A HANDBOOK ON

OCCUPATIONAL HEALTH PRACTICE IN THE SOUTH AFRICAN MINING INDUSTRY

CHAPTER 14

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Chapter 14

Ergonomics

Ergonomics is specifically mentioned in the Mine Health and Safety Act, Act 29 of 1996, but generally speaking, the nature and scope of the subject are not well understood. This chapter gives an overview of ergonomics, why it is important to recognise ergonomics-related hazards during risk assessment, and the importance of correctly designed equipment and workplaces. Shift work is addressed briefly, as is computer work environments. Guidance is provided on how to set up an ergonomics programme, including a checklist that will assist the interested reader to identify potential problem areas.

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14.1 Introduction

The South African mining industry (SAMI) has undergone significant changes since the late 1980s, with increased mechanisation and development of new technologies (1). Despite changes, many jobs continue to be labour intensive, physically demanding, and repetitive, and human-centered design principles have often been neglected in the design and development of new equipment and technologies.

With the promulgation of the Mine Health and Safety Act No. 29 of 1996 (MHSA) (2), the concept of 'ergonomics' was legislated in South Africa in 2019, when the Ergonomics Regulations were gazetted under the Occupational Health and Safety Act No. 85 of 1993 (3). For the first time in South Africa, specific reference was made to ergonomics in legislation, such as the application of 'ergonomic principles'.

However, the responsibility was limited to the manufacturers and suppliers of mining equipment. as stipulated in section 21 (1) (c) of the MHSA. Unfortunately, this section in the Act does not include the workplace and work procedures, and no regulatory guidelines are provided as to what is actually meant by 'ergonomic principles'. Details are provided in **Appendix 14.2.**

Thus, the Ergonomics Regulations were promulgated to cover employers or self-employed persons who carry out work at a workplace, which may expose any person to ergonomic risks in that workplace (4). These Regulations cover information, instruction, training, and specific duties for employers and persons who may be at risk of exposure to ergonomics, including designers, manufacturers, importers, and suppliers. Additionally, the Regulations cover risk assessment, control, and medical surveillance associated with ergonomics hazards.

Section 21 (1) c of the Act reads as follows:

"21. Manufacturer's and supplier's duty for health and safety

(1) Any person who –

(c) designs, manufactures, erects or installs any article for use at a mine must ensure, as far as reasonably practicable, that ergonomic principles are considered and implemented during design, manufacture, erection, or installation."

The applied science of ergonomics was formally established in the late 1940s, and continues to evolve with changes in technologies. This chapter provides a better understanding of ergonomics and how it relates to occupational health and safety (OHS) issues in the mining industry. Some guidelines are also given to identify ergonomic hazards, and associated preventive strategies will be outlined.

Ergonomics covers a wide field and can only be addressed superficially in this chapter and focuses on health-related issues within the mining industry. One cannot deal with ergonomic hazards without considering the environmental factors, wellbeing and health of the human operator. However, environmental stressors (occupational hygiene factors) will not be discussed, as they are addressed in other chapters of this Handbook.

14.2 Definitions of Ergonomics

The term ‘ergonomics’ is derived from the two Greek words *ergon*, meaning *work*, and *nomos*, meaning *law*. Literally translated, ergonomics means ‘the laws of work’. The Ergonomics Regulations define ergonomics as *“the scientific discipline concerned with the fundamental understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimise human wellbeing and overall system performance”* (4).

‘Ergonomics’ and ‘human factors’ are often used synonymously. Both describe the interaction between the operator and the job demands, and are concerned with reducing unnecessary stress in the workplace. The term ‘human factors’ is preferred in the USA, while the term ‘ergonomics’ is preferred in Europe, the UK, Australia, and South Africa.

The International Ergonomics Association defines ergonomics as *“the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data, and methods to design in order to optimize human well-being and overall system performance”* (5).

As a science, ergonomics studies human capabilities, limitations, and other characteristics for the purpose of developing human-system interface technology. As a practice, ergonomics applies human system interfaces to the design, standardisation, and control of systems. Ergonomics promotes human reliability and improved health and safety. It ensures that equipment, tasks, and the physical work environment are designed to take account of the capabilities and limitations of people.

In the present context, a succinct definition would be that ergonomics seeks to design equipment, tools, workstations, and tasks to be compatible with human capabilities and limitations, with the purpose of providing working conditions that assure safety, health, wellbeing, and efficiency.

14.2.1 The objectives of ergonomics

The goals of ergonomics are to decrease the risk of injury and illnesses (especially those related to the musculoskeletal system), to improve worker performance, to decrease worker discomfort, and to improve the quality of work life. The benefits of well-designed jobs, equipment, work methods, and workplaces include:

- Enhanced safety and health performance
- Improved quality and productivity
- Reduction in errors
- Heightened employee morale
- Reduced compensation and operating costs
- Accommodation of diverse populations

The ultimate goal of ergonomics is to improve and maintain the wellbeing of the individual worker. At the same time, the wellbeing of the organisation will also be improved and maintained. Although ergonomics is an evolving science, proper application of its principles can achieve benefits that are significant and immediate.

14.2.2 Interdisciplinary nature of ergonomics

Ergonomics draws on various fields in the human sciences and technology, including anthropometrics, biomechanics, physiology, psychology, toxicology, mechanical engineering, industrial design, information technology, and industrial management. It has gathered, selected, and integrated relevant knowledge from these fields.

Ergonomics differs from many other fields by its interdisciplinary approach and applied nature. The interdisciplinary character relates to different human facets, while its applied nature results in the adaptation of the workplace or environment to fit people, rather than the other way around.

14.2.3 Physical, cognitive, and organisational ergonomics

Ergonomics is divided into three interconnected areas, which work together to create a more efficient, safe, and comfortable work environment. These are physical, cognitive, and organisational ergonomics (6).

14.2.3.1 Physical ergonomics

This branch or ergonomics focuses on the design of workplaces, tools, and equipment to minimise physical strain and injury. It considers factors like posture, repetitive motions, and the physical demands of tasks. For example, an ergonomically designed office chair helps employees maintain a healthy posture while working.

14.2.3.2 Cognitive ergonomics

This area of ergonomics investigates how people perceive, think about, and interact with their environment. It aims to improve task performance and reduce errors by optimising information presentation, user interfaces, and cognitive processes. For example, a well-designed dashboard on a computer system can improve a user's ability to understand and control the system's functions.

14.2.3.3 Organisational ergonomics

This discipline or ergonomics focuses on the impact of organisational factors on employee wellbeing and productivity. It considers aspects like work schedules, communication, and team dynamics. For example, implementing flexible work hours or improving communication channels can enhance employee satisfaction and productivity.

14.2.4 Ergosystem

A useful concept in understanding the occupational application of ergonomics is that of an ‘ergosystem’. An ergosystem consists of three primary interacting components, namely human, machine or technology, and environment.

The most general approach to ergonomics is to consider a person interacting with technology (man-machine system). Typical examples are persons driving a vehicle, using a computer, speaking over a telephone, and using a lift. The interaction occurs by means of displays, whereby the machine or technology provides information to the user, and controls, whereby the user passes information to the machine (**Figure 14.1**). There is, therefore, a complete information flow loop with a proper functioning of all the parts. In order to ensure successful, safe, and effective use, there should be no delays in the information flow (7).

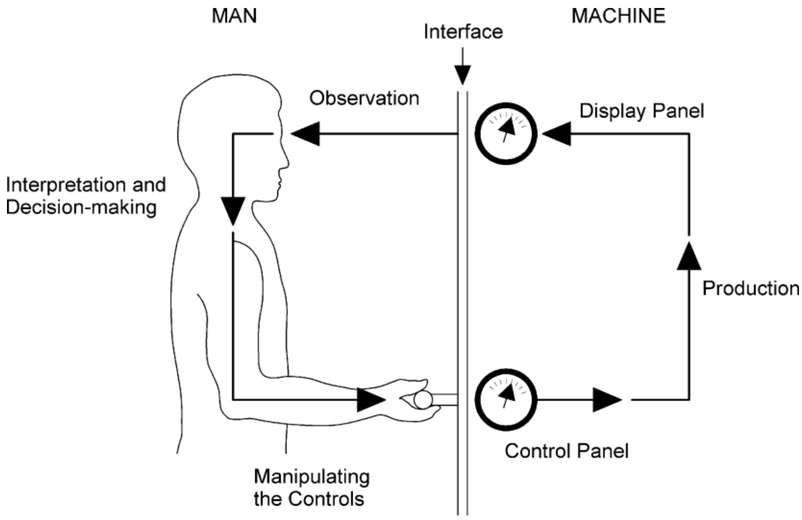

Figure 14.1. Communication between human and machine viewed as an information flow loop

Source: Galer (2016) (7)

Tasks are not performed in a vacuum. The interaction between human and technology always takes place in a certain workspace, which is located in a specific physical and psychological environment (**Figure 14.2**). The characteristics of the workspace and the environment will affect the task performance of the human.

The workspace is described in terms of the size and layout of workbenches, control desks, consoles, and other, e.g. mining equipment. Factors like size and layout will have an effect on the body position, body posture, and reach distances of the expected user population, and consequently on comfort and efficiency.

The environment can be described in terms such as temperature, lighting, noise and vibration, presence, and effect of chemical and biological agents, as well as in psychological terms such as teamwork, management structure, shift conditions, and psychosocial factors.

The human-technology-workspace-environment model (**Figure 14.2**) is useful in identifying the factors that will have an effect on comfort, task performance, and safety. Applied consistently, this model will ensure that no potential ergonomic factors are omitted. It is, however, primarily a descriptive aid and does not spell out specifically how and in which sequence a system should be analysed and designed. This systems approach is a formal analysis method, which has been used successfully in a large number of ergonomics investigations.

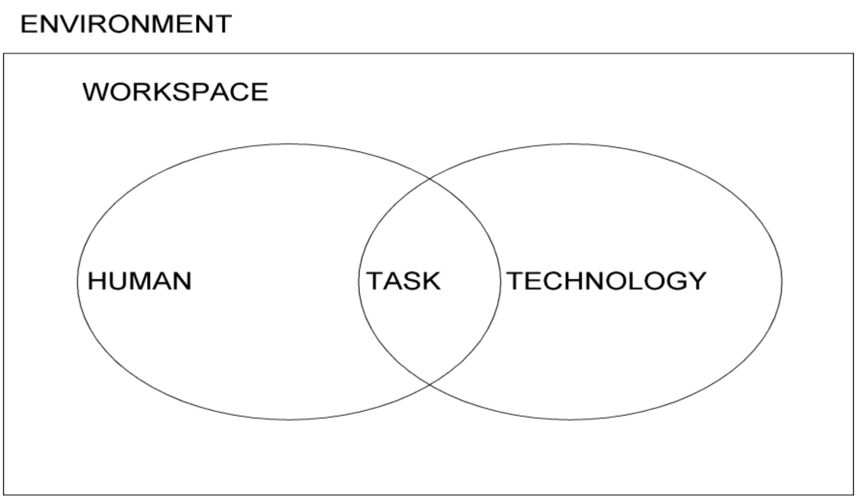

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Figure 14.2. Human-technology-workspace-environment model

Source: James et al. (2006) (8)

14.3 Ergonomics – Related Hazards in the Workplace

14.3.1 Basic ergonomics considerations

The crux of ergonomics is that humans can only, and to a limited extent, adapt to poorly designed human-machine systems and, therefore, the systems must be designed and adapted to fit the human restrictions.

In the application of ergonomics in the workplace, there are two primary considerations. In the first instance, ergonomics provides guidelines and specifications according to which tools, machines, work procedures, and workplaces are to be designed and developed for effective, efficient, and safe use by the operator. Safe use implies that they do not constitute a health risk. This first role is the proactive approach to effective ergonomics, which designers and developers of mining equipment should be applying to comply with the requirements of Section 21 of the MHSA.

The second important, but reactive, role is the use of criteria to assess whether existing tools, equipment, workplaces, and work procedures comply with ergonomic requirements to ensure health, safety, and efficiency.

In considering human abilities and limitations, there are five critical sets of factors that must always be considered (9):

- Anthropometrics
- Biomechanics
- Human sensory issues
- Human physiological wellbeing
- Human cognitive issues, including mental health

14.3.1.1 Anthropometrics

'Anthropometry' literally means the measurement of humans. Although one can measure humans in different ways, anthropometry focuses on the measurement of bodily features such as shape and size ('static anthropometry'), and body motion and use of space ('functional anthropometry').

The world's population can be divided into subpopulations of different average physical dimensions. Anthropometric surveys have shown that South African populations of different ancestries and social class differ significantly in average stature (10). Difference in stature is important in the design of equipment and work environments, reach distances in driving of vehicles, locos and the operation of equipment, or the postures at workbenches.

An anthropometric database can provide useful information for optimising the human-machine-equipment or system interface. Information on the anthropometry of South African mineworkers was reported by a SIMRAC study in 2003 (11). More recent information for the South African population is documented in the South African Military Standard RSA-MIL-STD-127 (12). The basic human body requirements for technology design are given in the International Organization for Standardization document ISO 7250:2017 (13).

14.3.1.2 Biomechanics

Biomechanics deals with the mechanical aspects of body movement and is, basically, the application of the principles of mechanics to the study of biological systems. Biomechanics, thus, utilises knowledge from anatomy, physiology, and mechanical engineering. The portion of biomechanics dealing with ergonomics (industrial or occupational biomechanics) is defined as *''the study of the physical interaction of workers with their tools, machines, materials so as to enhance the worker's performance while minimizing the risk of musculoskeletal disorders''* (14).

As with anthropometrics, some individuals will, due to factors such as muscle volume associated with physical size, lifestyle, gender, and socio-economic circumstances, have greater muscle power than others. Muscle power relates to the ability to lift and handle material, equipment, and heavy tools. Occupational biomechanics assessments are used to describe quantitatively the musculoskeletal loading during work, to determine the degree of risk associated with an occupational-related task.

14.3.1.3 Human sensory system

The human sensory system refers to sensors such as vision, hearing, smell, taste, balance, and the kinaesthetic sense. The kinaesthetic sense, or kinesthesia, is the ability to sense the position and movement of our body parts, even without visual aid. It relies on sensory receptors, particularly proprioceptors, located in muscles, joints, and tendons, to detect changes in position and movement.

Vision and hearing are of particular interest in the mining industry for safety and operational effectiveness. Clear vision is vital for navigating mine environments, operating machinery, and avoiding accidents. Hearing allows for timely responses to emergency alarms, communication with colleagues, and detection of hazards like gas leaks.

14.3.1.4 Human physiological homeostasis

This refers to the need of the human body to be in a state of physical wellbeing. Environmental stressors such as heat, barometric pressure, noise, vibration, and toxic substances often affect physical wellbeing. Work procedures requiring a considerable amount of energy can place additional stress on the human physiological system. These factors are common in the mining environment.

14.3.1.5 Psychological (cognitive) system and mental health

Body systems do not operate independently. If one system is adversely affected, then it can influence the others. For instance, during exposure to vibration, it is not only the limb or body segment vibrated that is affected; other systems are affected, as well as the psychological wellbeing of that person.

Effects on psychological wellbeing will be manifested in mental fatigue, stress, and motivational level, which can result in poor decision making, errors, and a predisposition to accidents. Recent literature continues to show mental health as a major factor in lost productivity and worker wellbeing, due to stress emanating both from within the work environment and from societal pressures (15,16). Some factors cited as contributors to mental health include sleep disorders, fatigue, and extended work hours.

When exposed to stress, the human body will attempt to counter it. If the body cannot adapt to or cope with the physical or mental stress because it has reached its limitations, health problems may occur. The most common reaction of the body to physical stressors beyond its limits is pain, which is the first indication of a series of events that can eventually result in a person becoming unfit for duty.

In practice, it is essential that the design of optimal working conditions with regard to human wellbeing, performance, and safety and health should take the following aspects into consideration:

- The physical size of people, and its implications for the fit of the person at the workplace and within the facility
- The cardiovascular system and its limitations on work, as measured by work physiology
- The major musculoskeletal system and its limitations on manual material handling
- The minor musculoskeletal systems and their limitations on fine work, manipulation, and dexterity
- The environmental factors such as lighting, noise, and thermal comfort, and their impact on human performance
- The cognitive capabilities of people and their impact on processing information and 'human error'

14.3.2 Ergonomic risk factors

According to the MHSA, a *"risk"* is the probability that injury or damage will occur. A risk has three elements to it, including the hazard involved, the probability that something can go wrong, and the resultant impact or severity.

Reference is often made to 'ergonomic hazards' or 'ergonomic risk factors' in the workplace. However, as ergonomics strives for a healthy and safe workplace, the hazards actually result from the absence of ergonomic considerations. These conditions are more correctly called 'ergonomic risk factors', rather than 'ergonomic hazards' or 'ergonomic problems' (15). **Table 14.1** summarises a number of the major ergonomic risk factors.

Table 14.1. Ergonomic risk factors.

Ergonomic risk factor	
Risk factor	**Causal factor**
Awkward posture of: • Hand/wrist • Arm/elbow • Shoulders • Back • Head/neck • Knee/ankle	Tool handles, control grips Working overhead or work surface/benches too high Height of work surface, benches, and desks, work layout Height of work surface and manual handling Visual angle to view work area Foot control angle, leg room at benches, and desks Static or sustained postures
Exertion of force: • Grip (power vs pinch) • Manual material handling • Crouching • Static strain • Pushing/pulling • Lifting • Reaching	Tool handle size and force needed to operate Lifting, lowering, and carrying loads, pulling loads Work in confined space Computer work, fixed work posture, holding equipment Forceful exertions Compression or contact stress
Work procedures: • Work pace. • Rest periods • Shift work	Machine-paced work tempo Insufficient rest, breaks, and recuperation period Duration and type of work shift
Repetitive motions: • Number • Frequency	Keyboard work, other repetitive work Times cycles are repeated, not sufficient rest
Contact stress: • Surface	Uneven, abrasive, and slippery surface Small-diameter tool handles

• Diameter • Edges	Thin, sharp, and square edges
Environment: • Noise • Vibration • Temperature extremes (heat/cold) • Radiation • Lighting • Air quality	Environmental stressors in the work environment that affect the physical and psychological wellbeing of the worker

Source: Adapted from Jaffar et al. (2011) (15)

14.3.3 Synergism of risk factors

In the workplace, the worker may be exposed simultaneously to more than one ergonomic or other risk factor. Such factors may act independently, but the effects may also be additive.

In this regard, it is important to take notice of the synergistic effect. Synergism simply means the simultaneous and combined effect of two or more factors, where the combination is greater than the sum of their individual effects.

In industry vibration for example, in conjunction with other stressors such as heavy manual work, poor posture leads synergistically to cumulative trauma disorder (16). It was concluded that vibration stress is an important contributor to the development of musculoskeletal disorders in workers using handheld vibrating tools. The heavy manual work needed to control the power tool and to manipulate the workpiece is also a contributing factor.

While many situations can be the cause of ergonomic hazards, individual differences in susceptibility do exist and one individual's response may not be the same as that of another.

14.4 Work–Related Musculoskeletal Disorders and Manual Handling

14.4.1 Work-related musculoskeletal disorders

Musculoskeletal disorders are injuries and problems of the muscles, tendons, ligaments, joints, nerves, vessels, and supporting structures involved in locomotion. They are usually manifested by pain, numbness, tingling, swelling, or loss of function, and are primary located in the upper limb, back and, to a lesser extent, the lower limbs.

The term 'work-related musculoskeletal disorders' (WMSD) refers to the musculoskeletal disorders to which the work environment and performance of work contribute significantly, or that are made worse or longer lasting by work conditions (17). Work-related musculoskeletal disorders are known by a variety of terms across the world such as 'cumulative trauma disorders' in the USA, 'repetitive strain injuries' in Canada and Australia and, more recently, in Australia as 'occupational overuse syndrome'. Lately, WMSD has gained popularity, worldwide, as the preferred designation for this group of disorders. Examples of WMSD are given in **Table 14.2**.

Table 14.2. Examples of work-related musculoskeletal disorders

Anatomical structure involved	Example of possible work-related musculoskeletal disorder
Tendons	Tendonitis/peritendonitis/tenosynovitis/synovitis of most joints, in particular shoulder, elbow, and hand-wrist Epicondylitis De Quervain's disease (stenosing tenosynovitis) Trigger finger Gamekeeper's thumb
Nerves	Median nerve entrapment: carpal tunnel syndrome (CTS) (entrapment at the wrist) and pronator teres syndrome (entrapment at the elbow) Ulnar nerve entrapment: cubital tunnel syndrome (entrapment at the elbow) and Guyon's canal syndrome (entrapment at Guyon's canal) Radial tunnel syndrome (radial nerve entrapment at the elbow) Thoracic outlet syndrome (TOS) (neurogenic TOS is entrapment of the brachial plexus at different locations) Cervical syndrome (radiculopathy) (compression of the nerve root) Sciatica
Circulatory/vascular structures	Hand-arm vibration syndrome (involves vascular and nerve damage) Hypothenar hammer syndrome Raynaud's syndrome
Joints (cartilage and bone)	Osteoarthritis of most joints/degenerative joint disease Arthrosis of the hip
Muscles	Tension neck syndrome. Trapezius myalgia
Bursa	Bursitis of most joints
Neurovascular- related	Brachial plexus compression injuries

Source: Adapted from Korhan (2019) (17)

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Risk factors that are known, based on epidemiological evidence, to be associated with the development or aggravation of musculoskeletal disorders include personal characteristics (such as gender, age, body mass, physical limitations), psychosocial, and work-related aspects.

Factors that commonly contribute to WMSD are tasks requiring repetitive, forceful, or prolonged exertion of the hands, frequent or heavy lifting, pushing, pulling, or carrying heavy objects, and prolonged awkward postures. Vibration and cold may also contribute. Multiple risk factors will have a higher probability of causing a musculoskeletal problem, and the level of risk depends on the intensity, frequency, and duration of the exposure, plus the individual's capacity to cope.

Information on the job activities and tasks typically associated with common WMSD of the upper extremities are given in **Table 14.3**.

Table 14.3. Job activities and Tasks typically associated with common work-related musculoskeletal disorders

Disorder	Typical job/task activities
Carpal tunnel syndrome	Buffing, grinding, polishing, sanding, assembly work, typing, packing, scrubbing, hammering, repetitive or forceful grip and prehensile tasks, especially in extremes of flexion, extension and ulnar deviation, video display terminal work
Cubical tunnel syndrome	Resting forearm near the elbow on a hard surface or sharp edge or reaching over an obstruction, repetitive or static elbow flexion
De Quervain’s syndrome	Buffing, grinding, polishing, sanding, pushing, pressing, sawing, use of pliers, use of small tools, ‘turning’ control, such as on motorcycle, inserting screws in holes, forceful hand wringing
Epicondylitis (‘tennis elbow’)	Turning screws, small parts assembly, hammering, repetitive wrist extension and repetitive grasp, video display terminal work
Neck tension syndrome	Belt conveyor assembly, typing, small part assembly, load carrying in hand or on shoulder
Pronator (teres) syndrome	Soldering, buffing, grinding, polishing, sanding
Shoulder tendonitis (rotator cuff syndrome or tendonitis, supraspinatus tendonitis, subacromial bursitis, subdeltoid bursitis, partial tear of the rotator cuff)	Punch press operation, overhead assembly, overhead welding, overhead painting, belt conveyor assembly, work with the arms away from the body, electrical work, packing, construction work, reaching, lifting, carrying load on shoulders
Tendonitis, Tenosynovitis, tendovaginitis)	Punch press operation, assembly work, wiring, packaging, use of pliers, buffing, grinding, polishing, sanding, punch press operation, sawing, cutting, use of pliers, ‘turning’ control, such as on motorcycle, inserting screws in holes, forceful hand wringing
Thoracic outlet syndrome (brachial plexus compression injuries)	Work with arms overhead or in front of the body, mechanical stress applied to the brachial plexus, truck driving, material handling, office workers, carrying heavy loads with extended arms
Guyon’s tunnel syndrome (‘biker’s finger’)	Repeated/prolonged pressure on the outside of the palm, prolonged flexion and extension of the wrist, carpentry, brick laying, use of pliers, soldering, hammering
Trigger finger (or thumb)	Operating trigger finger, using hand tools that have sharp edges pressing into the tissue, or whose handles are too far apart for the user
White finger (Raynaud’s syndrome, vibration syndrome)	Working with chain saws and jackhammers, using a vibrating tool that is too small for the hand, often in a cold environment

The relationship between occupational factors and low back pain is often difficult to determine, as objective evidence of low back pain is often lacking and exact exposure is usually difficult and, sometimes, impossible to quantify. Further complicating the situation is the fact that exposure to several occupational risk factors often occurs in the same job. For example, a truck driver may have to load and unload their truck (lifting), sit for many hours in an unchanged posture (static loading), and be exposed to whole-body vibration. The most frequently mentioned risk factors for low back pain include heavy physical work, static work posture, frequent bending, twisting, lifting, pushing, and pulling, and whole-body vibration.

The diagnosis of WMSD requires expertise in evaluating workers in light of the biomechanical, personal, and work organisational factors that cause such a condition. Ergonomics is important in preventing WMSD, and the following concerns should be addressed at the work area to minimise the risk of developing these disorders:

- Cramping of the worker
- Twisting and turning
- Repeated reaching motions
- Misalignment of body parts
- Manual material handling

More information on WMSD can be obtained from the web pages of the Occupational Safety and Health Administration (OSHA) of the US Department of Labour (http://www.osha.gov/SLTC/ergonomics/).

14.4.2 Manual material handling

Manual material handling refers to lifting, lowering, pushing, pulling, holding, and dragging offloads without the help of mechanical devices or tools (18). These activities often require static and dynamic efforts that place great strain on the human musculoskeletal system. Manual material handling is a major hazard due to the injuries that can arise. These include cuts and bruises, hernias, and back injuries. In the mining industry where manual material handling is performed, mostly underground in restricted areas and with the body often in an unnatural posture, this aspect is particularly important and should receive specific attention.

A frequently asked question is, *"What can a person be reasonably expected to handle?".* There is unfortunately no straightforward answer due to the great diversity of people, different strengths and physical conditions, size, and shape of objects to handle. The International Labour Organization (ILO) has provided guidelines, which are generally accepted as the norm for lifting tasks (19). The guidelines emphasise keeping loads close to the body, avoiding twisting or bending, and using appropriate lifting techniques. The guidelines also highlight the importance of training and instruction for workers on how to perform manual handling tasks safely, as well as the use of technical devices to facilitate the manual transport of loads.

The US National Institute for Occupational Safety and Health (NIOSH) had developed a comprehensive index to calculate the risk involved in manual handling tasks: Work Practices Guide for Manual Lifting, which was revised in 1994 to reflect the new recommended weight for lifting and lowering as 23 kg (20), which corresponds closely with the ILO.

Manual-handling tasks will always exist in the workplace, and it is often lifting a small load that triggers a problem.

Some considerations to counter the effects of manual material handling are:

- Workers must be trained in correct load-handling procedures.
- If the worker is uncertain whether they can handle the load, they must get help.
- Use leg lift instead of back lift.
- Work must be done between knuckle and shoulder height.

- Do not twist and rotate the body when handling a load, rather use the feet to turn.
- Avoid stretching with a load in the arms.
- Avoid awkward body postures.
- Keep the load close to the body.
- Use a firm grip on the load.
- Balance the load, especially where it has an awkward shape.
- Use mechanical assistance, hoists, conveyors, and trolleys, wherever possible.
- Where possible, design the workplace to push and pull rather than lift and lower.
- Keep walkways clear of obstacles.
- Provide small ramps instead of stairs, where possible.
- Ensure the underfoot surface is not uneven or slippery.
- Minimise heights between surfaces where loads are handled.
- Consider the physical condition of the worker.

A comprehensive guide with recommendations to address manual material handling activities has been prepared by Mital et.al. (1997) (18), and more information on ergonomic guidelines for manual material handling is available from the US Centers for Disease Control and Prevention (21).

14.5 Equipment and Workplace Design

In the SAMI, literally thousands of different tasks are performed in different settings and environments. The ergonomic recommendations for the dimensions of workstations are, to some extent, based on anthropometric data, but behavioural patterns of people and specific requirements of the work itself must also be considered. Poor ergonomics in human-machine work systems can result in accidents and injuries, but can also result in health-related problems if the lack of consideration for human abilities and limitations results in stresses and strains on the body.

Further guidelines, one dealing with the ergonomic design of trackless mining machines and the other with the ergonomics of locomotive design in gold and platinum mines, are available for more information (22).

14.5.1 General guiding principles and considerations regarding workplace design

Workplace design should be guided by taking these principles into consideration:

- Know and understand the tasks of the operator. Identify and analyse the task to be performed, especially to identify potential ergonomics risk factors.
- ‘Fit the task to the human and not the human to the task’. The human is fitted to the task only if very specific characteristics are required and selection takes place through training programmes.
- Identify the user population. Design for the correct anthropometrics and biomechanical abilities of the user population. Design for a range and not for the average. Use adjustability to fit different sizes.
- Consider population expectancy or stereotypes, which may differ from country to country, as these may be the cause of errors and accidents. It becomes especially important if equipment is being imported from countries where the stereotypes differ from that of the South African population.
- Use Standards and other verified scientific information and ergonomics data.
- Do not design for extremes of postural reaches. Work activities should be at about the midpoint of limb ranges.
- Avoid unnecessary stretching and turning. Controls should be within functional reach.
- Avoid unnecessary repetitive actions or static muscular postures, especially with the arms above

shoulder level.

- Design for adequate rest pauses during a work period. Consider the work pace, especially if set by the system, e.g. conveyor belts.
- Consider comfortable viewing postures (viewing angles). In the sitting position, 15° below horizontal and, while standing, 10° below horizontal are the best for attention, scanning, and ability to see detail, as well as lessening stress on the neck and shoulder muscles.
- Design for maintainability and emergency situations.
- Height of the work surface, e.g. workbenches, must be related to the task. Variable height work surfaces for different tasks should be considered.
- Design for functional comfort and ease, but not for luxury.
- Consider the principles for manual material handling.

14.5.2 Seated/standing work operations

Work should be arranged to be done, of the worker's choice, in either a seated or standing position. The correct height of work surfaces is important. Standing work is preferable when the operator has to move frequently and/or when knee room is limited, where force has to be applied, where front and rear space is 14
limited, and a large number of controls and displays needs attention. Height-adjustable seating is essential.

The seat, work surface, and/or desk should be designed as a unit to achieve the preferred body posture, namely, trunk erect, body weight appropriately supported, elbows at the side of the body, and forearms approximately horizontal.

14.5.3 General guiding principles regarding display design

A display is a device that allows the operator to monitor the status of a system. Deciding on the applicable type of display is one of the most important decisions a designer can make, and this must be part of the
14 task analysis process. It is commonly assumed that a display is a device relating to sight, but in practice, displays can make use of auditory, tactile, and smell senses. Visual displays are, however, favoured and, therefore, sometimes overemphasised in system design.

The cardinal principle in the design of visual displays is to establish precisely what information the user requires in their task, and to display no more or no less in a form that is visible, legible, and intelligible. The nature and design of displays should ensure unambiguous perception.

The nature and number of displays should be compatible with the characteristics of the information.

General guiding principles concerning the design of displays include:

- 'Importance' principle: the most important and emergency displays should be placed in the primary vision area.
- Frequency of use: frequently used displays should be placed in the primary area.
- Grouping: related displays should be grouped together. Borders could be used to emphasise grouping.
- Sequence of use: displays should be placed in sequence of use.
- Intelligibility: the information displayed must be clearly understandable.
- Legibility: it must be easy to read the display.
- Visibility: account should be taken of the visual angle, size, contrast, and prominence.
- Unambiguity: displays should not be confusing. Rate and direction of change of displayed information must be compatible with the rate and direction of change of the primary source of that information.
- Expectancy: displays must operate according to the common expectations of the user population. For example, a red display is generally associated with a danger situation.

- Type: digital or analogue. Analogue is generally used to check the status of a system, while a digital display gives very precise information.
- Coding: light, colour, and symbols must be done in such a manner that all users will interpret the information in the same way.
- Information processing: too much information or information displayed too fast may overload the operator.
- Auditory displays: must be limited and clearly different to avoid any confusion. They must also be at a sound level and frequency clearly audible above background noises.

14.5.4 General guiding principles regarding control design

Controls are human-machine interface devices that allow an operator to change the status of a system. Examples are steering wheels, hand wheels, cranks, levers, push buttons, joysticks, and switches. Controls are usually used in conjunction with displays, the latter allowing the operator to see and regulate the amount of change they have activated.

General guiding principles regarding the design of work systems (ISO 6385:2016) include (23):
- Controls should be selected, designed, and laid out in such a way as to be compatible with the characteristics (particularly of movement) of that part of the body by which they are operated.
- Type, design and layout of controls should correspond to the control task, considering human characteristics, including learned and innate responses.
- Travel of controls and control resistance should be selected based on the control task and of biomechanical and anthropometrical data.
- Control movement, equipment response, and display information should be mutually compatible.
- Function of the controls should be easily identifiable to avoid confusion.
- Where controls are numerous, they should be laid out so as to ensure safe, unambiguous, and quick operation. Critical controls should be visually and tactilely identifiable.
- Critical controls should be safeguarded against inadvertent operation.

14.5.5 Display and control integration

Controls and displays are the means by which people operate machinery. In difficult circumstances such as underground, poor control and display design could lead to hazardous operation. The integration of the control with its specific display needs careful consideration to ensure that no errors of observation and/or interpretation occur. The most important considerations in this respect are:
- Control-display compatibility: direction of movement on the display should be compatible with the movement on the control. This movement should also conform to the common expectations of the particular user population.
- Control-display movement ratio: describes how much a control must be moved to adjust a display. No fixed relationship exists and is dependent on the task requirements. For accuracy, a relatively high number of rotations on a control is needed for a small amount of change in the display, e.g. searching for frequency on a radio.
- Control-display layouts: two aspects should be considered here. The first is that the organisation of the control-display must be such that it is obvious which control belongs to which display. Second, labels must be placed to be clearly associated with their respective controls. The usual approach is to place them above the controls. This ensures that the hand does not cover labels once it is on the control.

14.5.6 Computer work environment

Computer work may seem low-risk, but prolonged sitting, repetitive movements, and poorly designed workstations create a cluster of ergonomic hazards that can lead to musculoskeletal disorders, eye strain, and cognitive fatigue. Pain in the neck and shoulder muscles due to a forward bent neck is a problem manifesting more regularly. Computer keyboard users who cannot touch type are experiencing severe neck pain and headaches. These are due to the extended manner in which the neck has to be craned to identify the keyboard keys. This is often aggravated by the head being tilted upwards, so that the eyes can focus on the visual display unit of the computer. It is erroneously believed that a computer screen should be read with the line of sight horizontal. This requires a backwards arching of the neck, especially with a computer user with bifocal spectacles. The ideal height for the computer screen is a viewing angle of 10 to 15 degrees downwards from the horizontal line of sight.

Repetitive hand or wrist movements during computer work such as typing can irritate the tendons and increase pressure in the tunnel. This can cause carpal tunnel syndrome, a condition caused by pressure on the median nerve as it passes through the carpal tunnel, a narrow passageway in the wrist. Prolonged exposure can lead to symptoms such as numbness, tingling, pain, and weakness in the hand and fingers.

ISO 9241-112:2017 provides extensive information on human-computer interaction, including task design, hardware (screens, input devices), software, and the work environment (24).

14.5.6.1 Fitting the task to the human and fitting the human to the task paradigms

The ergonomics approach is to fit the task to the human. However, it is not always possible to design all workplaces or systems to fit all possible users and pose no ergonomic risks for them. There are situations where particular work conditions or circumstances require workers with special skills or abilities and, in this case, a psychologist and/ or physiologist may be required to fit the human to the task.

On the psychological side, knowledge is drawn from the behavioural sciences to select those workers who need to possess certain traits and mental skills in order to perform specific tasks. The special skills for selection as a test pilot or astronaut are generally well known and, in the same vein, not all people are suited nor psychologically equipped to do mine work underground, to be a member of a mine proto-team, or to be a member of a shaft-sinking group. In the same context, but from an anatomical and physiological point of view, aircraft fighter pilots are selected for their special mental skills and physical abilities. This is a typical example of fitting the human to the task.

The SAMI conducts research on selecting and acclimatising workers to be able to withstand the harsh (hot) environment of underground mining. This process is also part of fitting the human to the task.

14.5.6.2 Operator job specifications

Through task analysis, the characteristics needed in individuals to perform tasks successfully may be identified. These should be recorded as an ‘operator job specification’ (also known as a ‘’man specification’). The operator job specification, if properly designed, will give valuable information on the educational, training, mental, and physical requirements the task requires from the worker. Such documents are of particular use for occupational health practitioners responsible for pre-employment and pre-placement medical examinations.

14.6 Shift Work and Related Issues

14.6.1 Shift work and extended work hours

The term ‘shift’ is defined as the hours of the day that a worker is required to be in the workplace. Workers may have permanent hours, with their shift simultaneously every workday. Many workers have rotating hours, with the time of day of the work changing in a scheduled way. Some workers are employed to work irregular hours, with shift starting times and/or durations varying in an erratic or unpredictable way.

The problems that shift workers experience relate to both the phase-displacement of their work-sleep periods, and adverse negative working conditions that may be combined with shift work. The effects of phase-displacement lead to disruption in the physiological ‘circadian’ rhythms.

Circadian rhythms occur in many physiological functions, such as body temperature, blood pressure, heart rate, and hormones, as well as in cerebral functions. Research has shown that it is generally difficult to make quick and large changes in the timing of the biological clock, including in circadian variation (25).

Shift workers who are chronically exposed to night or rotating shift work have biological, social, and cultural problems. In the long run, sleep deprivation, besides having an influence on the de-synchronisation of circadian rhythms and on the ‘shift-lag’ syndrome, can cause persistent and severe disturbances of sleep itself, chronic fatigue, and psychoneurotic syndromes (such as chronic anxiety and depression), which often require treatment with hypnotic or psychotropic drugs.

Sleep disturbances, chronic fatigue, and oscillatory fluctuations of vigilance and performance can also be important contributing factors to ‘human error’ and the resulting accidents. Moreover, sleepiness or fatigue due to a too-early starting hour on morning shifts, or prolonged duty periods, can also favour higher frequencies of errors and accidents during day shifts.

Long-term exposure to shift work or extended hours may have deleterious effects on the health of individuals. Evidence from studies of shift work indicates a higher incidence of gastrointestinal disorders (peptic ulcers, heartburn, nausea), cardiovascular disease (palpitations, hypertension), and complaints associated with stress such as anxiety and depression, for example.

Work-related fatigue may arise in situations requiring concentration for extended periods during work hours, performing strenuous physical work (especially in unnatural body postures), working in temperature extremes, working in noisy environments, or being exposed to vibration (hand-arm or whole-body vibration). Fatigue is a functional state, which in one direction grades into sleep, and in the opposite direction grades into a relaxed, restful condition. People with practical concerns prefer a more operational definition such as *“fatigue is a state of declining alertness, which eventually ends in sleep”*.

In a fatigued condition, workers feel tiredness or dullness in their bodily parts, are inhibited from doing work, and are forced to give up. Generally, sensation manifests itself in three ways: sensation of bodily drowsiness, sensation of weakened cognitive processes and motivation, and physical complaints.

14.6.2 Design of shift systems

Scheduling employees' work to eliminate or minimise potential health and safety risks is a complex issue. Because there are no ‘optimal shift systems’, a reasonable compromise must be found between workers’ needs and business demands. Guidelines are available to assist with the design of shift systems. Examples are the Night Work Convention (No. 171) adopted by the ILO (26) and Knauth (27)

Some useful suggestions for shift pattern design are:

- Clockwise (forward) rotation (morning to afternoon to night) is preferable to counterclockwise (afternoon-morning-night) rotation.
- Minimise the occasions on which employees are required to work more than 10 hours in a period.

- Minimise the use of nightshifts.
- Minimise consecutive night shifts (only 1–3 night shifts in succession, where possible) to limit reductions in performance levels caused by circadian disruption, fatigue, and reduced alertness.
- Continuous night work without rotation should be avoided.
- Avoid rapid shift changes, such that at least a 24-hour break is provided before rotating to a new shift.
- Ensure employees have regular time (at least 24 hours) free of work in a seven-day period.

Workers' fitness for shift and night work should be evaluated by occupational health physicians before assignment, at regular intervals, and in the case of health problems. It appears reasonable to consider exemption from night work for people suffering from severe disorders that can be either directly related to shift and night work, or can be worsened by irregular working hours because of their interference with sleep, diet, or drug treatment. Examples of such conditions are clinical sleep disorders, severe gastrointestinal diseases, ischemic heart disease and severe hypertension, insulin-dependent diabetes, severe nervous disorders, and women in pregnancy.

14.6.3 Fatigue and sleep disorders

Closely associated with shift work are sleep disorders and fatigue. These factors are closely linked in the human physiological and psychological systems. Fatigue is often the reason for physical and mental performance not being at the required level. Many industrial, vehicle, and other accidents are attributed to operator fatigue.

Human fatigue refers to two sets of conditions. One is exhaustion, as found after a day's physically demanding work, and the other is a psychological experience of mental fatigue. This latter condition is not only due to mentally demanding work, but can also be the result of boredom and/or sleep deprivation.

Fatigue, especially mental fatigue, is a complex phenomenon deeply embedded in the neurophysiological system of humans and not yet fully understood. In medical terms, it is not a distinct entity. It refers, generally speaking, to a group of phenomena associated with impairment, or loss of efficiency and skill, and the development of anxiety, frustration, or boredom. In common usage, it is not unlike the word 'unconscious', which has become a convenient category used to classify certain phenomena that are not clearly understood, yet are none the less real.

The kind of fatigue caused by hard muscular work is termed 'acute fatigue'. This results in a loss of efficiency, which is temporary and is overcome by rest. Chronic fatigue, which will not improve by rest or sleep, is largely a psychological problem characterised by boredom, loss of initiative, and progressive anxiety. One of the explanations of this condition is that it is an outcome of conflict and frustration within the individual.

The intricate relationship between the human physiological homeostasis, neuro-hormone balances, sleep deprivation, and fatigue unfortunately has not yet been explained. In a study by DeSanctis (2017), it was found that levels of a neuro-hormone 'melatonin' in subjects display a positive correlation with accident tendencies on mines (28). The production of melatonin is affected by sleep deprivation, and to control or prevent fatigue an adequate, not excessive, amount of sleep is necessary per day. One of the disadvantages of shift work is that workers do not have adequate sleep and chronic fatigue could result.

Shift work, fatigue, sleep disorders, and neuro-hormone dysfunctions and their role in accident causation is an area that requires further research, especially in the mining industry where shift work is commonplace.

14.7 Ergonomics Risk Assessments

14.7.1 Risk assessments process

Risk assessment is part of the proactive OHS planning approach emphasising prevention. Generally, the following steps are necessary to carry out a risk assessment:

- Identify hazards
- Estimate the risk from each hazard, e.g. the likelihood and severity of harm
- Decide if the risk is tolerable
- Prepare risk control action plans (if necessary)

The risk management methodology (including risk assessment) is well documented and addressed in this Handbook. A practical guide to the risk assessment process is available from the Mine Health and Safety Council (MHSC) (29).

Section 6 of the Ergonomics Regulations of 2019 provides guidelines for risk assessment of ergonomics in the workplace. In this guideline, employers must have an ergonomic assessment performed by a competent person, before the commencement of any work that may expose employees to ergonomic risks. Section 6(2(b)) further directs that ergonomic risk assessments should be conducted at intervals not exceeding two years.

As most physical and biological hazards are covered elsewhere in this Handbook, this section addresses occupational surveillance as a form of hazard identification, as it relates to the practice of industrial ergonomics and the prevention of musculoskeletal disorders.

Surveillance is a *''continuous analysis, interpretation, and feedback of systematically collected data, generally using methods distinguished by their practicality, uniformity, and frequently their rapidity, rather than by their accuracy or completeness''* (30). Occupational surveillance provides the data needed to identify, control, and prevent work-related injuries and illnesses.

Effective occupational surveillance systems include the following components: data collection, analysis of the data (such as to evaluate their meaning), and some action or response to ensure that surveillance activities are translated into preventive action.

Many surveillance programmes begin with efforts to document the number of WMSDs that have occurred in recent history (establish a baseline). Data can be obtained from a review of existing medical records. If existing records are incomplete or unreliable, then questionnaires or worker surveys may be used to determine how many workers are experiencing symptoms potentially caused by work activities. Additionally, because prevention depends on identification and elimination of hazardous working conditions, hazard surveys may be used to identify jobs at risk.

Worker surveys may be oral (administered by an interviewer) or written; and they may rely heavily on pictures or charts. Examples of worker surveys include the 'body part discomfort scale' by Marley and Kumar (1996) (31), the Nordic Musculoskeletal Questionnaire, and the computerised ''discomfort assessment system' by Saldana (1996) (32). Common features of surveys include the use of body part diagrams where workers can indicate the location of symptoms, questions about the onset and duration of symptoms and the nature of job activities, and the use of rating scales to indicate severity of pain or discomfort. Worker surveys should be conducted when there is evidence from any data source of increased musculoskeletal injury, or at the commencement of new jobs or tasks. Ideally, actions to prevent ergonomics-related hazards should proceed before injuries and/or symptoms develop.

The first step in a hazard survey is to establish whether functional job descriptions are available. A functional job description typically identifies essential functions, or fundamental job duties, and the physical and mental abilities needed to perform these functions. If functional job descriptions are available, then they can provide useful information for identifying potentially stressful jobs, or jobs requiring unique skills or special endurance.

The next step in the identification of ergonomic risk factors in the workplace is a walk-through survey. Investigators observe job activities to detect obvious risk factors, interview workers and supervisors to obtain job information not apparent from observation, and use checklists to score job features against a listing of risk factors.

Examples of checklists that might be used for ergonomic hazard identification are a generic checklist compiled by the OSHA of the Department of Labor in the USA (http://www.osha.gov/), and the NIOSH checklist for qualitative assessment of lifting hazards. An example of a checklist for use in the mining industry is given in **Appendix 14.1**.

Hazard surveys should be conducted whenever a job, task, or process is changed substantially, when new jobs are introduced, and periodically (especially after new cases of musculoskeletal disorders are reported) to detect whether trends exist across jobs that use similar equipment, tools, or processes.

14.8 Implementing an Ergonomics Programme

A strategy to implement ergonomics in the mining industry was developed by Schutte and James (2009) as part of the Safety in Mining Research Advisory Committee (SIMRAC) research programme (33). The strategy involves four groups of role players, namely the state, employers, employees and manufacturers/suppliers of mining equipment, on the basis of participatory ergonomics.

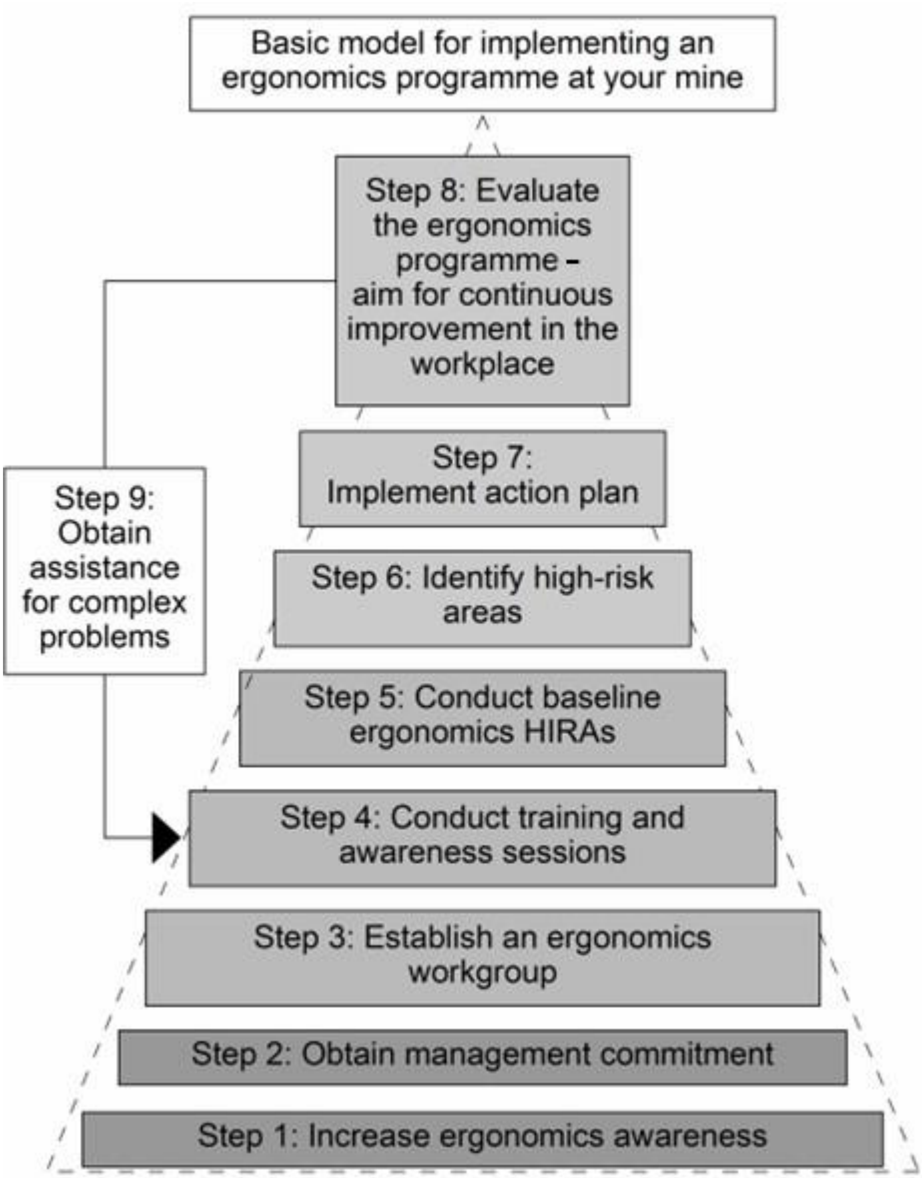
The specific involvement proposed for role players entails reviewing of existing legislation addressing ergonomics, and the drafting of an ergonomics implementation plan in the case of the state; the establishment of formal ergonomics programmes on mines by employers; the active participation and involvement in the ergonomics programmes by employees; and the use of ergonomics design guidelines and specifications suitable for the local user population and mining conditions ('cultural and environmental calibration') by manufacturers/suppliers of mining equipment.

A comprehensive and well-thought-out ergonomics programme is part of modern organisational and management practice in many industrial settings. The introduction of ergonomics programmes in various industries has proved to be instrumental in increasing worker comfort, safety, and health. From a business viewpoint, a corporate ergonomics programme also makes a great deal of sense.

Du Plessis (2014) (34) suggests the following steps for the development and implementation of an ergonomics programme (**Figure 14.3**):

- Define the programme goals, priorities, and objectives. Also define the budgets, resources, and limitations.
- Select a qualified ergonomics resource in order to achieve the programme goals and objectives.
- Conduct a professional ergonomics assessment to identify priority problem areas.
- Utilise the ergonomics resources to train supervisors, safety personnel, and engineers in the principles of ergonomics.

- Conduct systematic workplace assessments, together with safety personnel and engineers.
- Develop and implement practical and cost-effective engineering solutions, where possible, or plan other preventative activities, e.g. adjustment of procedures.
- Evaluate the programme, as well as the impact of the changes implemented. Conduct a cost/benefit analysis of the solutions.
- Refine the solutions on an ongoing basis.



HIRA: hazard identification and risk assessment

Figure 14.3. Implementing an ergonomics programme

Source: Du Plessis (2014) (34)

The key ingredients of any successful ergonomics programme are top management commitment and the support of people from all other levels in the organisation. Top management must approve and support such a programme, and it should be part of an organisation's mission. The active involvement of employees on all levels must be accomplished during each phase of the programme. This concept of participatory ergonomics, which can be defined as *"the involvement of people in planning and controlling a significant amount of their own work activities, with sufficient knowledge and power to influence both processes and outcomes in order to achieve desirable goals"*, has proved to be very successful to introduce ergonomics in industrial settings (6). It is, therefore, recommended that the same approach be followed at mines.

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Appendix 14.1 Ergonomics Risk Checklist

The screening for risk factors for work-related musculoskeletal disorders should involve:

- Walk-through observational surveys of the work facilities using the Ergonomics Risk Checklist to identify risk factors.
- Interviews with workers and supervisors to obtain information and other data not so apparent during the walk-through survey.
- Task analysis and measurements in the workplace (to be conducted by suitably qualified ergonomists).

A14.1.1 Standardised ergonomics questionnaires

Examples of standardised ergonomics questionnaires are provided below.

A14.1.1.1 Ergonomics risk checklist

Area:	
Number of workers:	

(Tick either the 'Yes' or 'No' block next to the question. A 'Yes' response indicates that an ergonomic risk factor may be present, which requires further investigation.)

Manual Material Handling	**Yes**	**No**	**Comments**
Is there lifting of loads, tools, equipment?			
Is there lowering of loads, tools, equipment?			
Is there overhead reaching for loads, tools, equipment?			
Is there bending at the waist to handle loads, tools, equipment?			
Is there twisting at the waist to handle loads, tools, equipment?			
Physical Energy Demands	**Yes**	**No**	**Comments**
Do tools and equipment used weigh more than 25 kg?			
Is reaching more than 55 cm?			
Physical Energy Demands	**Yes**	**No**	**Comments**
Is bending, stooping, or squatting a primary task activity?			
Is lifting or lowering loads a primary task activity?			
Is walking or carrying loads a primary task activity?			
Is stair or ladder climbing with loads a primary task activity?			
Is pushing or pulling of loads a primary task activity?			
Is reaching overhead a primary task activity?			
Is operating equipment or tools above shoulder height a primary task activity?			

Other Musculoskeletal Demands	Yes	No	Comments
Do manual tasks require frequent, repetitive motions?			
Does work posture require frequent bending of neck, shoulder, elbow, wrist, or finger joints?			
Does the worker kneel (on one or both knees)?			
Other Musculoskeletal Demands	**Yes**	**No**	**Comments**
Is the worker unable to change body position often?			
Does the work involve forceful, quick, or sudden motions?			
Does the work involve whole hand grasping with straight elbows?			
Other Musculoskeletal Demands	**Yes**	**No**	**Comments**
Does job posture involve sustained muscle contraction of any limb for periods of more than 30 minutes?			
Does the worker stand continuously for periods of more than 30 minutes?			
Environment	**Yes**	**No**	**Comments**
Is the temperature too hot or too cold?			
Is there dust?			
Is the workplace poorly lit?			
Is the environment noisy?			
Is the worker working with vibrating hand tools or equipment?			
Is the worker working with hazardous chemicals?			
Is the worker subjected to whole-body vibration?			

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General Workplace	Yes	No	Comments
Are the walkways uneven?			
Is the floor surface free of obstacles and flat?			
Is the workplace at a gradient?			
Is the ceiling height less than 2.5 m?			
Is there inadequate clearance or accessibility for performing the task?			
Is housekeeping poor?			

Source: Occupational Health and Safety Council of Ontario (OHSCO), Musculoskeletal Disorders Prevention Series, Part 3C: MSD Prevention Toolbox

A14.1.1.2 Checklist evaluating the cab design of a construction or mining vehicle

(Tick either the 'Yes' or 'No' block next to the Question. A 'Yes' response indicates that an ergonomic risk factor may be present, which requires further investigation.)

#	Areas of Consideration	Yes	No	N/A
1	Is the seat height adjustable?			
2	Can the seat be adjusted horizontally?			
3	Is the seat set at the right height?			
4	Does the seat have back support?			
5	Does the seat have lumbar support?			
6	Are there arm rests?			
7	Are the armrests adjustable?			
8	Are the arm rests set at the proper height?			
9	Is any vibration from the equipment felt through the seat?			
10	Is any vibration from the equipment felt through the floor?			
11	Is any vibration from the equipment felt through the controls?			
12	Is the seat firmly mounted to the floor of the cab?			
13	Can the seat be tilted backwards?			
14	Can the seat swivel?			

#	Areas of Consideration	Yes	No	N/A
15	Is the location of the controls or levers adjustable?			
16	Can the levers or controls be easily reached?			
17	Can the levers or controls be easily operated?			
18	Can the pedals be easily reached?			
19	Can the pedals be easily operated?			
20	Is the cab area large enough (e.g. uncramped area) for the operator?			
21	Is there sufficient upward visibility?			
22	Is the view of the operation obstructed (e.g. cab guards, pipes/hose)?			
23	Is the cab noisy?			
24	Can the temperature of the cab be controlled?			
25	Does the equipment have steps?			
26	Does the equipment have proper means for entering the cab?			
27	Can the cab doors be easily opened/closed?			
28	Does the equipment have proper means for exiting the cab?			
29	Is there a good general view of the ground?			
30	Are the cab windows free from distracting reflections?			

A14.1.1.3 NIOSH manual material handling checklist

This checklist is not designed to be a comprehensive risk assessment technique, but rather as a tool to quickly identify potential problem jobs. Additional risk factors may exist that are not accounted for in this checklist. It is common practice to follow up checklist observations with more precise techniques to confirm problem risk factors.

'No' responses indicate potential problem areas that should be investigated further.

1	Are the weights of loads to be lifted judged acceptable by the workforce?	yes	no
2	Are materials moved over minimum distances?	yes	no
3	Is the distance between the object load and the body minimized?	yes	no
4	Are walking surfaces level?	yes	no
	wide enough?	yes	no
	clean and dry?	yes	no
5	Are objects easy to grasp?	yes	no
	stable?	yes	no
	able to be held without slipping?	yes	no
6	Are there handholds on these objects?	yes	no
7	When required, do gloves fit properly?	yes	no
8	Is the proper footwear worn?	yes	no
9	Is there enough room to maneuver?	yes	no
10	Are mechanical aids used whenever possible?	yes	no
11	Are working surfaces adjustable to the best handling heights?	yes	no
12	Does material handling avoid:		
	movements below knuckle height and above shoulder height?	yes	no
	static muscle loading?	yes	no
	sudden movements during handling?	yes	no
	twisting at the waist?	yes	no
	extended reaching?	yes	no
13	Is help available for heavy or awkward lifts?	yes	no
14	Are high rates of repetition avoided by job rotation?	yes	no
	self-pacing? sufficient pauses?	yes	no
15	Are pushing or pulling forces reduced or eliminated?	yes	no
16	Does the employee have an unobstructed view of handling the task?	yes	no

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17	Is there a preventive maintenance program for equipment?	yes	no
18	Are workers trained in correct handling and lifting procedures?	yes	no

Source: Centers for Disease Control and Prevention at (https://www.cdc.gov/niosh/docs/2007-131/pdfs/2007-131.pdf)

A14.1.1.4 Hazard evaluation checklist for lifting, carrying, pushing, or pulling

This checklist is not designed to be a comprehensive risk assessment technique, but rather as a tool to quickly identify potential problem jobs. Additional risk factors may exist that are not accounted for in this checklist. It is common practice to follow up checklist observations with more precise techniques to confirm problem risk factors.

'Yes' responses are indicative of conditions that pose a risk of developing low back pain. The larger the percentage of 'Yes' responses that are noted, the greater the possible risk.

Risk factors		**YES**	**NO**
1	**General**		
1.1.	Does the load handled exceed 22.7 kg (50 lb)?		
1.2	Is the object difficult to bring close to the body because of its size, bulk, or shape?		
1.3	Is the load hard to handle because it lacks handles or cut outs for handles, or does it have slippery surfaces or sharp edges?		
1.4	Is the footing unsafe? For example, are the floors slippery, inclined, or uneven?		
1.5	Does the task require fast movement, such as throwing, swinging, or rapid walking?		
1.6	Does the task require stressful body postures, such as stooping to the floor, twisting, reaching overhead, or excessive lateral bending?		
1.7	Is most of the load handled by only one hand, arm, or shoulder?		
1.8	Does the task require working in extreme temperatures, with noise, vibration, poor lighting, or airborne contaminants?		
1.9	Does the task require working in a confined area?		
2	**Specific**		
2.1	Does lifting frequency exceed 5 lifts per minute?		
2.2	Does the vertical lifting distance exceed 0.305 m (3 ft.)?		
2.3	Do carries last longer than 1 minute?		
2.4	Do tasks that require large, sustained pushing or pulling forces exceed 30 seconds duration?		
2.5	Do extended reach static holding tasks exceed 1 minute?		

Source: T. R. Waters, Manual Materials Handling, in: Physical and Biological Hazards of the Workplace (Second edition). Edited by P. Wald and G. Stave. New York: John Wiley and Sons, 2002.

A14.1.2 Cost implications

The cost implications of an ergonomics survey will depend on the type of questionnaire administered. Some questionnaires such as the Rapid Upper Limb Assessment (RULA) and Rapid Entire Body Assessment (REBA) do not require specific expertise. The cost to administer these questionnaires will mainly involve initial training of the observers on how to capture data, and explaining the procedure on how to calculate the final score. **Table A14.1.a** provides a summary of ergonomic observational methods, with an indication of level of training required and cost (low/high).

Table A14.1.a Summary of ergonomic observational methods with an indication of the level of training required and cost (low/high)

Assessment tool	Training required	Cost
Multiple hazards considered		
MSD Hazard Risk Assessment Checklist	Low	Low
Washington State Checklists (Caution/Hazard Zone)	Low	Low
Manual material handling (lifting, lowering, pushing, pulling, carrying)		
ACGIH Lifting TLV	Low	
NIOSH Lifting Equation	Low	Low
Snook Tables	Low	Low
MAC (UK)	Low	Low
Mital Tables	Low	Low
Upper limb		
ACGIH	Medium	High
RULA	Medium	Low
Strain Index	Medium	Low
CTD Risk Index (CTD-RAM)	Medium	High
LUBA	Medium	Low
OCRA	Medium	Low
Combined methods (not checklist)		
QEC	Medium	Low
REBA	Medium	Low

ManTRA	Medium	Low
OWAS	Medium	Low

ACGIH: American Conference of Governmental Industrial Hygienists, CTD-RAM: Cumulative Trauma Disorder-Risk Assessment Method, MSD: Musculoskeletal Disorder, LUBA: Loading on the Upper Body Assessment, MAC: Manual Handling Assessment Charts, ManTRA: Manual Task Risk Assessment, NIOSH: National Institute for Occupational Safety and Health, OCRA: Occupational Repetitive Action, OWAS: Ovako Working Posture Assessment System, QEC: Quick Exposure Check, REBA: Rapid Entire Body Assessment, RULA: Rapid Upper Limb Assessment

A14.1.3 Other analysis methods

- NIOSH Lifting Equation. Available from: https://www.cdc.gov/niosh/docs/94-110/. Accessed 15 April 2025.
- ACGIH Threshold Limit Values (TLVs) for Lifting:
  Jorgensen, MJ, Hafez, K and Hakansson, NA, 2024. The ACGIH TLV for lifting: Estimated TLVs for torso asymmetry beyond 30 degrees. *Work*, (Preprint), p.1-14.
- University of Michigan 3D Static Strength Prediction Program. Available from: https://c4e.engin.umich.edu/tools-services/3dsspp-software/
  Accessed 15 April 2025.
- Ohio State Lumbar Motion Monitor. Available from: https://spine.osu.edu/research/precise-human-measurement
  Accessed 15 April 2025.
- Snook's Psychophysical Tables.
  Available from: https://safetyresourcesblog.com/wp-content/uploads/2014/08/liberty-mutual-snook-tables.pdf.
  Accessed 15 April 2025.

A14.1.4 Methodology for task and workplace analyses

The assessment of tasks and workplaces to identify potential risk factors that contribute to the development of musculoskeletal disorders should be based on:

- Workstation measurements (e.g. working surface heights; reach distances, ceiling heights, gradient)
- Observing the workers performing tasks (time-activity analysis)
- Measuring of environmental factors such a temperature, noise, illumination levels (Relevant ISO and South African standards can be used to assess environmental factors)
- Determination of physical energy demands
- Evaluation of manual material handling tasks (NIOSH Work Practice Guide to Manual Lifting can be used to determine recommended weight limits)
- Questionnaire to determine the amount of perceived exertion (Modified Borg Scale)

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"21. (1) Any person who –

(a) *designs, manufactures, repairs, imports, or supplies any article for use at a mine must ensure, as far as reasonably practicable –*

(i) *that the article is safe and without risk to health and safety when used properly; and*

(ii) *that it complies with all the requirements in terms of this Act.*

(b) *erects or installs any article for use at a mine must ensure, as far as reasonably practicable, that nothing about the manner in which it is erected or installed makes it unsafe or creates a risk to health and safety when used properly; or*

(c) *designs, manufactures, erects, or installs any article for use at a mine must ensure, as far as reasonably practicable, that ergonomic principles are considered and implemented during design, manufacture, erection, or installation.*

(2) *Any person who bears a duty in terms of subsection (1) is relieved of that duty to the extent that is reasonable in the circumstances, if –*

(a) *that person designs, manufactures, repairs, imports, or supplies an article for or to another person; and*

(b) *that other person provides a written undertaking to take specified steps sufficient to ensure, as far as reasonably practicable, that the article will be safe and without risk to health and safety when used properly and that it complies with all prescribed requirements.*

(3) *Any person who designs or constructs a building or structure, including a temporary structure, for use at a mine must ensure, as far as reasonably practicable, that the design or construction is safe and without risk to health and safety when used properly.*

(4) *Every person who manufactures, imports, or supplies any hazardous substance for use at a mine must –*

(a) *ensure, as far as reasonably practicable, that the substance is safe and without risk to health and safety when used, handled, processed, stored, or transported at a mine in accordance with the information provided in terms of paragraph (b).*

(b) *provide adequate information about –*

(i) *the use of the substance.*

(ii) *the risks to health and safety associated with the substance.*

(iii) *any restriction or control on the use, transport, and storage of the substance, including but not limited to exposure limits.*

(iv) *the safety precautions to ensure that the substance is without risk to health or safety.*

(v) *the procedure to be followed in the case of an accident involving excessive exposure to the substance, or any other emergency involving the substance; and* *vi) the disposal of used containers in which the substance has been stored and any waste involving the substance; and*

(c) *ensure that the information provided complies with the provisions of the Ergonomics Regulations 2019."*