Ergonomics

Ergonomics - Greek word meaning Ergon (Work) & Nomos (Natural Laws).

The formal definition of ergonomics, approved by the IEA (International Ergonomics Association), reads as follows:
Ergonomics or human factors is the scientific discipline concerned with understanding of the 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. Ergonomics is employed to fulfill two goals of health & productivity.

Zero – Gee Ergonomic Computer and Gaming Workstation.

Background……..

The Philosophy of ergonomics operates on the premise “better design for people”. Whatever we design should cater to the needs of common man.

Ergonomics developed into a recognized field during the second world war, when for the first time, technology and human sciences were systematically applied in a co-ordinated manner. Physiologists, Psychologists, anthropologists, medical doctors, work scientists and engineers together addressed the problems arising from the operation of complex military equipments. The results of this inter- disciplinary approach appeared so promising that the cooperation was pursed after the war, in industry.

The Browning M2HB or the Browning .50 Calibre Machine Gun, as it is also known, is heavy machine gun. Developed by the famed gun-designer John Browning in the United States towards the end of the First World War. The M2 saw widespread use during the Second World War. It was mainly used against aircraft and vehicles because of immense penetrating power

The formal history describes activities in known chronological order. This can be divided into 5 markers:

- Developments prior to World War I
- Developments during World War I
- Developments between World War I and World War II
- Developments during World War II
- Developments after World War II

Developments prior to World War I:

Prior to WWI the only test of human to machine compatibility was that of trial and error. If the human functioned with the machine, he was accepted, if not he was rejected. There was a significant change in the concern for humans during the American civil war. The US patent office was concerned whether the mass produced uniforms and new weapons could be used by the infantry men.

Developments during World War I:

With the onset of WWI, more sophisticated equipment was developed. The inability of the personnel to use such systems led to an increase in interest in human capability. Still, the war did not create a Human Factors Engineering (HFE) discipline, as such. The reasons attributed to this are that technology was not very advanced at the time and America's involvement in the war only lasting for 18 months.

Developments between World War I and World War II:

This period saw relatively slow development in HFE. Although, studies on driver behavior started gaining momentum during this period, as Henry Ford started providing millions of Americans with automobiles. Another major development during this period was the performance of aeromedical research. By the end of WWI, two aeronautical labs were established, one at Brooks Airforce Base, Texas and the other at Wright field outside of Dayton, Ohio. Many tests were conducted to determine which characteristic differentiated the successful pilots from the unsuccessful ones. This led to the identification which suggested that motivational factors could significantly influence human performance.

Developments during World War II:

With the onset of the WW II, it was no longer possible to adopt the principle of matching individuals to preexisting jobs. Now the design of equipment had to take into account human limitations and take advantage of human capabilities. This change took time to come into place.
There was a lot of research conducted to determine the human capabilities and limitations that had to be accomplished. A lot of this research took off where the aeromedical research between the wars had left off. An example of this is the study done by Fitts and Jones (1947), who studied the most effective configuration of control knobs to be used in aircraft cockpits. A lot of this research transcended into other equipment with the aim of making the controls and displays easier for the operators to use.

Developments after World War II:

The beginning of cold war led to a major expansion of Defense supported research laboratories. Also, a lot of labs established during the war started expanding. Most of the research following the war was military sponsored. Large sums of money were granted to universities to conduct research. The scope of the research also broadened from small equipments to entire workstations and systems. Concurrently, a lot of opportunities started opening up in the civilian industry. The focus shifted from research to participation through advice to engineers in the design of equipment. After 1965, the period saw a maturation of the discipline. The field has expanded with the development of the computer and computer applications.

The focus of ergonomics and the factors that play a role ….

In the design of work and everyday-life situations, the focus of ergonomics is human beings.

Unsafe, unhealthy, uncomfortable or inefficient situations at work or in everyday-life are avoided by taking account of the physical and psychological capabilities and limitations of humans.

A large number of factors play a role in ergonomics; these include :

1. Biomechanical background,
2. Physiological background
3. Anthropometric background
4. Body postures
5. Environmental Factors –
   Noise, Vibration, Illumination, Climate & Chemical substances
6. Information and operation -
   - Informations gathered through different sense organs
   - Controls for operation
7. Work organization
   - Appropriate tasks, interesting jobs

General and Individual Ergonomics

Ergonomically equipments, technical systems and tasks have to be designed in such a way that they are suited to every user. Most designs, in the first instance, are suited only to 95 percent of populations because of the variability within populations. The rest require special, individual ergonomic measures.

Improvement options for tools

Good design and proper maintenance can help reduce pressure points on the hands, awkward postures (e.g., bent wrists), forceful exertions, and other contributing factors.

Pliers or cutting-type tools—a maximum grip span of 2 to 3 inches and an adjustable spring return to reduce fatigue and provide a better fit to the hand.

Handles

- Rounded, soft, and padded—no sharp edges or deep grooves (reduce pressure points on fingers and hands)
- At least 1 to 2.5 inches in diameter (allows a power grip) and 5 incheslong (do not dig into palms)
- High-friction surfaces or moldable substances may be added to handles to improve the grip

Three domains of ergonomics……..

International ergonomics association (IEA) broadly divides ergonomics into:

1. Physical Ergonomics 2. Cognitive Ergonomics 3. Organizational Ergonomics

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1. Physical Ergonomics: It is concerned with human anatomical and some of anthropometric, physiological & biomechanical characteristics as they relate to physical activity. (Relevant topics include working postures, material handling, repetitive movements, lifting, work related musculoskeletal disorders, work place layout, safety and health).

Seat too small with poor back support—leads to poor back and neck posture

Larger, more comfortable adjustable seat with improved back support

2. Cognitive Ergonomics: It is concerned with mental processes such as perception, memory, reasoning & motor response, as they affect interactions among humans and other elements of a system (Relevant topics include mental work load, decision making, skilled performance, human - computer interaction, human reliability, work stress and training as these may relate to human system design).

Goal -

- user-centered design of human- machine interaction and human computer interaction (HCI).
- Design of information technology systems that support cognitive tasks (e.g., cognitive artifacts).
- Development of training programs
- work redesign to manage cognitive workload and increase human reliability.

A forearm-mounted, 11-ounce WT4000 Series wearable computer from Motorola. An answer for out in the field or warehouse jobs.

3. Organizational Ergonomics: It is concerned with the optimization of socio technical systems, including their, organizational structures, policies and processes. (Relevant topics include communication, crew resource management work design, design for working times, team work, participatory design, community ergonomics, cooperative work, new work programmes, virtual organizations, telework & quality.

Benefits-

- Increased productivity and organisational effectiveness
- Improved management of risk

- Reduced costs in product development and training
- Increased product sales

- Improved wellbeing of staff
- More effective personnel selection
- Improved communication within/across teams
- Safer conditions of work

- Tasks completed more efficiently and effectively
- Equipment and tools are easier to learn and use
- Improved procedures and training programmes
- Fewer errors occur

Anthropometric, Biomechanical &Physiological background

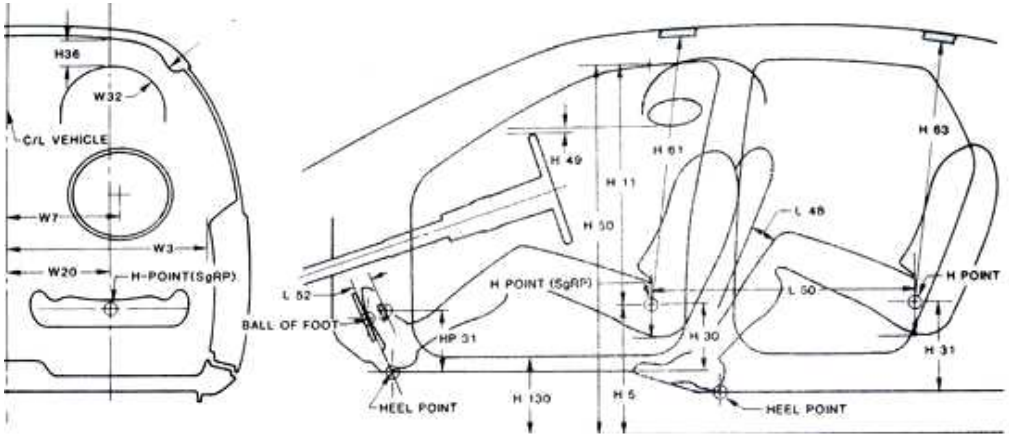
Ergonomics and its relation with Anthropometry

Anthropometry is concerned with the size and proportions of the human body. Anthropometry in Greek means measurement of humans.
Anthropometry in physical anthropology, refers to the measurement of human individual for the purposes of measuring human physical variations. A few anthropometric principles of importance to the ergonomics of posture and movements are given below.

We all acknowledge the necessity of manufacturing garments in a range of sizes, but would it also be true to say that chairs and tables, for example, should be supplied in a range of sizes as well? The answer is “only to a limited extent”.

In order to optimize such scenario/ system there are three types of information that is required:

1. Anthropometric data (human dimensions) of the user population.
2. The ways in which the anthropometric data might impose constraints upon the design.
3. The criteria which define an effective match between the product and the user.



Anthropometric data dimensions

Below is a list of anthropometric dimensions taken from one of the most well known book on anthropometry: ‘ Bodyspace : anthropometry, ergonomics, and design’ by Stephen Pheasant. Each dimension is numbered and this number is corresponding to the illustration as shown in the figures.

1. Stature - the vertical distance from the floor to the vertex (i.e. the crown of the head). [for vertical clearance]

2. Eye height - vertical distance from the floor to the inner canthus (corner) of the eye. [centre of the visual field]

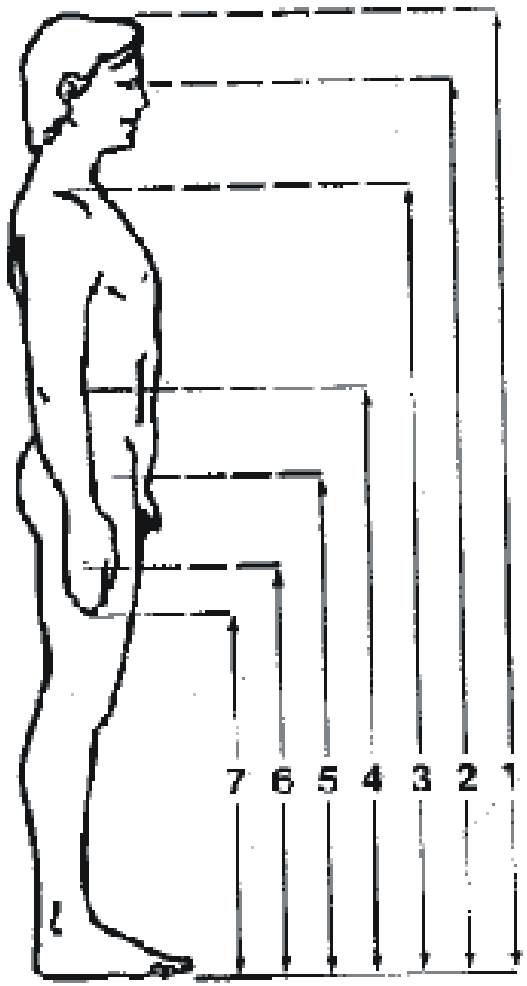
3. Shoulder height - vertical distance from the floor to the acromion (i.e. the bony tip of the shoulder). [centre of rotation of the upper limb]

4. Elbow height - [determination of work - surface heights]

5. Hip height - [centre of rotation of hip joint]

6. Knuckle height - [reference level for handrails and handgrips]

7. Fingertip height - [lowest acceptable level for finger operated controls]



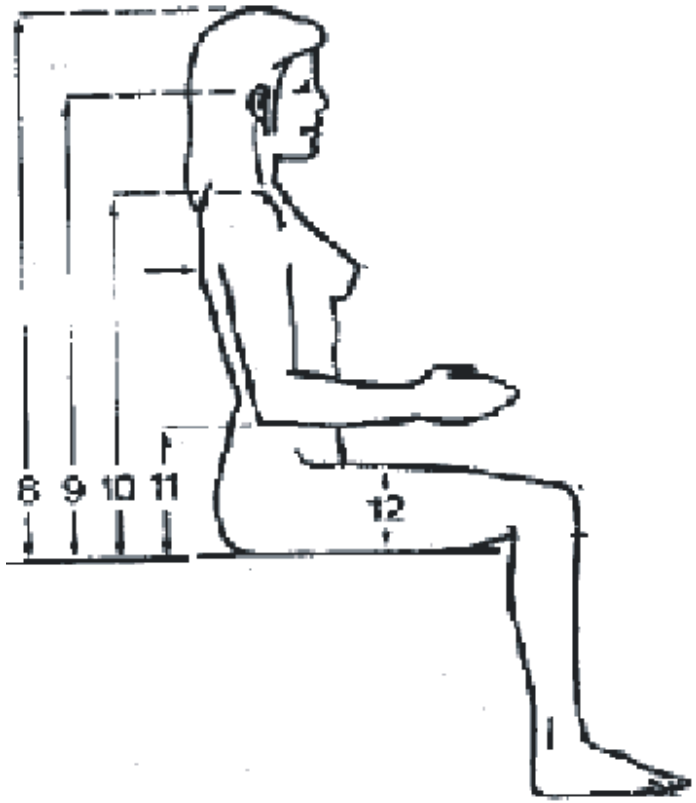
8. Sitting height - vertical distance from the sitting surface to the vertex [for clearance]

9. Sitting eye height - vertical distance from the sitting surface to the inner canthus (i.e. the corner of the eyes). [centre of visual field]

10. Sitting shoulder height - vertical distance from the seat surface to the acromion (i.e., the bony point of the shoulder). [centre of rotation of the upper limb]

11. Sitting elbow height - vertical distance from the seat surface to the underside of the elbow. [heights of armrest, desk tops, keyboards]

12. <u>Thigh thickness</u> - Vertical distance from the seat surface to the top of the uncompressed soft tissue of the thigh at its thickest point, generally where it meets the abdomen. [for clearance between seats and tables]



13. Buttock - knee length - horizontal distance from the back of the uncompressed buttock to the front of the kneecap. [clearance between rows of seats]

14. Buttock - popliteal length - horizontal distance from the back of the uncompressed buttock to the popliteal angle, at the back of the knee, where the back of the lower legs meet the underside of the thigh. [seat depth]

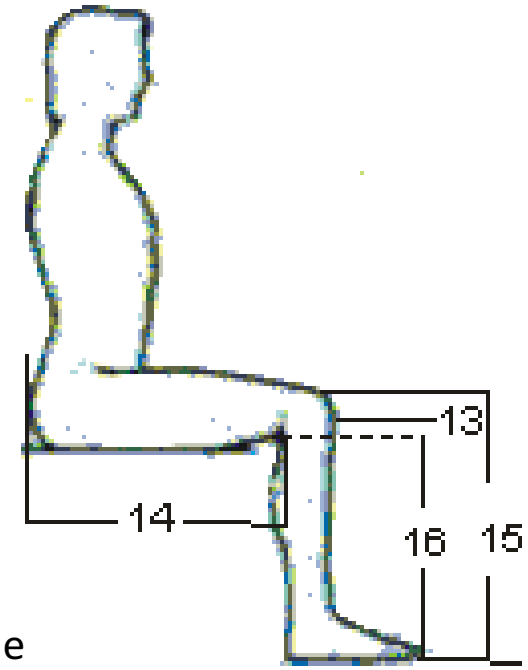
15. Knee height - [clearance beneath tables]

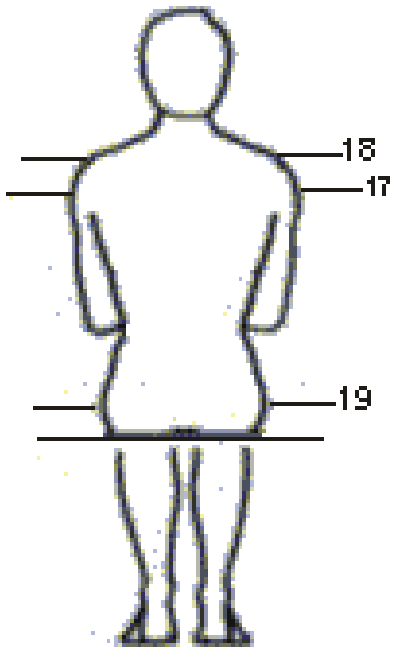
16. Popliteal height - vertical distance from the floor to the popliteal angle at the underside of the knee. [maximum acceptable height of a seat]

17. Shoulder breadth (bideltoid) - maximum horizontal breadth across the shoulders, measured to the protrusions of the deltoid muscles. [clearance at shoulder level]

18. Shoulder breadth (biacromial) - horizontal distance across the shoulders measured between the acromion (bony points). [lateral separation of the centres of rotation of the upper limb]

19. Hip breadth - [clearance for the width of a seat]



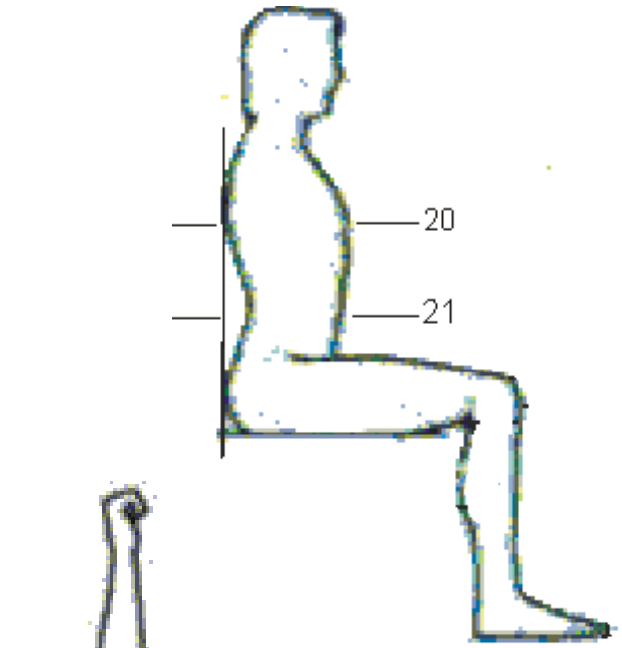


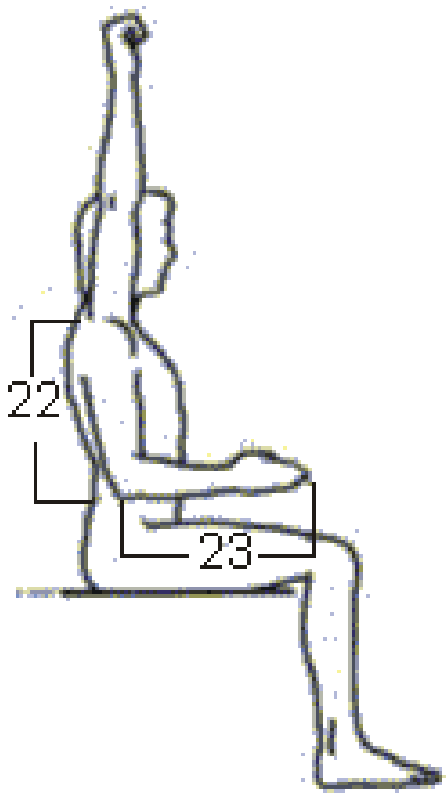
20. Chest depth - maximum horizontal distance from the vertical reference plane to the front of the chest in men or breast in women. [clearance between seat backs and obstructions]

21. Abdominal depth - maximum horizontal distance from the vertical reference plane to the front of the abdomen in the standard sitting position. [clearance between seat back and obstructions]

22. Shoulder - elbow length - distance from the acromion to the underside of the elbow in a standard sitting position.

23. Elbow - fingertip length - distance from the back of the elbow to the tip of the middle finger in a standard sitting position. [forearm reach; used in defining normal working area]





24. Upper limb length - distance from the acromion to the fingertip with the elbow and wrist straight (extended).

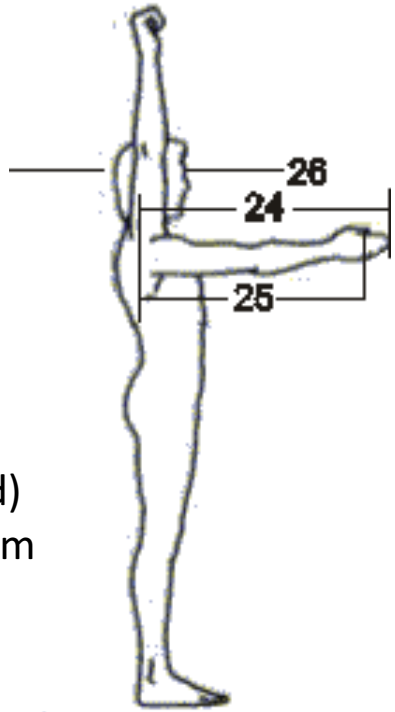
25. Shoulder - grip length - distance from the acromion to the center of an object gripped in the hand, with the elbow and wrist straight. [functional length of upper limb; used in defining zone of convenient reach]

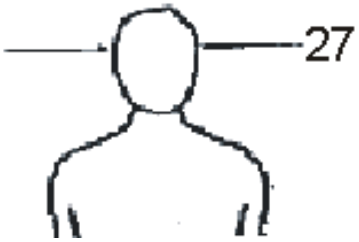
26. Head length - distance between the glabella (the most anterior point on the forehead between the brow ridges) and the occiput (back of the head) in the midline. [reference datum for location of eyes, approximately 20 mm behind glabella]

27. Head breadth - maximum breadth of the head above the level of the ears. [clearance]

28. Hand length - distance from the crease of the wrist to the tip of the middle finger with the hand held straight and stiff.

29. Hand breadth - maximum breadth across the palm of the hand (at the distal ends of the metacarpal bones. [clearance required for hand access, e.g., grips, handles, etc.]



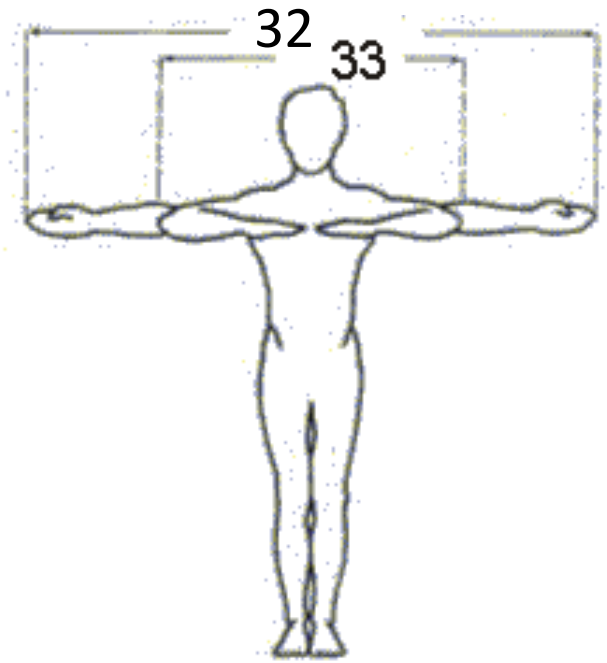


30. Foot length – distance, parallel to the long axis of the foot, from the back of the heel to the tip of the longest toe. [clearance for foot, design of pedals]

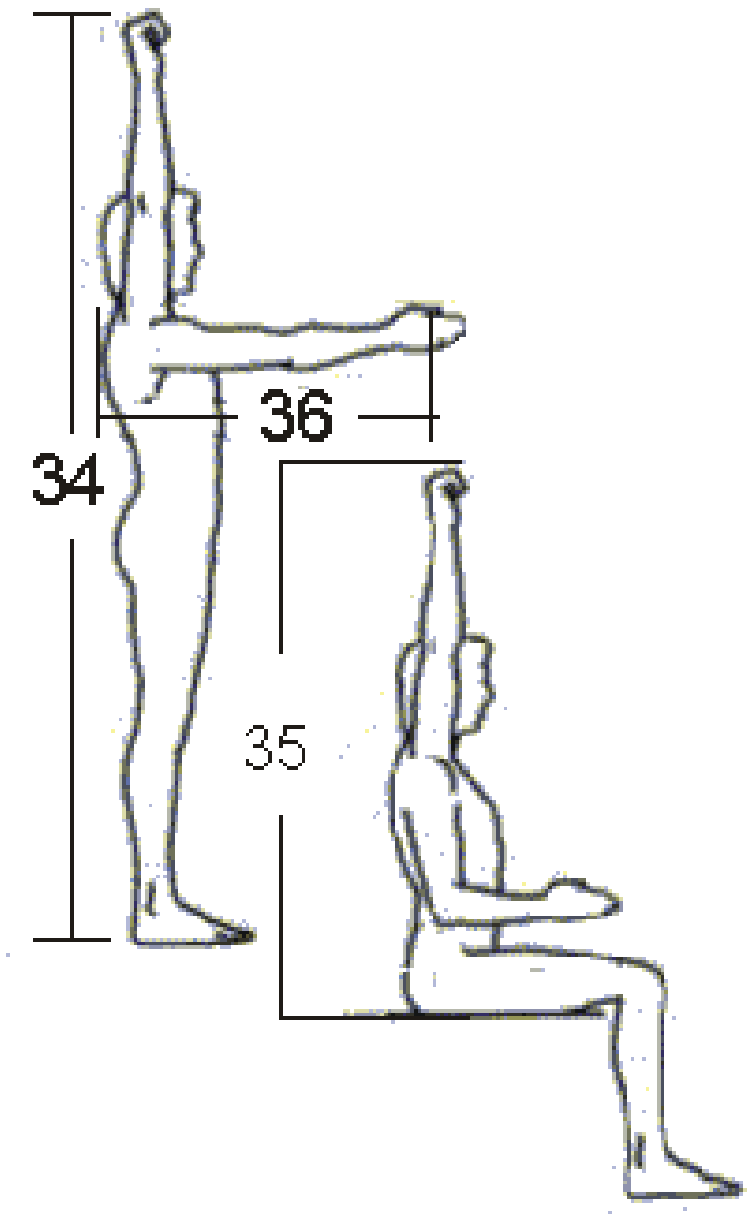
31. Foot breadth - maximum horizontal breadth, wherever found, across the foot perpendicular to the long axis. [clearance for foot, spacing of pedals, etc.]

32. Span - the maximum horizontal distance between the fingertips when both arms are stretched out sideways. [lateral reach]

33. Elbow span - distance between the tips of the elbows when both upper limbs are stretched out sideways and the elbows are fully flexed so that the fingertips touch the chest. [a useful guideline when considering “elbow room” in the workspace.]



34 – 36. Grip reaches - in each case the measurement is made to the center of a cylindrical rod fully grasped in the palm of the hand. In dimensions 34 and 35 the arm is raised vertically above the head and the measurement is made from the floor or seat surface, respectively. In dimension 36 the arm is raised horizontally forward at shoulder level and the measurement is taken from the back of the shoulder blades. In each case these are “easy” reaches made without excessive stretch.



Body Somatotypes

The human body is composed of 35% water & 65% solids in terms of its total body weight, fat, muscles, bones & other minerals etc form the solid part. According to the proportions of the fat , muscle & bone content a range of body or figure types is formed. Constitutional psychology is a theory developed in 1940s by American psychologist William Herbert Sheldon, associating body types with human temperament types. Sheldon developed a theory that there are three basic body types , or SOMATOTYPES (based on three tissue layers: Endoderm, Mesoderm & Ectoderm) each associated with personality characteristics , representing a correlation between physique & temperament.

Like Tyson or Serena most pure mesomorphs will respond to a good training program a lot easier than an ectomorph or endomorph yet they still want to always hit it hard and heavy. They will also be able to engage in more advanced training protocols and adapt to various modalities a lot quicker than their counterparts.

1. Endomorphy - Focused on the digestive system particularly the stomach (endoderm); has the tendency toward plumpness, corresponds to viscerotonia. Temperament - tolerant, love of comfort & luxury, extrovert.

Endomorphic Body Type

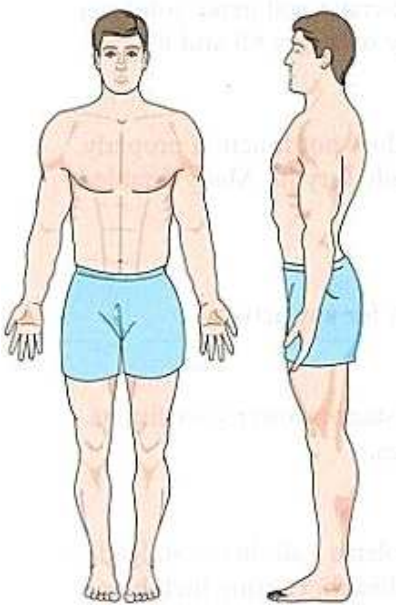
- soft body
- underdeveloped muscles
- round shaped
- over-developed digestive system

Associated personality traits:

- love of food
- tolerant
- evenness of emotions
- love of comfort
- sociable
- good humored
- relaxed
- need for affection

2. Mesophorphy - Focused on musculature & circulatory system (Mesoderm), has the tendency towards muscularity, corresponds to the somatotonia. Temperament courageous, energetic, active, dynamic, assertive, aggressive, risk taker.

Mesomorphic Body Type



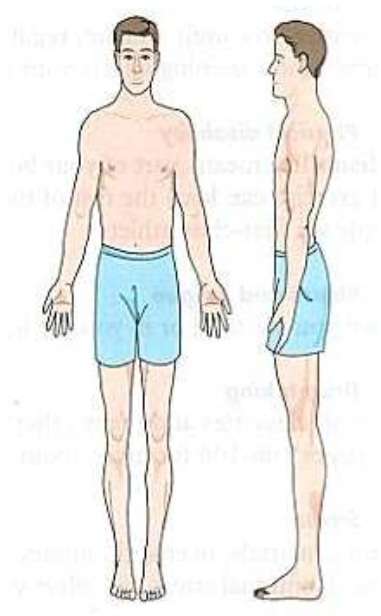
- hard, muscular body
- overly mature appearance
- rectangular shaped
- thick skin
- upright posture

Associated personality traits:

- adventurous
- desire for power and dominance
- courageous
- indifference to what others think or want
- assertive, bold
- zest for physical activity
- competitive
- love of risk and chance

3. Ectomorphy - Focused on the nervous system and the brain (ectoderm) – the tendency towards slightness, corresponds to cerebrotonia, Temperament - artistic, sensitive, introvert, apprehensive.

Ectomorphic Body Type



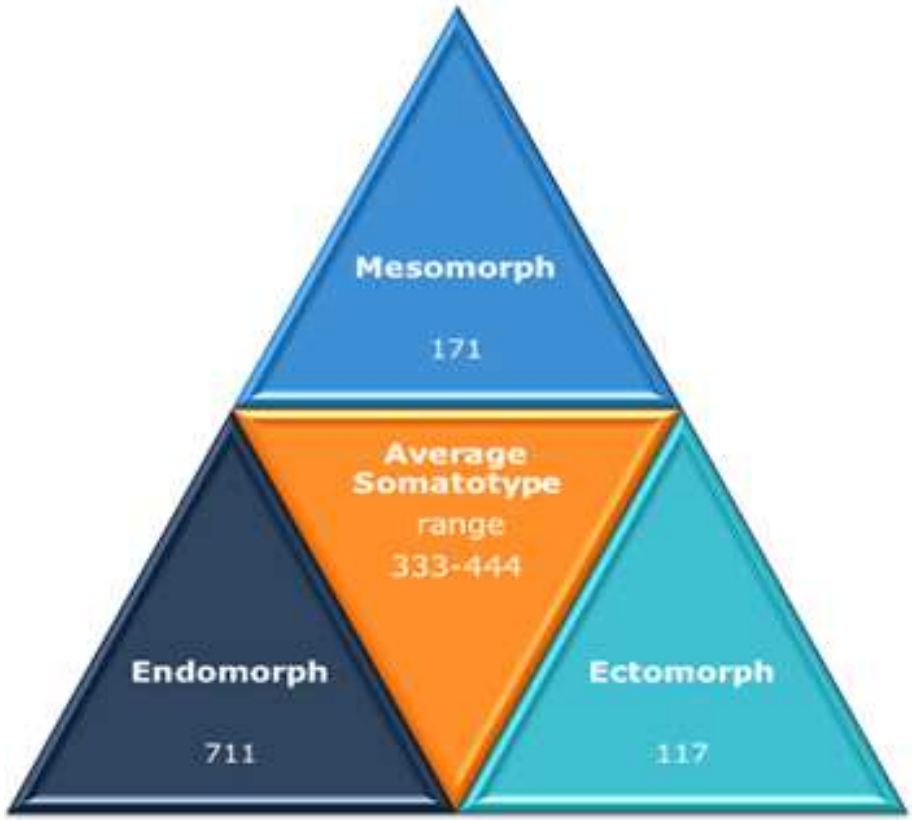
- **Thin**
- **Flat chest**
- **Delicate build**
- **Young Appearance**
- **Tall Lightly Muscled**
- **Stoop shouldered**
- **Large brain**

Associated personality traits

- **Self Conscious**
- **Preference of privacy**
- **Introvert**
- **Inhibited**
- **Socially anxious**
- **Artistic**
- **Mentally tense**
- **Emotionally restrained**

The activity types of the three somatotypes namely Endomorph, Mesomorph & Ectomorph differ from each other.

Most of us reflect a dominant somatotype in our anatomy, we each possess qualities of the other 2. The average individual is deemed to stand in the central region of the somatotype triangle (below), somewhere between 333 and 444 (Heath-Carter method).



The first digit corresponded to the degree of roundness or "endomorphy", the second to the extent of muscularity or "mesomorphy“ & the third to the stringiness or "ectomorphy." Accordingly, a person with extreme muscular tendencies can be classified by the number 171. Individuals displaying rounder Endomorph tendencies would be classified as 711, while those showing extreme Ectomorph characteristics would be classified by the number 117.

The different somatotypes are not only distinguishable by the length, shape and density of the bones, muscles and lengths of the tendons, but also by individual metabolic tendencies and physiological constitutions.

Percentile

A percentile is best described as a comparison score. It is a common term in all kinds of testing data. Unlike percentages where you are given a percent number that is related to only your performance, percentiles relate the number to the performance usually of hundred similar candidates/ cases.

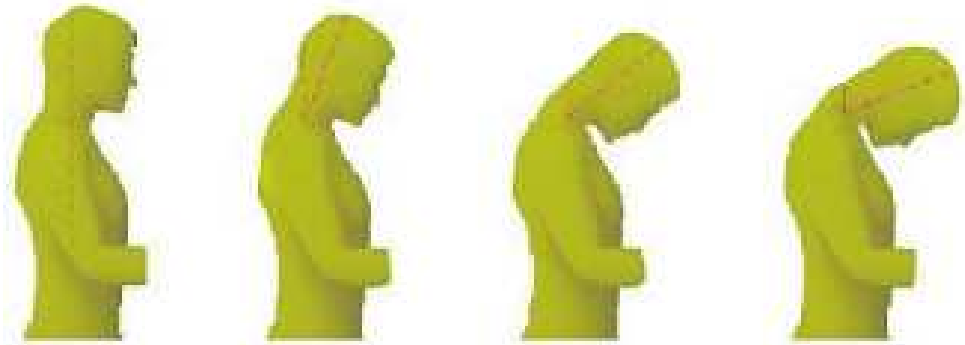
Or in other words A percentage scale from 0 to 100 that is associated with an item to show which percentage of the distribution is above and below the item.

In other words A percentile (or centile) is the value of a variable below which a certain percent of observations fall. So the 20th percentile is the value (or score) below which 20 percent of the observations may be found. A score at the 95th percentile is equal to or better than 95 percent of the scores.

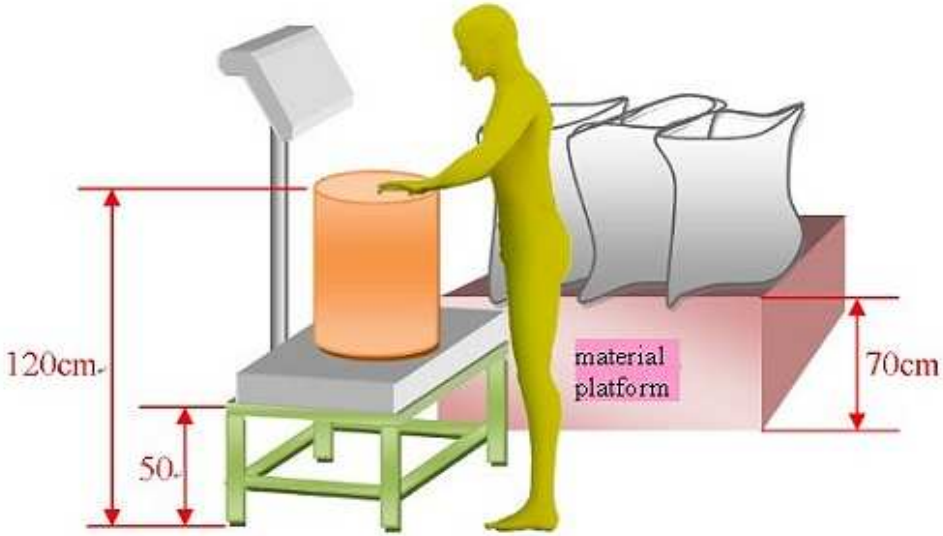
Biomechanical background

In biomechanics, the physical laws of mechanics are applied to the human body.
It is thereby possible to estimate the local mechanical stress on muscles and joints which occurs while adopting a posture or making a movement. A few biomechanical principles of importance to the ergonomics of posture and movement are outlined below.

- Joints may be in neutral position

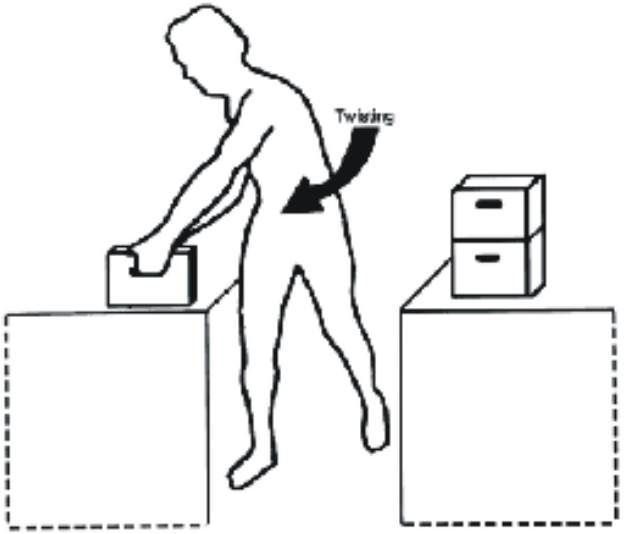


- Keep the work close to



- Avoid bending forward

- A twisted trunk strains the back



Physiological Background

In physiology, estimates are made of the energy demands on the heart and lungs resulting from muscular effort during movements. General body fatigue can develop from carrying out physical tasks over a long period. The limiting factor here is the amount of energy which the heart and lungs can supply to the muscles to allow postures to be retained.

Postures and movements

Posture is often imposed by the task or the workplace. Prolonged postures can in time lead to complaints of muscles and joints.

Work with keyboard and input device (mouse, trackball, touchpad) at your elbow height for straight (neutral) wrist positions.

Keyboard Below Elbow Height – Incorrect

Keyboard at Elbow Height– Correct

Assure keyboard remains flat for straight (neutral) wrist positions. Lower flippers on back side of the keyboard.

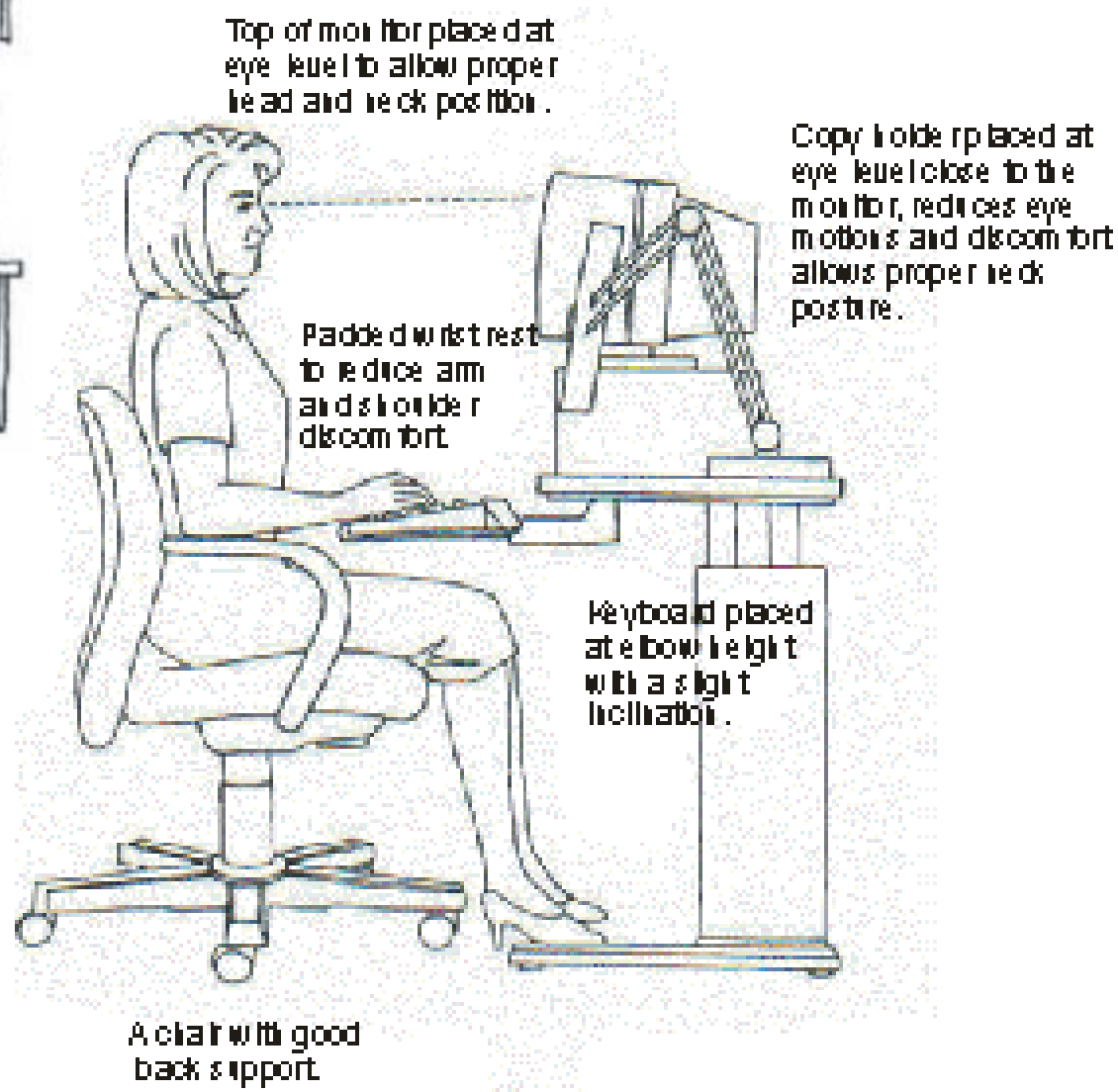
Keyboard Legs Up, Wrists Bent–Incorrect

Keyboard flat, Wrists Straight - Correct

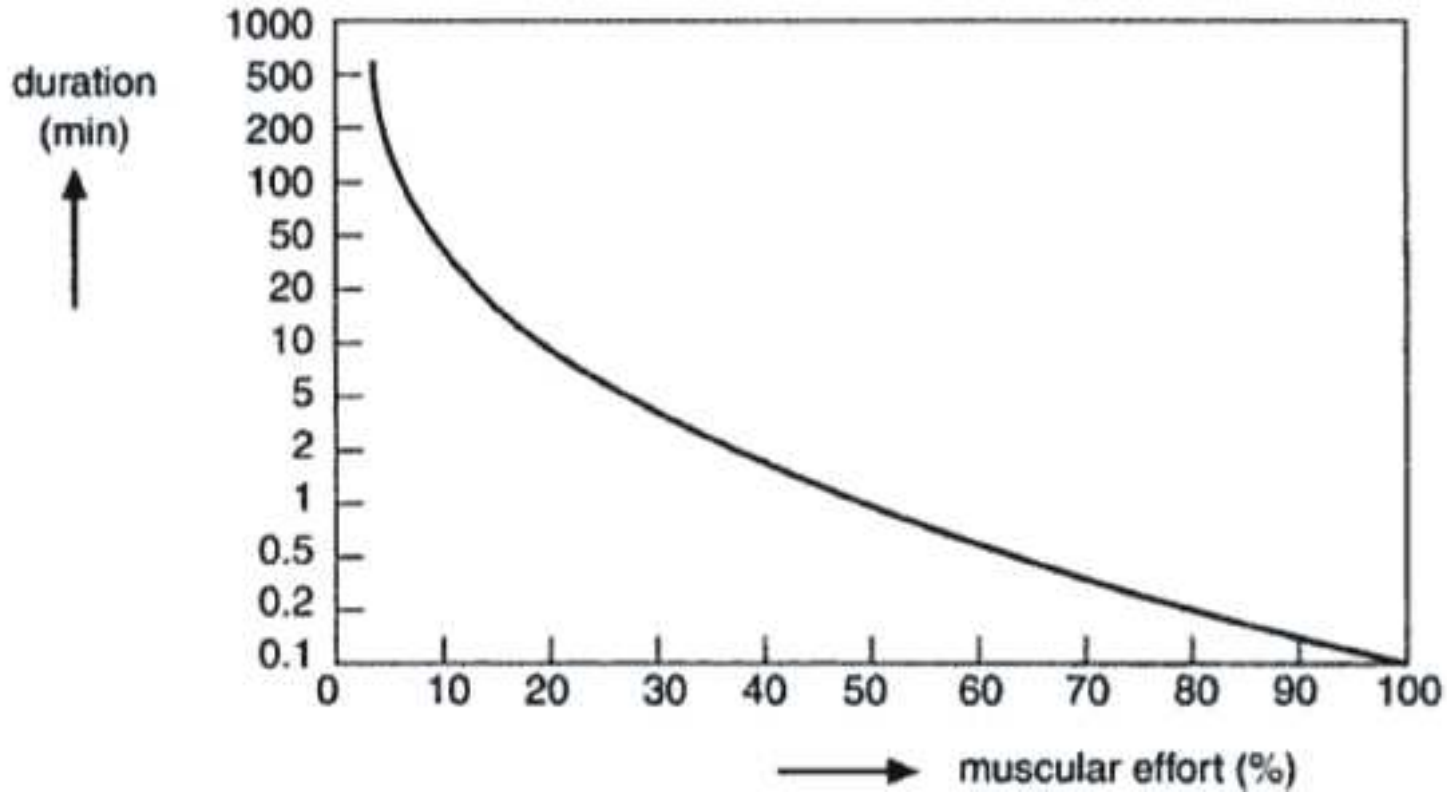
Postures and movements play central role in ergonomics. At work and in everyday life, postures and movements are often imposed by the task and workplace. The body's muscles, joints and ligaments are involved in adopting a posture, carrying out a movement or applying a force. The muscles provide the force necessary to adopt a posture or to make a movement. The ligaments, on the other hand, have an auxiliary function, while the joints allow the relative movement of the various parts of the body. Poor posture and movement can lead to local mechanical stress, on muscles, ligaments and joints, resulting in complaints in various parts of musculoskeletal system.

Bad postures examples

Working in neutral

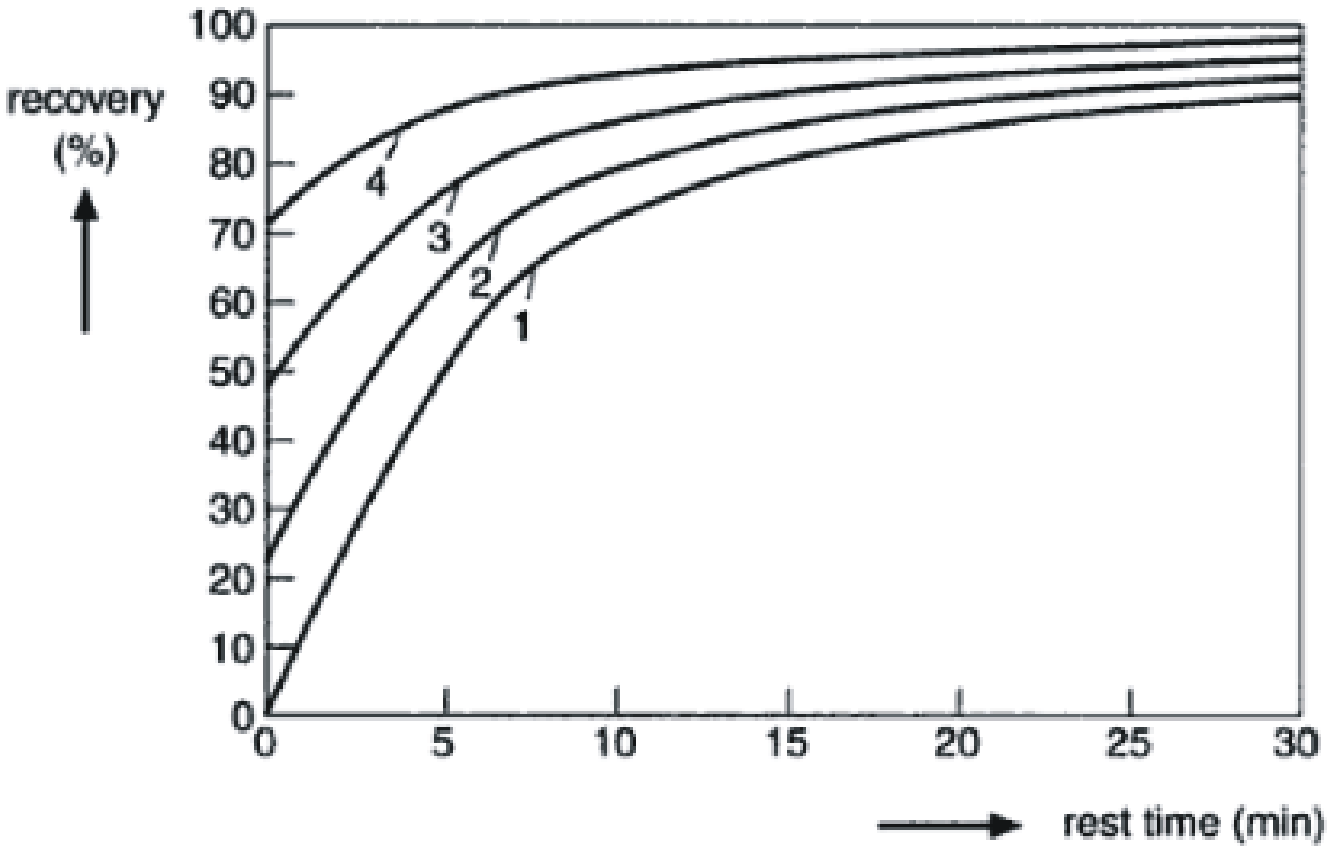


Exerted force as a percentage of maximum force versus maximum possible duration.



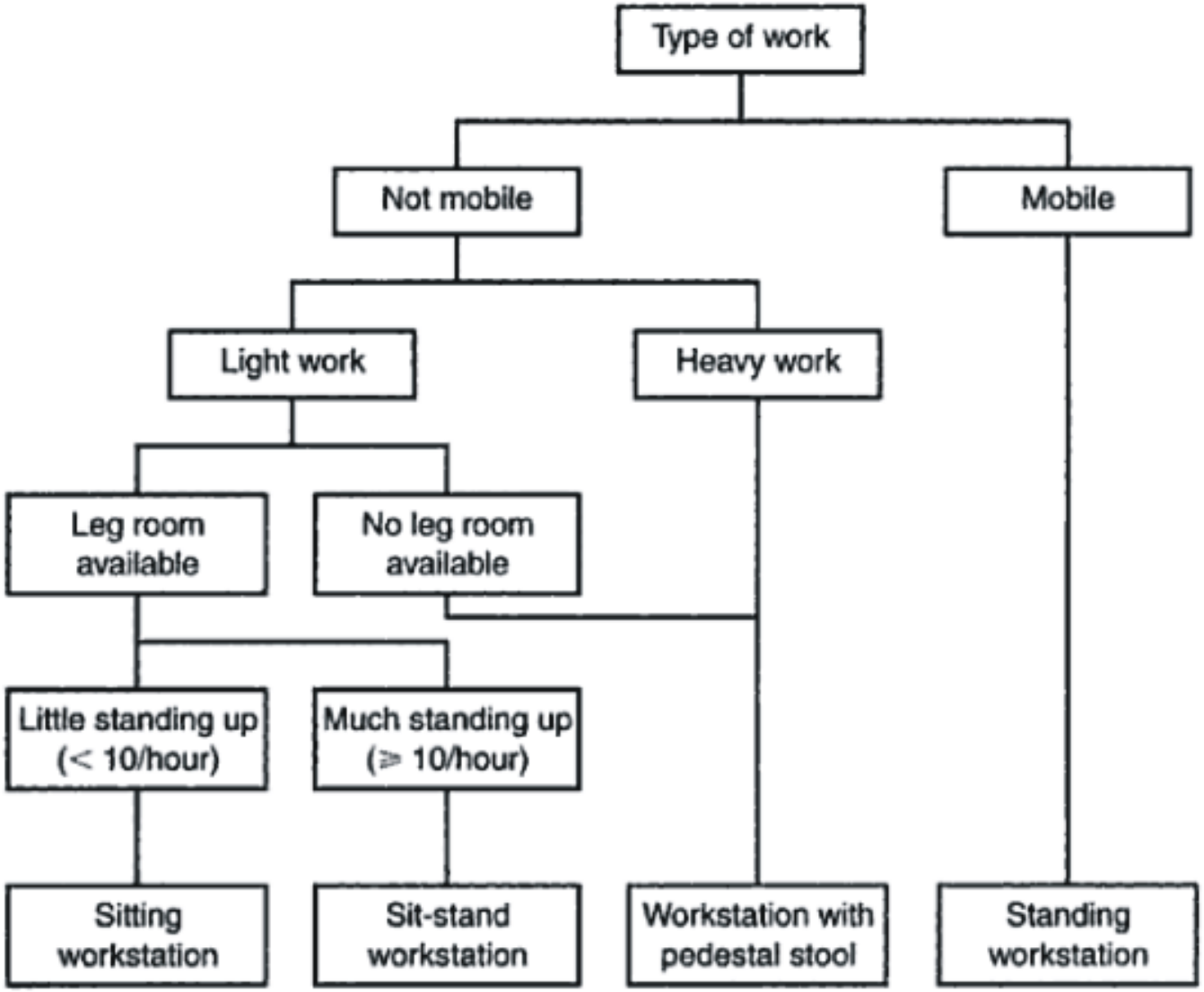
The duration of the continuous localized muscular effort must be limited. The figure shows the relationship between muscular effort (extended force as a percentage of maximum force) and the maximum possible duration (in mins) of any continuous muscular effort.

Muscle recovery in percentages versus rest time



Recovery curves for muscles which have been exhausted (curve 1) or partially exhausted (curves 2-4) after continuous muscular effort.
The graph is an example of recovery curves after a muscle has been partially or totally exhausted from continuous effort. In this example an exhausted muscle needs to rest for 30 mins to achieve a 90% recovery. Muscles in a half exhausted state will recover to the same degree after 15 mins. Complete recovery can take many hours.

The table below provides a selection procedure for the best basic posture.



What are work related musculoskeletal disorders (WMSDs)?

The general term “musculoskeletal disorders” describes the following:

a. Disorders of muscles, nerves, tendons, ligaments, joints, cartilage, or spinal discs.

b. Disorders that are not typically the result of any instantaneous or acute event (such as a slip, trip or fall) but reflect a more gradual or chronic development (nevertheless acute events such as slips and trips are very common causes of musculoskeletal problems such as low back pain).

c. Disorders defined primarily by the location of the pain (i.e. low back pain).

The term “WMSDs” refer to –

1. musculoskeletal disorders to which the work environment and the performance of the work contribute significantly, or
2. musculoskeletal disorders that are made worse or longer lasting by working conditions.

Environmental Factors

Physical and chemical environmental factors such as noise, vibration, lighting, climate and chemical substances can affect people's safety, health, comfort and performance.

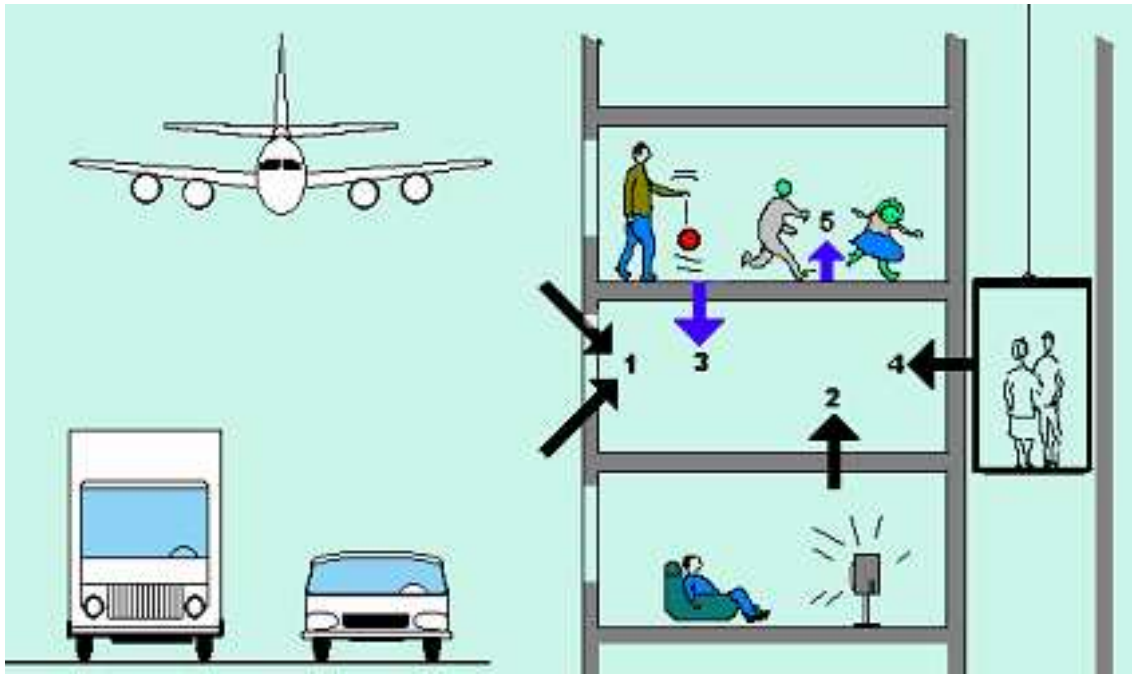
In general three types of measure can be applied to reduce or eliminate the adverse effects of environmental factors:

- At source (eliminate or reduce source)
- In the transmission between source and man (isolate source and/or man)
- At the individual level (reduction of exposure duration, personal protective equipment)

Muscles fatigue faster in hot conditions and gripping objects or tools can become difficult to maintain with sweaty palms. Alternating between tasks, or taking more frequent breaks from the task may be required when working in hot weather or confined spaces.
In cold conditions, blood flow to the extremities is reduced and consequently muscle performance is reduced. Wearing appropriate clothing and warming up the working muscles with light exercise before commencing the work duties may minimize the impact of cold weather.

Noise

The presence of high noise levels during a task can be annoying and, in time, result in impaired hearing. The first symptom of impaired hearing is a perceived difficulty in understanding speech in a noisy environment (party, pub, etc.). Annoyance, such as interference in communication or reduction of concentration, can occur even at relatively low noise levels. Annoyance and impaired hearing can be avoided by setting upper limits for noise levels.

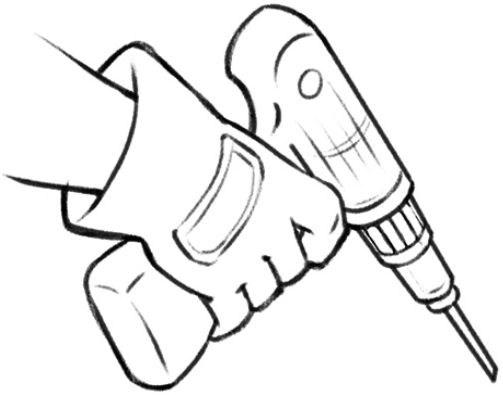


1. External air borne noise
2. Internal air borne noise
3. *Transmitted impact noise*
4. Equipment noise
5. *noise induced by a walk i.e. impact noise from type of floor covering installed in the room*

Vibration

In any discussion of vibration, a distinction has to be made between whole-body vibration and hand–arm vibration. In whole-body vibration, the whole body is brought into vibration via the feet (in standing work) or via the seat (in seated work). Usually, the vibration is predominantly vertical, such as in vehicles. Hand–arm vibration affects only the hands and arms, and often arises when using motorized handheld tools.

The blood supply to vibrating areas of the body is reduced, which reduces the ability of the muscles to contract and leads to more rapid fatigue. Whole body vibration is experienced by operators of vehicles, particularly heavy vehicles. Hand-arm vibration occurs in workers using vibrating or impact tools such as rattle guns, drills or hammers.

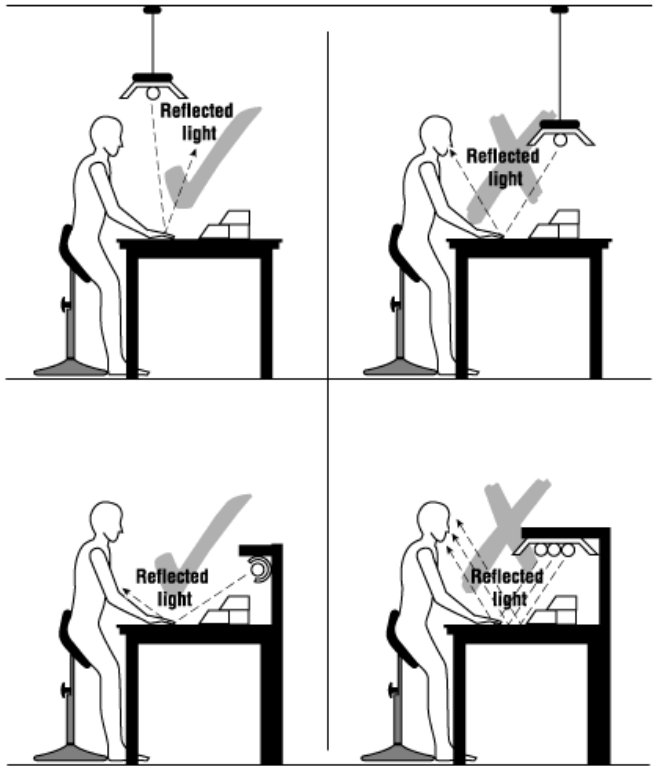


Illumination

Illumination can affect a person's performance and well-being. The light intensity, which is the amount of light that falls on the work surface, must be sufficiently high whenever visual tasks have to be carried out rapidly and with precision and ease. Apart from light intensity, the differences in luminance (contrast) in the visual field are also important. Luminance is the amount of light reflected back to the eyes from the surface of objects in the visual field. The color of the light and the presence of daylight can affect a person's mood and therefore performance.

The amount of light we need varies and depends on:

* the type of task being done (such as demands for speed and accuracy),
* type of surfaces (does it reflect or absorb light),
* the general work area, and
* the individual's vision.



Chemical Substances

Chemical substances occur in the environment as liquids, gases, vapors, dusts or solids. Some substances can cause discomfort or present a health hazard if inhaled or ingested or if they come into contact with the skin or eyes.

Silica is a common, naturally-occurring crystal. Silica is a main component of sand, so glass workers and sand-blasters also receive heavy exposure to silica. Risk factors include any work that includes exposure to silica dust. Mining, stone cutting, quarrying, road and building construction, work with abrasives manufacturing, sand blasting and many other occupations and hobbies involve exposure to silica.

Inhaling finely divided crystalline silica dust in very small quantities over time can lead to silicosis, bronchitis or (much more rarely) cancer as the dust becomes lodged in the lungs and continuously irritates them, reducing lung capacities (silica does not dissolve over time).

A cloud of dust engulfs a group of Chinese workers shoveling coal at a coal mine. China is the world's leader of sulphur dioxide emissions, up to 90 per cent of which are as a result of coal.

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