social attitudes towards working women;
- the need for environmental protection;
- more comprehensive laws on occupational health and safety;
- job expectations and
- increasing multicultural influences.

Where unemployment is high, people may place a higher value on their work and turnover may be less. Economic constraints may mean that organisations have to do more with fewer resources.

In these circumstances there are increasing demands placed on managers to perform a wide range of roles and this may be difficult where support from further up the management chain is not forthcoming. However, managers can do a great deal to reduce conflict and improve work organisation, ergonomics and productivity. Consultation with employees, overcoming language and other communication difficulties and increasing flexibility in how the work is organised and performed may make the difference between discord and harmony.

KEY PRINCIPLES

- Social support and assistance at work helps to reduce adverse effects of day-to-day stressors in the work environment.
- Social interaction is a necessary part of work and workers should not be isolated without opportunities to communicate with fellow workers.
- Work should be a very important and positive component of people's lives.

Part C: Measuring the benefits of ergonomics

Measuring human capabilities and limitations

In the last 20 years there has been a lot of progress in the development of measures of effectiveness, performance and outcomes in occupational health and safety (OHS). Most of these methods are estimations of some kind and are useful in particular situations and are reasonably reliable. As some of these are estimates or indirect measures they should be used as only indicators to identify possible areas for further investigation.

In ergonomics we know a lot about what people can and cannot do because of extensive research and observation carried out in laboratories and workplaces all over the world. As well, some data on limits are derived from statistical analyses and estimates of risks. These are based on outcomes rather than progress or performance.

Most research and statistical findings apply to the majority of the population most of the time. However, every workplace has its own unique set of people, workplace and systems factors that may not fall neatly into categories commonly used in ergonomics. In addition to this people with particular disabilities, educational deficiencies or other conditions that might limit their capacities in some way may need special attention in order to accommodate their needs.

Nevertheless, for the majority of the population there are ways of determining roughly whether or not the work or the environmental conditions are exceeding their capacity to work safely and without risks to their health.

Simple techniques

There are three well-known and easily learned methods for identifying obvious OHS problems in the workplace. When used together they provide excellent information.

1. Observation – a walk-through visit can reveal much about normal day-to-day operations and the people involved. Observation can be formal or informal, structured or unstructured, subjective, with workers who do the job, or objective.

2. Consultation with employees – most people have a good idea about their work and the demands it places on them and whether these could be damaging. Talking with one person can be very helpful but talking to a group is usually more helpful. Given the right environment of trust and openness even shy people will contribute to a general discussion.

3. Statistical data and records. These need careful interpretation and may tell you more about what has happened in the past rather than what is happening now. However, when applied with care they are a useful addition to observation and consultation. They can take the form of:

- fixed data eg plans and layouts, job descriptions, company reports, strategic plans; production records; injury treatment records; workers' compensation records; risk assessments; personnel data records eg job data, individual data, accident and injury data; costing data – eg cost-benefit analysis, overheads, labour costs per hour; near miss or 'near hit' data.

There can be drawbacks to using data and records in terms of what they tell you – or do not tell you. Data may be collected, analysed and interpreted to show the organisation in the best light or to cover up cost overruns. In some cases data are simply missing or inaccurate because people fail to understand what they are doing or to follow-up. Therefore this information can be considered historically useful at best and unreliable at worst. (See also Ergonomics Risk Management.)

KEY PRINCIPLES

- Every workplace is unique and may not fall neatly into categories commonly used in ergonomics.
- There are ways of determining roughly whether or not the work or the environmental conditions are exceeding the capacity of the majority of the population.
- The simplest methods of identifying problems at work are things that everyone can do – observation, consultation and examining any records or statistics.

Further reading: *• NOHSC 1.3: National Code of Practice for Manual Handling • NOHSC 1.16: Manual Handling*

Measuring physical workload

There are a number of different ways in which we can measure or estimate workloads. However they all have limitations and should be used with care. An individual's knowledge and experience are extremely important in judging when loads may cause him or her harm. The estimations of workloads outlined below supplement but do not replace these personal skills.

There is a range of measures that can be used to quantify physical and psychophysical load on the body. Those outlined below are just of few of the more commonly used ones. For a more detailed description of these methods and many others refer to Book 15: Wilson & Corlett.

Biomechanical methods

Biomechanical methods estimate the mechanical loads on different parts of the body (most notably the low back) through mathematical modelling eg the two dimensional static strength prediction model (2D) or 3D Michigan model, or the Lumbar Motion Monitor (LMM™).

Estimations in the 2D model are made on a split-second movement and calculated using a software package. It is based on a model developed by the USA National Institute of Occupational Safety and Health (NIOSH) and known as the NIOSH equation (see below). The values in the 2D model are given in terms of forces on different parts of the body including the lower lumbar spine given the weight being handled, distance from the body, body posture.

The model is used to evaluate the strength requirements at the major joints and to estimate the low back spinal compression forces for lifting tasks. However, there are many limitations using this method especially where there are unbalanced postures and movements and/or dynamic lifting tasks. In these cases it may underestimate strength and compression forces. The 3D model has overcome some of the problems of the original 2D Model but it is complex to use and there are still limitations in practical work situations.

The LMM™ is a portable stretch gauge shaped rather like the skeleton with a harness that attaches it to the body. It is connected to a portable computer with software that analyses a number of components of movement of the spine including acceleration, velocity and range of movement in three planes. The package allows for comparison of results against LMM™ benchmarks. It has proved useful in research but is less usable in real world situations in highly varied tasks or in cramped spaces.

Physiological methods

Effort can be estimated measuring the cardio-respiratory system's capacity for work eg heart rate, oxygen uptake, and circulation. Heart rate can be measured continuously using telemetry. It may involve the use of equipment including an electronic belt with a transmitter worn around the chest and a receiving microcomputer worn on the wrist. From these measurements energy expenditure can be calculated. This is usually done using the individual's own resting heart rate for base line comparison as no two people are exactly the same. (See also Physical Strength and Work Capacity)

In the Borg rating of perceived exertion (often referred to as the RPE) workers are asked at intervals how hard they think they are working. They can nominate one of 15 precisely defined categories ranging from 'no exertion at all' (6) through 'very light' (9) and 'hard (heavy)' (15) to 'maximal exertion' (20). By adding a zero to the numbers the resulting values roughly equate with heart rate. Higher numbers are then related to the resting heart rate to get an estimation of the individual's capacity and exertion. Modified versions for localised areas such as the legs, back, arms and neck are also used.

Postural methods

These methods estimate the numbers of undesirable postural combinations (those found to be associated with the development of back pain and other sprains and strains) and the proportion of the work task where these postures are required. eg Ovako working posture analysis system (OWAS), rapid upper limb assessment (RULA), rapid entire body assessment (REBA).

In OWAS video recordings are made of work tasks for later analysis of postural load. The working postures adopted during the work are classified by a method that defines the positions of the back, upper and lower limbs as well as force used. Recordings of observations are made on work postures and activities are made on anything from a five to 30 second intervals. They are entered into a computer and a program estimates the proportion of time in certain postures. The least desirable ones are the bent, or bent and twisted postures (work below the knees with or without twisting to the side), standing or balancing on one leg or in an awkward posture, and work above the shoulders. Weights can be added to the calculations but are considered in gross terms only. Combinations of these factors are classified by an experienced ergonomist according to the percentage of time spent in non-neutral postures and force exerted.

RULA and REBA are survey methods developed for use in ergonomics investigations of workplaces where musculoskeletal disorders are reported. They provide a quick assessment of postures along with muscle function and the external loads experienced by the body. A coding system is used to generate an action list that indicates the level of intervention required to reduce risks due to physical loading.

Psychophysical methods

Estimation of the individual's capacity to undertake certain types of physical work can be achieved through questioning people during the task. They are asked to put a numerical or word value on how hard they think they are working and/or whether or not they could maintain that pace for a specified period (usually an eight-hour-shift).

In the USA tables have been developed based on individuals' judgments of acceptable loads for a given work period. These are often referred to the Snook tables after the man who compiled them. The method takes into account the whole job and integrates biomechanical and physiological factors. However, some studies have found that many subjects overestimate and some underestimate their capacities. The tables are useful for assessing weights on the basis of acceptability rather than on safety.

An alternative approach developed in the USA uses three common lifting indices. The first is the lifting index, which was developed with the NIOSH equation (see below). This uses the ratio of the load to be lifted to the recommended weight limit as calculated by the equation. The second is the job severity index. This is calculated from the job demands that are identified through tasks analysis against worker capacity that is either measured or estimated. The third index is the lifting strength rating. It is calculated from the weight handled in the job and the strength of a strong person in the postures observed for handling the weight.

All three indices aim to assess the job demand against the capacity of people working under the job conditions. The last one can be used to assess lifting demands where load and workplace factors vary. Nevertheless they do not quantify precisely the risk involved. They are more useful in comparing the relative severity of two jobs.

NIOSH guidelines and equation

The NIOSH guidelines use biomechanical, physiological and psychological criteria to set lifting limits that are integrated. These are set in terms of the recommended weight limit, which is a formula that takes into account the height at which the lift commences, the vertical travel of the lift, the reach distance, and the frequency of lift. The formula is usually referred to as the NIOSH equation and recognises that risk factors interact and multiply the risk. However, it cannot be used for other manual handling activities such as carrying, pushing pulling or lifting people. It also does not take in account sudden or unpredicted conditions such as a shift in loads or foot slip.

Epidemiological methods

Epidemiology is the study of diseases and disorders in populations. In this approach measures of the health effects of work on people are studied. The effects of exposure to certain hazards such as manual handling can be indirectly calculated by examining the numbers of new or recurring injuries or illnesses recorded in people who carry out manual handling. If the occurrence of certain disorders is higher in a particular group than expected statistically then these can be linked with general or specific parts of the work.

However, some disorders such as those of the musculoskeletal system occur normally as the result of life activities and they are also cumulative in nature. It may take many years before the detrimental effects of the work become apparent and even then the contribution of work to a disorder can be unclear. These disorders are very difficult to study in epidemiology because of this.

A simple epidemiological method that is frequently used to collect information on sprains and strains (musculoskeletal disorders) is the Nordic questionnaire. This is a standardised questionnaire that is used in conjunction with other measures of occupational or task-related workloads. It consists of a series of questions concerned with the individual's history of musculoskeletal problems in both the last week and the last 12 months. Some questions relate specifically to the low back. The rest cover the neck, shoulders, elbows, wrists/hands, upper back, hips, knees and ankles/feet.

Body maps are included with the questionnaire. These are drawings of the body on which individuals mark where they are experiencing discomfort or pain. The questionnaire is easy to administer but requires some specialist knowledge to analyse and interpret.

KEY PRINCIPLES

There are number of other methods that have been developed but all need care in their administration and some specialist knowledge.

There is a range of methods available to measure different aspects of physical load at work. Most are indirect methods and all have practical and functional limitations when used to measure real jobs in the workplace.

Different measures are useful:

- to compare jobs and loads, differences between individuals or groups
- when usable information is to be fed back to manufacturers and suppliers
- if the solution is critical in terms of injury control
- where costs of injuries are unacceptable and the effectiveness of the control needs to be demonstrated
- where information is needed for the record or is required by law.

Further reading: *• Book 15: Wilson and Corlett • Book 20: Rodahl • Other material 8.10: NIOSH. Work Practices Guide for Manual Lifting*

Measuring mental workload

There are four broad methods for measuring loads on human cognitive capabilities. The first is the primary task measure where the performance of a particular task under certain circumstances is assessed. Secondary task measures on the other hand measure the performance of additional tasks to the primary one. Where the secondary task cannot be performed this is taken as an indication the primary task is more demanding than if the secondary task can be performed.

A third method is subjective rating measures including direct and indirect enquiries from subjects about their opinions on the workload of the task under study. This is one of the easiest ways to estimate mental workload.

Finally physiological (or psychophysiological) measures examine changes in a variety of physiological functions as the result of mental workload.

Measuring the impact of ergonomics

There are several measurement tools and techniques that may be used to measure the impact of OHS and ergonomics outcomes.

Positive performance indicators (PPIs)

PPIs (also known as Lead Indicators) can give information about the effectiveness of activities especially within OHS management systems. Ergonomics is one of the areas where these indicators can be useful. However, they will not tell the whole story nor will they in themselves improve performance – they are merely flags indicating progress or the lack of it. Nevertheless PPIs allow an organisation to set standards that are above the minimum and allow efforts towards preventive health and safety programs to be recognised and encouraged.

When benchmarking and making comparisons with other organisations or industries it is important that different measures can be compared. Therefore they need to be reliable (consistent), repeatable, comparable (with other areas or organisations) and valid (measure what they say they are measuring). This can be very complex when systems are so different. As a result organisations often resort to lost time injury frequency rates (LTIFRs) which are a negative performance indicator (NPI) (see below) but which can be applied across a range of industries.

Aspects that lend themselves to the development of PPIs for ergonomics include those used to define OHS systems.

Applying PPIs to ergonomics

Systems area	*Possible measures of performance*
1. Commitment	% of jobs with OHS and ergonomics responsibilities defined
2. Documentation	Level of awareness and use of manuals by the workforce Frequency and timeliness of document updates
3. Purchasing	% of purchase orders with OHS (ergonomics) requirements specified
4. Safe working systems	% of systems controls compared with individual controls % of risk assessments results that have been included in systems management plans
5. Identifying, reporting and correcting deficiencies	Frequency of reviews and % of actions achieved % of incidents/problems where remedial action was taken within an appropriate time frame
6. Monitoring, recording and reviewing	% of OHS standards conformance Level of record keeping required by regulation against potential recorded events
7. Developing skills and competencies.	% of employees assessed as conforming to competency standards

PPIs are process indicators and the way they can be used is often not understood very well. The development of PPIs is still in the early stages in many organisations even though there are often significant positive actions that can be measured and documented.

Negative performance indicators (NPIs)

NPIs (also known as Lag Indicators) such as the LTIFR only tell what has happened in the past and that something went wrong. They give no indication of what has been done well. Simply measuring negative outcomes such as injury rates or the costs of workers' compensation claims may not give a true indication of what is happening now and how effective current risk control measures are. In fact they may give wrong information when they fluctuate or when there are subtle differences in reporting criteria. They may also allow concealing of injuries to provide an apparently better result. Most importantly they are very limited in predicting high consequence, low probability accidents.

However, they measure actual failures and they allow statistics to be compared across industries and from company to company. Organisations can benchmark themselves against others and this is comparison can be useful to a limited degree.

Injury/illness rates

When used in conjunction with some or all of the above measures, injury /illness rates can provide valuable information concerning program implementation. It is important to recognise that there may be a latent period before the rates begin to improve due to the time it takes to implement a mature, effective safety program.

Program evaluation

Evaluation of an ergonomics program needs to measure how well program implementation is progressing as well as whether or not the program objectives were achieved.

What is measured will depend on what is considered necessary to determine if the program is on track. You can:

- determine if the process is working. For instance, if the program involves consultation with users, the identification of problems and development of solutions these can all be measured simply by determining if they have been done and what they have achieved;
- estimate or assess the risks associated with poor ergonomics in broad terms and then reassess these after changes have been implemented. People involved can be asked about the degree of difficulty of the job, the number of near misses or other incidents and perhaps the number of times accidents or injuries have actually occurred;
- ask how workers feel about solutions and if they think the solutions have been effective or not.

However, in many cases it is difficult to show that injuries have been reduced by the changes made. This is because there are so many causes of most injuries and in some cases they develop over time. It takes time and sophisticated measurement techniques to establish that particular interventions have lead to a reduction of injuries.

It is important to develop methods of evaluating positive indicators of work being done that address areas requiring improvement. Then these indicators and resulting improvements can be measured over time. The use of both positive and negative performance indicators give the most balanced approach to evaluation and can act as effective safety program drivers if used carefully.

Strategic planning

Performance can be measured from strategic plans. The mission statement of an organisation can be used to measure performance. The board can be measured by the goals outlined for the organisation. The manager can be measured by the objectives and the staff can be measured by action plans. Key performance indicators (see below) can be identified from strategic plans.

Key performance indicators (KPIs)

KPIs are derived from the use of statistics in process control in manufacturing. The basic concept of statistical process control is that variation in outcomes is inevitable and that the control of this variation determines the quality of the outcome. If there is reduction of variation in one or more stages of the process, then there will be a consistent reduction in the variation of the outcome of the process. Recently this concept has been applied successfully to business processes. The result has been that the whole business process outcome has been developed by the improvement of key variables within the process. This method can also be applied to the process of OHS and ergonomics in organisations.

Program audits

These give a comparison over time of improvements in implementation. They involve the using of a series of predetermined questions to establish how much work has been done to implement and maintain a program. Information provided at audit is verified through document reviews, random sampling, discussions with staff, observation of behaviours and activities and physical conditions surveys.

As with all audits there are always problems in getting the balance right. The evaluation of a program is never black and white – there are always shades of grey. These are hard to evaluate in questionnaires. However they need to be recognised and some credit given where progress has been made but the outcome has not be achieved fully. Therefore the development and use of the audit tools is critical to how much useful information can be derived.

Accident and incident investigation

Accident and incident investigations are part of every OHS program. They are undertaken to find the real and not immediately obvious causes of an accident and to assess the risk of recurrence. Based on this information appropriate control measures can be developed. These may involve changes to the structure of the OHS program as well as fixing the immediate damage or providing the injured person with appropriate medical treatment.

Poor ergonomics is often overlooked in accident investigations because it is not always immediately obvious and its analysis may require specialist input.

Information obtained as a result of the investigations can also be pooled to determine trends and used in to assist program implementation planning.

Cost-benefit models

Justifying expenditure to improve OHS has been difficult in the past. Often direct compensation and medical expenses were the only indicator that poor OHS practices were costly. However, now it is possible to calculate the real costs of injuries to companies using methods and programs that are available commercially. These range in complexity from full company accounting systems to methods that apply to individual jobs or groups of workers.

The feasibility, availability and cost of changes needed to improve ergonomics may be considered in relation to the size and cost of the problem. Sometimes it may be necessary to justify the cost of change or of different changes (termed cost effectiveness) or the costs of doing nothing at all. This is where conducting a cost-benefit or cost effectiveness analysis can be useful.

Such analyses are best done prior to and after changes have been made. Where they are conducted beforehand payback periods can be estimated for budgets. If the payback period is short (3-12 months) this can be used to justify expenditures

Cost-benefit and cost effectiveness programs require some basic information in the following five areas:

- Actual number of productive hours worked per employee per year;
- Salary or wage costs per hour worked;
- Employee turnover and training costs;
- Productivity and product/service quality losses due to absent employees;
- Cost of implementation of intervention(s).

Costs per hour of OHS problems can then be calculated. To this, costs of solutions can be added and a payback period can be estimated. Not all the information is essential but the more that can be supplied and the more accurate it is, the better the true costs and benefits can be predicted.

The costs of wasted product, increased time to undertake the tasks, inadequate or poor quality workmanship, and damage to equipment and product as may have identified in the process can also be added to the OHS costs.

Risk assessment techniques

An essential part of a risk management program is the risk assessment process. If risk is not assessed and analysed accurately money and time can be wasted. Therefore the techniques that an organisation employs to assess risks are critical to long-term success in the prevention of injury and illness at work.

In the past specialist ergonomists have undertaken assessments as individuals, consulting workers and managers as necessary and providing recommendations based on their individual experience and knowledge of ergonomics, systems and OHS. This may still be acceptable for some assessment and analysis, particularly if the job or area is small and uncomplicated.

However, due to the complexity of modern work systems and the interrelated nature of many hazards and risks many risk assessment methods now use a consultative team of people. This includes workers and supervisors as well as specialists in systems, processes, machinery, OHS and ergonomics. Depending on the nature of the problem the team uses different techniques to identify, assess and analyse risks for their potential to cause harm. (See also Ergonomics Risk Management). The team is also valuable in considering possible solutions to problems.

Safety professionals have developed many techniques that are excellent for systematic determination of risk, particularly high-level safety risks. These include:

- hazard and operability studies (Hazop);
- failure mode and effect analysis (FMEA);
- fault tree analysis (FTA);
- machinery hazard identification;
- potential human error identification (PHEI);
- workplace risk identification and control (WRAC).

These techniques are used for specific types of risk assessment such as commissioning of facilities and the implementation of procedures (Hazop); identifying the potential for human error and designing prevention strategies (PHEI); and identifying potential production or maintenance operation problems (WRAC).

Most of these approaches are interactive with a focus on gaining consensus from the group. They use a qualitative rather than a quantitative approach and the team members' experience and opinion are the main sources for the estimates of risk. If they are to include ergonomics the approach will need to be modified and team members are likely to need training in ergonomics. Alternatively including a specialist ergonomist in the team can provide the necessary expert input that also serves as training for team members. This is especially important in the analysis of the risks. (See also Employee Participation in Problem Solving)

In the oil and chemical industries it is possible to calculate the size of the possible outcomes/impacts mathematically and therefore the risk assessment methods may be quantitative. However, in most other industries and processes this not possible as statistics are not available. Therefore the qualitative approach using people's judgment and experience is most useful.

Many of the techniques assess the range of potential consequences and the likelihood (exposure and probability) of their occurrence. All require some insight by those involved as to what could go wrong. Therefore these approaches may be limited if there is insufficient understanding of what could happen, such as in the more subtle or slowly developing health problems. This may result in an underestimation of risk.

Nevertheless, in most cases, team members' experience, incident and accident reports and injury statistics will be a good guide. However, that information may not help in the development of new systems and new controls where there have been no reports of injury or disorders, or where the link between aspects of the work and the disorder have not been made. In these cases a more exploratory approach may be required and pilot studies and mock-ups will be critically important. These methods should be included in the process of developing solutions to anticipated problems.

Further reading: • Industry material 6.2: MDG 1010 • NOHSC 1.12: Positive Performance Indicators • NOHSC 1.13: Benchmarking OHS • Book 9: Oxenburgh, Marlow & Oxenburgh • Other material 8.1: Benchmarking OHS

Evaluating solutions directly

Ergonomics solutions to current problems, new innovations and new technology all require evaluation to determine if they work in reality. Are people happy with the arrangements? Could the solutions be improved? Have employees been adequately trained and could they improve on the situation if they had input? It is very likely that not all potential problems can be identified in the design or redesign phase.

Evaluation of the solution in operation is often forgotten as people move to solving the next problem. Sometimes the people responsible for the solution are so committed to it they are unwilling to recognise that there are residual difficulties or that it does not work at all. Therefore evaluation is essential.

It is also necessary to evaluate solutions adopted from other workplaces. A solution that is successful elsewhere may be introduced to solve a problem without assessment of local requirements. This may create other problems. Assumptions about the benefits of new equipment, tools, furniture or systems of work need to be challenged and tested before they are universally accepted. It is important that the people who are most likely to be affected make the decision but they must be fully informed of the options, problems and advantages.

Solution must be evaluated at the appropriate time(s). Its immediate success does not guarantee that it will remain successful especially when circumstances or workers change. Evaluations of some sort should be conducted at a minimum of six to 12 monthly intervals.

Ongoing monitoring of ergonomics problems and their solutions should be built into the company's OHS audit system.

Recording and communicating what has been achieved

Gathering information

Information on the effectiveness of solutions may be gathered through informal feedback or discussions with users or with informal or structured interviews. Many people take 'before and after' photographs or videos, undertake follow-up risk assessments, fill out checklists or questionnaires, or repeat measurements made before the changes.

Evaluative evidence information may be gathered by using 'dummy runs', mock-ups or prototypes. Guidance from an ergonomist, to ensure that all key issues have been addressed, can be useful when using these methods.

More formal evaluations may be required:

- when usable information is to be fed back to manufacturers and suppliers;
- if the solution is critical in terms of injury or damage control;
- where costs of injuries are unacceptable and the effectiveness of the control needs to be demonstrated;
- where information is needed for the organisation's records or is required by law.

Keeping records

Keeping a record of ergonomics activities and the lessons learned is important if progress is to be made. So often, particularly when there are changes in personnel, previous work and improvements or the reasons why certain designs were implemented are forgotten. Obviously over time some reassessment must be made but this should be done with all the historical facts to hand.

Information for records can include:

- OHS Committee initiatives and minutes;
- hazard identification processes and reports;
- risk assessment reports;
- design specifications for equipment and work environments;
- modifications to equipment and systems of work;
- risk control measures proposed and implemented;
- risk control monitoring and reviews;
- consultants' and technical reports;
- training and education of employees and other stakeholders.

Feedback

Some OHS professionals consider feedback to employees and senior managers on progress and outcomes of programs, activities, initiatives and suggestions to be one of the most powerful positive influences in improving workplace health and safety. Crew or toolbox talks; newsletters; OHS Alerts; reports and completed audit forms; training sessions; intranet sites; emails; and person-to-person communication all may be used to impart information both from upper management and from the ‘shop floor’ or ‘coal face’. ‘Top down’ should be matched by ‘bottom up’ information flow. Comments, suggestions and improvements should be invited as part of the evaluation and feedback process.

If changes are suggested they need to be considered, action taken and further feedback given. When a proposal for change has been made and is rejected then objective reasons for the rejection need to be given. No suggestion should be ruled out simply on the basis of its cost. Benefits that can be derived from changes need to be considered carefully in the context of the work situation. On the other hand no change should be implemented unless there is a demonstrated need for it and it has been evaluated in some way for the particular work situation. These cost-benefit analyses can be done quickly and easily using basic data. This process provides a mechanism for continuous improvement.

KEY PRINCIPLES

- The effectiveness of ergonomics solutions can be measured or assessed in the same way as many other management and engineering changes through positive and negative indicators, and with investigative and risk management techniques.
- It is also necessary to evaluate the immediate impact of ergonomics solutions with respect to solving problems and improving productivity. Often this can be done using relatively simple techniques.
- Keeping records of information on ergonomics activities is necessary to ensure that changes are built upon and there is continuous improvement.
- Feedback to employees and senior managers on progress and outcomes of programs, activities, initiatives and suggestions is essential.

Part D: Further reading
Glossary of Terms
Index

FURTHER READING

Books and other publications

Level 1: Introductory, basic technical information.

Level 2: Written for the ergonomist but technically not too difficult.

Level 3: Technically complex but important reading on the subject.

General

1: Dul and Weerdmeester B. Ergonomics for Beginners. London, Taylor & Francis, 1993.

Level 1:This is an updated version of one of the original textbooks in ergonomics under the heading Vademecum Ergonomie by the early pioneers of ergonomics in the Netherlands. It has since been updated and contains information mainly on physical ergonomics useful for many types of industrial and office work. Unusually it contains some valuable tips on how to make ergonomics work in practice.

2: Kroemer K and Grandjean E. Fitting the Task to the Human – A Textbook of Occupational Ergonomics Approach. London, Taylor & Francis 1997 (5th Ed)

Level 1: This is another early and successful text first written in 1963. The late Professor Etienne Grandjean was a founding father of ergonomics and wrote the original text. Professor Karl Kroemer has updated the latest edition. Although some of the information is not as up-to-date as more specialised publications it is still a classic. It covers most areas in ergonomics very broadly although it does not deal with systems (Organisational design and management).

3: Sanders MS, McCormick EJ. Human Factors in Engineering and Design. New York, McGraw-Hill, 1993.

Level 2: Sanders has revised another classic written by the late Professor Ernest McCormick first published as Human Engineering in 1957. It has strong engineering and design focus and has some excellent summaries of issues and discussions as well as historical information, anthropometric tables and design guidelines.

4: Stevenson MG. Notes on the Principles of Ergonomics. Revised edition. Sydney, Mike Stevenson Ergonomics 1999. (Available from Dr Stevenson, 11 Willawa Street, Balgowlah NSW 2093 Australia).

Level 2: Professor Stevenson has compiled these excellent bound notes suitable for undergraduate ergonomics students. They concentrate on physical aspects of work rather than organisational or psychological aspects. Some information is quite technical and may be more detailed than many people would require in order to solve a problem in the workplace. Nevertheless the Notes contain some information that is not readily available elsewhere such as the Australian anthropometric tables, which are invaluable.

Engineering and Design

5: Clark TS, Corlett EN. The Ergonomics of Workspaces and Machines: A Design Manual. London, Taylor & Francis, 1995, (2nd Ed).

Level 2: This text is written for industrial designers and engineers responsible for implementing ergonomics in the workplace. It contains a range of information on human dimensions and capabilities needed in the design process and has an extensive section on displays, codes and symbols for equipment.

6: Stevenson M. Safety by Design. Sydney, Mike Stevenson Ergonomics. 2003. (Available from Dr Stevenson).

Level 2: This is a handbook for engineers, designers and those responsible for designing safer workplaces. It gives lots of examples of design hazards and their redesign for industrial and construction applications. It includes legal obligations, falls, machine guarding, vehicles accidents and manual handling and a section on ergonomics application.

7: Woodson W, Tillman B, Tillman P. Human Factors Design Handbook: Information Guidelines for the Design of Systems, Facilities, Equipment and Products for Human Use. New York, McGraw-Hill, 1992 (2nd Ed).

Level 2: Like 'The Ergonomics of Workspaces and Machines' this book contains information on design parameters for designers and engineers. It is very comprehensive so it is also useful for professional ergonomists advising clients on design parameters for equipment and systems.

Occupational Health

8: McPhee B, Foster G, and Long A. Bad Vibrations. A Handbook on Whole-body Vibration in Mining. Joint Coal Board Health and Safety Trust, Sydney 2001.

Level 1: This Handbook outlines the sources of Whole-body Vibration (WBV) exposures and their prevention. It aims to assist people to identify and manage the risk of WBV exposure at work. It covers a description of WBV and its effects on humans; how it is measured; identification, assessment, control and monitoring of WBV; check sheets and case studies.

9: Oxenburgh M, Marlow P, and Oxenburgh A. Increasing Productivity and Profit Through Health and Safety. London, Taylor & Francis, 2003 (2nd Ed).

Level 2: This book and the accompanying computer program are invaluable resources for those who wish to understand more about cost benefit in occupational health and safety including ergonomics. The book outlines a number of case studies where improvements have led to savings as well as the method for estimating these. The figures derived from this program can be used to develop a financial justification for change – one of the hardest parts of ergonomics.

10: Pheasant S. Ergonomics, Work and Health. Basingstoke, MacMillan Academic and Professional Ltd, 1991.

Level 1: This is another classic ergonomics text written in an easy-to-read style by the late Dr Stephen Pheasant. It was one of the first books to describe the link between various work-related disorders and ergonomics in such a way that everyone could understand it. It covers physical and psychological factors, job design and work organisation including shiftwork. It was written in 1991. Sadly Dr Pheasant died in 1996 so it may be a little outdated in some technical areas such as vibration. Nevertheless it still remains an excellent introduction to occupational ergonomics.

Office ergonomics

11: Victorian WorkCover Authority (WorkSafe Victoria). Officewise. Melbourne, Victorian WorkCover Authority, 1997.

Level 1: This is a useful book for those interested in office ergonomics and occupational health and safety. It covers different aspects of office work and describes the standards that need to be met in general terms for physical, psychological and social health. It is available as a Handbook and on Victorian WorkCover website under publications.

Shift work and extended work hours

13: Curuso CC, Hitchcock EM, Dick RB, Russo J, Schmidt JM. Overtime and Extended Work Shifts: recent Findings on Illnesses, Injuries and Health Behaviors. Department of Health and Human Sciences, Centers for Disease Control and Prevention, NIOSH (CDC – NIOSH website, see below)

Level 2: This is a review of 52 published studies on long working days conducted all over the world. It is well written and covers a range of topics that impact health and safety in the workplace. It is well worth a read if you want to know what the most recent studies are saying about extended shifts.

14: Monk TH, Folkard S. Making Shift Work Tolerable. London, Taylor & Francis, 1992.

Level 1: This is an information textbook aimed at workers, managers and health and safety professionals who are dealing with shiftwork and its possible negative effects. It is practical and easy to read and is a useful summary of the issues including physical, psychological and social stresses, health and performance consequences and coping and management strategies.

Methods in ergonomics

15: Wilson JR, Corlett EN. Evaluation of Human Work. London, Taylor and Francis, 1995. (2nd Ed)

Level 3: This is a comprehensive guide to the measurement of human activity and its outcomes at work including physiological, psychological, epidemiological and survey techniques. It is one of the most useful textbooks for students of ergonomics who want to get a grasp of the different methods of measuring and their strengths and weaknesses.

Anthropometry

16: Diffrient N, Tilley A, Bardagjy JC. Human Scale 1/2/3. Cambridge, Mass. MIT Press, 1974.

17: Diffrient N, Tilley A, Harman D. Human Scale 4/5/6 and 7/8/9. Cambridge, Mass. MIT Press, 1981.

Level 2: These are set of anthropometric tables and handbooks that are classics, used by designers, ergonomists and students of ergonomics for over 30 years. They consist of ranges of dimensions for different applications printed on plastic wheels. These able to be set at a given dimension and other dimensions can be derived.

18: Pheasant S. Bodyspace. Anthropometry, Ergonomics and Design. London, Taylor & Francis, 1996 (2nd Ed).

Level 1: This book provides good descriptions of human diversity and the need to consider body dimensions in all aspects of design – at work and in the home. It includes detailed anthropometry tables that can be useful to almost anyone and an outline of different aspects of anthropometry as it is applied in different areas. It is an excellent introduction to anthropometry.

Physiology

19: Parsons K. Human Thermal Environments. London, Taylor and Francis, 2003 (2nd Ed)

Level 3: This is a most important text on human work in hot and cold conditions. It is very technical in parts because the subject matter is complex but it is well worth persisting if you need reliable and up-to-date information in this area.

20: Rodahl K. The Physiology of Work. New York. Taylor & Francis, London. 1989.

Level 2: As an introduction to work physiology and the application of physiological knowledge to the design of work this book is an excellent place to start. It covers a range of areas including measurement and assessment in the workplace, shiftwork, stress, muscle tension, and working in polluted atmospheres. It is clear and well written and full of interesting facts.

Task design

21: Violante F, Armstrong T and Kilbom A (Eds). Work Related Musculoskeletal Disorders of the Upper Limb and Back. . London, Taylor and Francis, 2000

Level 3: Contains important information on the causes of work-related musculoskeletal disorders particularly epidemiological research and measurement.

Stress

22: Devereux J. Work related Stress and Musculoskeletal Disorders [Summary of Technical Report] Robens Institute, University of Surrey 2004. Website address: http://www.eihms.surrey.ac.uk/robens/erg/stress.htm

Level 1: This is a recent and excellent summary of research undertaken on the link between musculoskeletal disorders and stress at work.

Work-Related Musculoskeletal Disorders

23: Kuorinka I, Forcier L (Eds). Work Related Musculoskeletal Disorders (WMSDs). A Reference Book for Prevention. London, Taylor & Francis, 1995.

Level 3: This book is for those who need a detailed summary of research and other findings on how musculoskeletal disorders are managed and prevented at work. It covers the history and work-relatedness of these disorders, risk management, surveillance and training. It also contains two excellent chapters on managing solutions, managing change and training.

24: McPhee BJ. Ergonomics for the Control of Sprains and Strains in Mining. Sydney, Worksafe Australia and the Joint Coal Board, 1993. Website address: www.nohsc.gov.au/OHSInformation/Publications

Level 1: This handbook was written in an attempt to introduce the subject of ergonomics to mining, particularly coal mining. It is basic and outlines the process of risk management in manual handling. It also contains information of mining machinery seat design and a broad checklist on the ergonomics of mining machines.

25: Stevenson M (ed). Readings in RSI. The Ergonomics Approach to Repetition Strain Injuries. Sydney, NSW University Press, 1987.

Level 1: This little book may not be available now but it still may be held in university and other libraries. It is well worth a browse if you are interested in the mechanics, management and prevention of overuse injuries (OOS or RSI). It contains some early Australian papers (written in the 1970s and 1980s) on the issues of overuse of the upper limb and what can be done. Despite the enormous adverse publicity that was given to the problem at the time, the amount of research that has been done on the subject since and a plethora of textbooks that have emerged these papers still read well today and contain useful information.

Systems Ergonomics (Organisational Design and Management)

26: Noro K, Imada AS. (Eds). Participatory Ergonomics. London, Taylor & Francis, 1991.

Level 2: This is an excellent summary of the history and approaches that can be used in participatory ergonomics.

27: Langford J, McDonagh D (Eds). Focus Groups. London, Taylor & Francis, 2003.

Level 2: This is a good overview of different methods and tools that can be used by focus (participatory) groups in human factors and ergonomics design. It contains a useful summary of learning for older people.

Aging at work

28: Kumashiro M. (Ed) Aging and Work. London, Taylor & Francis, 2003.

Level 3: Unlike many collections of papers this edited version of conference proceedings contains some seminal contributions including measuring work ability, stress and physiological fitness in older workers.

29: Skiöld L: A look into modern working life. National Institute for Working Life, Stockholm, 2000

Level 2: The Institute of Working Life initiated this book as one of its programs during the Swedish Presidency of the European Union in the first half of 2001. It is the outcome of a series of 63 international scientific workshops held throughout Europe from 1997 to 2000 led by distinguished researchers and practitioners. The aim was to provide a solid base of knowledge through state-of-the-art reports on many different aspects of working life. It covers a wide range of topics and captures the issues in working life of the time very well. It is unlikely that such a broad and deep summary of these issues will appear again for some time.

Human Error

30: Reason J. Human error. Cambridge University Press, New York, 1990.

Level 3: This is one of the bibles on the theory and application of human error principles.

Australian Government Codes and Standards

1: National Occupational Health and Safety Commission [NOHSC]
Website address:
www.nohsc.gov.au/OHSInformation/Publications

NOHSC has produced many Standards, Codes and Guidelines that need to be referred to when implementing ergonomics mainly because they are basis of most other state-based legislative Codes and Guidelines in Australia.

The most relevant Codes related to ergonomics are:

1.1: National Code of Practice for the Prevention of Occupational Overuse Syndrome. [NOHSC 2013 (1994)]

1.2: National Standard for Manual Handling [NOHSC 1001(1990)]

Note: A new Australian National Code of Practice for the Prevention of Musculoskeletal Disorders from Manual Handling at Work is being prepared. Notice of its publication will be made on the NOHSC website.

1.3: National Code of Practice for Manual Handling. [NOHSC 2005 (1990)]

1.4: National Code of Practice for Noise and Protection of Hearing at Work. [NOHSC: 2009(2004) 3rd Edition]

1.5: National Code of Practice for the Prevention of OOS [NOHSC 2013 (1994)]

Some useful Guides include:

1.6: Control Guide – Management of Noise at Work

1.7: Guidance Note on the Prevention of OOS in Keyboard Employment [NOHSC:3005 (1996)]

1.8: Guidance Note on the Prevention of OOS in the Manufacturing Industry [NOHSC:3015 (1996)]

1.10: Plant in the workplace. Making it safe. A guide to managing risks from plant in the workplace for employers and employees.

1.11: Plant in the workplace. Making it safe. A guide to risk management for designers, importers, suppliers and installers of plant.

1.12: Positive Performance Indicators. Beyond Lost time injuries. Parts 1 & 2

1.13: Benchmarking Occupational Health and Safety

1.14: Ergonomics Principles and Checklists for the Selection of Office Furniture and Equipment

Factsheets include:

1.15: Managing Back Pain

1.16: Manual Handling

1.17: Noise

1.18: Overuse Injuries

1.19: Shiftwork

1.20: Stress and Burnout at Work

1.21: Workplace Health and Safety Responsibilities

1.22: Workplace Layout and Design

1.23: Comfort at Work – Too Hot? Too Cold?

2: NSW Workcover Authority

Website: www.workcover.nsw.gov.au

Useful publications are:

2.1: Risk Management at Work

2.2: OHS Consultation

3: Victorian WorkCover Authority (WorkSafe Victoria)

Website: www.workcover.vic.gov.au

Useful publications are:

3.1 Sun Protection for Construction and Other Outdoor Workers

3.2 Managing Manual Handling Risks in a Small Organisation

3.3 Managing Manual Handling Risks in a Large Organisation

3.4 Code of Practice for Manual Handling (2000)

4: Queensland Department of Workplace Health and Safety.

Website: www.whs.qld.gov.au

Useful publications are:

4.1 Heat Stress: Managing the Risk

4.2 Queensland Advisory Standard: Manual Tasks 2000.

4.3 Queensland Advisory Standard: Manual Tasks Involving the Handling of People 2002.

Australian Standards

Australian Standards assembles groups of experts from industry, government, consumer and other relevant sectors to prepare Standards. The requirements or recommendations contained in published Standards are a consensus of the view of representative interests and also take into account the comments received from other sources. They should reflect the latest scientific and industrial experience. Australian Standards are reviewed from time to time and are updated to take account of changing technology and circumstances. In some cases they are joint Australian and New Zealand Standards.

In some cases, such as earth moving equipment design, Australian Standards may indicate the minimum standards as they are applied to the workplace. They usually supplement and support OHS Standards, Codes of Practice and Guides prepared by NOHSC and other government bodies in Australia.

Local or industry standards may give contrary information to Australian Standards. The most appropriate Standard must then be followed.

5.1 AS 3590 – 1990: Screen-based Workstations. Part 1: Visual Display Units, Part 2: Workstation Furniture, Part 3: Input Devices.

5.2 AS/NZS 4443 – 1997: Office panel systems – Workstations

Level 2: These Standards are somewhat overshadowed by more recent publications from state and Commonwealth governments and do not contain any more information. Nevertheless they are Standards and as such can be helpful.

5.3 AS 1680.2.1 – 1993: Interior lighting – Circulation spaces and other general areas

5.4 AS 1680.2.2 – 1994: Interior lighting – Office and screen-based tasks

5.5 AS 1680.2.3 – 1994 – Interior lighting – Educational and training facilities

5.6 AS/NZS 1680.2.4 – 1997 – Interior lighting – Industrial tasks and processes

5.7 AS/NZS 1680.2.5 – 1997: Interior lighting – Hospital and medical tasks

Level 2: Again these Standards are part of an array of information that is now freely available on Australian and overseas websites. Nevertheless they contain useful information.

5.8 AS 1319 – 1994: Safety signs for the occupational environment

Level 2: Safety signage has been standardised to everybody's relief but this may not contain everything you need to know especially about the ergonomics of signage. Refer to ergonomics textbooks listed here for more on issues such as readability and location.

5.9 AS/NZS 4240 – 1994: Remote controls for mining equipment.

Level 2: This is an essential reference for anyone designing remote control devices. It contains information on ergonomics and the design of controls for remote devices.

5.10 AS 2670 – 2001: Evaluation of human exposure to whole-body vibration – General requirements.

Level 3: This Standard is identical to the International Standard ISO 2631.1 – 1997: Mechanical vibration and shock – Evaluation of human exposure to vibration. The standards for measurement, analysis and exposure to whole-body vibration are significantly upgraded from the previous Australian Standard with more emphasis placed on the assessment of shocks. Many pieces of equipment in use today would not meet the required standards for 7-hours exposure.

5.11 AS 2763 – 1988: Vibration and shock – Hand-transmitted vibration – Guidelines for measurement and assessment of human exposure

Level 3: A lot of research work was done on this subject in the 1970s and 1980s due to increasing problems arising from the use of vibrating mechanical tools in colder climates such as the Nordic countries, Canada and the USA. Although some updating may be required the methods recommended in this Standard are still valid.

5.12 AS 2953.1 – 1988: Earth-moving machinery – Human dimensions. Minimum access.

5.13 AS 2953.2 – 1988: Earth-moving machinery – Human dimensions. Physical dimensions of operators and minimum operator space envelope.

5.14 AS 2956.5 – 1988: Earth-moving machinery – Instrumentation and operator's controls. Zones of comfort and reach for controls.

5.15 AS 2956.6 – 1988: Earth-moving machinery – Instrumentation and operator's controls. Crawler tractors and crawler loaders – Operator's controls.

5.16 AS 3868 – 1991: Earth-moving machinery – Design guide for access systems.

Level 1: These five Standards stipulate the minimum standards for mobile machinery design in terms of cabs space and layout, displays and controls and access. Ergonomics standards are a good deal more demanding than these and therefore are much more likely to be applied in new machines.

5.17 AS/NZS 4360 – 2004: Risk Management.

5.18 HB 436 – 2004: Risk Management Guidelines. Companion to AS/NZS 4360 – 2004

Level 1: This Standard and its accompanying Handbook cover the main generic issues of Risk Management. It is essential reading for anyone required to undertake formal or informal risk management procedures.

5.19 AS/NZS 4804 – 2001: Occupational health and safety management systems – General guidelines on principles, systems and supporting techniques.

5.20 AS/NZS 4801 – 2001: Occupational health and safety management systems – Specification with guidance for use.

Level 1: These two Standards and the accompanying Handbook give guidance on how OHS Management Systems can be set up, monitored and improved. The requirements for ergonomics in OHS are much the same. AS/NZS 4801 – 2001 specifically deals with certification, evaluation and auditing criteria. They are important for those wishing to integrate ergonomics into OHS.

5.21 HB 205- 2004: OHS Risk Management Handbook

Level 1: The handbook is designed to show how AS/NZS 4360 – 2004 and AS/NZS 4804 – 2001 can be adopted to meet the requirements of OHS risk management systems. Again it is essential reading for those involved in making OHS work.

5.22 HB59 -1994: Ergonomics – The human factor. A practical approach to work systems design.

Level 1: Despite its title this publication is somewhat limited in its coverage of ergonomics particularly with respect to the wider field of systems and organisational ergonomics. It contains basic information that can be found in other publications. However, as an Australian Standard publication it may be referred to legitimately and it may be used by some organisations.

Website: www.standards.com.au/catalogue/script

Industry material

Website : www.mineralsnsw.gov.au

NSW Department of Primary Industry (DPI) – Coal Mining Inspectorate – formally with the NSW Department of Mineral Resources (DMR) printed publications.

6.1 MDG 1. Guideline for Free Steered Vehicles. 1995.

MDG 1010. Risk Management Handbook for the Mining Industry. 1997

Note: MDG 1 and MDG 1010 are being revised and the new editions are due for release in the second half of 2005. They may not necessarily have the same number or name.

Australian Council of Trade Unions

Website: www.actu.asn.au

Level 1: The ACTU Guidelines available on this website are comprehensive and give information and guidance in some key areas. These include:

7.1 Screen Based Work

7.2 Working in Seasonal Heat

7.3 Shiftwork and Extended Working Hours

The website also contains extensive links to associated organisations' websites many of which have OHS information.

Other Codes, Standards and Guidelines

Health and Safety Executive (HSE) Britain.

Website: www.hse.gov.uk

The HSE is the British OHS regulatory authority. It publishes numerous information sheets that can be downloaded. Some of the more useful ones in ergonomics include:

8.1 Benchmarking in OHS

8.2 Display screen equipment

8.3 Understanding ergonomics (mainly offices and factories)

8.4 Manual Handling

8.5 Office work

8.6 Stress

Guidance material includes:

8.7 Health & Safety Executive (UK). Manual Handling. Manual Handling Operations Regulations 1992. Guidance on Regulations. L23 (3rd Edition) HSE Books, 2004.

Level 2: This presents a different way to consider manual handling risks. Contains some useful material not covered in the Australian Code of Practice or other NOHSC guidance material. It is available only in the printed version and is awkward to find on the HSE website.

8.8 Getting to Grips with Manual Handling. HSE

Level 1: This is an easy-to-read guide the above Regulation. It is available on the HSE website.

National Institute for Occupational Safety & Health (NIOSH) USA – Centers for Disease Control and Prevention (CDC).
Website: www.cdc.gov/niosh/nioshtic

NIOSH is primarily concerned with OHS research and information. It has a huge website with thousands of publications. Finding what you want is the problem. However the website has a search facility that can lead you the subject matter that you want by using keywords. It is called NIOSHTIC-2.

One recent publication worth a look is:

8.9 Overtime and Extended Work Shifts: recent Findings on Illnesses, Injuries and Health Behaviors. (See Shift Work)

8.10 National Institute for Occupational Safety & Health (NIOSH). Work Practices Guide for Manual Lifting. Cincinnati, NIOSH, 1981. (Publication No 1034 Under Ergonomics/ Musculoskeletal disorders on the website).

Level 3: Some of NIOSH's research has generated codes and guides that have been very useful to both researchers and practitioners. Although this is rather old it is a good summary of methods defining the ways in which disorders associated with manual handling can be analysed.

Robens Institute, University of Surrey, England.
Website address:
www.eihms.surrey.ac.uk/robens/erg/stress.htm

This is a highly esteemed research institute in occupational health and safety and particularly ergonomics.

One recent publication merits reading. It briefly discusses findings of a large research report into the relationship between stress and musculoskeletal disorders. There are some problems getting onto the website but these may have been rectified. It is:

8.11 Devereux J. Work Related Stress and Musculoskeletal Disorders [Summary of Technical Report]

Canadian Centre for Occupational Health and Safety.
Website: www.ccohs.can

This website has a number of useful documents on ergonomics in OHS. Some headings worth exploring are:

8.12 Ergonomics (including a complete summary of the Revised NIOSH Lifting Equation)

Physical agents (especially working in hot and cold environments)

8.13 Workplace schedules (shiftwork)

GLOSSARY OF TERMS:

Accident
An unplanned event that interrupts the completion of an activity, and that may or may not include injury or property damage.

Anthropometry
The dimensions of the human body and how these are measured. It covers the size of people; the length and range of movement of their limbs, head and trunk; and their muscle strength.

Australian Standard
Issued by Standards Australia and provides guidelines relating to the design, operation and maintenance of equipment and systems. An Australian Standard always has a standard number e.g. AS 1470

Awkward
A posture or action required for a task that creates some discomfort for or is unable to be maintained by the worker.

Benchmarking
A tool to identify and assess systematically the differences between an enterprise and world-class performers. It can be used to introduce best practice into enterprises. It is conducted in such a way that there is wide consultation and people are in a position to understand and achieve their full potential.

Best Practice
Refers to the cooperative way in which enterprises and their employees work together continuously to strive to be the best possible in all key business processes. The benefits can be seen in improvements in health and safety, timeliness, cost, quality and customer service.

Biomechanics
The interaction of human movement and posture. It deals with the levers and arches of the skeleton and the forces applied to them by the muscles and gravity.

Change management
An organised and systematic approach to anticipating and managing change in an organisation.

Circadian rhythm
Daily cycles of the human body in terms of physiological and psychological parameters such as temperature, hormone levels, mood, heart rate and blood pressure. These are largely internally generated (endogenous) and often resistant to abrupt changes such as those caused by shift work or intercontinental flights.

Cognitive
The processing of stimuli from the environment and from within the individual. These stimuli are relayed by the sense organs to the brain.

Constrained
Forced, cramped, restrained or unnatural, confined or restricted.

Consultation
The sharing of information and exchange of views between employers, employees and/or employee representatives on health and safety issues. It includes the opportunity to contribute to decision-making in a timely fashion to minimise OHS risks.

Continuous Improvement
This is a keystone of Best Practice. It refers to the incremental beneficial changes that occur through the cooperative efforts of all people in the enterprise. In enterprises that embrace a philosophy of continuous improvement people bring their ideas forward and management provides consistent encouragement, support and feedback.

Decision latitude
The degree to which an individual or group has control over their work processes and outcomes. It implies a certain degree of autonomy with respect to how and when a task/ job is undertaken and completed.

Due diligence
In OHS due diligence requires that employers, supervisors and others understand and carry out their legal duties, assess the risks and hazards in the workplace on an ongoing basis, and take all reasonable precautions with respect to those hazards and risks. Evidence of due diligence may be a defence against prosecution under OHS laws.

Ergonomics
The scientific discipline concerned with the understanding of the interactions among humans and other elements of the system and the profession that applies theory, principles, data and methods to design in order to optimise human well being and overall system performance.

Fatigue
Weariness from physical and/or mental effort.

Hazard
Anything that has potential to cause harm to a person

Health
Freedom from the presence of ill heath, disease or injury in the body.

Human error
An inappropriate or undesirable human decision or behaviour that reduces, or has the potential to reduce effectiveness, health and safety, or system performance.

Hierarchy of controls
Matching appropriate controls (solutions) to the level of risk

Injury
Immediate damage to the body caused by exposure to a hazard.

Job
Specific set of ongoing tasks to be performed by an individual.

Job Analysis
Evaluation of all tasks and factors involved in and completion of various phases of a job in a particular sequence.

Job Design
The process of deciding on the tasks and responsibilities to be included in a particular job. The aim is to satisfy the social and personal requirements of the job holder as well as technological and organisational requirements.

Job Rotation

The planned interchange of jobs among a group of workers at regular intervals in order to increase variety of motions and postures, share the most stressful tasks, add interest and increase versatility.

Kinesiology

The science of human movement as it relates to the structure of the musculoskeletal system. It describes motions of the body segments and identifies the muscle actions responsible for those.

Macro ergonomics

An approach in ergonomics that examines problems and issues in respect to the overall system so that it achieves effective and lasting change.

Mutual Handling

Includes a wide range of human work activities such as lifting, pushing, pulling, holding, throwing and carrying as well as repetitive tasks including packing, typing, assembling, cleaning and sorting.

Micro ergonomics

An ergonomics approach that examines localised or individual ergonomics problems and issues with the aim of finding and implementing solutions at that level.

Musculoskeletal system

The system of bones, muscles and connective tissues (tendons, ligaments, fascia, cartilage) that support and protect the human body and its organs and provide motion. Joints are the junction between bones and allow motion.

Motivation

An individual's intention or willingness to perform a task to achieve a goal or reward that will satisfy them. Each individual experiences differing amounts and types of motivation and considers different rewards or incentives as being attractive

NIOSH

National Institute for Occupational Safety and Health (USA) is the federal agency responsible for conducting research and making recommendations for the prevention of work-related injury and illness. It is part of the Centers for Disease Control and Prevention (CDC) in the US Department of Health and Human Services.

NOHSC

The National Occupational Health and Safety Commission (NOHSC) is Australia's national body that leads and coordinates national efforts to prevent workplace death, injury and disease in Australia.

Noise

Unwanted sound. High noise levels can be annoying, distracting, fatiguing and may also result in impaired hearing if loud enough.

Occupational ergonomics

Ergonomics as is applied at work to the design of the workplace and tasks and to work organisation.

OHS

Occupational Health and Safety (OHS) is the promotion and maintenance of the highest degree of physical, mental and social well-being of workers in all occupations; the prevention among workers of departures from health caused by their working conditions; the protection of workers in their employment from risks resulting from factors adverse to health and safety; the placing of and the maintenance of the worker in an occupational environment adapted to physical and mental needs.

ODAM

Organisational Design and Management. See Macro ergonomics

OOS

Occupational overuse syndrome (OOS) refers to a range of conditions marked by discomfort or persistent pain and/or other dysfunction in muscles, tendons or other soft tissues of the hand, arm or shoulder and sometimes occurs in the foot and ankle. Synonyms are: repetition strain injury (RSI), cumulative trauma disorder (CTD) and work-related musculoskeletal disorders (WMSD).

Optimum/Optimal

Best or most favourable balance between the needs of people and real-life limitations such as availability of solutions, their feasibility and costs.

Parallax error

Mistakes made reading the position of a pointer on a dial or gauge when viewing it at an angle.

Physiology

The science dealing with the functioning of living organisms or their parts.

PPE

Personal Protective Equipment (PPE) includes a wide range of devices that are designed to give individual protection from health and safety hazards. Common examples include ear plugs, respirators, glasses and gloves.

Psychophysical factors

These are concerned with the relationship between physical stimuli from the 'outside world' and the sensations these produce in the body's 'inside' world. They are measured for various reasons at work in such areas as perceived exertion, the development of effort scales, acceptable weights to be lifted, and the design of chairs and workstations.

Psychosocial factors

Subjective aspects of work organisation and how workers and managers perceive them eg career considerations, clarity of the work role, work schedules, workload and work pace, and the social and technical work environment.

RSI

See OOS

Risk

Factor that contributes to the occurrence of injury or loss from a hazard.

Risk Assessment

Process used to determine the likelihood of people being exposed to injury, illness or disease from any situation identified during the hazard identification process and the severity of the illness, injury or disease.

Risk Control

Process used after conducting a risk assessment identifying all practicable measures for removing or reducing the likelihood of injury, illness or disease, implementing these measures and reviewing them to ensure their effectiveness.

SAE
Society of Automotive Engineers (USA). Over many years the Society has produced guidelines and recommendations for driver spaces in cars and other vehicles within various design guidelines. These are used all over the world as the basis for cab design.

Safe Work Procedure
A standardised procedure developed for a task or a job to minimise workplace health or Standard Work and safety risks and to optimise efficiency. Procedure (SWP)

Sprain/Strain
Traumatic or cumulative injury resulting in damage to and inflammation of joints and adjacent muscles and connective tissues. It is usually accompanied by pain and stiffness. Swelling and loss of function in the area involved may also result.

Stakeholder
A person, a group or an organisation that has either an interest in, concern for, and/or involvement with OHS and the outcomes of work in OHS. The stakeholder may be directly or indirectly affected by this interest, concern or involvement, which may be seen as a gain or a loss. Stakeholders may be clients (individuals to whom the service is directed), customers (those who pay for the service), fellow workers, employers, trade unions and/or other professionals. The wider community may also be a stakeholder in the sense that it benefits from good OHS practice and it may also pay for such services, or the lack of them, through insurance, taxes, prices for goods and services etc.

Stress
A person's reaction when demands exceed an individual's ability to cope physically and/or mentally. These demands can be personal or work-related or both. It may sometimes be referred to as distress.

System
Systems are the structures that underlie complex situations. A system is a set of interrelated and interdependent parts arranged so that it appears to be and acts like a unified whole.

Task
Set of human actions that contribute to a specific functional objective and ultimately to the output goal of a system.

Task Design
The study of the components of a particular task to improve efficiency and minimise deleterious effects on the people who will perform the task. It includes planning and review of task elements with respect to human capabilities and limitations, and the design of equipment they use, the work environment and the work organisation.

Telemetry
Automatic measuring of something distant or inaccessible and the transmission of measurements to a recording/displaying device.

Violation
An incorrect (inappropriate) action that a person knowingly performs. The actions are carried out as intended.

Vibration
The oscillating or periodic motion of a particle, group of particles, or solid object about its equilibrium position

WMSD
See OOS

INDEX:

Page numbers in **bold** indicate Key Principles.
Page numbers in *italics* indicate diagrams and figures.

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Barbara McPhee is a Certified Professional Ergonomist and Physiotherapist who has worked in occupational health and safety for over 30 years as a consultant, teacher and researcher most particularly in ergonomics. During this time she has worked in all aspects of the field at every level of industry and government throughout Australia and overseas.

Over the last 15 years she has worked mainly in mining concentrating on reducing risks to employees' health and safety through improved ergonomics design. She also provides specialised ergonomics advice to clients in a range of other industries including light and heavy manufacturing, aviation, retail food and government.

Barbara is a Past President and Fellow of the Human Factors and Ergonomics Society of Australia. She is an Executive Council Member of the Pan Pacific Council on Occupational Ergonomics and is a former Board Member of the International Commission on Occupational Health. She is a Life Member of the Australian Physiotherapy Association.

ISBN 09579062-1-8

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