Rehabilitation engineering

Rehabilitation engineering is the branch of biomedical engineering that is concerned with the application of science and technology to improve the quality of life of individuals with disabilities. Areas addressed with in rehabilitation engineering include wheelchairs and seating systems, access to computers, sensory aids, prosthetics and orthotics, alternative and augmentative communication, home and work-site modifications, and universal design. Because many products of rehabilitation engineering require careful selection to match individual needs and often require custom fitting, rehabilitation engineers have necessarily become involved in service delivery and application as well as research, design, and development.

Rehabilitation engineering deals with many aspects of rehabilitation including applied, scientific, clinical, technical, and theoretical. Various topics include, but are not limited to, assistive devices and other aids for those with disability, sensory augmentation and substitution systems, functional electrical stimulation (for motor control and sensory-neural prostheses), orthotics and prosthetics, myoelectric devices and techniques, transducers (including electrodes), signal processing, hardware, software, robotics, systems approaches, technology assessment, postural stability, wheelchair seating systems, gait analysis, biomechanics, biomaterials, control systems (both biological and external), ergonomics, human performance, and functional assessment.

However, with the explosion of technology and the growth of the field over the past decade, one must now specialize not only within research or service delivery but often within a specific area of technology.

One can further differentiate between rehabilitation and assistive technology. ***Rehabilitation technology*** is a term most often used to refer to technologies associated with the acute-care rehabilitation process. Therapy evaluation and treatment tools, clinical dysfunction measurement and recording instrumentation, and prosthetic and orthotic appliances are such examples. ***Assistive technologies*** are those devices and services that are used in the daily lives of people in the community to enhance their ability to function independently, examples being specialized seating, wheelchairs, environmental control devices, workstation access technologies and services are now communication aids. Recognition and support of assistive technology devices and services are now embedded in all the major disability legislation that has been enacted over the last decade.

Introduction to specific disabilities areas to which assistive technology applications are commonly used

1- Mobility

Mobility technologies include wheelchairs, walkers, canes, orthotic devices, FES (functional electrical stimulation), laser canes, and any other assistive device that would assist a person with a mobility impairment, be it motor or sensory, to move about in his or her environment

2- Sitting

Many people cannot use the wheelchairs as they come from the manufacturer. Specialized seating is required to help persons to remain in a comfortable and functional seated posture for activities that enable them to access work and attend educational and recreational activities. Orthotic supports, seating systems in wheelchairs, chairs that promote dynamic posture in the workplace, and chairs for the elderly that fit properly, are safe, and encourage movement all fit into the broad category of sitting technology.

3- Sensation

People with no sensation are prone to skin injury. Special seating technology can assist in the preventions of tissue breakdown. Specially designed cushions and backs for wheelchairs and mattresses that have pressure-distributing characteristics fall into this category. Technology also has been developed to measure the interface pressure. These tools are now used routinely to measure and record an individual's pressure profile, making cushion selection and problem solving more of a science than an art.

4- Access (Person–Machine Interface)

In order to use assistive technology, people with disabilities need to be able to operate the technology. With limitations in motor and/or sensory systems, often a specially designed or configured interface system must be assembled. It could be as simple as several switches or a miniaturized keyboard or as complex as an integrated control system that allows a person to drive a wheelchair and operate a computer and a communication device using only one switch.

5- Communication

Because of motor or sensory limitations, some individuals cannot communicate with spoken or written word. There are communication systems that enable people to communicate using synthesized voice or printed output. Systems for people who are deaf allow them to communicate over the phone or through computer interfaces. Laptop computers with appropriate software can enable persons to communicate faster and with less effort than previously possible.

6- Transportation

Modified vans and cars enable persons with disabilities to independently drive a vehicle. Wheelchair tie-downs and occupant restraints in personal vehicles and in public transportation vehicles are allowing people to be safely transported to their chosen destination.

7- Activities of Daily Living (ADL)

ADL technology enables a person to live independently as much as possible. Such devices as environmental control units, bathroom aids, dressing assists, automatic door openers, and alarms are all considered aids to daily living. Many are inexpensive and can be purchased through careful selection in stores or through catalogues.

Others are quite expensive and must be ordered through vendors who specialize in technology for independent living.

8- School and Work

Technology that supports people in the workplace or in an educational environment can include such applications as computer workstations, modified restrooms, and transportation to and from work or school.

Engineering Concepts in Sensory Rehabilitation

Of the five traditional senses, vision and hearing most define the interactions that permit us to be human. These two senses are the main input channel through which data with high information content can flow. We read; we listen to speech or music; we view art. A loss of one or the other of these senses (or both) can have a devastating impact on the individual affected. Rehabilitation engineers attempt to restore the functions of these senses either through augmentation or via sensory substitution systems. Eyeglasses and hearing aids are examples of augmentative devices that can be used if some residual capacity remains. A major area of rehabilitation engineering research deals with sensory substitution systems.

Engineering Concepts in Motor Rehabilitation

Limitations in mobility can severely restrict the quality of life of an individual so affected. A wheelchair is a prime example of a prosthesis that can restore personal mobility to those who cannot walk. Given the proper environment (fairly level floors, roads, etc.), modern wheelchairs can be highly efficient. In fact, the fastest times in one of man's greatest tests of endurance, the Boston Marathon, are achieved by the wheelchair racers. Although they do gain the advantage of being able to roll, they still must climb the same hills, and do so with only one-fifth of the muscle power available to an able-bodied marathoner.

While a wheelchair user could certainly go down a set of steps, climbing steps in a normal manual or electric wheelchair is a virtual impossibility. Ramps or lifts are engineered to provide accessibility in these cases, or special climbing wheelchairs can be purchased. Wheelchairs also do not work well on surfaces with high rolling resistance or viscous coefficients, so alternate mobility aids must be found if access to these areas is to be provided to the physically disabled.

PROSTHESIS AND ORTHESIS

An orthopedic prosthesis is an internal or external device that replaces lost parts or functions of the neuroskeletomotor system.

An orthopedic orthosis is a device that augments a function of the skeletomotor system by controlling motion or altering the shape of body tissue.

For example, an artificial leg or hand is prosthesis, whereas a brace is an orthosis. When a human limb is lost through disease or trauma, the integrity of the body is compromised in so many ways that an engineer may well feel daunted by the design requirements for a prosthetic replacement.

Designers of orthotic and prosthetic devices are aware of the three cardinal considerations — function, structure, and **cosmesis**.

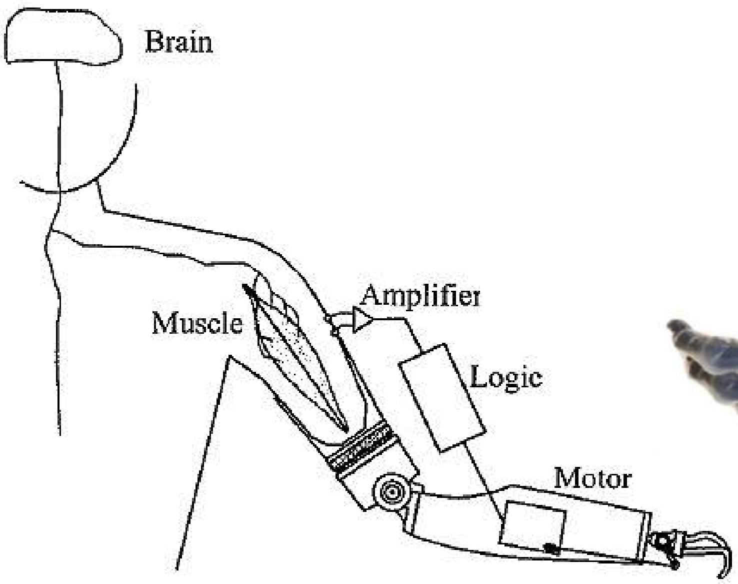
For requirements of function, we must be very clear about the objectives of treatment. **This requires first an understanding of the**

clinical condition. **Functional prescription** is now a preferred route for the medical practitioner to specify the requirements, leaving the implementation of this instruction to the prosthetist, orthotist, or rehabilitation technologist. The benefits of this distinction between client specifications and final hardware will be obvious to design engineers. Indeed, the influence of design procedures on the supply process is a contribution from engineering that is being appreciated more and more.

The second requirement for function is the knowledge of the biomechanics that underlies both the dysfunction in the patient and the function of proposed device to be coupled to the patient. Kinematics, dynamics, energy considerations, and control all enter into this understanding of function. Structure is the means of carrying the function, and finally both need to be embodied into a design that is cosmetically acceptable.

The third element of cosmesis completes the trilogy. As examples, special effects familiar in science fiction films also can be harnessed to provide realistic cosmetic covers for hand or foot prostheses.

Upper limb prostheses are often seen as a more interesting engineering challenge than lower limb, offering the possibilities for active motor/control systems and complex articulations. However, the market is an order of magnitude smaller and cost/benefit less easy to prove — after all, it is possible to function fairly well with one arm, but try walking with one leg. At the simplest end, an arm for a below-elbow amputee might comprise a socket with a terminal device offering a pincer grip (hand or hook) that can be operated through a Bowden cable by shrugging the shoulders. Such body-powered prostheses may appear crude, but they are often favored by the wearer because of a sense of position and force feedback from the cable, and they do not need a power supply. Another, more elegant method of harnessing body power is to take a muscle made redundant by an amputation and tether its tendon through an artificially fashioned loop of skin: the cable can then be hooked through the loop.



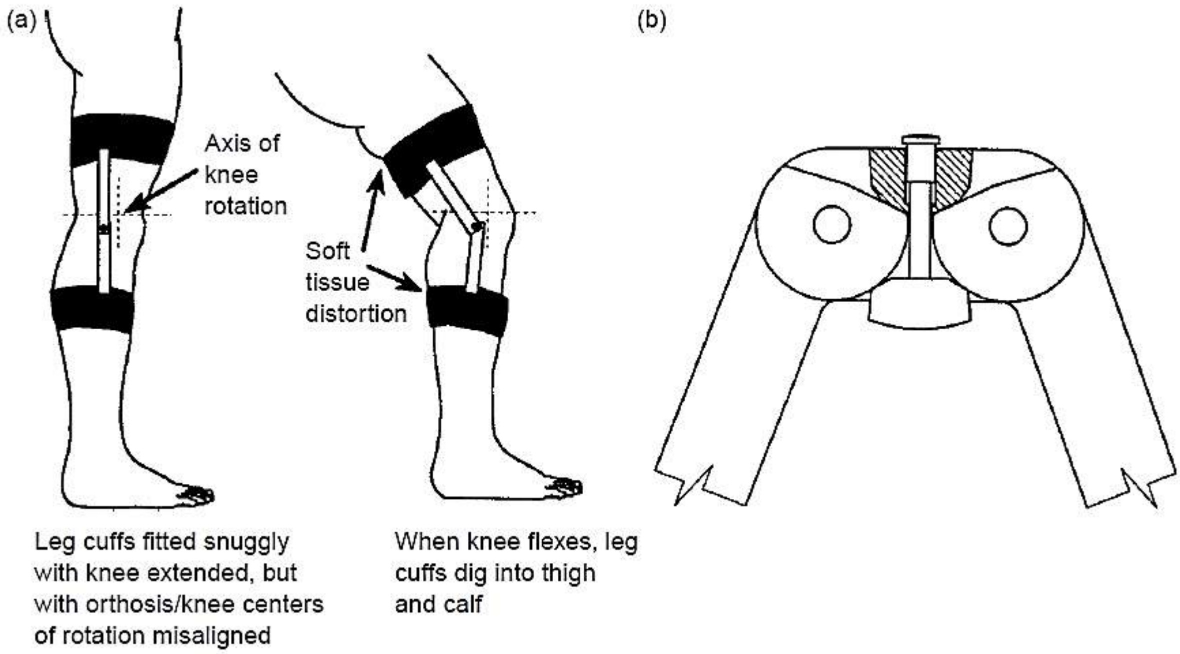
Externally powered devices have been attempted using various power sources with degrees of success. Pneumatic power in the form of a gas cylinder is cheap and light, but recharging is a problem that exercised the ingenuity of early suppliers.

Computer-Aided Engineering in Customized Component Design

Computer-aided engineering has found a fertile ground for exploitation in the process of design of customized components to match to body shape. A good example is in sockets for artificial limbs. What prosthetics particularly seek is the ability to produce a well-fitting socket during the course of a single patient consultation. Traditional craft methods of casting the residual limb in plaster of pairs, pouring a positive mold, manual rectification, and then socket fabrication over the **rectified** cast takes too long. By using advanced technology, residual limb shapes can be captured in a computer, rectified by computer algorithms, and CNC machined to produce the rectified cast in under an hour so that with the addition of vacuum-formed machinery to pull a socket rapidly over the cast, the socket can be ready for trial fitting in one session

Orthotic Knee Joint

Knee orthosis are often supplied to resist knee flexion during standing and gait at an otherwise collapsing joint. The rigid locking mechanisms on these devices are manually released to allow knee flexion during sitting. Fitting is complicated by the difficulty of attaching the orthosis with its joint accurately aligned to that of the knee.



Wheeled Mobility: Wheelchairs and Personal Transportation

These wheelchairs were designed to provide the veteran some mobility within the hospital and home, and not to optimize ergonomic variables. Just as among the ambulatory population, mobility among people with disabilities varies. Mobility is more of a functional limitation than a disability related condition. Powered mobility can have tremendous positive psycho-social effects on an individual. Power wheelchairs provide greater independence to thousands of people with severe mobility impairments.

Power wheelchairs began in the 1940s as standard cross-brace folding manual wheelchairs adapted with automobile starter motors and an automobile battery. The cross-braced wheelchair remained the standard for a number of years. When the rigid power wheelchair frame was developed, space became available under the seat for electronic controls, respirators, communication systems, and reclining devices. By the mid-1970s, wheelchairs had evolved to the point where people had acquired a significant level of mobility.

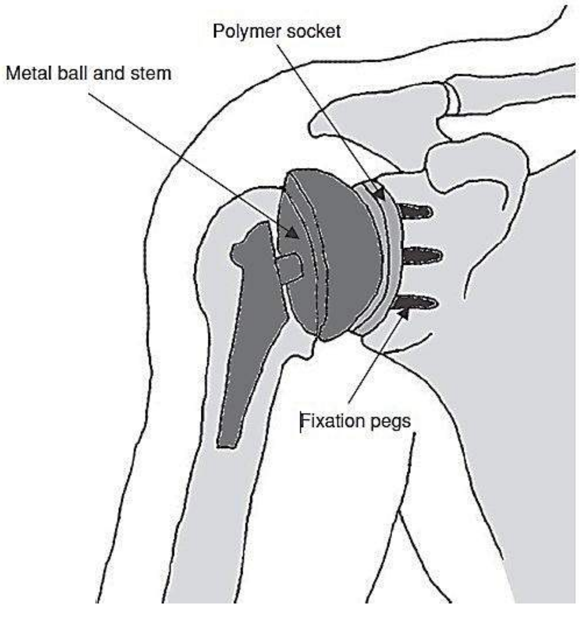
A wheelchair is suitable for short distances, and for many situations where an unimpaired person would walk. Modifications to vehicles may be as simple as a lever attached to the brake and accelerator pedals or as complex as a complete joystick controlled fly-by-wire system. Modifications to other components of the vehicle may be required to provide wheelchair access.

JOINT REPLACEMENT is still one of the major successes of modern medical treatment, transforming the lives of the increasing number of older individuals in the population as well as now offering a realistic return to normality in younger patients with problem joints.

The design and development of new joint replacements is a highly interdisciplinary activity, calling for the combination of sound biomechanical understanding, detailed knowledge of anatomy and surgical experience and insight

Although failure mechanisms in general are still much as they were in the time of the pioneers, there have been advances in the understanding of joint failure from the point of view of both the mechanical and biological processes involved as more sophisticated investigative methods become available. An area in which there is a need for improvement is the analysis of clinical performance.

As example the ***shoulder replacement*** usually comprises a ball and socket joint. One part is fixed to the glenoid region of the scapula by screws (see Figure). The socket (glenoid) may be constructed from (Ultra-high Molecular Weight Polyethylene) UHMWPE which can be backed by porous trabecular titanium alloy. The ball component, the humeral head, can be made from cobalt-chromium alloy. The stem component, the humerus, can be manufactured from metal alloys such as stainless steel, or alloys that include tantalum, titanium, vanadium, and cobalt-chromium.



The Future of Engineering in Rehabilitation

The traditional engineering disciplines permeate many aspects of rehabilitation. Signal processing, control and information theory, materials design, computers are all in widespread use from an electrical engineering perspective. Neural networks, microfabrication, fuzzy logic, virtual reality, image processing and other emerging electrical and computer engineering tools are increasingly being applied. Mechanical engineering principles are used in biomechanical studies, gait and motion analysis, prosthetic fitting, seat cushion and back support design, and the design of artificial joints. Materials and metallurgical engineers provide input on newer biocompatible materials. Chemical engineers are developing implantable sensors.
Industrial engineers are increasingly studying rehabilitative ergonomics. The challenge to rehabilitation engineers is to find advances in any field, engineering or otherwise, that will aid their clients who have a disability.