1. **Biomechanics** 
   1. **Introduction**

**Biomechanics** is the application of mechanical principles to living organisms. This includes [bioengineering](http://en.wikipedia.org/wiki/Bioengineering), the research and analysis of the [mechanics](http://en.wikipedia.org/wiki/Mechanics) of living [organisms](http://en.wikipedia.org/wiki/Organism) and the application of engineering principles to and from biological systems. This research and analysis can be carried forth on multiple levels, from the [molecular](http://en.wikipedia.org/wiki/Molecule), wherein [biomaterials](http://en.wikipedia.org/wiki/Biomaterials) such as [collagen](http://en.wikipedia.org/wiki/Collagen) and [elastin](http://en.wikipedia.org/wiki/Elastin) are considered, all the way up to the tissue and organ level. Some simple applications of [Newtonian mechanics](http://en.wikipedia.org/wiki/Classical_mechanics) can supply correct approximations on each level, but precise details demand the use of [continuum mechanics](http://en.wikipedia.org/wiki/Continuum_mechanics).

It has been shown that applied [loads](http://en.wikipedia.org/wiki/Load) and [deformations](http://en.wikipedia.org/wiki/Deformation_%28engineering%29) can affect the properties of living tissue. There is much research in the field of growth and remodeling as a response to applied loads. For example, the effects of elevated [blood pressure](http://en.wikipedia.org/wiki/Blood_pressure) on the mechanics of the [arterial](http://en.wikipedia.org/wiki/Artery) wall, the behavior of [cardiomyocytes](http://en.wikipedia.org/wiki/Cardiac_muscle) within a heart with a cardiac [infarct](http://en.wikipedia.org/wiki/Infarct), and [bone](http://en.wikipedia.org/wiki/Bone) growth in response to exercise, and the acclimative growth of plants in response to wind movement, have been widely regarded as instances in which living tissue is remodeled as a direct consequence of applied loads.

**1.2. History**

[Aristotle](http://en.wikipedia.org/wiki/Aristotle) wrote the first book on biomechanics, *De Motu Animalium*, or [On the Movement of Animals](http://en.wikipedia.org/wiki/On_the_Movement_of_Animals). He not only saw animals' bodies as mechanical systems, but pursued questions such as the physiological difference between imagining performing an action and actually doing it. Some simple examples of biomechanics research include the investigation of the forces that act on limbs, the [aerodynamics](http://en.wikipedia.org/wiki/Aerodynamics) of [bird](http://en.wikipedia.org/wiki/Bird_flight) and [insect](http://en.wikipedia.org/wiki/Insect) [flight](http://en.wikipedia.org/wiki/Flight), the [hydrodynamics](http://en.wikipedia.org/wiki/Hydrodynamics) of [swimming](http://en.wikipedia.org/wiki/Aquatic_locomotion) in [fish](http://en.wikipedia.org/wiki/Fish), and [locomotion](http://en.wikipedia.org/wiki/Animal_locomotion) in general across all forms of life, from individual [cells](http://en.wikipedia.org/wiki/Cell_%28biology%29) to whole [organisms](http://en.wikipedia.org/wiki/Organism). The biomechanics of [human](http://en.wikipedia.org/wiki/Human) beings is a core part of [kinesiology](http://en.wikipedia.org/wiki/Kinesiology).

**1.3. Applications**

The study of biomechanics ranges from the inner workings of a [cell](http://en.wikipedia.org/wiki/Cell_%28biology%29) to the movement and development of [limbs](http://en.wikipedia.org/wiki/Limb_%28anatomy%29), to the mechanical properties of [soft tissue](http://en.wikipedia.org/wiki/Soft_tissue), and [bones](http://en.wikipedia.org/wiki/Bone). As we develop a greater understanding of the physiological behavior of living tissues, researchers are able to advance the field of [tissue engineering](http://en.wikipedia.org/wiki/Tissue_engineering), as well as develop improved treatments for a wide array of [pathologies](http://en.wikipedia.org/wiki/Pathology).

Biomechanics is also applied in studying human muscle skeleton systems. In recent years, research applied force platform to study human joint reaction forces, 3D human movement. Human motion is also captured through the human [Motion capture](http://en.wikipedia.org/wiki/Motion_capture) systems (e.g. Vicon systems) to study human 3D motion. With the help of force platform and vicon systems. It is possible to study the human muscle skeleton behavior, including joint reaction forces, human postural control etc. Research also applies [Electromyography](http://en.wikipedia.org/wiki/Electromyography) (EMG) system to study the muscle activation. By this, it is feasible to investigate the muscle responses to the external forces as well as perturbations.

**1.4. Continuum mechanics**

It is often appropriate to model living tissues as [continuous media](http://en.wikipedia.org/wiki/Continuous_media). For example, at the tissue level, the arterial wall can be modeled as a [continuum](http://en.wikipedia.org/wiki/Continuum_mechanics). This assumption breaks down when the [length scales](http://en.wikipedia.org/wiki/Length_scale) of interest approach the order of the micro structural details of the material. The basic postulates of continuum mechanics are conservation of [linear](http://en.wikipedia.org/wiki/Linear_momentum) and [angular momentum](http://en.wikipedia.org/wiki/Conservation_of_angular_momentum), [conservation of mass](http://en.wikipedia.org/wiki/Conservation_of_mass), [conservation of energy](http://en.wikipedia.org/wiki/Conservation_of_energy), and the [entropy](http://en.wikipedia.org/wiki/Entropy) inequality. Solids are usually modeled using "reference" coordinates, whereas fluids are often modeled using "spatial" coordinates. Using these postulates and some assumptions regarding the particular problem at hand, a set of equilibrium equations can be established. The [kinematics](http://en.wikipedia.org/wiki/Kinematics) and [constitutive relations](http://en.wikipedia.org/wiki/Constitutive_relation) are also needed to model a continuum.

Second and fourth order tensors are crucial in representing many quantities in electromechanical. In practice, however, the full tensor form of a fourth-order constitutive matrix is rarely used. Instead, simplifications such as [isotropy](http://en.wikipedia.org/wiki/Isotropy), [transverse isotropy](http://en.wikipedia.org/wiki/Transverse_isotropy), and [incompressibility](http://en.wikipedia.org/wiki/Incompressibility) reduce the number of independent components. Commonly-used second-order tensors include the [Cauchy stress tensor](http://en.wikipedia.org/wiki/Cauchy_stress_tensor), the second [Piola-Kirchhoff stress tensor](http://en.wikipedia.org/wiki/Piola-Kirchhoff_stress_tensor), the [deformation gradient tensor](http://en.wikipedia.org/w/index.php?title=Deformation_gradient_tensor&action=edit&redlink=1), and the [Green strain tensor](http://en.wikipedia.org/w/index.php?title=Green_strain_tensor&action=edit&redlink=1). A reader of the mechanic's literature would be well-advised to note precisely the definitions of the various tensors which are being used in a particular work.

**1.5. Circulation**

Under most circumstances, [blood](http://en.wikipedia.org/wiki/Blood) flow can be modeled by the [Navier-Stokes equations](http://en.wikipedia.org/wiki/Navier-Stokes_equations). Whole blood can often be assumed to be an incompressible [Newtonian fluid](http://en.wikipedia.org/wiki/Newtonian_fluid). However, this assumption fails when considering flows within arterioles. At this scale, the effects of individual red blood cells becomes significant, and whole blood can no longer be modeled as a continuum. When the diameter of the blood vessel is slightly larger than the diameter of the red blood cell the [Fahraeus–Lindquist effect](http://en.wikipedia.org/wiki/Fahraeus%C3%A2%C2%80%C2%93Lindquist_effect) occurs and there is a decrease in wall [shear stress](http://en.wikipedia.org/wiki/Shear_stress). However, as the diameter of the blood vessel decreases further, the red blood cells have to squeeze through the vessel and often can only pass in single file. In this case, the inverse Fahraeus–Lindquist effect occurs and the wall shear stress increases.

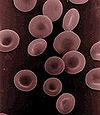


Fig: Red blood cells

**1.6. Bones**

Bones are [anisotropic](http://en.wikipedia.org/wiki/Anisotropic) but are approximately [transversely isotropic](http://en.wikipedia.org/w/index.php?title=Pivotal_isotropy&action=edit&redlink=1). In other words, bones are stronger along one axis than they are along a pivotal (i.e., normal or orthogonal) axis, and are approximately the same strength no matter how they are rotated around the one axis.

The stress-strain relations of bones can be modeled using [Hooke's law](http://en.wikipedia.org/wiki/Hooke%27s_law), in which they are related by [elastic moduli](http://en.wikipedia.org/wiki/Elastic_moduli), e.g., [Young's modulus](http://en.wikipedia.org/wiki/Young%27s_modulus), [Poisson's ratio](http://en.wikipedia.org/wiki/Poisson%27s_ratio) or the [Lamé parameters](http://en.wikipedia.org/wiki/Lam%C3%83%C2%A9_parameters). The constitutive matrix, a fourth-order [tensor](http://en.wikipedia.org/wiki/Tensor), depends on the isotropy of the bone.

σ*ij* = *Cijkl*ε*kl*

**1.7. Muscle**

There are three main types of muscles:

* [**Skeletal muscle**](http://en.wikipedia.org/wiki/Skeletal_muscle) **(striated):** Unlike cardiac muscle, skeletal muscle can develop a sustained condition known as [tetany](http://en.wikipedia.org/wiki/Tetany_%28action_potential_summation%29) through high frequency stimulation, resulting in overlapping twitches and a phenomenon known as wave summation. At a sufficiently high frequency, tetany occurs, and the contracticle force appears constant through time. This allows skeletal muscle to develop a wide variety of forces. This muscle type can be voluntary controlled. [Hill's Model](http://en.wikipedia.org/wiki/Hill%27s_Model) is the most popular model used to study muscle.
* [**Cardiac muscle**](http://en.wikipedia.org/wiki/Cardiac_muscle) **(striated):** Cardiomyocytes are a highly specialized cell type. These involuntarily contracted cells are located in the heart wall and operate in concert to develop synchronized beats. This is attributable to a refractory period between twitches.
* [**Smooth muscle**](http://en.wikipedia.org/wiki/Smooth_muscle) **(smooth - lacking striations):** The stomach, vasculature, and most of the digestive tract are largely composed of smooth muscle. This muscle type is involuntary and is controlled by the enteric nervous system.

**1.8. Soft tissues**

Soft [tissues](http://en.wikipedia.org/wiki/Biological_tissue) such as [tendon](http://en.wikipedia.org/wiki/Tendon), [ligament](http://en.wikipedia.org/wiki/Ligament) and [cartilage](http://en.wikipedia.org/wiki/Cartilage) are combinations of matrix proteins and fluid. In each of these tissues the main strength bearing element is collagen, although the amount and type of collagen varies according to the function each tissue must perform. Elastin is also a major load-bearing constituent within skin, the vasculature, and connective tissues. The function of tendons is to connect muscle with bone and is subjected to tensile loads. Tendons must be strong to facilitate movement of the body while at the same time remaining compliant to prevent damage to the muscle tissues. Ligaments connect bone to bone and therefore are stiffer than tendons but are relatively close in their tensile strength. Cartilage, on the other hand, is primarily loaded in compression and acts as a cushion in the joints to distribute loads between bones. The compressive strength of cartilage is derived mainly from collagen as in tendons and ligaments, however because collagen is comparable to a "wet noodle" it must be supported by cross-links of glycosaminoglycans that also attract water and create a nearly incompressible tissue capable of supporting compressive loads.

Recently, research is growing on the biomechanics of other types of soft tissues such as skin and internal organs. This interest is spurred by the need for realism in the development of medical [simulation](http://en.wikipedia.org/wiki/Simulation).

**1.9. Viscoelasticity**

[Viscoelasticity](http://en.wikipedia.org/wiki/Viscoelasticity) is readily evident in many soft tissues, where there is energy dissipation, or hysteresis, between the loading and unloading of the tissue during mechanical tests. Some soft tissues can be [preconditioned](http://en.wikipedia.org/wiki/Preconditioning) by repetitive cyclic loading to the extent where the [stress-strain curves](http://en.wikipedia.org/wiki/Stress-strain_curve) for the loading and unloading portions of the tests nearly overlap. The most commonly used model for viscoelasticity is the Quasilinear Viscoelasticity theory (QLV). In addition, soft tissues exhibit other viscoelastic properties, including creep, stress relaxation, and preconditioning.

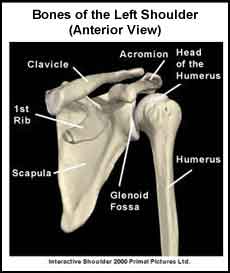
**1.10. Nonlinear theories**

[Hooke's law](http://en.wikipedia.org/wiki/Hooke%27s_law) is linear, but many, if not most problems in biomechanics, involve highly nonlinear behavior, particularly for soft tissues. Proteins such as collagen and elastin, for example, exhibit such a behavior. Some common material models include the Neo-Hookean behavior, often used for modeling elastin, and the famous Fung-elastic exponential model. Non linear phenomena in the biomechanics of soft tissue arise not only from the material properties but also from the very large strains (100% and more) that are characteristic of many problems in soft tissues.

1. **Shoulder biomechanics**

**2.1 Overview**

The shoulder is composed of three bones: the clavicle (collar bone), the scapula (shoulder blade), and the humerus (long bone of the upper arm). The rotator cuff surrounds the shoulder and provides muscular stability for the humeral head. The shoulder blade controls shoulder motion. Nine of the fifteen muscles that attach to the scapula provide this motion.

There are three joints in the shoulder complex. The main joint is the glenohumeral joint. It is a ball and socket (modified ovoid) joint and it is the most mobile joint in the body. The top of the humerus is shaped like a ball and it sits in a socket on the end of the scapula. The ball is called the head of the humerus and the socket is called the glenoid fossa, hence the term "glenohumeral" joint.

The other two joints in the shoulder complex are the sternoclavicular joint and the acromioclavicular joint. The sternoclavicular joint connects the inner (medial) part of the collarbone (clavicle) to the breastbone (sternum). The acromioclavicular joint connects the outer (lateral) part of the clavicle to a projection at the top of the shoulder blade (scapula) called the acromion process. The scapula sits on the ribs and moves as the arm moves.

The movements of the glenohumeral joint include forward lifting of the arm (flexion), backward lifting of the arm (extension), inward (internal) rotation, outward (external) rotation, movement of the arm away from the body (abduction) and movement of the arm towards the body.

The muscles of the shoulder complex provide stability and movement. During shoulder movements such as lifting, certain muscle groups help to move the shoulder, while other muscle groups help to stabilize the shoulder complex. Much of the stability in the shoulder complex is provided by this muscular coordination.

Poor posture, muscle weakness or ligament injury can lead to abnormal biomechanics of the shoulder, which can result in abnormal forces in the shoulder. Over time these abnormal forces can cause injury to the soft tissues or the articular cartilage of the glenohumeral joint.

# Reducing Joint Forces: Ergonomic Principles for Preventing Shoulder Pain/Arthritis

**Injury Prevention Principles for the Shoulder Joint/Joint Protection Concepts for Arthritis:**

1. Reduce High Repetition. Reducing high repetition will both reduce tissue stress and allow increased blood flow to the working muscle tissues, thus preventing tissue overload and microtrauma. This is especially critical in high stress activities such as; overhead lifting and reaching; forward lifting; forward reaching; and activities that require shoulder abduction and horizontal abduction positions.

2. Reduce Forceful exertions. Reducing forceful exertions will both reduce tissue stress and allow increased blood flow to the working muscle tissues, thus preventing tissue overload and microtrauma. The proper use of body mechanics is important to reduce the strain on the shoulder structures. Use the whole body and larger shoulder muscle groups to exert force and accomplish work tasks as opposed to using the smaller shoulder muscle groups or the shoulder joint only, when generating a force.

3. Reduce Static Work and Static Muscle Contractions. Reduce static work and static muscle contractions to allow increase blood flow to the working muscle tissues, thus preventing tissue overload and microtrauma. If static work is required, emphasize good posture and the use of the stronger, larger shoulder muscles. Rehabilitation should focus on the strength and endurance of the stabilizing muscles including the scapular stabilizers and the rotator cuff. If dynamic work is required, emphasize good posture and the use of the stronger, larger shoulder muscles. Rehabilitation should focus on the strength and endurance of the stabilizing muscles including the scapular stabilizers and the rotator cuff.

4. Dynamic Work-rest Cycles. Ensure dynamic work cycles are adequate to allow sufficient blood flow to working tissues to prevent tissue overload and microtrauma.

5. Reduce Postural Joint Forces and Awkward Positions. Reducing postural joint forces and awkward positions this will both reduce tissue and joint stress while allowing increased blood flow to the working muscle tissues, thus preventing tissue overload and microtrauma. For the shoulder joint, promote and maintain, as much as possible, the ideal positions of the shoulder joint that produce the least amount of exertion and compressive stresses to the joint and shoulder structures. Minimize lifting and reaching over 90 degrees of shoulder abduction, flexion and horizontal abduction. In addition, minimize shoulder extension activities beyond the midline. It is important to promote good postures of the neck, elbow and wrist joints, as awkward positions at adjoining joints may result in awkward positions and excessive tissue strain in the shoulder region. By minimizing the awkward postures at the joints above and below the shoulder joint, proper postures of the shoulder joint will be encouraged and therefore the risk for CTDs will be reduced.

Many shoulder injuries are the result of intrinsic mechanisms known as chronic repetitive micro- trauma. In this type of overuse injury, repetitive stresses

are occurring faster than the tissue can repair itself, leading to the accumulation of micro- trauma within the affected tissue. Injuries also occur as a result of extrinsic mechanisms, such as the application of high loads and the resulting stresses at the end range of motion of a limb. The type of muscle loading (concentric or eccentric) can also contribute to shoulder injuries with influence from either intrinsic or extrinsic mechanisms. Con centric contraction of a muscle is a shortening of the muscle as it contracts, producing acceleration of body segments. Eccentric muscle contractions, a lengthening of the muscle as it contracts, are crucial in preventing injury by decelerating body segments and providing shock absorption.

## Ergonomics

## Overview

**Ergonomics** is the science of designing the job, equipment, and workplace to fit the worker. Proper ergonomic design is necessary to prevent repetitive strain injuries, which can develop over time and can lead to long-term disability.

Ergonomics is a science concerned with the ‘fit’ between people and their work. It puts people first, taking account of their capabilities and limitations. Ergonomics aims to make sure that tasks, equipment, information and the environment suit each worker.

**To assess the fit between a person and their work, ergonomists have to consider many aspects. These include:**

■ The job being done and the demands on the worker.

■ The equipment used (its size, shape, and how appropriate it is for the task).

■ The information used (how it is presented, accessed, and changed).

■ The physical environment (temperature, humidity, lighting, noise, vibration) and

■ The social environment (such as teamwork and supportive management).

**Ergonomists consider all the physical aspects of a person, such as:**

■ Body size and shape.

■ Fitness and strength.

■ Posture.

■ The senses, especially vision, hearing and touch and

■ The stresses and strains on muscles, joints, nerves.

**Ergonomists also consider the psychological aspects of a person, such as:**

■ Mental abilities.

■ Personality.

■ Knowledge and

■ Experience.

**Health and Safety**

**Executive**

By assessing these aspects of people, their jobs, equipment, and working

environment and the interaction between them, ergonomists are able to design

safe, effective and productive work systems.

***The International Ergonomics Association defines ergonomics as follows.***

Ergonomics (or human factors) is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance.

Ergonomics is employed to fulfill the two goals of health and productivity. It is relevant in the design of such things as safe furniture and easy-to-use interfaces to machines.

Ergonomics is concerned with the ‘fit’ between people and their work. It takes account of the worker's capabilities and limitations in seeking to ensure that tasks, equipment, information and the environment suit each worker.

To assess the fit between a person and his work, ergonomists consider the job being done and the demands on the worker; the equipment used (its size, shape, and how appropriate it is for the task), and the information used (how it is presented, accessed, and changed). Ergonomics draws on many disciplines in its study of humans and their environments, including [anthropometry](http://en.wikipedia.org/wiki/Anthropometry), [biomechanics](http://en.wikipedia.org/wiki/Biomechanics), [mechanical engineering](http://en.wikipedia.org/wiki/Mechanical_engineering), [industrial engineering](http://en.wikipedia.org/wiki/Industrial_engineering), [industrial design](http://en.wikipedia.org/wiki/Industrial_design), [kinesiology](http://en.wikipedia.org/wiki/Kinesiology), [physiology](http://en.wikipedia.org/wiki/Physiology) and [psychology](http://en.wikipedia.org/wiki/Psychology).

Typically, an ergonomist will have a BA or BS in Psychology, Industrial/Mechanical Engineering or Health Sciences, and usually an MA, MS or PhD in a related discipline. Many universities offer Master of Science degrees in Ergonomics, while some offer Master of Ergonomics or Master of Human Factors degrees. In the 2000s, [occupational therapists](http://en.wikipedia.org/wiki/Occupational_therapists) have been moving into the field of ergonomics and the field has been heralded as one of the top ten emerging practice areas.

### Domains

The [International Ergonomics Association](http://en.wikipedia.org/wiki/International_Ergonomics_Association) (IEA) divides ergonomics broadly into three domains:

* **Physical ergonomics:** is concerned with human anatomical, and some of the anthropometric, physiological and biomechanical characteristics as they relate to physical activity. (Relevant topics include working postures, materials handling, repetitive movements, lifting, work related musculoskeletal disorders, workplace layout, safety and health.)
* [**Cognitive ergonomics**](http://en.wikipedia.org/wiki/Cognitive_ergonomics)**:** is concerned with mental processes, such as perception, memory, reasoning, and motor response, as they affect interactions among humans and other elements of a system. (Relevant topics include mental workload, decision-making, skilled performance, human-computer interaction, human reliability, work stress and training as these may relate to human-system design.)
* **Organizational ergonomics**: 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 of working times, teamwork, [participatory design](http://en.wikipedia.org/wiki/Participatory_Ergonomics), community ergonomics, cooperative work, new work programs, virtual organizations, telework, and quality management.

## History and etymology

The foundations of the science of ergonomics appear to have been laid within the context of the culture of [Ancient Greece](http://en.wikipedia.org/wiki/Ancient_Greece). A good deal of evidence indicates that Hellenic civilization in the 5th century BCE used ergonomic principles in the design of their tools, jobs, and workplaces. One outstanding example of this can be found in the description Hippocrates gave of how a surgeon's workplace should be designed and how the tools he uses should be arranged (see Marmaras, Poulakakis and Papakostopoulos, 1999). It is also true that archaeological records of the early Egyptians Dynasties made tools, household equipment, among others that illustrated ergonomic principles. It is therefore questionable whether the claim by Marmaras, et al., regarding the origin of ergonomics, can be justified (I G Okorji, 2009).

The term *ergonomics* is derived from the Greek words *ergon* [work] and *nomos* [natural laws] and first entered the modern lexicon when [Wojciech Jastrzębowski](http://en.wikipedia.org/wiki/Wojciech_Jastrz%C3%84%C2%99bowski) used the word in his 1857 article *Rys ergonomji czyli nauki o pracy, opartej na prawdach poczerpniętych z Nauki Przyrody* (The Outline of Ergonomics, i.e. Science of Work, Based on the Truths Taken from the Natural Science).

Later, in the 19th century, [Frederick Winslow Taylor](http://en.wikipedia.org/wiki/Frederick_Winslow_Taylor) pioneered the "[Scientific Management](http://en.wikipedia.org/wiki/Scientific_Management)" method, which proposed a way to find the optimum method for carrying out a given task. Taylor found that he could, for example, triple the amount of coal that workers were shoveling by incrementally reducing the size and weight of coal shovels until the fastest shoveling rate was reached. [Frank](http://en.wikipedia.org/wiki/Frank_Gilbreth) and [Lillian Gilbreth](http://en.wikipedia.org/wiki/Lillian_Moller_Gilbreth) expanded Taylor's methods in the early 1900s to develop "Time and Motion Studies". They aimed to improve efficiency by eliminating unnecessary steps and actions. By applying this approach, the Gilbreths reduced the number of motions in [bricklaying](http://en.wikipedia.org/wiki/Bricklaying) from 18 to 4.5, allowing bricklayers to increase their productivity from 120 to 350 bricks per hour.

[World War II](http://en.wikipedia.org/wiki/World_War_II) marked the development of new and complex machines and weaponry, and these made new demands on operators' cognition. The decision-making, attention, situational awareness and hand-eye coordination of the machine's operator became key in the success or failure of a task. It was observed that fully functional aircraft, flown by the best-trained pilots, still crashed. In 1943, [Alphonse Chapanis](http://en.wikipedia.org/wiki/Alphonse_Chapanis), a lieutenant in the U.S. Army, showed that this so-called "pilot error" could be greatly reduced when more logical and differentiable controls replaced confusing designs in airplane cockpits.

In the decades since the war, ergonomics has continued to flourish and diversify. The [Space Age](http://en.wikipedia.org/wiki/Space_Age) created new human factors issues such as weightlessness and extreme [g-forces](http://en.wikipedia.org/wiki/G-forces). How far could environments in space be tolerated, and what effects would they have on the mind and body? The dawn of the [Information Age](http://en.wikipedia.org/wiki/Information_Age) has resulted in the new ergonomics field of [human-computer interaction](http://en.wikipedia.org/wiki/Human-computer_interaction) (HCI). Likewise, the growing demand for and competition among [consumer goods](http://en.wikipedia.org/wiki/Consumer_goods) and [electronics](http://en.wikipedia.org/wiki/Electronics) has resulted in more companies including human factors in product design.

At home, work, or play new problems and questions must be resolved constantly. People come in all different shapes and sizes, and with different capabilities and limitations in strength, speed, judgment, and skills. All of these factors need to be considered in the design function. To solve design problems, physiology and psychology must be included with an engineering approach.

## Applications

More than twenty technical subgroups within the Human Factors and Ergonomics Society (HFES) indicate the range of applications for ergonomics. Human factors engineering continues to be successfully applied in the fields of [aerospace](http://en.wikipedia.org/wiki/Aerospace), aging, health care, [IT](http://en.wikipedia.org/wiki/Information_technology), product design, transportation, training, nuclear and virtual environments, among others. Kim Vicente, a University of Toronto Professor of Ergonomics, argues that the [nuclear disaster in Chernobyl](http://en.wikipedia.org/wiki/Chernobyl_disaster) is attributable to plant designers not paying enough attention to human factors. "The operators were trained but the complexity of the reactor and the control panels nevertheless outstripped their ability to grasp what they were seeing [during the prelude to the disaster]."

Physical ergonomics is important in the medical field, particularly to those diagnosed with physiological ailments or disorders such as [arthritis](http://en.wikipedia.org/wiki/Arthritis) (both chronic and temporary) or [carpal tunnel syndrome](http://en.wikipedia.org/wiki/Carpal_tunnel_syndrome). Pressure that is insignificant or imperceptible to those unaffected by these disorders may be very painful, or render a device unusable, for those who are. Many ergonomically designed products are also used or recommended to treat or prevent such disorders, and to treat pressure-related [chronic pain](http://en.wikipedia.org/wiki/Chronic_pain).

Human factors issues arise in simple systems and consumer products as well. Some examples include cellular telephones and other handheld devices that continue to shrink yet grow more complex (a phenomenon referred to as "creeping featurism"), millions of VCRs blinking "12:00" across the world because very few people can figure out how to program them, or alarm clocks that allow sleepy users to inadvertently turn off the alarm when they mean to hit 'snooze'. A [user-centered design](http://en.wikipedia.org/wiki/User-centered_design) (UCD), also known as a systems approach or the [usability engineering](http://en.wikipedia.org/wiki/Usability_engineering) lifecycle aims to improve the user-system.

### Design of ergonomics experiments

There is a specific series of steps that should be used in order to properly design an ergonomics experiment. First, one should select a problem that has practical impact. The problem should support or test a current theory. The user should select one or a few dependent variable(s) which usually measures safety, health, and/or physiological performance. Independent variable(s) should also be chosen at different levels. Normally, this involves paid participants, the existing environment, equipment, and/or software. When testing the users, one should give careful instructions describing the method or task and then get voluntary consent. The user should recognize all the possible combinations and interactions to notice the many differences that could occur. Multiple observations and trials should be conducted and compared to maximize the best results. Once completed, redesigning within and between subjects should be done to vary the data. It is often that permission is needed from the Institutional Review Board before an experiment can be done. A mathematical model should be used so that the data will be clear once the experiment is completed.

The experiment starts with a pilot test. Make sure in advance that the subjects understand the test, the equipment works, and that the test is able to be finished within the given time. When the experiment actually begins, the subjects should be paid for their work. All times and other measurements should be carefully measured and recorded. Once all the data is compiled, it should be analyzed, reduced, and formatted in the right way. A report explaining the experiment should be written. It should often display statistics including an ANOVA table, plots, and means of central tendency. A final paper should be written and edited after numerous drafts to ensure an adequate report is the final product.

### Ergonomics in the workplace

Fundamentals for the Flexible Workplace Variability and compatibility with desk components, that flex from individual work activities to team settings. Workstations provide supportive ergonomics for task-intensive environments.

Outside of the discipline itself, the term 'ergonomics' is generally used to refer to physical ergonomics as it relates to the workplace (as in for example ergonomic chairs and [keyboards](http://en.wikipedia.org/wiki/Ergonomic_keyboard)). Ergonomics in the workplace has to do largely with the safety of employees, both long and short-term. Ergonomics can help reduce costs by improving safety. This would decrease the money paid out in workers’ compensation. For example, over five million workers sustain overextension injuries per year. Through ergonomics, workplaces can be designed so that workers do not have to overextend themselves and the manufacturing industry could save billions in workers’ compensation.

Workplaces may either take the reactive or proactive approach when applying ergonomics practices. Reactive ergonomics is when something needs to be fixed, and corrective action is taken. Proactive ergonomics is the process of seeking areas that could be improved and fixing the issues before they become a large problem. Problems may be fixed through equipment design, task design, or environmental design. Equipment design changes the actual, physical devices used by people. Task design changes what people do with the equipment. Environmental design changes the environment in which people work, but not the physical equipment they use.

* 1. **Ergonomics Problems**

**Ergonomic problems** can be caused by both work-associated and non-work associated conditions can either individually, or by both interacting with each other.

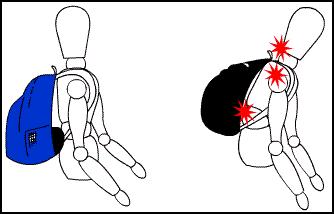
There are many ways to determine which is conditions of workplace can lead to Ergonomic Problems. The main risk for *Ergonomic problems* like [Repetitive Strain Injury](http://www.safecomputingtips.com/repetitive-strain-injury.html) and [Carpal Tunnel Syndrome](http://www.safecomputingtips.com/carpal-tunnel-syndrome.html) are the frequent repetitive motion tasks, awkward posture, vibrations, forceful movements, stress at workplace, poor workplace setup.

**3.8. The main causes of are:**

1. Awkward posture
2. Frequent repetitive motion tasks
3. Stress at workplace
4. Vibrations
5. Forceful movements
6. Poor workplace setup
7. Sitting in same posture for continuous long hours
8. Lower back support is inadequate

**3.9. Types of Ergonomic Problems**

1. [Musculoskeletal Disorders](http://www.safecomputingtips.com/musculoskeletal-disorders.html)
2. [Ergonomic Problem-Eye](http://www.safecomputingtips.com/ergonomic-problems-eye.html)
3. Repetitive Strain Injury
4. Carpal Tunnel Syndrome
5. Other Ergonomic Problems



## Fields of ergonomics

### Engineering psychology

***Engineering psychology*** is an interdisciplinary part of ergonomics and studies the relationships of people to machines, with the intent of improving such relationships. This may involve redesigning equipment, changing the way people use machines, or changing the location in which the work takes place. Often, the work of an engineering psychologist is described as making the relationship more "user-friendly."

Engineering psychology is an applied field of [psychology](http://en.wikipedia.org/wiki/Psychology) concerned with psychological factors in the design and use of equipment. [Human factors](http://en.wikipedia.org/wiki/Human_factors) is broader than engineering psychology, which is focused specifically on designing systems that accommodate the information-processing capabilities of the brain.

### Macroergonomics

Macroergonomics is an approach to ergonomics that emphasizes a broad system view of design, examining organizational environments, culture, history, and work goals. It deals with the physical design of tools and the environment. It is the study of the society/technology interface and their consequences for relationships, processes, and institutions. It also deals with the optimization of the designs of organizational and work systems through the consideration of personnel, technological, and environmental variables and their interactions. The goal of macroergonomics is a completely efficient work system at both the macro- and micro-ergonomic level which results in improved productivity, and employee satisfaction, health, safety, and commitment. It analyzes the whole system, finds how each element should be placed in the system, and considers all aspects for a fully efficient system. A misplaced element in the system can lead to total failure.

* + 1. **History**

Macroergonomics, also known as organizational design and management factors, deals with the overall design of work systems. This domain did not begin to receive recognition as a sub-discipline of ergonomics until the beginning of the 1980s. The idea and current perspective of the discipline was the work of the U.S. Human Factors Society Select Committee on the Future of Human Factors, 1980-2000. This committee was formed to analyze trends in all aspects of life and to look at how they would impact ergonomics over the following 20 years. The developments they found include:

1. Breakthroughs in technology that would change the nature of work, such as the desktop computer,
2. The need for organizations to adapt to the expectations and needs of this more mature workforce,
3. Differences between the post-World War II generation and the older generation regarding their expectations the nature of the new workplace,
4. The inability of solely microergonomics to achieve reductions in lost-time accidents and injuries and increases in productivity,
5. Increasing workplace liability litigation based on safety design deficiencies.

These predictions have become and continue to become reality. The macroergonomic intervention in the workplace has been particularly effective in establishing a work culture that promotes and sustains performance and safety improvements.

* + 1. **Methods**
* **Cognitive Walk-through Method:** This method is a usability inspection method in which the evaluators can apply user perspective to task scenarios to identify design problems. As applied to macroergonomics, evaluators are able to analyze the usability of work system designs to identify how well a work system is organized and how well the workflow is integrated.
* **Kansei Method:** This is a method that transforms consumer’s responses to new products into design specifications. As applied to macroergonomics, this method can translate employee’s responses to changes to a work system into design specifications.
* **High Integration of Technology, Organization, and People (HITOP**): This is a manual procedure done step-by-step to apply technological change to the workplace. It allows managers to be more aware of the human and organizational aspects of their technology plans, allowing them to efficiently integrate technology in these contexts.
* **Top Modeler:** This model helps manufacturing companies identify the organizational changes needed when new technologies are being considered for their process.
* **Computer-integrated Manufacturing, Organization, and People System Design (CIMOP):** This model allows for evaluating computer-integrated manufacturing, organization, and people system design based on knowledge of the system.
* **Anthropotechnology**: This method considers analysis and design modification of systems for the efficient transfer of technology from one culture to another.
* **Systems Analysis Tool (SAT):** This is a method to conduct systematic trade-off evaluations of work-system intervention alternatives.
* **Macroergonomic Analysis of Structure (MAS):** This method analyzes the structure of work systems according to their compatibility with unique sociotechnical aspects.
* **Macroergonomic Analysis and Design (MEAD):** This method assesses work-system processes by using a ten-step process.

**5. Ergonomics for School children**

* 1. **Children and Ergonomics**
* There is mismatch between a child’s body size and the size of adult furniture, computer equipment and books.
* Challenges presented by children:
* Range of body sizes.
* Rate of growth.
* Strength of capabilities.
* Cognitive characteristics.

**Range of body sizes**

* Different sizes of second grade children.
* In general, girls grow faster than boys.
* By age 7, girl’s bone size is 80% of their peak bone size

**Rate of Growth**

* Obesity in children has tripled from the 1960’s -1990’s:
* *Children aged 6-11 years increased from 4% -13%*
* *Children aged 12-19 years increased from 5% -14%*
* Prevalence of overweight children and adolescents in the United States:



**Strength Capabilities**

* Boys are stronger than girls by the age of 10
* By age 16, males are much stronger than females
* Maximum strength does not increase after the age of 16
* Children’s abilities are often over-estimated
* Children have smaller muscle fibre and slower muscle relaxation

**Cognitive Characteristics**

* Children want to do activities they enjoy, and tend to do these in excess:
  + *Sports*
  + *Surfing the web*
  + *Video games*
  + *Musical Instruments*
  + *Handwriting*

**School bags**

* In the United States, 40 million youth carry their school materials in backpacks.

• In 1999, the use of backpacks resulted in more than 6000 injuries in the United States.

• 23% of elementary students and 33% of secondary students complain of back aches.

• 60% of orthopedics report seeing children with pain caused by heavy backpack.

* Carrying schoolbags may contribute to low back pain in children.

• The maximum load should be 15% of body weight.

1. • Secondary school children carry backpacks around 7.0kg.
2. • High school students carry backpacks around 6.3kg.

* In one study, musculoskeletal symptoms were reported by 77.1% of students.
* The musculoskeletal system has limited rejuvenation possibilities.
* Damage that is inflicted in youth may show up years later in even more serious back injuries.

• Scientific studies have not yet been performed to show that backpacks cause permanent back damage.

* Factors that contribute to MSIs from school bags:
* *Heavier school bags*
* *Longer carriage durations*
* *Carrying additional bags*
* *Lack of access to lockers*
* **How heavy is too heavy?**

|  |  |
| --- | --- |
| **Person’s Weight (lb.)** | **Maximum Backpack Weight (lb.)** |
| 60 | 5 |
| 60-75 | 10 |
| 100 | 15 |
| 125 | 18 |
| 150 | 20 |
| 200 or more | 25\*\* |

\*\* No one should carry more than 25 lb.

**5.2 Backpacks**

Schools often have a uniform requirement, with backpacks which may carry the school badge or a preference in colour. Some children are very keen on strongly-marketed brand names. These bags are often quite expensive and may have a tendency to allow for some growth as an economic measure. This can be quite detrimental to the growing child.

* Carrying excessive weight in poorly-designed school bags can accelerate the onset of related pain and spinal injury.
* The recommended maximum weight for a child to carry is 10 per cent of their body weight.
* This weight should be carried with the heaviest items closest to the body and with the supporting straps done up to prevent sagging from the back.
* The base of the bag should not be below the line of the hips.

These recommendations followed a study by the University of South Australia and a five-year longitudinal study by the Centre for Allied Health, which resulted in the PhysiopakII being the only backpack endorsed by the Australian Physiotherapy Association (APA).

On starting kindergarten, many children use a backpack and will often add some of their own items to the pack. At this time, we should encourage the child to wear the backpack correctly — with a strap over each shoulder — and to unpack it at the end of the day, ready to be repacked the next day. This begins the early training of not just adding extra items in the bag, but making sure that each item is necessary for the day — and overcoming the messy business of stale fruit in the bottom of the bag!

The problem at upper-primary and high school level is compounded by the number of books which young people require during the day — there must be more discussion in schools about limiting this as much as possible. Repacking each night can also be a useful way of making sure that there is no forgotten weight in the bag.

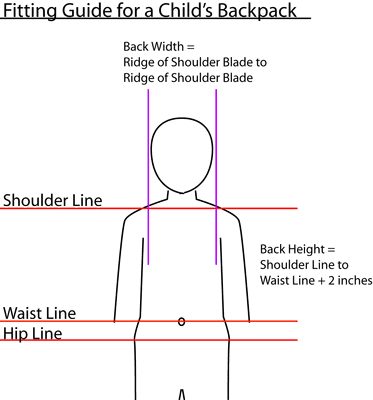
Nowadays, there is increasing concern about back pain in children, due to carrying unsuitable bags to and from school. We have to know that carrying these heavy loads in a poorly designed bag can cause lasting damage to the child’s back. We must ask ourselves why they have back pain: they are sitting for a long period at school, heavy bags, lack of exertion: decreased physical activities at school, poor eating habits, junk food, lack of sleeping etc...

Statistics show that students are sitting 1000h/year and carry a school bag around 300 to 400h/year. So imagine the damage if the children are not sitting in good posture and carrying their bags improperly. Luckily, children move a lot so they can easily recover. Thus prevention is the key. According to safety guidelines reported by the American Academy of Pediatrics, the maximum that a child should carry as a backpack should not exceed 10 % to 20 % of his body weight. No one should carry more than 25lbs in a backpack. Many Children are carrying up to 40lbs and above and they are hurting themselves. If children are feeling headaches, neck aches, bad posture, decreased performance, strained muscles, lower back pain, tingling hands, and increased scoliosis complications, they are carrying too much weight. They don’t have to carry any more weight than they have to. Also, how a child carries his bag is important to avoid strains and possible back injury. Using just one strap causes an imbalance of weight and adds stress to one side of the body. It also forces the wearer to adjust their posture in an uneven manner (slouching, bending… leading to traction on the back, rounding shoulders with difference in height and inclined head). Overall, there is imbalance between muscle strengths. And don’t forget the wheeled bags; the child thinks that he can put everything in it. Besides twisting while walking, how can he carry it up down the stairs? So shouldering it as he climbs to his class on the second floor, carrying also the extra weight of that rolling frame. Also consider that the more room in the pack the more stuff they will try to fit in it!



**Now, what’s an ergonomic bag and what do we need to know?**

* Size: the pack should not be larger than the child’s back. Max height is shoulder line + waist line (belly button) + 2 inches.
* Use both shoulder straps and pack belts.
* By wearing both straps and belts, the weight is distributed and proper posture is promoted, relieving pressure on the neck. Adjust the shoulder straps so that the pack is properly placed on the mid-section of the back. These straps have to be in midway between neck and shoulder joint. Loose straps will allow the pack to slip so insure that they are tight enough to stay in place. Tighten the shoulder straps so that the backpack hangs slightly below the shoulders with no more that 4 inches hanging below the waist line. The straps should be placed so that the child has free movement of their arms and do not have to struggle to remove the pack. Two wide, padded shoulder straps - straps that are too narrow can dig into shoulders.
* A lumbar support in the padding will also help prevent slouching.
* Separate compartments keeps things neat and organized and keeps the load where you placed it. Remember to pack the heaviest, flattest items in back (i.e. the area that touches your child's back). The goal is to transfer the weight to the hips. The lever arm will be closed to the back.
* Use lightweight pack that doesn't add a lot of weight to the body (for example, even though leather packs look cool, they weigh more than traditional canvas backpacks).
* Pack only what is needed for that day. Check the agenda daily and don’t buy heavy notebooks. Check every pocket and pouch. Throw everything unnecessarily.



**No matter how nice the pack is, if it's not worn properly it will not work properly.**

1. Keep your back strong and lift properly.  
2. Keeping physically fit and learn the proper way to lift will help to avoid back injuries. Learn a few simple steps to help lifting these heavy loads properly.  
3. Bend your knees and keep your back straight.  
4. Tighten your stomach muscles.  
5. Tightening your abdominal muscles will hold your back in a good lifting position and will help prevent excessive force on the spine.  
6. Lift with your legs.  
7. Your legs are many times stronger than your back muscles.  
8. Never bend your back to pick something up. Hold the object close to your body.  
9. Healthy food, good sleep, adequate hydration are very important for vertebral discs.  
10. Regular fitness. Don’t forget the warming up and cooling down.

Listen to the body! Good habits are learned from childhood!

Finally, schoolchildren can hope to have some load taken off their backs. In a welcome move, the Kendriya Vidyalayas across the state are soon going to implement a major step to reduce the load of schoolbags. The move comes following the directions of the the Kendriya Vidyalaya Sangathan (KVS), prescribing weight limits on schoolbags of its students across the country.

In order to reduce the adverse effect on health by carrying school bags disproportionate to body weights of the children, which could result in spinal cord disorders, Kendriya Vidyalayas across the country issued fresh directives to reduce the weight of school bags carried by the students.

However, the new rules will be applicable only from April. The direction of the KVS comes in the wake of repeated complaints by the parents and their wards. The KVS has fixed different weights for different classes and age groups. In Jaipur, there are more than 2,000 students studying in six Kendriya Vidyalayas across the city.

HC Chawla, coordinator of KVS, Jaipur, told DNA, "The new directives will be implemented by April. In the initial months, we will be monitoring and weighing the school bags continuously. Students can bring A4 papers to school instead of notebooks."

According to physiologists, the weight of a school bag should not be more than 1/5th of student's body weight. However in India, schoolchildren are often seen trudging with heavy bags which are disproportionate to their weight. The step taken by KVS has been highly appreciated by other school principals as well. Many of them believe that strict orders should be issued by the human resources ministry to reduce the weight of bags. They also advocated that the rules should be introduced in every school, notwithstanding their affiliation to any particular board. Bela Joshi, principal of Subodh Public School said, "This is a very welcome step. It's a serious issue and should be taken into consideration by all schools. Things become worse when children have to climb up the stairs to reach their respective classes."

Echoing Joshi, principal of Step-by-Step School, Jaishree Periwal said, "There should be a locker system in every school, where students can deposit their notebooks so that they needn't carry them home. Parents should also check the bags of their children to see if they are carrying some useless notebooks."   
City doctors also endorsed the decision of the KVS, saying that lot of students come to them complaining of back aches. Dr Santosh Gupta of SMS Hospital said, "Heavy bags can cause compression to the intervertebral discs, which act as a cushion between the vertebrae, causing back aches in many students. Parents should also take care of this. Schools should provide a way out so that the students can carry minimum books."   
  
BOX: School bags of classes I and II should not weigh not more than 2 kg, classes III-V not more than 3 kg, classes VI- VII not more than 4 kg and 6kg for classes VIII-XI. There should be a lockers in every class. Students should avoid hardbound notebooks.

In a latest decision, the Central Board of Secondary Education (CBSE) is all set to take heavy bags off tender shoulders.

In a circular issued to all heads of institutions, the Board has instructed schools to lighten the weight of school bags, especially at the primary level.

In order to implement the mentioned guidelines, the Board has also decided to reduce the number of books prescribed to students.

At times, schools recommend books of private publishers which are not part of the syllabus so that ‘students have in-depth knowledge’.

Taking serious note of this practice, the Board has asked schools to prescribe only those textbooks that are made mandatory by the National Council of Education Research and Training (NCERT).

Apart from limiting the number of books, schools have also been asked to make arrangements so that students up to Class II can deposit their books in the school itself.

1. **Ergonomics design of bag**

**6.1. Overview**

By assessing the aspects of people, their jobs, equipment, and working

environment and the interaction between them, ergonomists are able to design

safe, effective and productive work systems.

Here we are going to mention the designing procedure for an ergonomic bag in very understanding and lucid manner so that the concern people can easily cope up with the same.

It is aimed to reduce the stress, injuries of shoulder joint with the aid of this specially designed bag. This design is basically innovated for Army personal (for carrying armor) and for school children.

**6.2 Constructional details**

This specially designed ergonomic bag consists of two aluminum links which are further hinged with a cup shaped fiber body. This is done by keeping in mind to reduce the total weight of the designed model. Other end of the link is made to carry the bag. This is done by fastening nut & bolts at the edge of link. Other mechanisms may be apply to do the same. Bag with full or partial load is attached with these aluminum links, with the aid of this mechanism. The cup shaped body is directly fitted on arms (just below the elbow). And the whole load is distributed to the arm rather than to the shoulder via these links. Our main motto is to distribute the load to muscle rather than to bone. And this is done by this mechanism. Because our arms have capacity to carry more load than shoulder, it acts like a lever. We have to do one thing after fitting of cup shaped body on hands. We have to make the arm in position of 900 and this is done by simply lift the same so that whole weight headed towards the hand and concentrated on it.

**Main components**

* Aluminum links (two in numbers).
* Cup shaped fiber body (two in numbers).
* Bag.

**CUPPED SHAPED FIBER BODY**

**LINK**

C:\Documents and Settings\Administrator\Desktop\Copy (2) of a6df69f795f33a2fad74.jpeg

Fig. viewed from side Fig. viewed from front

**Advantages**

* Minimize stresses, strains of shoulder joint.
* Ergonomic problems solved.
* Shoulder is free from any kind of injuries related to carrying load.
* Lucid design.
* Useful both for school children & Army personal.

1. **Conclusion and Bibliography**

**7.1. Conclusion**

From the overall context we may conclude that, due to self innovation and self design of the “Ergonomic bag” and also as a initial stage of design we had to restrict the manufacturing or commercializing of Ergonomic bag. But its an obvious fact that or we strongly believe that we have been able to present the better way for further designing of Ergonomics bag.

Here we have mentioned the designing procedure for an Ergonomic bag in very understanding and lucid manner, so that the concern people can easily cope up with the same.

**7.2 Bibliography**

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