

ABSTRACTS OF RECENT ARTICLES

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For this issue of Rehabilitation Research and Development, Joan Edelstein has selected articles drawn from many aspects of rehabilitation, with theoretical, experimental, and clinical-practice orientations. You will find 21 abstracts of articles in the following general categories:

Upper-limb prosthetics 1 article
 Upper-limb orthotics 2
 Lower-limb prosthetics 6
 Lower-limb orthotics 2
 Spinal/cervical orthotics 1
 Gait analysis 6
 General 4

These have been drawn from the following journals:

Prosthetics and Orthotics International 5 articles
 Physical Therapy 4
 Orthotics and Prosthetics 3
 Ergonomics 2
 American Journal of Occupational Therapy 2
 Archives of Physical Medicine and Rehabilitation 1
 Acta Orthopaedica Scandinavica 1
 Journal of Biomechanics 1
 Medical and Biological Engineering and Computing 1
 Scandinavian Journal of Rehabilitation Medicine 1

Wrist-Driven Flexor-Hinge Orthosis: Linkage Design Improvements: Jerome Stenehjem, James Swenson, and Charles Sprague (School of Medicine, University of Utah, Salt Lake City, Utah) Archives of Physical Medicine and Rehabilitation 64:566-568, November 1983.

Appropriate selection of linkage lengths and angles provides the user of the wrist-driven orthosis with maximum pinch force and 60 degrees of metacarpophalangeal motion without the need for adjustable components. The original orthosis was described by Bisgrove in 1954. It provides three-point prehension for patients with hand paralysis who retain active wrist extension, particularly C6-7 quadriplegics. The orthosis can be modified by adding carbon dioxide or electric motor power, passively positioned ratchet, or shoulder-driven components.

The basic orthosis is a four-bar linkage, four bars connected at four pivot points. The orthosis forms an exoskeleton for the forearm and hand with a forearm piece, a palmar piece, and phalanx piece. The palmar piece holds the thumb rigidly. The phalanx piece allows only metacarpophalangeal flexion and extension. The pieces are hinged at the wrist and metacarpophalangeal joint. A connecting rod links motion of the wrist joint with motion of the fingers, so that when the wrist extends, the fingers flex. The force generated by wrist extensors creates a torque about the wrist pivot which is transmitted via the linkage

bar to produce a torque at the finger pivot.

Analysis of various linkage configurations showed that the Rancho and Engen orthoses do not effectively utilize the nonlinear characteristics of the four-bar linkages. Redesign consisted of moving the pivot point on the forearm distally to provide higher pinch force, while retaining 60-degree finger excursion without the need for adjustable linkages. The Rancho orthosis linkage has a fairly constant torque ratio (pinch force) throughout the range of wrist positions, resulting in suboptimal pinch force in all positions. The Engen pinch forces decrease as the wrist is extended, resulting in adequate pinch when large objects are grasped, but poor pinch when small objects are held. The modified orthosis provides adequate force for large objects and high force for small objects.

Location of the forearm pivot point was determined using a geometric location method on five orthoses resulting in improved function. Each user noted an increase in pinch force of approximately threefold after the change. Users could accomplish more activities with less fatigue and did not have to adjust the orthotic linkage during activities.

Immediate Effects of Positioning Devices on the Normal and Spastic Hand Measured by Electromyography: Virgil Mathiowetz, Deborah Bolding, and Catherine Trombly (University of Wisconsin-Milwaukee, Milwaukee, Wisconsin) American Journal of Occupational Therapy 37:247-254, April 1983.

Eight normal and four hemiplegic adults participated in a study in which they wore a variety of hand orthoses while electromyographic recordings of the flexor carpi radialis and flexor digitorum profundus of the opposite hand were made. The rationale of examining the contralateral muscle activity was that muscle action irradiates, or overflows, when one hand is exercised. Recordings were made while subjects gripped at 80 percent (for normals) or 50 percent (for hemiplegics) of their maximal voluntary contraction as displayed on an oscilloscope, and for three postgrasp periods after the grasp meter returned to the baseline. Subjects were tested wearing no device, a custom rigid thermoplastic volar resting splint, and prefabricated firm cone, and a finger-spreader made of a block of foam rubber in which five holes were drilled.

Normal subjects had significantly greater muscle activity with the finger spreader as compared with no device. Hemiplegics displayed somewhat higher activity with the volar splint. No orthosis evoked less muscle activity than was the case when hemiplegics wore no device. Both normal and hemiplegic subjects demonstrated no significant differences between devices or no device during the postgrasp periods. The volar splint produced the highest muscle records for all hemiplegics.

The response of normal subjects to the finger spreader could be based on the stretch it exerted; passive stretch stimulates some muscle activity. Inasmuch as hemiplegics did not score

highest with the spreader, the effect of stretch cannot be proved conclusively. The study demonstrated that no positioning device reduces flexor spasticity significantly while the device is worn nor in the immediate period upon removal of the device. The volar splint increased muscle activity during the grasping period, perhaps because spastic wrist and finger flexors were stretched during donning. Although motor activity was greater during donning and grasping with the volar splint (as compared with the other devices and with no device worn) the difference was not significant. Nevertheless, use of a volar splint for a spastic hand is contraindicated while the subject is grasping firmly.

The Use of a Four-Channel Electrical Stimulator as an Ambulatory Aid for Paraplegic Patients: Tadej Bajd, Alojz Kralj, Rajko Turk, Helena Benko, and Janez Sega (Faculty of Electrical Engineering, Edvard Kardelj University, Ljubljana, Yugoslavia) *Physical Therapy* 63:1116-1120, July 1983.

Functional electrical stimulation has been used to provide for paraplegics who have complete lesions, the ability to rise from sitting to standing, to remain standing, and to walk using a reciprocal gait pattern. Candidates are patients with spastic paraplegia without contractures or pressure sores, thrombophlebitis, or heterotropic ossification. They must also understand the benefits and limitations of functional electrical stimulation. Preliminary training emphasized reversal of disuse atrophy of the thigh muscles by cyclic electrical stimulation to the quadriceps using surface electrodes for a half-hour daily and increasing their use to three hours daily. When the maximal knee-joint torque provided by stimulation exceeded 30 to 50 Nm (depending on the patient's weight), the standing program was started. Continuous stimulation to knee extensors allowed standing. Through the use of two stimulation channels and arm support, patients stood for one or more hours. The patient then received stimulation to both knees to enable rising from the wheelchair with the aid of the arms.

A minimum of four channels are required for reciprocal gait. Stimulation must be controlled during double stance, right swing, and left swing; control is achieved by two hand switches. When neither switch is pressed, both knee extensor muscles are stimulated. Pressing the right switch stimulates the right leg to flex. Switches were built into crutch handles. The duration of swing is preset by stimulator potentiometers. Electrodes are located over the common peroneal, sural, saphenous, and superficial peroneal nerves. Walking commenced when patients could stand for at least 20 minutes. Initially, patients walk in a frame comparable to parallel bars on wheels. After one week, most patients could walk for several minutes without resting. A half-hour of stimulation was applied to the quadriceps before gait training to reduce spasticity.

During stance phase, the hip and ankle muscles were not stimulated. Hip and trunk stabilization was achieved by use of crutches. Ankle stability was provided by ankle-foot orthoses.

Twelve patients have completed the program, being able to stand for at least 20 minutes. Four have progressed to walking; three of these have T5 lesions and one has T10 lesions. One patient now walks for 3 to 4 hours daily in and outside his home, and can step over small obstacles. One patient quit the program because positioning the electrodes was time-consuming and

clothing became wet from the water-soaked electrodes. Another patient withdrew because his vocation took too much of his time.

A Physiological Assessment of the Rolling Crutch: F. C. Gillespie, J. Fisher, C. S. Williams, E. E. McKay, and M. C. H. Curr (Department of Clinical Physics and Bio-Engineering, West of Scotland Health Boards, Glasgow, Scotland) *Ergonomics* 26:341-347, April 1983.

The rolling crutch is an axillary crutch with the lower section replaced by two uprights terminating in a curved base. It was first developed in 1917. The long curved base, the point at the center of curvature being 1 meter above ground level, moves parallel to the ground during stance phase. At the start and end of each step, however, the points of the base contact the floor, and the crutch behaves in a manner similar to that of conventional crutches, rotating about fixed points. Theoretically, the rolling crutch should reduce the vertical displacement of the center of gravity.

Twenty normal young adults performed the swing-through gait with rolling crutches and axillary crutches while oxygen consumption was measured. The rolling crutches weighed 3.3 kg per pair, but axillary ones 2.2 kg per pair. Subjects ambulated on a level linoleum-covered floor for 5 minutes of continuous walking at self-selected speed.

With rolling crutches, walking speed was approximately 6 percent slower, the number of strides taken differed significantly, and strides were slightly longer. Oxygen consumption was 9 percent lower with the rolling crutch; women showed an even greater diminution. The distance covered for each liter of oxygen was greater for rolling crutches, especially for women. Nevertheless, eight subjects preferred the axillary crutch and five had no preference.

Rubbers and Plastics in Shoes and Flooring: The Importance of Kinetic Friction: D. I. James (Rubber and Plastics Research Association of Great Britain, Shawbury, Shrewsbury, Shropshire, England) *Ergonomics* 26:83-99, January 1983.

While it is universally recognized that slippery surfaces are dangerous for walking, defining the requirements for safety is difficult. Previous studies have demonstrated that there is little or no relative movement between the foot and the floor during mid-stance, unless the floor is oily or soapy. Other experiments showed that the friction of rubber was markedly dependent on velocity. Kinetic friction is measured by setting one of the contacting surfaces in motion at a known velocity and measuring the force exerted on the stationary surface with a load cell. Measurement of static friction is more difficult and is influenced by the cleanliness of the rubber; however, the part played by static friction in walking is minimal.

The friction of polyurethane on steel (measured dry) rises extremely rapidly indicating the combination to be safe for walking, while polyvinyl chloride on steel provides low friction, rendering the situation unstable. Natural rubber slides easily on polytetrafluorethylene, but as velocity increases, the coefficient of friction also increases, preventing sudden slipping. Area of contact, pressure, and temperature also affect friction; rubber shoe soles become unsafe at temperatures below the freezing point, for example.

Newly introduced testing machines, the Tortus friction tester and the British Portable Skid Tester, measure kinetic friction. A practical method of judging the slip resistance of shoe soles and flooring materials is to use a ramp. The angle of the ramp is gradually increased until the subject feels it unsafe. The level of friction adequate for a normal step is inadequate if stride length increases. It is not possible to design either footwear or flooring that will completely overcome the problem of contamination of friction by water; spillages must be dried up to prevent accidents.

Kinetic friction should be high enough for a large stride to be taken without slipping. Inherently high levels of friction associated with many rubbers and plastics, coupled with the tendency for friction to rise with velocity, contribute to improved safety. Contaminants drastically alter the friction of all materials. Mud and liquids are extremely dangerous. Sole patterns on shoes and profiled floors help to reduce the contaminant layer.

Clinical Gait Assessment in the Neurologically Impaired: Reliability and Meaningfulness: Maureen Holden, Kathleen Gill, Marie Magliozzi, John Nathan, and Linda Piehl-Baker (Massachusetts General Hospital, Boston, Massachusetts) *Physical Therapy* 64: 35-40, January 1984.

Sixty-one adults having hemiparesis or multiple sclerosis participated in a study in which they walked 30 feet on a paper walkway with ink patches on their shoes. Analysis of the resulting footprint record and time reports indicated that temporal-distance measurement is a clinically feasible, quantitative approach to gait assessment which is inexpensive, easy to learn, takes little time to administer, and permits comparisons of outcomes across different subjects or treatments. Test-retest and interrater reliability studies revealed very high reliabilities for all measures except stride-time differential (the absolute value of average stride time for one limb minus the average stride time for the other limb). No significant differences in reliability occurred when subjects were grouped by diagnostic category. Seven therapists rated the subjects' gaits.

Velocity, cadence, step length, stride length, and the ratio of stride length to lower-limb length were all significantly related to the functional ambulation category, based on a scale developed at the reporting institution. The scale has five categories: physical assistance continuously or intermittently, supervision only, independence on level surfaces, and full independence.

Reliabilities were high regardless of the functional category in which the subjects performed, although reliability was somewhat less among subjects who required supervision when walking. The significant relationship of velocity, cadence, step and stride length, and stride length to leg-length ratio to the functional ambulation status supports the validity of their use as outcome measures. Step-time differential may be a better indicator of overall cosmetic appearance of gait rather than the functional ambulation status.

Quantification of Gait Abnormalities on the Basis of Continuous Foot-Force Measurement: Correlation between Quantitative Indices and Visual Rating: S. Miyazaki and T. Kubota (Institute for Medical and Dental Engineering, Tokyo Medical and Dental University, Tokyo, Japan) *Medical and Biological Engineering and Computing* 22:70-76, January 1984.

Forty-eight hemiparetic subjects participated in a gait analysis study intended to validate a newly developed foot-force measurement device. The subjects ranged from 16 to 77 years of age; 6 wore ankle-foot orthoses and 27 walked with a cane. They walked on a walkway at self-selected cadences. Two physical therapists and two physicians rated gaits independently. While raters were evaluating each subject, foot forces were measured by a device that detects vertical forces exerted by the forefoot and the heel. The output permits calculation of the total force of one foot, the muscle moment at the ankle, and the center of pressure of the foot. A load cell on the cane measured vertical force. Eight waveform indices corresponding with eight visual evaluation items were calculated from the foot-force device. The items are: fluctuation of the upper body, gait symmetry, supportability of the body weight by the affected leg, step-to-step variation, shock at foot contact, briskness of push off, cane dependence, and sequence of foot contact.

Five temporal factors were derived, including ratio of stance of the affected leg to that of the sound leg, duration of single stance, duration of double support, and duration of cane contact.

Although grades given by raters show positive correlation, there are more than 10 cases in which different grades are given to the same subject. Each rater has his own bias, inter-rater correlation is not so high as might be expected, and perfect agreement occurred in less than 40 percent of cases in any evaluation item. Bias of grades is not due to the rater's personality, but rather to the discrepancy in interpretation of evaluation criteria among raters. Intra-rater correlations are generally higher than inter-rater correlations. Visual rating thus has several problems: scattering of grades among raters, bias, dependence of judgment, and confusion of the meaning of the evaluation item.

It is assumed that the mean of the visual grades given by the four raters approximates the degree of abnormality. Correlation between the mean grade and the waveform index reveals that all indices except shock at foot contact present correlation coefficients equal to or higher than inter-rater coefficients. Waveform indices are superior to temporal factors in quantifying more abnormalities, and are not subject to discrepancy in interpretation of evaluation criteria. Validity of the indices is established by the overall consistency of the evidence because no absolute external measure exists.

A Simple Method of Measuring the Footsole Pressure of Normal Subjects Using Prescale Pressure-Detecting Sheets: Hiroshi Aritomi, Masafumi Morita and Koichi Yonemoto (Kitasato University School of Medicine, Sagamihara, Japan) *Journal of Biomechanics* 16:157-165, 1983.

Prescale sheets consist of two sheets. The upper is coated with microcapsules containing a color-producing agent, the lower is coated with a color-developing agent. Each capsule on the upper sheet has a different size which tends to be broken according to a

different force. The value of the pressure applied determines the number of capsules that rupture. Rupture releases color-producing agent that colors the bottom sheet in shades corresponding to the applied pressure. The original Prescale made direct measurement of low pressures difficult, but a new intensifying device allows measurement of pressures as low as 0.5 kg/cm². When pressure is to be measured, the subject walks on a metal ball mat over the sheets and an acrylic plate under the sheets. The color sheet is interpreted by eight shades of color corresponding to the applied pressure.

Sixty-four healthy young adults participated in a validation study. They had X-ray examination of the anterior and lateral structures of their feet taken while standing. Height of the longitudinal transverse arch, medial arch, and valgus inclination of the hallux were measured. Subjects also stood on the Prescale, allowing recording of pressure patterns which corresponded closely with the X-ray determinations. Consequently, Prescale offers the advantages of ease of measurement, immediate access to results of pressure distribution and absolute values, evidence of varying amounts of pressure by shading, good storage capability, and low cost. Prescale has problems with reproducibility of the pattern (some individuals lack balance when standing on one foot) and the material only permits measurement of vertical pressure.

Cardiovascular Responses during Nonweight-Bearing and Touchdown Ambulation: Bess Kathrins and Susan O'Sullivan (Department of Physical Therapy, Sargent College of Allied Health Professions, Boston University, Boston, Massachusetts) *Physical Therapy* 64:14-18, January 1984.

Oxygen consumption of 10 healthy young adults was measured as they performed non-weightbearing and touchdown partial weightbearing ambulation with axillary crutches. Heart rate and systolic blood pressure were also measured as subjects ambulated for 5-minute periods at 50 m/min. A Limb Load Monitor footplate was inserted into the shoe; it signalled whenever excessive weight was borne, defined as more than 10 percent of body weight, during the touchdown gait sequences. The foot was off the ground throughout the gait cycle during the non-weightbearing sequences.

Heart rate and blood pressure were significantly higher during the non-weightbearing ambulation; oxygen consumption was also higher, although not to a significant extent. Subjects perceived non-weightbearing to be more strenuous, and they walked at significantly slower cadences to maintain the uniform velocity; mean stride length was greater during non-weightbearing. During crutch walking a combination of concentric, eccentric, and isometric exercise is performed. Non-weightbearing ambulation requires lower-limb muscles to perform sustained isometric contraction, and the upper limbs also sustain isometric contraction during swing phase when neither leg is touching the ground. Touchdown ambulation, in contrast, reduced the amount of weight carried by the arms and required both isometric and isotonic exercise of the involved leg.

Both modes of ambulation are highly stressful. Oxygen consumption rose to nearly four times basal rate, heart rate rose by approximately 50 percent, systolic blood pressure increased about 13 percent, and estimated myocardial oxygen consumption doubled.

Heart-Rate Response of Elderly Women to Nonweight-Bearing Ambulation with a Walker: Ingrid Baruch and Kurt Mossberg (Texas Woman's University, School of Physical Therapy, Houston, Texas) *Physical Therapy* 63:1782-1787, November 1983.

Twenty-five women between the ages of 60 and 80 in good health performed the three-point non-weightbearing gait with a walker while the heart rate was monitored. Subjects walked at self-selected speeds for 3 minutes. On average, the three-point gait resulted in an increase of 64 percent over the resting heart rate, equal to 83 percent of the age-predicted maximum heart rate. Half of the subjects returned to resting heart rates within 5 minutes after cessation of walking. The average speed of gait was 12 meters per minute.

The results of the study confirm other investigations which demonstrated excessive stress on the cardiovascular system induced by non-weightbearing gait, as performed by both elderly and young adults.

Two-thirds of the study participants demonstrated heart rates exceeding 120 beats per minute, generally recognized as the maximum tolerable stress. Nearly all the subjects displayed heart rate increases exceeding 30 beats per minute over the resting rate. Comparing the results with tables of work-load classifications, 12 subjects performed heavy work comparable to heavy shoveling and carrying objects weighing between 60 and 90 pounds. Four did very heavy work, on the basis of physiologic demand. The fact that half of the group did not return to resting heart rate after a 5-minute rest period emphasizes the severity of the work.

Subjects chose to use the walkers at speeds considerably slower than normal walking. The duration of walking, 3 minutes, and the distance, 36 meters, are similar to ordinary functional requirements. The slow speed and high heart-rate response indicate that the activity was costly in terms of energy expenditure.

Functional Studies in 79-Year-Olds: Walking Performance and Climbing Capacity: Birgitta Lundgren-Lindquist, Amelie Aniansson, and Ake Rundgren (Department of Rehabilitation Medicine, University of Goteborg, Goteborg, Sweden) *Scandinavian Journal of Rehabilitation Medicine* 15:125-131, 1983.

Two hundred twenty-six subjects, approximately two-thirds of whom had no signs or symptoms in the lower extremities, walked 30 meters at self-selected speed and then were asked to walk as fast as possible. Walking time was registered and heart rate registered by telemetry. Subjects also climbed up and down steps of various heights; a hand rail was available. Subjects also rated their perceived exertion.

Men generally walked faster than women. A third of the healthy women and three-fourths of the healthy men walked faster than 1.4 meters per second. When comparing healthy participants with those having cardiovascular, locomotor, and/or neurological disorders, no significant differences were observed except for maximal walking speed in men. All subjects could climb low steps using the handrail. A fifth of the women and 6 percent of the men could not negotiate 40-cm steps. A quarter of the women who could climb the highest step reported difficulties when using public transportation. High correlation existed between comfortable walking speed and the ability to climb steps for

both men and women, both with and without disabilities. A significant correlation was found in women between climbing steps and difficulties in using public transportation.

Because a walking speed of 1.4 meters per second is the norm for pedestrians at signalized traffic intersections, a slower walking speed is a detriment. No one in the present study population could manage the stipulated speed comfortably. Elderly individuals may walk even slower outdoors, especially when streets are slippery. Comfortable walking speed averaged approximately three-fourths of the maximal speed.

No compulsory norms for step heights on public transport vehicles exist in Sweden, although 35 cm is recommended. Subjects with low quadriceps strength can compensate by using arm strength. Women as a group had greater difficulties than men. A handrail is of great importance in climbing. Ability to climb correlates well with walking speed. Since very few elderly individuals drive their own cars, public transportation adapted to the needs of the elderly is important. In addition, the norms at signalized intersections are much too high for elderly pedestrians.

Tubular Orthoses: R. E. Hannah, J. Foort, and D. G. Cooper (Medical Engineering Resource Unit, University of British Columbia, Vancouver, Canada) *Prosthetics and Orthotics International* 7:157-164, December 1983.

Orthoses may be constructed of interlinked plastic tubes to provide a strong and lightweight frame to which pads and straps may be attached. The orthoses have been applied to patients with spinal injuries, arthritis, head injuries, burns, and congenital disabilities. Rigid nylon bushing stock, in pre-cut lengths from 2 inches to 2 feet in various diameters, is used. The tubes can be linked in a rapid manner by components such as T-junctions, hinges, ball-and-socket joints, crossovers, and others. Tubes provide selected directional rigidity, favorable strength-to-weight ratio, and three-point counterloading; they allow contralateral body stabilization.

Six orthoses using the system are in clinical trial. One, a cervical orthosis for control of neck flexion and extension, consists of short tubes linked to form an open collar, and a breastplate ring and chin support (heat-formed in three sizes) with a small chin cup clipped to the chin-support rod. Fabrication requires a maximum of 45 minutes. The orthosis weighs 110 grams. Eight of 10 patients fitted with it continue to use it regularly. Advantages over Plastazote collars were coolness, reduced weight, and increased rigidity.

A spinal-extension orthosis has two concentric anterior rings joined at the top and bottom. Additional abdominal support is given by a ring network similar to a corset. Half of a group of 47 patients continue to wear it. The orthosis provides support while the wearer bathes.

A hip-abduction orthosis has a rigid tubular beam between the legs. It has been fitted to a child with Legg Perthes disease and one who required hip stabilization after surgery.

A shoulder-abduction orthosis is constructed of two curved sections of tubing placed slightly anterior and posterior to the lateral aspect of the torso and continuing along the medial aspect of the arm. Two patients with severe burns have worn it.

An elbow-extension orthosis made with straight tubing from wrist to axilla has been fitted successfully to six patients who had elbow-flexion contractures. Tubing frames have also been

fabricated for two patients with pressure sores on the lower portion of the leg and foot; the frames relieve pressure allowing sores to heal.

Patients remark on the lightness, coolness, and improved appearance of the tubing orthoses, which are fast and easy to construct and adjust.

Biomechanics of the Through-Knee Prosthesis: J. Hughes (National Centre for Training and Education in Prosthetics and Orthotics, Glasgow, Scotland) *Prosthetics and Orthotics International* 7:96-99, August 1983.

The problems of the through-knee amputee are very similar to those of the above-knee amputee; however, the through-knee limb end is normally adapted to weightbearing and offers a long lever arm for the exertion of control forces by the hip muscles, which are largely intact. The socket of the through-knee prosthesis is designed so that the limb takes the largest part of the vertical support load on the end. In the mediolateral plane, body weight exerts a toppling effect about the point of support; the summated effects of lateral and medial stabilizing forces prevent a fall. The greater length of the through-knee limb decreases the pressure and increases the couple arm attainable, therefore reducing magnitude of forces and further lessening pressure. The lateral wall of the socket must be snug to prevent force being transmitted as shear in the tissue at the end of the limb. The socket should also transmit the medioproximal stabilizing force. In the knee-disarticulation prosthesis, there is usually no ischial support, so rotation tends to occur about the support point at the end of the limb. A generous flare at the medial brim minimizes any tendency toward painful pressure near the groin. The socket must also be designed to allow transmission of an extension moment on the knee at heel strike; force is transmitted on the anteroproximal and posterodistal aspects of the socket. During swing phase, the socket must resist slippage; the socket is usually fitted over the condylar flares. If the socket has a window to accommodate a bulbous end, the window should be medial to avoid the area which must transmit the lateral stabilizing force.

The problems of knee function are the same as for the above-knee amputee, namely, stability in early stance and the ability to initiate flexion in late stance. Stability for the amputee fitted with an articulated knee may be provided by aligning the knee behind the load line from hip to foot, or by a stabilizing device which develops, as a result of axial loading, a stabilizing moment at the knee, or by a polycentric knee that raises the instantaneous center of rotation to reduce the hip-extension moment. The polycentric unit does not increase the difficulty of initiating flexion. During swing phase, the amputee must decelerate the upward movement of the shank after toe-off and decelerate the shank at the end of swing. Mechanical or fluid friction may be helpful, together with an elastic extension aid. The through-knee amputee is at an advantage because of the physiological integrity of the thigh muscles and the length of the lever arm, although the spatial distribution available for the provision of knee control mechanisms is restricted.

Knee Mechanisms for Through-Knee Prostheses: K. Oberg (Biomechanics Laboratory, College of Health and Care, Jonkoping, Sweden) *Prosthetics and Orthotics International* 7:107-112, August 1983.

Three principal types of design are used for knee-disarticulation prostheses. The most common type originally incorporated a leather socket with metal side-bars and heavy-duty joints, similar to those used in some knee orthoses or below-knee prostheses. The prosthesis often has a bulky appearance and the joints did not incorporate any device to control the stance and swing phase characteristics of the knee.

The second type of knee unit are like those used for above-knee amputees. Such units lengthen the thigh and shorten the shank, reducing comfort and good appearance when the amputee sits.

The third type of mechanism uses polycentric linkages, usually four-bar. They can be placed within the shank below the amputation limb when in the sitting position. The first design was from the Orthopaedic Hospital of Copenhagen, now commercially available. Later, other similar mechanisms had been introduced to the market. The mechanisms are attractive while controlling stance and swing phase by fluid friction, manual lock, or other means.

Experimental mechanisms include the six-bar linkage which offers the possibility of increased range of motion, better appearance, improved stability, and better swing control, although the units are more complex and heavier. Another experimental design (used in West Germany and Holland) has the shank tube connected by rollers to a track in a metal arch fixed to the posterior part of the socket end. The center of knee rotation is located within the femoral condyles. A survey of clinical practice in Sweden revealed that nearly half the fittings were dominated by special through-knee designs such as that of the Orthopaedic Hospital of Copenhagen. About a third of the patients wore weightbearing controlled single-axis and stabilized polycentric knees. About a fourth of the amputees had manually locked single axis mechanisms.

A polycentric joint changes the instantaneous center of rotation as the knee flexes. The location of the center is at the intersection of the two lines that pass through a pair of joints respectively that are connected by a linkage between the shank and thigh. Muscular hip flexion and extension influence knee stability, as does the load line. The zone of voluntary stability is bounded by the load line at heel-contact and that at push-off. If the amputee does not use hip musculature, the zone is reduced and the prosthetic knee must be aligned to place its center behind the load line for heel contact. The reduced zone requires a higher location of the instantaneous center of knee rotation, to maintain voluntary control of knee stability. The polycentric knee offers a higher center than does the single-axis unit.

A Thermoplastic Endoskeletal Prosthesis: Drew Hittenberger (Prosthetics Research Study Center, Seattle, Washington), *Orthotics and Prosthetics* 37:45-52, 1983.

A below-knee prosthesis consists of an endoskeletal polyvinyl chloride tube, thermoplastic total-contact socket, and prosthetic foot. The system allows changes in alignment, foot placement, and socket contour, accomplished by heating the pylon or sock-

et. The system is lightweight; the average finished prosthesis weighs between 2 and 3 pounds. Materials cost is less than for a conventional endoskeletal prosthesis, and fabrication time is half that needed for conventional limbs. The system can be modified to meet temporary, definitive, and water activity use.

The socket is made of colyene, a thermoplastic copolymer made of 85 percent polypropylene and 15 percent polyethylene; it is more durable and more flexible than polypropylene and has better impact resistance. The pylon is made of schedule 40, 1 ¼ inch ID tubing available in most plumbing supply stores. The tubing is held to the socket and foot by polyvinyl chloride plugs and hose clamps. The plastic is then reinforced with fiberglass, which prevents further adjustment of the pylon.

Conventional foam and lamination procedures can be followed or a cosmetic cover applied, such as Ethafoam or an Otto Bock cover. Conventional alignment procedures using the vertical alignment fixture are followed. Since thermoplastics shrink due to the stress applied during fabrication, a three-ply sock must be applied over the cast before the plastic is pulled. A distal end pad of Pelite and Plastazote is formed. A semicircular attachment plate of half-inch Lexan is glued to the polyvinyl chloride plug at the end of the socket.

Designed as a temporary prosthesis, the system accommodates changes in socket and alignment. The system can be made waterproof depending on the type of foot used. Rubber sleeve suspension may be worn.

Interface Modalities of Technical Aids Used by People with Disability: Ron Levy (Facultes de l'Aménagement et de Médecine, Université de Montréal, Québec, Canada) *American Journal of Occupational Therapy* 37:761-765, November 1983.

An initial conceptual framework is presented regarding interface mechanisms used by disabled persons and their aids. An "interface" is described as a means of access to an object, mechanism, machine, or system of machines. The means may incorporate mechanical, electrical, or pneumatic characteristics; an electrical switch to activate a machine is an example. The interface is that part of the person/machine system that directly connects the user to the machine, making use of all or some of the user's senses. The interface has considerable influence on user motivation, function, achievement, and performance, as well as on the impact of the aid on user needs and goals. The interface prescribes to a great extent the effectiveness of the outcome of a user/device relationship.

Ergonomic principles should form the basis for design criteria for special interfaces of technical aids for the disabled, especially consumer ergonomics, hand-tool ergonomics, and workstation and instrumentation design.

Rehabilitation technical aids can be divided into four categories: prostheses, orthoses, adaptive aids, and general consumer products. The latter two categories involve devices that are not attached directly to the body but do permit mobility and communication in the case of adaptive aids, or allow independent access by a disabled individual to any ordinary consumer product, in the case of a general consumer product category. Users include the disabled individual, his nonprofessional companions, and his professional associates—each has different needs and goals. Activities relating to a particular operation include perception (detecting, discriminating, for example); mediating

(categorizing, translating, and others); motion (activating, pressing, connecting, for example); and communicating. The basic information required for development of functional specifications for an interface system relates directly to user abilities including cognition and motor function, as well as situational characteristics including the physical, social, and temporal environment.

A four-level hierarchy of interface types is presented. Level 1 concerns the morphological characteristics of an interface. Level 2 concerns the actuation characteristics of an interface—its physical connection to other components. Level 3 involves amplification characteristics of an interface—its ability to carry out work by expending energy—the machine attributes. Level 4 concerns the transformational characteristics of an interface—its ability to modify input functions to a system; it carries the notion of design in the required compensation for the limitation of the user's physique, intellect, perception, and cognition.

Fabrication of the Water-Resistant Recreational B/K Prosthesis: Kenneth LaBlanc (Veterans Administration, New York, New York) *Orthotics and Prosthetics* 37:42-49, 1983.

A water-resistant prosthesis uses commercially available components and can be made faster than the Ultra Light or Otto Bock methods. A negative impression is taken, using standard prosthetic procedures. The positive model is then made and modified, and the socket laminated. The Staros/Gardner alignment fixture is attached below the foam distal socket extension. Fitting and dynamic alignment proceed, with the rubber sole cemented to the foam ankle block.

The rubber sole is removed and new aluminum holding device secures the foot during transfer procedure. Polyvinyl chloride tubing is inserted between the ankle block and the sock, and then epoxy-bonded. A small hole is drilled at the posterodistal end of the socket in the polyvinyl chloride tubing, and flexible tubing is installed to allow air to escape as water enters the larger tube. The flexible tubing should terminate at least 2 inches above the posterior socket brim to prevent resin from blocking the tube during final lamination. A polyethylene or X-ray sheet is secured around the pylon to form a cavity which will be filled with foam. After the foam hardens, it is shaped to match the contour of the patient's opposite leg. Conventional lamination completes the prosthesis. The rubber sole is cemented in place, matching the hole in the rubber sole to the polyvinyl chloride tubing opening. To allow water to drain out of the socket, several small holes are drilled at the distal end of the socket within the plastic tubing. If a liner is used, a hole should be drilled in the same area.

The tubing allows water to enter the prosthesis as the amputee walks, making it less buoyant. Air escapes via the air tube. As the amputee exits from the water, water drains out the bottom of the foot. If swim sneakers are used, holes should be made in the sole to allow water to enter and exit the tube.

A waterproof suspension strap can be added.

Flexible Above-Knee Socket Made from Low Density Polyethylene Suspended by a Weight Transmitting Frame: Ossur Kristinsson (Reykjavik, Iceland) *Orthotics and Prosthetics* 37:25-27, 1983.

Flexible sockets made of nylon stockinette, fiberglass stockinette, and silicone resin provide greater comfort and tactile feedback when the amputee sits, as compared with rigid sockets. The design originated in response to the request of a bilateral amputee who was accustomed to laced leather sockets. The new socket, which can also be made of other soft laminating resins such as polyester, acrylic, polyurethane, or lynadure, is relatively unstretchable. Currently, the socket is made of low-density polyethylene. The socket is fitted into a rigid frame with a medial upright; the frame is reinforced with carbon fiber.

The socket is vacuum-formed from a polyethylene sheet. Because polyethylene shrinks appreciably, the positive model for the socket is made slightly larger than would be required for a rigid socket. The frame is laminated with nylon stockinette, fiberglass, and carbon fiber tape. Acrylic or polyester resin is used. The socket and frame are riveted, or double adhesive tape may be used to fix the socket to the frame. The frame covers less than 40 percent of the socket, exposing the lateral aspect as well as most of the anterior and posterior portions. It is thus easy to add or remove material from the positive model when fabricating a new socket to accommodate volume decrease in the new amputee. The socket is left uncovered in order to allow rapid heat exchange, tactile contact, and better dynamic interaction between the amputation limb and socket. Socket exchange is described as simple and inexpensive.

Approximately 300 prostheses with the new socket have been made. Two breakdowns have occurred, both due to lamination failures.

The Early Rehabilitation of Lower-Limb Amputees Using A Pneumatic Walking Aid: R. G. Redhead (The Limb Fitting Centre, Roehampton, London, United Kingdom) *Prosthetics and Orthotics International* 7:88-90, August 1983.

The pneumatic walking aid originated by Little in 1971 overcomes the disadvantages of the prefabricated adjustable above-knee socket, and is easier to apply than the plaster immediate postoperative socket.

The apparatus originally had a single-compartment pneumatic sleeve long enough to extend from the groin to below the amputation limb. Subsequently, it was modified to have anterior and posterior compartments which communicated with each other through a small transfer port. End support was improved by a subsidiary airbag. Simple webbing slings supported the distal end of the sleeve in a support frame, and allowed length adjustment. The frame has a padded ring superiorly and a simple rocker at the distal end.

The device suits amputees with below-knee, through-knee, and (with slight modification), above-knee amputations. It is applied when the patient is seated between parallel bars with the limb extended. The small end bag is positioned and held in place as the long sleeve is pulled over the limb up to the groin. The frame is then passed over the bags. The end bag is partially inflated, then the main bag inflated to 40 mmHg. When the patient bears weight, pressure in both bags rises to 60 mmHg or more.

The apparatus is worn continuously for 2 hours and is generally applied twice a day. It is intended for use in ambulation only under supervision, with use begun, on average, 17 days post-operatively. No complications attributable to pressure damage were recorded. Several patients fell, but the aid protected the leg. The overall contact and pressure variation during walking reduces edema and hastens shaping and maturation of the amputation limb. Early ambulation preserves postural reflexes. The aid is commercially available, and is described as inexpensive and readily available. It has been in regular use since 1976.

Increased Incidence of Lower-Limb Amputation for Arterial Occlusive Disease: Einar Liedberg and Bjorn Persson (Department of Orthopaedic Surgery, University Hospital, Lund, Sweden) *Acta Orthopaedica Scandinavica* 54:230-234, April 1983.

Analysis of medical records from 1910 through 1979 indicated the incidence of amputation related to the age, sex, and occurrence of diabetes in the population of a county in Sweden. There has been a fourfold age-adjusted increase in amputations in the 8 decades studied; the actual number of amputations increased more than 10 times and the geriatric population increased 2.4 times.

Explanation for the results includes the observation that the indications for ischemic amputation have become more liberal and the geriatric population has also increased somewhat, but the age distribution in the population 80-and-older has remained similar during the studied time. The effects of exogenous factors like food, drugs, and poisons could account for earlier vascular changes. During the study period, vascular surgery has become a fairly common treatment modality. Insulin has increased the survival rate of diabetics, although diabetics account for only about a third of the amputees. The increased incidence of amputation for ischemia, especially after 1950, can be explained somewhat by the increased number of elderly nondiabetic and diabetic patients.

A Field Evaluation of Arm Prostheses for Unilateral Amputees: A. Van Lunteren, G. H. M. van Lunteren-Gerritsen, H. G. Stassen, and M. J. Zuithoff (Department of Mechanical Engineering, Delft University of Technology, Delft, The Netherlands) *Prosthetics and Orthotics International* 7:141-151, December, 1983.

Forty-two adults with traumatic amputation were evaluated with regard to the problems confronting them and use of the prosthesis. Participants had a medical examination, two psychological tests, and a multiple-choice questionnaire administered at a rehabilitation center. At a home visit they responded to a semistructured interview covering psychosocial aspects and the prosthesis, and an investigator noted performance of daily life activities.

The group consisted of 39 men and 3 women, most of whom were right-handed. Approximately two-thirds had amputation of the dominant limb. The group was almost evenly divided among wrist, below-elbow, and above-elbow amputees. Nearly half the group wore myoelectrically controlled hands. Most had good stump condition without pain.

Use of grasping function of the prosthesis is highest for myoelectric hand wearers, followed by users of a body-powered hook. Below-elbow amputees use grasp more often than above-elbow amputees. In general, active grasping is executed indirectly, that is, the object is put into the prosthesis by the amputee's own hand. Fixation against the body is a frequent alternative for grasping. Regarding activities in which the prosthesis is important, many mentioned hobbies, while fewer noted driving or cycling and work; only six included daily activities. Many fewer above-elbow amputees used the prosthesis for riding than did below-elbow. Positive comments are led by appearance, and secondarily motor function. Negative comments are also headed by appearance, mainly vulnerability of the glove; technical reliability, lack of touch, and hindrances due to harness for body-powered wearers and to socket for myoelectric wearers are other drawbacks.

A brief duration between amputation and fitting has a positive influence on use of the gripping function. Myoelectric wearers make more use of gripping than do body-powered prosthesis wearers.

Psychosocial factors include the cause of the amputation, which may have involved the patient in a lengthy lawsuit. Admission to a rehabilitation center is a positive turning point. Talking with other amputees is also valuable, as is provision of a prosthesis. People first discover the cosmetic function, then realize what they cannot do with the prosthesis before learning what they can do with it. Adjustment after leaving the rehabilitation center is difficult; family attitudes and hobbies which require some manual dexterity can have positive effects. It is very important for the individual to have an outlook for the future.