UNIT 3 ERGONOMICS*

Structure

3.0 OBJECTIVES

After studying this Unit, you should be able to:

- Define and explain the importance ofergonomics;
- Discuss the history behind the conception of ergonomics;
- Describe the types of Ergonomics and Systems Design Methods for it;
- Enumerate the factors governing Manual Material handling;
- Highlight the causes of Accidents; and
- Explainthe assessment of various ergonomic hazards and risk factors.

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3.1 INTRODUCTION

You have been reading about the various occupational hazards in the previous unit. To reduce the risk of occupational hazards it is important to consider the design of the working environment. In case we can modify the environment in such a way that the risks and hazards can be reduced, we can work for a hazard-free environment. In this Unit,our focus will be on the history behind the conception of ergonomics, its importance and types, Systems Design Methods for Ergonomics, factors governing Manual Material handling, causes of accidents, and assessment of various ergonomic hazards and risk factors. This unit will also acquaint you with the common types of accidents and the steps of risk assessment.

3.2 WHAT IS ERGONOMICS?

Coming from the word "ergon", meaning work, and the term "nomos", which translates to laws, ergonomics refers to the design of an object that aims to enhance usability, comfortability and efficiency for the user. The Oxford Dictionary defines ergonomics as "relating to or designed for efficiency and comfort in the working environment".

Ergonomics can roughly be defined as the study of people in their working environment. More specifically, an ergonomist (pronounced like an *economist*) designs or modifies the work to fit the worker, not the other way around.

The goal is to eliminate discomfort and risk of injury due to work. In other words, the employee is our priority in analysing a workstation.

3.2.1 History of Ergonomics

The study of ergonomics dates back to the beginning of the century when *Mr. F.W. Taylor* - a mechanical engineer designed a shovel in order to improve productivity with no ergonomic approach but vague ideas about Ergonomics, later he came to be known as the "Father of Ergonomics".

In the early 1900s, the production of industry was still largely dependent on human power/motion, and ergonomic concepts were developing to improve worker productivity. Scientific Management, a method that improved worker efficiency by improving the job process, became popular.

WORLD WAR II prompted greater interest in human-machine interaction as the efficiency of sophisticated military equipment (aeroplanes) could be compromised by bad or confusing design.

In 1910, Gilbreth and his wife (psychologist) carried out systematic observations of work, time and motion and they were regarded as "Parents of Ergonomics".

Design concepts of fitting the machine to the soldier and logical/understandable control buttons evolved. After WORLD WAR II, the focus of concern expanded to include worker safety as well as productivity giving birth to the modern concept of ergonomics integrating the interaction between the man, machine and the environment.

3.2.2 Importance of Ergonomics

i) Ergonomics prevents the accidental injuries of workers who are a valuable resource.

ii) Musculoskeletal disorders can be prevented along with unnecessary injuries that :

- Costs the Indian economy over lakhs of rupees annually, and
- Results in missed work, increased pain, and decreased morale among the affected workers.

iii) Integrating good ergonomics into job and workplace design costs no more than choosing a bad design.

iv) Good ergonomic programmes focus on ways to reduce costs to companies by

- Reducing injuries
- Reducing errors
- Reducing absenteeism
- Maximizing productivity

v) Good ergonomic programmes are always cost-effective –they save more than they cost through the following ways:

a) Evaluation and Control of Work Site Risk Factors

Identification and quantification of existing work site risk conditions Recommendation of engineering and administrative controls to reduce the identified risk conditions

b) Education of Management and Workers to Risk Conditions

- **Higher Quality Work**

When people feel comfortable, they can focus on high-quality production. This combined with increased productivity levels

- **Eliminates Hazards**

Part of creating a more productive work environment is cleaning the daily hazards that can hurt your employees.These distractions are unsafe and can lead to worse consequences laser. Pay attention and know your office. Another good idea is to ask your employees what hazards they face daily, by asking for their input, you're showingthat you care. In this regard, implementing the change will show them they've been in safe hands.

- **Increased Employee Engagement**

Your employers will notice that your business provides the best conditions for increased employees' health and safety. Because they won't be experiencing fatigue and discomfort, you'll see an increase in the employee's involvement. You'll find their motivation will increase, the more they feel taken care of by the company.

This can reduce the turnover rate, and make your business one others want to work with.

- **Encourages Safety**

Ergonomics will create a safer work environment and increase awareness. You'll remove hazards, improve workstation file discomfit, and teach your employees to update their spaces with safety in mind Not to mention, the health benefits that come with ergonomics keep employees healthy at work.

- **Happier Employees, Happier You**

People who work in ergonomic workplaces have improved health. It typically starts within the cardiovascular system and spreads to other areas. Your heart will be healthier than it would be if you were working in a standard environment.

Also, you and your employees will feel less tension in your body because you'll be adjusting the workstations to fit your height. These natural positions will prevent you from straining your eyes and neck. You'll also reduce swelling in your legs because your blood flow will be optimal.

- **Improved Mental Insight**

When you feel comfortable, you can focus better on the task at hand. Ergonomics decreases pain, strengthens muscles, and increases blood flow. Combined, this improves mental insight. You and your employees will experience less anxiety, increased awareness, improved moods, and focus.

This means everyone can concentrate on their work more. The better focused they are, the higher their productivity levels.

3.3 BACKGROUND OF THE ERGONOMICS DOMAIN

Ergonomics occupies the 'no man's land' between engineering and medicine, architecture and health and safety, computer science and consumer product design. It is the only scientific subject that focuses specifically on the interaction between people and machines. Historically, ergonomics can be seen to have arisen as a response to the need for rapid design of complex systems. The modern ergonomist has an important role to play as a member of the design team, providing scientific information about humans (a scarce commodity in many organisations), and ensuring that all aspects of the system are evaluated from the users' or operators' point of view. The participatory approach seems to be the best way to ensure that the implementation of ergonomics will be effective.

3.3.1 Types of Ergonomics

There are several types or branches of ergonomics, each focusing on specific aspects of human interaction with different environments. Here are some prominent types of ergonomics:

1) ***Physical Ergonomics***

Physical ergonomics is a field of study that focuses on the investigation and evaluation

of the physical interaction that occurs between human beings and their surrounding environment. This field of study centres on the examination of human anatomy and employs anthropometric, physiological, and biomechanical attributes to develop products and surroundings that align with the physical capacities of individuals. This encompasses the development of ergonomic chair designs that facilitate proper posture, the arrangement of work objects nearminimise strain, and the innovation of instruments that necessitate reduced exertion. The primary focus is on preserving the natural curve of the back, facilitating appropriate alignment of the neck and spine, and advocating for postures that mitigate the likelihood of musculoskeletal diseases.

ii) ***Cognitive Ergonomics***

Cognitive ergonomics is a discipline that centres its attention on the cognitive processes implicated in human interaction, encompassing perception, memory, reasoning, and motor response. This study focuses on the optimisation of systems and surroundings to minimise cognitive overload and enhance cognitive functions. For instance, one potential application could include the development of a user interface that is intuitive, hence minimising the cognitive load required for successfully carrying out a given activity. Alternatively, it could involve the creation of an environment that effectively mitigates stress levels and facilitates enhanced levels of focus.

iii) ***Organisational Ergonomics***

The field of organisational ergonomics encompasses the optimisation of socio-technical systems, which includes the examination and improvement of organisational structures, policies, and processes. The primary focus of this study pertains to the influence of workplace organisation on human behaviour, with potential implications for enhancing health and well-being, productivity, and quality. For example, this could entail developing shift times that effectively improve sleep quality and overall performance or establishing team frameworks that effectively maximise collaboration and boost morale.

iv) ***Environmental Ergonomics***

This area of ergonomics researches how people interact with their surroundings in terms of the weather, temperature, pressure, illumination, and noise. The primary objective of this study is to comprehend the impact of these variables on human performance and overall well-being, and afterwards employ this knowledge to develop environments that maximise these outcomes. As an example, this might include the selection of lighting settings that mitigate ocular fatigue or the provision of adequate ventilation and ambient temperature within a workplace.

v) ***Ergonomics for Specific Needs***

This particular subdivision of physical ergonomics centres its attention on the design requirements suited to individuals with distinct requirements, like children or individuals with disabilities. The objective is to establish favourable circumstances that facilitate the independent and efficient functioning of these individuals. For example, this involves the development of areas that are accessible for individuals using wheelchairs, the establishment of educational environments that accommodate the physical requirements of children, or the adaptation of items to ensure usability for those with restricted mobility.

vi) ***Corrective Ergonomics***

The field of corrective ergonomics encompasses the evaluation of current surroundings and practices to discover opportunities for enhancing ergonomics. Frequently, a reactive strategy is employed, whereby problems are detected and rectified after their recognition. For instance, in cases when employees are encountering physical pain or sustaining injuries, the implementation of corrective ergonomics would entail a comprehensive evaluation of the work environment followed by the implementation of appropriate modifications.

vii) ***Preventive Ergonomics***

In contrast to the field of corrective ergonomics, preventative ergonomics takes a proactive approach. The primary objective of this approach is to proactively detect and mitigate any ergonomic concerns before their manifestation as significant issues. This may involve conducting periodic evaluations of workstations, providing training on optimal methodologies, and ensuring that work environments are meticulously constructed to prioritise ergonomics.

viii) ***Micro-Ergonomics***

Micro-ergonomics pertains to the meticulous design of discrete components within a given system, encompassing tools, interfaces, and equipment, to ensure their functionality, reliability, comfort, and safety. This field of study focuses on the micro-level aspects of ergonomics, specifically emphasising the intricacies that impact an individual's direct engagement with different items.

ix) ***Macro-Ergonomics***

In contrast, macro-ergonomics encompasses a more expansive viewpoint, encompassing an integration of human and technical elements within an organisational context. This field of study pertains to broader systems, with a specific emphasis on the interconnections between these systems and the individuals who interact with them. For example, it could entail the development of software solutions aimed at enhancing the efficiency of organisational processes.

For ergonomics to be applicable in practical settings, it is crucial to have a comprehensive understanding of the environment in which ergonomics findings are derived and how they can be effectively implemented. The aforementioned setting will likewise influence the perception of ergonomics in society, as well as its perceived worth and relevance in contemporary times. The pertinent contextual elements can be categorised into financial, technological, legal, organisational, social, political, and professional factors. Ergonomics operates within a context of conflicting financial goals, encompassing both organisational and commercial considerations such as shareholder pressures and the need for return on investments, as well as social considerations involving choices between expenses on health, education, defence, and other areas. One notable financial contextual aspect that holds significance in the field of occupational ergonomics presently is the prevailing tendency of downsizing, which refers to the deliberate reduction in worker number. Financial pressures are a contributing factor to certain organisational violations or deviations from established procedures and best practices. These violations and deviations have been recognised as the underlying causes for numerous significant reliability failures observed over the previous two decades.

The technological context for ergonomics is critical, given the rapid rate of change in technology development and the complexity of systems. The rapid rate of change in technology development and the complexity—which may be unnecessary in some cases—of systems provide a rich field for ergonomics contributions in areas such as control rooms, personal and wearable computers, transportation systems, and virtual environments.

Ergonomics is not always a straightforward career to be a part of. In addition, the inherent diversity inside and between individuals makes it extremely difficult to provide precise and universal evidence and design guidance. However, the power and utility of ergonomics come from the fact that it takes this human heterogeneity into account. More than anything else, ergonomics will continue to be of tremendous significance in promoting both the quality of life and the growth of the economy since it is recognised as a cohesive field in its own right. Ergonomics, like other contemporary philosophies and practises, can combine scientific methods with more subjective approaches like craft, engineering, and art. Both its methodology and its data could be qualitative or quantitative, depending on the circumstances. Ergonomics occupies a special and distinct position among the contemporary academic and professional fields of study and practice. This is because ergonomics is the field that gives the inter- and multidisciplinary theoretical understanding of all interactions in human-technology systems as well as the application of such understanding in the design process.

3.3.2 System Design and Ergonomics

Systems Ergonomics is the term for the set of techniques used to apply the knowledge base of ergonomics to the design of systems. Successful design requires that the expertise of different specialists is carefully managed and utilised at appropriate stages in the design process so that ergonomics can be integrated with the engineering and personnel functions. Systems design is an open-ended process and open-ended methods can be used to gather information for requirements specification.

3.3.3 Systems Design Methods for Ergonomics

According to the ISO/DIS 6385 (Ergonomic Principles in the Design of Work Systems), there are six basic steps needed for an ergonomic approach to design. These are:

i) Formulation of the System's Goals

ii) Analysis and Allocation of Function and Requirement Analysis

iii) Design Concept

iv) Detailed Design

v) Realisation, Implementation and Validation

vi) Evaluation

i) ***Formulation of the System's Goals and Requirement Analysis*****:** It takes the form of a specification of the requirements. The focus is on what is needed, not how it is to be achieved. When existing systems are being upgraded, the requirements may already be known and only the parameter values may need

to be changed (e.g. the new requirement is to deliver 100 tonnes of product per hour, instead of 50). With new systems, information about the performance requirements of the work process may need to be gathered, including information about the role of human operators. In both cases, design should be regarded as an opportunity to solve any existing ergonomics problems and to avoid generating new ones.

ii) ***Analysis and Allocation of Function:*** A system's functions are the activities that enable it to achieve its goals. In the caseof new systems, they may first have to be identified before they can be allocated todifferent operators or machines. Information on functions can be obtained in several ways. Panel discussions, interviews with users and experts and observation can provide function-related information. System design methods often stress that initial functions be identified and described in abstract terms. Some advantages of abstract functional thinking are that:

- It encourages the search for new methods
- It provides a common language across disciplines
- The range of solutions is not limited by particular components or methods.

Allocation of function between operators and machines determines the level of automation in a system. In practice, functions usually fall into one of several categories:

- Those that must be carried out by machines (because it is impossible or unacceptable for humans to do them)
- Those that must be carried out by humans (because no adequate machines areavailable or machine execution of the function is not appropriate).
- Those that might be carried out by either humans or machines or both.

The goal of allocation of function is to design a system for which the performance is high; the tasks of the operator are achievable and appropriate to the operator's role; and the development of the system is technically and economically feasible. When allocating functions, then, designers need to consider safety, reliability and psychosocial factors to arrive at a set of tasks for the operator that will be coherent and consistent and provide the basis for a satisfying job.Thefunctions should be automated if they are separable from the operator's role and do not interact with it. Functions that are central to the operator's role, or provide information that critically affects the performance of the role, should not be automated. Workload analysis is a critical part of the function allocation process.

iii) ***Design Concept*:** The translation of the requirements specification and the function allocation into adesign concept may be facilitated using brain-storming techniques or structured methods of concept generation such as value engineering. The concept itself should bedetailed enough to describe the structure of the work system and the interactionsbetween the components, including the human-machine interactions. Those functions allocated to workers are organised into tasks, roles andjobs as part of the emerging design concept. The concept is reified, iteratively, usingmethods such as task description and analysis, the construction of scale models andmock-ups and discussions with users and consultants.

iv) ***Detailed Design*:** The key to modern systems engineering is that the human and machine components are designed in parallel to save development time. Traditional ergonomics acts as a link between these activities. The system doesn't need to be complete before training and job design can take place. The Apollo space programme is an example where all training and development took place offline using simulators and prototypes. It is during the detailed design phase that jobs are designed, either implicitly or explicitly.

Draft ISO 6385 suggests that detailed design should include all of the following:

- Design of work organisation
- Design of work tasks
- Design of jobs
- Design of the work environment
- Design of the work equipment, hardware and software

Product Form: How a product looks (characteristics and shape).
Product Function: How a product works.
Detailed Design = Product Form + Product Function
Total Design = Detailed Design + Market Pool (What a Consumer Wants)

- Design of workspaces and workstations

v) ***Realisation, Implementation and Validation*:**Realisation involves the procurement and installation of the new system on-site.Implementation involves management of the changeover from the old system introduction and training of operators. If necessary, a temporary backup systemmay be installed or there may be a handing-over period in which both systems runin parallel. Validation requires that the system be shown to function according tothe requirements specified earlier on – that it achieves its goals as intended.

vi) **Evaluation:** Evaluation occurs after the system is up and running. The integration and implementation phase are often characterised by 'teething troubles', which are temporary phenomena, not characteristic of the final design. It is for this reason that in activities such as facility design, a delay is introduced between implementation and final evaluation. This enables teething troubles to be overcome so that the true pros and cons of the facility can be more easily identified. For example, post-occupancy evaluations of new buildings are usually only carried out after one year of occupation.

Check Your Progress 1

Note : i) Use the space given below for your answers.

ii) Check your answer with those given at the end of the Unit.

1) Explain the various types of ergonomics.

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2) Highlight the basic steps needed for an ergonomic approach to design.

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3.4 ANTHROPOMETRY

Anthropometry is the branch of the human sciences that deals with body measurements, particularly with measurements of body size, shape, strength and working capacity.

Anthropometric data are used in Human Factor and Ergonomics (HFE) to specify the physical dimensions of workspaces, equipment, vehicles, and clothing to guarantee that these products physically fit the target population.

3.4.1 Types of Anthropometry

There are two core types of anthropometry, that are static and dynamic (functional).

i) ***Static Anthropometric Dimensions*** are measurements taken when the body is in a fixed (static) position. They consist of skeletal dimensions (between the centres of joints, such as between the elbow and the wrist, stature, eye height, hand length etc.) or contour dimensions (skin surface dimensions such as head circumference.

ii) ***Dynamic Anthropometric Dimensions*** are measurements taken under conditions in which the body is engaged in some physical activity. During physical activities (whether one is operating a steering wheel, assembling a mousetrap, or reaching across the table for the salt) the individual body members function in concert. The practical limit of arm reach, for example, is not the sole consequence of arm length; the limit is also affected by shoulder movement, partial trunk rotation, possible bending of the back, and the function to be performed by the hand.

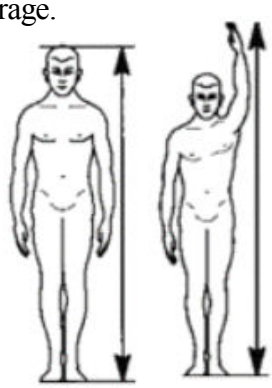
3.4.2 Principles in the Application Anthropometry

There are three following general principles for applying anthropometric data to specific design problems:

i) Design for Extreme Individuals (maximum or minimum),

ii) Designing for Adjustable Range, and

iii) Designing for the Average.



a) Stature (Static) b) Standing Over Head Reach (Dynamic)

Figure 3.1: Examples of different types of Anthropometric Dimensions

i) Design for Extreme Individuals

In designing certain features of our built physical world, one should try to accommodate all (or virtually all) the population in question.

*Designing for the maximum population*value is the appropriate strategy if a given maximum (high) value of some design feature should accommodate all (or virtually all) people. Examples include heights of doorways, sizes of escape hatches on military aircraft, and strength of supporting devices (such as a trapeze, rope ladder, or workbench).

Designing for the minimum population value is the appropriate strategy if a given minimum (low) value of some design feature has to accommodate all (or virtually all) people. Examples include the distance of a control button from the operator and the force required to operate the control.

However, in some circumstances, a specific design dimension or feature is a limiting factor that might restrict the use of the facility for some people. This limiting factor can dictate either a maximum or minimum value of the population variable or characteristic in question.

ii) Designing for Adjustable Range

Certain features of equipment or facilities can be designed so they can be adjusted for the individuals who use them. Some - examples are automobile seats, office chairs, desk heights, and footrests. In the design of such equipment, it frequently is the practice to provide for adjustments to cover the range from the 5th percentile female to the 95th percentile male of the relevant population characteristic (sitting height, arm reach, etc.). Generally, designing for an adjustable range is the preferred method of design, but of course, it is not always possible.

iii) Designing for the Average

A person may be average on one or two body dimensions, but because there are no perfect correlations it is virtually impossible to find anyone who is average on more than a few dimensions. Often designers design for the average as a cop-out so that they do not have to deal with the complexity of anthropometric data. So that there is no “average” individual. This is why designers and ergonomists should never design for the average. On the contrary, a thorough analysis of the situation may prove that an average value is acceptable. Such a situation would probably involve noncritical work where it is not appropriate to design for an extreme and where adjustability is impractical. Designing for the average should only be done after careful consideration of the situation and never as an easy way out.

3.4.3 Statistical Analysis of the Anthropometric Data

Anthropometric variables in the healthy population usually follow a normal distribution.

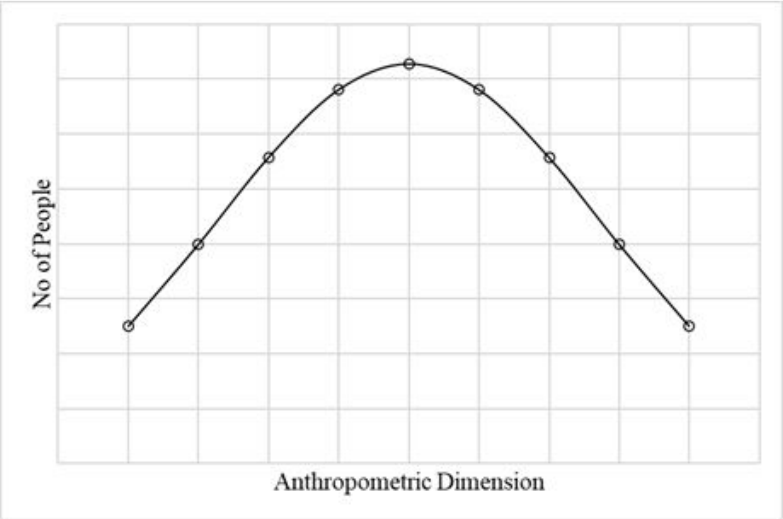


Figure 3.2: The normal Distribution of the Anthropometric Dimension

Average or Mean: Mean is the average of the given set of anthropometric values.In other words,it is the sum of all the observations divided by the number of observations.

$$\bar{x}_n = \frac{x_1 + x_2 + \cdots + x_n}{n}$$

Standard Deviation (S_D): Standard deviation is a measure of how dispersed the data is in relation to the mean.S_D indicates how far a value has varied from the mean value. A lower S_D shows data are close to the mean, and a higher S_D indicates data are more spread out.

$$S_D = \sqrt{\frac{(x - \bar{x})^2}{n}}$$

Standard Error of Mean (SEM): The SEM takes the S_D and divides it by the square root of the sample size. The SEM will always be smaller than the S_D.

$$SEM = \frac{S_D}{\sqrt{n}}$$

Z Score: It is a statistical measurement that describes a value's relationship to the mean of a group of values. A linearly transformed score in S_D unit, which has a normal distribution. If a Z-score is 0, it indicates that the data point's score is identical to the mean score. A Z-score of 1.0 would indicate a value that is one standard deviation from the mean. Z-scores may be positive or negative, with a positive value indicating the score is above the mean and a negative score indicating it is below the mean.

$$z = \frac{(x - \bar{x})}{s_D}$$

Percentile: In statistics, a percentile is a term that describes how a score compares to other scores from the same set. It is commonly expressed as the percentage of values in a set of data scores that fall below a given value. Most applicable method for anthropometric data analysis.

$$x\,th\ \text{Percentile} = \bar{x} + (z \cdot s_D)$$

3.5 MANUAL MATERIAL HANDLING

Any kind of transporting or supporting materials like lifting, lowering, carrying, pushing, pulling, shovelling or stacking of materials by one or more workers known as Manual Material Handling (MMH).

MMH may involve a few devices such as trolleys, dollies, carts or rigs, chains or pulleys. Mechanical devices like lift trucks and power hoists can replace manual efforts but they are not feasible for all workplaces. It is very common in almost all working environments like factories, mills, warehouses, building sites, farms, hospitals, and offices, widely in unorganised sectors such as garages, food markets etc.

3.5.1 Risk Factors of Manual Material Handling

Manual Material Handling tasks may expose workers to physical risk factors. Repeated performance or prolonged exposure to MMH can lead to muscle fatigue i.e. weakness also injury can happen.

Over time, injury to the muscles, tendons, nerves, ligaments, joints and blood vessels in parts of the body may occur. Injuries of this type are known as musculoskeletal disorders or MSDs.

Common areas where MSDs take place are in the neck, back, shoulders, elbows, wrists or hands. The damaged tissue is commonly caused by wear and tear versus a single incident. MSDs are typically made worse with repeated exertions, awkward positions, and/or forceful movements.

- Environmental factors- temperature, relative humidity, glare, illumination, noise, floor surface- improper management of any of these can act as a risk factor. The working environment lacking sufficient space, having slippery floors, uneven or unstable floors, extreme temperatures or poor lighting are very common risk factors seen in most workplaces.
- General health- Height, reach, flexibility, strength, weight, aerobic capacity, etc if not suited to the performed job, then that could cause injury.
- Awkward postures (bending, twisting)
- Repetitive motions (frequent)
- Forceful exertions (heavy loads carrying and lifting)
- Pressure points (grasping loads, leaning against parts or surfaces that are hard or have sharp edges)
- Static postures (maintaining a fixed position for a long time)
- Weight, size and shape of the load
- Coupling (type of grip on the load)
- Slippery or damaged surfaces
- Absent of handles or inappropriate handles
- Imbalance (changing centre of gravity)

- Pushing or pulling
- A poor workstation designs
- Carrying, pulling, or moving the load over large distances – any of these could act as a risk factor for MMH.

3.5.2 Occupational Health Effects of Manual Handling

Manual handling can result in fatigue or weakness of the body and may cause injuries to the back, neck, shoulders, arms, wrist or other body parts.

Two following groups of injuries may result from manual handling:

- Cuts, fractures etc, due to sudden, unexpected events such as any sort of accidents
- Effect on the musculoskeletal system of the body (muscles, tendons, ligaments, bones, joints, bursa, blood vessels and nerves) due to gradual and cumulative wear and tear through repetitive manual handling.

3.5.3 Musculoskeletal Disorders

A person's musculoskeletal health determines how well their locomotor system works. This system includes their muscles, bones, joints, and connective tissues. Musculoskeletal impairments include about 150 distinct diseases/conditions that affect the system and are characterised by impairments in the muscles, bones, joints, and associated connective tissues, resulting in temporary or permanent restrictions in functioning and participation. Musculoskeletal problems are often characterised by discomfort (often persistent) and restrictions in mobility and dexterity, limiting people's ability to work and participate in society. Conditions of the musculoskeletal system can happen at any age, from birth to old age. They might be acute and temporary, like fractures, sprains, and strains (which cause pain and functional restrictions), or chronic and ongoing, like persistent primary low back pain and osteoarthritis.

Musculoskeletal conditions include conditions that affect:

- Joints, such as osteoarthritis, rheumatoid arthritis, psoriatic arthritis, gout, and spondylarthritis;
- bones, such as osteoporosis, osteopenia and associated fragility fractures, traumatic fractures;
- muscles, such as sarcopenia; and
- multiple body areas or systems, such as regional (e.g. back and neck pain) and widespread (e.g. fibromyalgia) pain conditions, inflammatory diseases such as connective tissue diseases and vasculitis that have musculoskeletal manifestations, for example, systemic lupus erythematosus, or amputation as a result of disease or trauma.

Musculoskeletal Disorders (MSDs) can be classified into the following 3 groups:

a) Neck and upper limb disorders,

b) Lower limb disorders, and

c) Back pain and back injuries.

Further deterioration of the musculoskeletal system may happen through continuous lifting/handling activities, e.g. chronic low back pain.

Factors that increase the risk of injury include the load being too heavy, large, difficult to grasp or unstable, the task being too strenuous or involving awkward postures or movements.

Low Back Pain

It is one of the most common and important clinical, socio-economical and public health problems affecting the human population both young and elderly people worldwide.

Symptoms experienced by People with Low Back Pain

- If we consider Anatomy, the human spine is made up of spinal bones, called vertebrae. Vertebrae are stacked on top of one another to create the spinal column. The spinal column gives the body its form. It is the body's main upright support.
- The lower back, also called the lumbar spine, curves slightly inward. An inward curve of the spine is called lordosis.
- If the region of pain persists below the costal margin and above the inferior gluteal folds with or without referred leg pain then it may be referred to as low back pain.
- The signs of low back pain may be experienced as aching, burning, stabbing, sharp or dull, well-defined, or vague with intensity ranging from mild to severe. It can occur suddenly and develop gradually.

As per pain duration, Low Back Pain can be of the following three types:

- Acute low back pain generally lasts from a few days to a few weeks not more than three months. It is mainly caused by any sort of accident.
- Sub-acute pain is defined as low back pain lasting between six weeks and three months.
- While chronic low back pain persists longer than three months generating major risks, if not treated.
    - Usually, low back pain is related to vertebrae, intervertebral discs, muscles, ligaments, soft connective tissue, joint capsules cartilage, blood vessels, spinal cord, nerves or internal organs of the pelvis and abdomen.
    - These connective tissues may be pulled, strained, stretched or sprained and rapidly produce inflammation with the release of inflammatory chemicals such as cytokines and/or chemokines.
    - There are many known causes of lower back pain. Common causes of low back pain include lumbar strain, nerve irritation, lumbar radiculopathy, bone encroachment, etc.

For the best understanding of the cause of low back pain, it can be divided into the following two broad categories:

- Mechanical pain, and
- Neurogenic pain.

In Mechanical pain the pain is caused by wear and tear in the parts of the lumbar spine, it usually starts from degenerative changes in the disc. As the disc begins to collapse and the space between the vertebrae narrows, the facet joints may become inflamed. Mechanical pain typically gets worse after activity due to strain on the moving parts of the spine.

This pain is usually felt in the back, but it may spread into the buttocks, hips, and thighs. The pain rarely goes down past the knee. Mechanical back pain usually doesn't cause weakness or numbness in the leg or foot, because the problem is not from pressure on the spinal nerves.

Neurogenic Pain Neurogenic pain means pain from nerve injury. It occurs when spinal nerves are inflamed, squeezed, or pinched. This can happen when a disc herniates or when a nerve gets pinched where it leaves the spine.

These can be summarized as LBP can take place due to several factors including individual subjective characteristics, design or condition of work such as heavy physical work, awkward working postures static and dynamic, as well as manual handling and lifting of loads, lifestyle factors and psychosocial factors. Also, low back pain results from trauma to the back and osteoporosis.

As non-mechanical causes vertebral infections, tumours, bone metastasis etc may present behind the scenes.

Management of low back pain is strongly connected to diagnosis, treatment, and prevention. The most important item in this chain is prevention. This management can be classified in a pharmacological and non-pharmacological way.

3.5.4 Work-Related Upper Limb Disorders

This type of disorder has also been referred to as Repetitive Strain Injuries or Musculoskeletal Disorders of the Upper Limbs covers a range of medical conditions which include tenosynovitis and carpal tunnel syndrome, which can be caused or made worse by work.

The conditions are often difficult to treat and are very painful. They are a growing cause of concern in the workplace and can be caused by other activities such as sports or housework e.g., tennis elbow.

The term "upper limb" relates to the part of the body extending from the tips of the fingers to the shoulders and extending to the neck. It includes soft tissues and connective tissues (tendons and ligaments) and the bony structures as well as the skin, along with the circulatory and nerve supply to the limb.

Work-Related Upper Limb Disorders (WRULDs) can occur in jobs that require repetitive fingers, hand or arm movements. These could be twisting, pressing, squeezing,

pushing, pulling, lifting or any number of similar movements. Working with display screen equipment at computer workstations should be managed and assessed to reduce the risks of upper limb disorders.

Several risk factors may result in Work-Related Upper Limb Disorders and these include the following:

- ***Repetition*:** When work is repetitive, it requires the same muscle group to be used over and over again during the working day and such repetition may not allow sufficient time for recovery and can cause muscle fatigue.
- ***Poor Work Posture*:** Certain jobs require a worker to assume a variety of awkward postures including fixed body positions that cause significant biomechanical stress to the joints of the upper extremity that restrict the blood flow to the muscles and tendons, resulting in less opportunity for recovery.
- ***Sustained Force*:** The level of force which is generated by the muscles is affected by several factors such as work posture, size of objects handled and speed of movement. These are the causal factors for upper limb disorders.
- ***Poor Work Environment*:** A poor work environment would be poor lighting or temperature control.
- ***Duration of Exposure*:** The duration of a task can increase the risk of injury.

An individual can get symptoms, even though several workers may do the same task with no problem. Other workers may have symptoms in their upper limbs such as:

- Aches and pains, tenderness, weakness, tingling, numbness, cramps, burning, redness and swelling; and
- Stiffness, pain or reduced movement in their joints.

There are certain symptoms, which may be signs of clinical disorders, such as:

- Carpal Tunnel Syndrome (CTS);
- Tendonitis Or Tenosynovitis;
- Osteoarthritis;
- Cramp of the Hand or Forearm from Prolonged Periods of Repetitive Movement; and
- Hand-Arm Vibration Syndrome (HAVS).

Musculoskeletal ailments are also the leading cause of global rehabilitation requirements. They are one of the most significant contributors to the demand for rehabilitation services among children, accounting for around two-thirds of all adults in need of rehabilitation. Musculoskeletal disorders frequently coexist with other

noncommunicable diseases and raise the risk of developing other noncommunicable diseases, such as cardiovascular diseases. People who have musculoskeletal ailments are also more likely to suffer mental health problems. According to a new review of Global Burden of Disease (GBD) 2019 statistics, roughly 1.71 billion individuals worldwide are affected by musculoskeletal diseases such as low back pain, neck discomfort, fractures, severe injuries, osteoarthritis, amputation, and rheumatoid arthritis. While the frequency of musculoskeletal diseases varies depending on age and diagnosis, people of all ages experience them all over the world. In terms of population, high-income nations are the most impacted (441 million), followed by countries in the WHO Western Pacific Region (427 million) and South-East Asia Region (369 million). Musculoskeletal problems are also the leading cause of Years Lived with Disability (YLD) in the world, accounting for 17 per cent of all YLDs with a total of roughly 149 million YLDs caused by musculoskeletal conditions. The most significant contributor to the global burden of musculoskeletal diseases is low back pain, which affects 570 million people all over the world and is responsible for 7.4 per cent of all global YLDs. Fractures, osteoarthritis, neck discomfort, amputations, rheumatoid arthritis, gout, and other musculoskeletal illnesses are some of the additional factors that contribute to the overall burden of musculoskeletal conditions.

Musculoskeletal diseases are more common in older individuals, but younger people can still be impacted by them, and it's typically during the years when they earn the most money. Low back pain is the leading cause of premature retirement from employment and the early retirement of workers has a significant negative impact on society, both in terms of the direct expenses associated with health care and the indirect costs (such as absenteeism and decreased productivity). The number of people suffering from low back pain will continue to grow in years to come, particularly rapidly in nations with low and middle incomes. This trend is expected to be more pronounced in developing nations

Workers in a wide variety of fields and occupations may be subjected to risk factors while on the job. These variables include uncomfortable body postures, lifting heavy objects, bending, reaching high up, pushing and dragging huge loads, and lifting heavy goods while bending. Other risk factors include performing the same or similar tasks repeatedly. The likelihood of a worker being hurt increases when they are subjected to these established risk factors for MSDs.One of the most often reported reasons for missed or restricted work time is a musculoskeletal disorder that is job-related. The use of ergonomic principles in the workplace has the potential to significantly cut down on the frequency, severity, and related expenses of MSDs that are caused by physical overexertion. It has been shown that implementing an ergonomic method helps lower the risk of getting MSDs in high-risk industries such as construction, food processing, firefighting, office work, healthcare, transportation, and warehousing.

Factors that should be considered by employers and employees are mentioned below.

Employers are required to consider the following:

- Developing policies to ensure all care plans determine whether ergonomic assistive devices are needed.

- Providing ergonomic assistive devices (such as slide boards or gait belts) when needed.
- Providing training on assistive ergonomic devices, their uses, the clinical situation requiring them, and how to order them in the plan of care.
- Develop policies to assess the caregiver's competence with the assistive devices once he or she has been trained and is using them.

Employees should consider:

- Participating in ergonomic training.
- Using ergonomic following assistive devices, if available:
  - Products such as slip sheets, slide boards, rollers, slings, belts, and mechanical or electronic hoists (to lift the client) have been designed to help healthcare workers and clients.
  - Equipment such as adjustable beds, raised toilet seats, shower chairs, and grab bars are also helpful for reducing risk factors for musculoskeletal injuries. These types of equipment can allow the client to help during transfer.
- Using proper body mechanics. Even when assistive devices are used during client care, some amount of physical exertion may still be necessary such as:
  - Move along the side of the client's bed instead of reaching while performing tasks at the bedside.
  - When manually moving the client, stand as close as possible to the client without twisting your back, keeping your knees bent and feet apart. To avoid twisting the spine, make sure one foot is in the direction of the move. Using gentle rocking motions can also reduce exertion.
  - Pulling a client up in bed is easier when the head of the bed is flat or down. Raising the client's knees and encouraging the client to push (if possible) can also help.
  - Apply anti-embolism stockings by pushing them on while you are standing at the foot of the bed. You can use less force in this position than standing at the side of the bed.
- Immediately notify the employer of any injury in the workplace.

3.6 WHAT ARE ACCIDENTS?

An undesirable or unfortunate happening that occurs unintentionally and usually results in harm, injury, damage, or loss; casualty; or mishap is termed as accidents.

3.6.1 Causes of the Accidents

i) ***Poor Lifting Techniques***

One of the most common causes of workplace injuries is using incorrect lifting

techniques. It's easy to tweak a muscle or strain your back when moving heavy objects. These accidents can result in mild issues that resolve quickly or lead to a severe injury that could be life-changing. All employees should pass an accredited course that teaches correct lifting techniques.

Employers should also encourage staff to work as a team when moving items and to use lifting equipment when possible.

ii) ***Low Light Conditions***

When considering how to keep employees safe, it's important to take the lighting conditions into account. When working outside, darkness can fall quickly, so employees need to have torches and bright clothing, so others know they are there. But, there can also be low lighting conditions when working indoors.

Employers need to ensure all aisles and rooms have adequate illumination, and that staff can easily report any areas that require more lighting.

iii) ***Trips and Falls***

If employees are wearing unsuitable footwear, rushing across the workplace, or there are slippery floors, they may suffer trips and falls. But, this is often easily avoidable. You can place mats near doors for staff to wipe muddy and wet feet. Also, it's useful to have plenty of available signs that employees can use to tell others there is water on a section of the floor.

a) ***Workplace Accidents and Fatigue***

Employees suffering from fatigue could be at an increased risk of suffering a workplace injury. This problem can arise in high-demand jobs when there are long duty shifts, and when people are generally overtired from reasons outside their working environment. It can also be challenging to determine if a staff member is fatigued.

It may not be obvious from their physical appearance, and they may not want to admit to being exhausted. Businesses must reassure employees that they can tell their supervisor they are fatigued and receive support. Not only does this help keep the staff member safe, but it also reduces the risk of the person putting their colleagues in harm's way.

b) ***Contact with Moving Objects***

There are many potentially dangerous moving objects in warehouses, on construction sites, and in other hazardous environments. For example, forklifts are a common piece of equipment, and it is not always easy for the operator to view the space around them. Cranes may also move heavy objects such as timber and metal beams, and employees need to be careful when this work is ongoing.

It's a good idea to ensure all staff wear high-visibility clothing, so colleagues know exactly where they are at all times. Employees should know they must never enter a precarious environment without wearing their safety gear. It's also helpful to have spare supplies that staff can borrow if they forget or damage their high-visibility jackets, vests, pants, or shirts.

c) ***Messy Workplace Environment***

When keeping employees safe, one of the crucial steps is to provide them with a tidy workplace environment. If they have to move items to perform their jobs, then they are more likely to hurt themselves. This can be a particular problem if there are heavy objects on top of shelves that could fall and hit a passerby.

You can provide cleaning staff with a checklist to ensure they don't miss any areas. A supervisor can also check the workplace is in order throughout the day and report any areas that need urgent attention. Employees will appreciate their company is taking steps to protect their welfare and to give them the best possible workplace.

d) ***Lack of Necessary Equipment***

If staff do not have the right tools to do their job, they can be tempted to cut corners and put themselves at risk. To ensure good workplace safety practices, it's essential to provide the right equipment for each task. You can also assign one team member to check the tools at the end of each shift.

If they notice any signs of wear and tear, you can then replace these items before the next use.

e) ***Too Many Distractions***

There is usually nothing wrong with a radio playing in the background or staff chatting while doing their jobs. However, some tasks may be particularly dangerous, and employees may become injured at work if they are not focused. While employees need to ensure they are concentrating, employers can also help.

You could put up signs advising a certain area is off-limits while others are working there. You can also add soundproofing to areas where workers are engaged in work that could lead to a serious injury.

3.6.2 Some Common Terms Associated with Accidents

A hazard is a physical situation with a potential for human injury that could lead to an accident. **Risk** is the likelihood that a person may be harmed or suffer adverse health effects if exposed to a hazard. While, an **accident** is an unintended event or series of events that results in death, injury, loss of system or service, or environmental damage.Therefore, an **accident** is an unplanned event that results in personal injury or illness and may also result in property damage while an **incident** is an unplanned event that does not result in personal injury or illness but may result in property damage.

A **near miss** is an event that does not result in injury, illness or damage, but has the potential to do so. A near miss is usually caused by a series of dangerous conditions that when unnoticed will eventually result in an accident. They are not accidents, but they could have been accidents if the circumstances had been slightly different. Near misses happen often because they are easy to forget. Near misses must be reported regardless of how severe, to ensure that the appropriate steps are taken to prevent a recurrence in which serious injury or loss may occur.

Figure 3.3: Hazard versus Risk

3.6.3 Steps to Risk Assessment

- Step 1: Identify the Hazard
- Step 2: Decide who might be Harmed and How
- Step 3: Evaluate the Risks and decide on Precautions
- Step 4: Record your Findings and Implement them
- Step 5: Review your Risk Assessment and Update, if necessary.

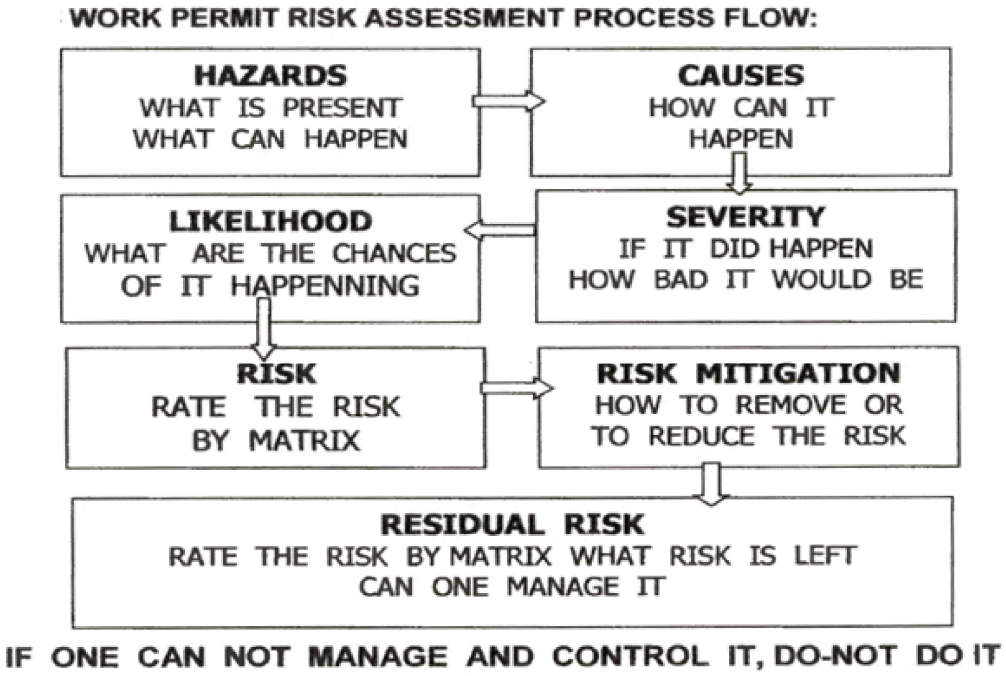


Figure 3.4: Work Permit Risk Assessment Process Flow

i) Identify the Hazard

Hazard identification is the process of identifying all hazards at risk in your work environment.

Many hazards exist in the workplace. Some of these can be easily identified such as manual handling, but others are less obvious and may not even show up on accident reports or injury logs. Consider how people work with plant equipment to identify hidden hazards that could cause harm without being detected by existing records (such as a new cleaning solution). Identifying what hazardous substances are used is also important when thinking about potential health risks for workers who use them regularly or come into contact during maintenance operations. For example, many workplaces contain asbestos which poses severe dangers if inhaled over time due to its link to respiratory illnesses like lung cancer.

Four risk categories are to be used to identify hazards: Extreme, High, Moderate, and Low.

ii) Assess the Risk

Once you have identified what hazards may be present. decide how likely it is that someone could be harmed by these and to what extent if so. This is assessing the level of risk for your business premises or workplace environment concerning those potential hazards. Decide: who might be harmed; what action you're already taking to reduce this harm from happening again (control measures); any further steps needed will carry out this necessary action; when they need to do it by

Risk Matrix

With all the risks that are out there, a Risk Matrix (Risk Assessment Matrix) can be an easy way to assess the risk. The Risk Matrix is an incredible tool for quickly calculating the risk of a Project. It helps to identify what could go wrong (likelihood) and how much damage it would cause if these outcomes

occurred (severity). This makes prioritizing issues quick and simple so you know which ones need attention.

Guidelines for Assessing Severity

- ***Major:*** Environmental Loss (Major pollution affecting life outside site), People (Fatality or Permanent disability.)
- ***Serious:*** Environmental Loss (Major pollution confined to the inside site), People (long-term absence / Offsite treatment)
- ***Moderate***: Environmental Loss (Significant pollution causing a shutdown of units), People (Moderate treatment / Shot term absence)
- ***Minor:*** Environmental Loss (Pollution above limits / Small spills, emissions), People (First aid case / No significant injury)

Guidelines for Assessing Likelihood

- ***Very unlikely:*** Little or no chance of occurrence
- ***Unlikely:*** Could occur, less than 50 / 50 chance
- ***Possible:*** 50 / 50 chance
- ***Probable:*** More likely to occur than not more than 50 / 50 chance

Risk Assessment Matrix

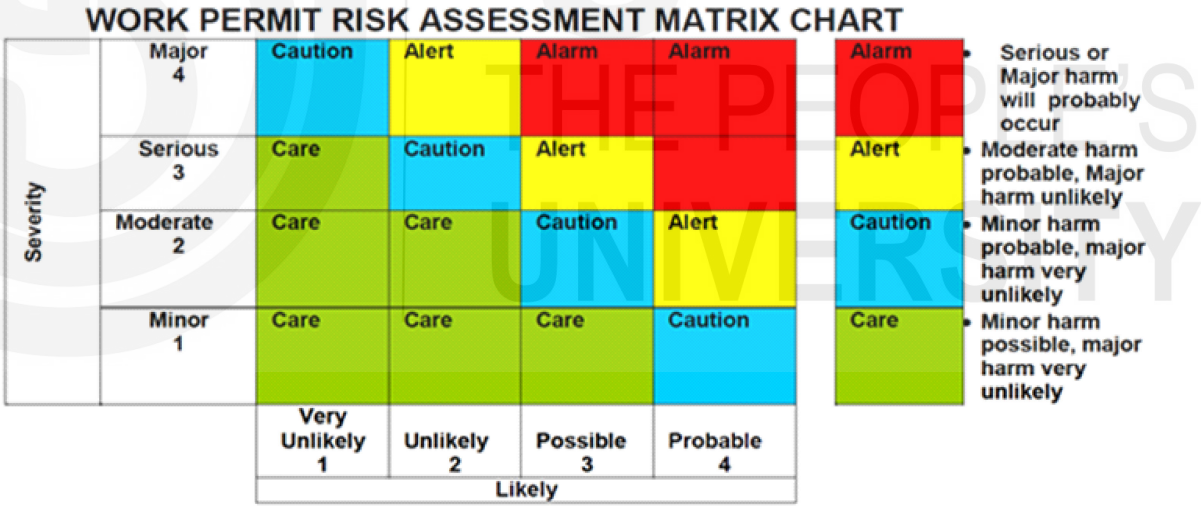


Figure 3.5: Methods for Analysing Risks

- ***Qualitative analysis*** isa simple and cost-effective approach that involves identifying and ranking hazards based on their likelihood and severity.
- ***Semi-quantitative analysis*** assigns numerical values to the severity and likelihood of risks to calculate a risk score.
- ***Quantitative analysis*** involves using statistical methods to quantify the probability of a risk occurring and its potential impact.

Risk Evaluation

- Determining whether risk levels are acceptable or unacceptable based on the results of the risk analysis

- Methods for evaluating risks: risk severity matrix, risk priority number, and risk ranking
- Developing controls that reduce risk to an acceptable level, considering the organization's priorities, resources, and overall business goals

iii) Risk Control: Put controls/safeguards in Place

a) *Definition of Risk Control*

Risk control refers to the implementation of measures or strategies to mitigate or eliminate the potential risks identified during the risk assessment process.

b) *Importance of Risk Control in Risk Assessment*

Risk control is a crucial part of the risk assessment process because it helps to ensure the safety and health of workers and others who may be affected by workplace hazards. Effective risk control measures can prevent accidents, injuries, and illnesses, and can also minimise financial losses and damage to equipment and property.

c) *Methods for Controlling Risks*

There are several methods for controlling risks in the workplace, including:

- ***Elimination:*** Elimination involves completely removing the hazard or risk from the workplace. This may involve replacing hazardous equipment or substances with safer alternatives or modifying work processes to eliminate the risk.
- ***Substitution***: Substitution involves replacing a hazardous substance, material, or process with a less hazardous alternative.
- ***Engineering Controls:*** Engineering controls involve designing or modifying equipment, tools, or processes to minimise the risk of exposure to hazardous conditions. Examples include ventilation systems, noise reduction measures, and machine guards.
- ***Administrative Controls:*** Administrative controls involve implementing policies and procedures to control the risk of exposure to hazardous conditions. Examples include training programs, job rotation, and work scheduling.
- ***Personal Protective Equipment (PPE):*** It involves providing workers with protective gear to reduce their exposure to hazardous conditions. Examples include hard hats, gloves, respirators, and safety glasses.

d) *Techniques for Effective Risk Control*

To ensure the effectiveness of risk control measures, it is essential to follow the following techniques:

- Involve workers in the risk assessment and control process;
- Implement a hierarchy of controls (starting with elimination, substitution, engineering controls, administrative controls, and PPE); and
- Regularly review and evaluate risk control measures and adjust them, if necessary.

e) *Examples of Controls Commonly Used in Workplaces*

Examples of common risk control measures in workplaces include:

- Installing guards or barriers around machinery,
- Providing Personal Protective Equipment (PPE) to workers,
- Implementing lockout/tag-out procedures to prevent accidental start-up of machinery,
- Using ventilation systems to control exposure to hazardous substances, and
- Providing training programs to workers to increase their awareness of workplace hazards.

iv) Re-assess the Risk with Control in Place

After implementing control measures to reduce or eliminate the identified risks, it is essential to re-assess the risks to ensure that they have been adequately controlled. This involves reviewing the effectiveness of the control measures in place and evaluating whether they have reduced the level of risk to an acceptable level.

To do this, ask yourself the following questions:

- Have the control measures been implemented as planned?
- Have they effectively reduced or eliminated the identified hazards or risks?
- Are there any new hazards or risks that have emerged as a result of the control measures?
- Have the control measures introduced any new risks?

Based on the answers to these questions, you may need to revise the control measures or implement additional ones to further reduce the risks.

v) Confirmation of Reduced Risk

Confirmation of the reduced risk is a crucial step in the risk assessment process. It involves reviewing the control measures that have been put in place and assessing their effectiveness in reducing or eliminating the identified hazards. This step can be done through a range of methods, including:

- Regular inspections of the workplace to identify any new hazards or potential risks that may have arisen.
- Monitoring the workplace to ensure that the control measures are being implemented correctly.
- Reviewing the incident records to see if there have been any incidents or near misses related to the identified hazards.
- Seeking feedback from employees to identify any issues or concerns related to the control measures in place.

It's important to regularly review and update the risk assessment to ensure that the control measures remain effective and that any new hazards or risks are identified and addressed promptly. By regularly reviewing the risk assessment, it's possible to ensure that the workplace remains safe and healthy for all employees.

Check Your Progress 2

Note : i) Use the space given below for your answers.

ii) Check your answer with those given at the end of the Unit.

1) 'There are threegeneral principles for applying anthropometric data to specific design problems'. Elaborate.

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2) What are the risk factors of manual material handling?

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3) Highlight the various methods for controlling risks in the workplace.

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3.7 CONCLUSION

Ergonomics refers to the design of an object that aims to enhance usability, comfortability and efficiency for the user. The Oxford Dictionary defines ergonomics as "relating to or designed for efficiency and comfort in the working environment". Ergonomics can be defined as the study of people in their working environment. More specifically, an ergonomist designs or modifies the work to fit the worker, not the other way around. The goal is to eliminate discomfort and risk of injury due to work. In other words, the employee is the priority in analysing a workstation. To reduce the risk of occupational hazards, it is important to consider the design of the working environment. In case we can modify the environment in such a way that the risks and hazards can be reduced, we can work for a hazard-free environment. In this Unit, we have focused on the history behind the conception of ergonomics, its importance and types, Systems Design Methods for Ergonomics, factors governing Manual Material handling, causes of accidents, and assessment of various ergonomic hazards and risk factors. This unit has also acquainted you with the common types of accidents and the steps of risk assessment.

3.8 GLOSSARY

Anthropometry: It is derived from the Greek words "Anthropos" (human) and "Metron" (measure), and means measurement of the human body. In other words,

'anthropometry' literally means "measurement of human". Anthropometry is the branch of the human sciences that deals with body measurements; particularly with measurements of body size, shape, strength and working capacity.

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3.10 ANSWER TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress 1

1) Your answer should include the following points:

- For details, refer to Sub-section 3.3.1

2) Your answer should include the following points:

- Formulation of the System's Goals
- Analysis and Allocation of Function and Requirement Analysis
- Design Concept
- Detailed Design
- Realisation, Implementation and Validation
- Evaluation

Check Your Progress 2

1) Your answer should include the following points:

- Design for Extreme Individuals (maximum or minimum),
- Designing for Adjustable Range, and
- Designing for the Average.

2) Your answer should include the following points:

- For details, refer to Sub-section 3.5.1

3) Your answer should include the following points:

- For details, refer to Sub-section 3.6.3 (iii-c)