Abstracts of Recent Articles

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For this issue of BPR, Joan Edelstein again sought articles in all phases of rehabilitation engineering, from a wide number of current journals. Accordingly, you will find:

Upper limb prosthetics 3 articles
Upper limb orthotics 1
Lower limb prosthetics 11
Lower limb orthotics 3
Spinal orthotics 1
Gait 3
Environmental control 1
Wheelchairs 2

These have been drawn from:

American Journal of Occupational Therapy 1 article
Physical Therapy 1
Orthotics and Prosthetics 3
Prosthetics and Orthotics International 8
Journal of Biomechanics 2
Journal of Bone and Joint Surgery 2
Clinical Orthopaedics 1
Archives of Physical Medicine and Rehabilitation 7


Definition of modularity is necessary. The crustacean (wood) exoskeletal array was modular in the assembly process, for the fitter assembled a knee-shank, foot-ankle, and socket module. It is difficult to replace a major component in such a system without remaking the whole prosthesis. The significance of endoskeletal modular designs is the speed with which components can be replaced, simplifying servicing of prostheses.

Modular hardware does not save time of the prosthetist who must cast the patient, fit the socket, and perform dynamic alignment. Modularity will save technician time because alignment transfer, shaping, and finishing are not necessary and assembly without glued joints is faster. The saving in technician time equals the additional initial cost of the hardware; thus, in the developing world, use of modular hardware would be financially unsound since labor-intensive methods are indicated for prosthesis production there.

Modularity is primarily advantageous in repair and maintenance, saving technician and patient time.

The Multiplex system, designed by the United States Manufacturing Co. in response to a Veterans Administration standard, permits interchange in the same shank among different kinds of fluid knee controls and mechanical friction systems. Manufacturers of various units cooperated in making their controls conform with the standard geometry of the Multiplex unit. A trial with actual performance analysis can be done quickly.

Successful experimentation with graphite fibre and epoxy composite material achieved weight reduction in the Multiplex frame, and in a rotator and SACH foot keel.


Modular systems provide functional prostheses quickly. The ideal system has the possibility of alignment adjustment through the life of the prosthesis, simple change of components to give prescription flexibility, and easy disassembly for replacement of faulty parts.

The Hosmer and United States Manufacturing systems require the alignment device to be removed after dynamic alignment. The Blatchford and Otto Bock units have the alignment facility as part of the final structure and have been supplied to patients for three years. Modular above-knee prostheses are slightly lighter than exoskeletal ones; the Blatchford and Bock are lighter than the American ones. Alignment devices do not necessarily reduce prosthetist time, but they increase alignment accuracy. The Bock arrangement has alignment capability both below and above the knee. The static alignment apparatus makes bench alignment very accurate. Socket shape has not changed much, but the attachment to knee units varies. The Blatchford system was designed for metal sockets, hence duralumin struts; that system has an attachment for plastic and wood sockets, but may not allow close access to the knee center, especially if the amputation limb is too long.

Shape of the cosmetic cover is more important than softness, whether one-piece or two-piece; the former is suitable for a fixed knee, and the latter offers better function and durability for the active amputee. The system should serve all amputation levels. The child hip disarticulate cannot be fitted easily. Modular assembly makes production possible in smaller units, with easier ordering and pricing.

A new socket was devised, based on the assumption that the amputation limb had an outer limiting skin envelope, and oblique pelvic roof, and a central femoral strut. The shape, but not the volume, of the contained soft tissue could be altered. A limb in a rigid socket conforming to its average shape and volume could be treated as a fixed volume hydrostatic system. The patient would be supported on the incompressible volume contained in the socket, minimizing ischial bearing and distributing pressure evenly.

Forces act normal to the surface, eliminating shear stress. Support pressure would be related to the area of the oblique pelvic wall. The patient sustains full weight on the prosthesis transiently as he shifts support from one foot to the other; periods of lower pressure at the interface permit blood circulation, and the pressure variation promotes venous and lymphatic return. Socket retention depends on friction at the interface, voluntary muscle contraction, and atmospheric pressure, assuming an airtight total contact socket. Distal stressing increases soft tissue stiffness for skeletal stability; downward movement under axial compression would be prevented by the incompressible limb volume in a rigid socket. Rotational stability is gained by the brim’s locking the socket to the limb.

The cast is taken with the patient supine to relax muscles and avoid edema. A casting board adjustable for height and flexion are used. An open-ended elastic sleeve stretches the limb distally with 4.5 kg (equal to the weight of the prosthesis plus a safety factor). With such a socket, pressure transducers enabled measurement of load distribution and level under axial compression. The socket had total contact, there was no skin movement, and skin color was uniform. Lowest pressures were noted on the proximolateral aspect, and angular foramina, unlike the intact limb in which bone and joints absorb stress. Ischial-bearing orthoses allowed early ambulation, may have encouraged bony deposition and healing, and avoided atrophy which would have necessitated socket alteration. Those who had non-weight-bearing treatment delayed prosthetic return, but all ultimately returned to previous functional levels.


Eight of a population of 341 lower limb amputees sustained femoral fracture. The group consisted of five dysvascular amputees (two bilateral below-knee and three unilateral below-knee), two traumatic amputees (a bilateral and a unilateral below-knee), and one individual who required above-knee amputation following knee infection. Fractures were ipsilateral among those with unilateral amputations and on the side of the initial amputation among the bilateral amputees. All but one of the fractures were closed. Five fractures were intertrochanteric or above.

Unilateral amputees with closed fractures had closed reduction and plaster casting. Bilateral amputees had open reduction and internal fixation. A Cathcart endoprosthesis was implanted in one patient with hemipelgia and unilateral below-knee amputation. The open fracture was debrided. All fractures healed primarily. Those with proximal fractures had ischial weight-bearing orthoses with knee locks attached to the patellar tendon-bearing prostheses and resumed ambulation an average of 20 days after fracture. The others had non-weight-bearing casts and crutches and averaged 54 days between injury and walking.

Fractures occurred an average of nineteen years after amputation, usually when the patient was not wearing a prosthesis, generally during transfer activity. Patients need to be trained in safe transfer with and without the prosthesis. The low incidence of fracture indicates that most amputees do not sustain serious falls. The prosthesis and stump-prosthesis interface absorb torsional and angular forces, unlike the intact limb in which bones and joints absorb stress. Ischial-bearing orthoses allowed early ambulation, may have encouraged bony deposition and healing, and avoided atrophy which would have necessitated socket alteration. Those who had non-weight-bearing treatment delayed prosthetic return, but all ultimately returned to previous functional levels.


During a 7-year period, 12 of 650 new amputees were blind. These geriatric amputees were followed for an average of nearly four years. Uncorrected visual acuity in both eyes was 20/200 or worse or the central visual field was 20 degrees or less, because of cataracts, glaucoma, retinopathy, trauma, or various etiologic combinations. Eleven were diabetic and all required amputation because of gangrene. Blindness preceded amputation in nine cases.

All received prostheses 6 months postoperatively or sooner. Most below-knee prostheses were patellar-tendon-bearing with soft insert, although one was a training prosthesis and another had supracondylar-suprapatellar suspension. Symes’s prostheses had medial openings. Above-knee prostheses had quadrilateral sockets, pelvic suspension, safety knees, and SACH feet.
All patients reached ambulatory status on an outpatient basis, requiring an average of 11 weeks training. Extra time was needed to teach donning, including counting the number of holes on straps and feeling for sock thickness and seam position, as well as manual inspection of the amputation limb. Ambulation progressed from parallel bars to regular cane or walker, first in familiar, then new areas, following verbal cues. The assistive device always served as both blind stick and weightbearing aid.

Nine (one bilateral Syme’s, six unilateral below-knee, and two bilateral below-knee) amputees walked 2 years after amputation. The other three (one bilateral below-knee, one unilateral above-knee, and one above-knee/below-knee) amputees used prostheses for cosmesis and transfer only. Outpatient care reduced the amount of adjustment required to complete training, and saved expense. None of the patients complained of phantom pain, attributed to the early fitting policy.

System of Reporting and Comparing Influence of Ambulatory Aids on Gait: Gary L. Smidt and M. A. Mommens (College of Medicine, University of Iowa, Iowa City, Iowa 52242), Physical Therapy 60:551–558, May 1980.

A new automated gait analysis system enabled measurements of the gaits of 25 normal young adults. The system included triaxial accelerometers, foot switches, signal-amplification unit, and computer which measured temporal and distance factors and body acceleration. Subjects walked at various velocities and with nine gait patterns utilizing canes or crutches: two-point contralateral cane (right hand/left foot); two point contralateral cane; two point contralateral crutch; two point ipsilateral cane; three point crutch; delayed two point contralateral cane; delayed three point crutch; four point crutch; and delayed five point walker. Walking speed with ambulatory aids was much slower than self-selected unaided velocity; using the walker produced the slowest locomotion. Patterns involving four counts were slower than those involving two or three counts. Swing/time and stance/time ratios were symmetrical for all gait patterns, but step length was not, especially with three-count and five-count gaits. The lead step was longer. Step time for three-count pain, attributed to the early fitting policy.

Increased left dorsiflexion was due to lack of sufficient intrinsic torque to counteract extrinsic ankle torque; the left knee remained flexed because of the dorsiflexion, necessitating more quadriceps activity. Compensatory contralateral knee flexion and ankle dorsiflexion during late stance was due to lack of ankle restraint; that foot contacted the floor prematurely to check the fall and the knee flexed to absorb impact, disturbing smooth weight transfer. Orthotic substitution for plantar flexor function should increase opposite-step length and reduce energy output.

Polyurethane Foam Wheelchair Cushions: Retention of Supportive Properties: Gary M. McFadyen and David L. Stoner (Department of Industrial Engineering, Texas A&M University, College Station, Texas), Archives of Physical Medicine and Rehabilitation 61:234–237, May 1980.

Indentation load deflection (ILD) due to steady loading and to cyclic loading were studied separately in five cushions of various polyether and polyester foams in different densities. Cushions should have a high ILD to prevent rapid bottoming out. A thick cushion has a high ILD but might upset patient stability. Too high an ILD would result in a cushion that feels stiff. A dense cush-
ion would retain ILD values after repeated loading, but its heaviness would decrease handling ease. High resilience, such as common in wheelchair cushions, resists permanent deformation.

Cushions were subjected to static fatigue testing by prolonged loading, dynamic cyclic fatigue testing, and to combination loading. Most of the ILD loss occurred within the first three hours of static testing, and after 200 cycles of dynamic testing; ILD loss due to dynamic loading was less than that due to static loading. Polyurethane foam recovered 80 percent of its supportive properties after 24 hours rest. Patient weight and duration of sustained loading thus have the greatest effect on cushion life. Consequently, alternating use of cushions might prolong the usefulness of both cushions. Change in surface properties of statically loaded foam is less at cold temperatures than at room or hot temperatures; the change in bulk properties is greater at either extreme than at room temperature.

Cushions should be prestressed statically before prescription at 75 percent deflection for 3-hours; a 4-inch foam would be compressed to 1 inch by placing the foam between two boards bolted together. The cushion should be tested for pressure distribution under the patient soon after.


Charts of 843 hemiplegics due to cerebrovascular accident admitted for active rehabilitation were reviewed. Approximately equal numbers of men and women, and right and left hemiplegics were studied. The mean age was 64 years. The average time from onset of stroke to rehabilitation admission was 65 days for the first 6 years studied, then was 50 days for the succeeding 4 years. The average stay was 78 days for the first 6 years; more recent stays were 64 days on average. Of those admitted as nonambulators, a third remained nonambulatory; 20 percent became functional ambulators, walking independently at home, but may have needed supervision outdoors; 42 percent became partially functional, walking with supervision at home and short distances outdoors. Two-thirds of those who were initially partially ambulatory advanced to functional ambulation.

No knee-ankle-foot orthoses were prescribed after 1976. Plastic ankle-foot orthoses were introduced in 1968, especially the posterior solid ankle, and in 1970 the first spiral posterior leaf spring and solid ankle-foot orthoses were used. By 1973, no metal orthoses were prescribed and only 43 percent of patients received any orthoses.

The most common orthoses are now hemispiral, posterior leaf spring, and hemiposterior leaf-spring ankle-foot orthoses. While prescription considerations remain unchanged, performance expectations for the spiral and solid ankle orthoses have changed. The spiral is unsuited for hemiplegics who exhibit strong inversion and dorsiflexion. The prime indication for solid ankle orthoses is strong equinus or equinovarus, yet immobilization of a spastic limb may increase spasticity. Many patients benefitted more by use of lateral heel flares or lateral heel and sole flares, sometimes with heel elevations, accommodating equinus, preventing pain from pressure sites, and increasing the lateral base of support.


A war veteran was amputated bilaterally at equal levels, 5 cm below the knee. High sockets caused painful compression of the posterior wall against the hamstrings during knee flexion. A thigh corset with side bars was not used because incongruity between side bar axis and natural knee would limit function. A usual patellar tendon bearing prosthesis is spherical when the amputation limb is short, reducing the efficiency of the moment transfer mechanism. To reduce socket sphericity, a supracondylar suspension was used with an extra long posterior wall which limited knee flexion. Siting pressure was a combination of hamstring wedging pressing obliquely against the brim and soft tissue bulging in the popliteal region. Three alternatives were outlined:

1. A sliding posterior wall with translation limited to 25 mm;
2. Concentric sockets with relative axial movement between them; the posterior support provided by the outer socket is augmented by anterior and mediolateral support from the inner one; excessive flexion would unlock the inner socket from the outer, relieving pressure; and
3. A stabilized socket attached above a four-bar mechanism; at a predetermined degree of knee flexion, the socket unlocks and rotates with respect to the shank, so the amputee can sit with his knee extended while the shank is vertical.

The solution for each prosthesis involved concentric sockets with posterior extensions and supracondylar suspension. A section of the posterior wall was cut from the inner socket and glued to the outer one. A guiding mechanism with self-locking was fitted between the sockets. Normally the mechanism was locked, holding the sockets tightly. When hamstrings compressed the unlocking lever, the inner socket ejects with the aid of a compression spring. Ejection exposes the posterior recess, relieving hamstring pressure. The mechanism allowed adequate knee flexion during gait, full flexion
in sitting, and sufficient support for stable ambulation. During a 9 month wear period, the patient’s gait as measured by force plate dynamometers was satisfactory and pressure sores in the hamstrings and popliteal region disappeared.

Recreational Activities of Lower-Extremity Amputees:

One hundred amputees responded to a questionnaire sent to 450 lower-limb amputees; 10 therapists and 6 prosthetists also replied. Forty of the 60 amputees who were recreationally active wear a prosthesis when participating in sports, but only 3 wear a specifically designed sports prosthesis. Two-thirds use a SACH foot, and one out of four uses a hydraulic knee. Very few have waterproof prostheses, rotators, or a Greissinger foot. Prosthetists had fabricated limbs for swimming, football, snowshoeing, basketball, fishing, waterskiing, and flying an airplane. In most cases, insurance companies did not pay for the sports limb.

Fishing was the most popular activity, followed by swimming, bowling, hunting, golf, baseball, horseback riding, and basketball, all of which were reported by at least 20 percent. Volleyball, waterskiing, snowsking, tennis, football, and jogging had fewer devotees. Skiers used either outriggers or conventional ski poles.

Many active amputees swim often. Some doffed the prosthesis at water’s edge, others removed it and hopped to the water, a few used crutches, some crawled, and four had waterproof prostheses to get to the water; two used them (or fins) in the water.

Inactive amputees noted pain, disinterest, fear of injury, lack of a waterproof prosthesis, family overprotection, embarrassment, lack of sports training, and lack of sports organization as reasons for nonparticipation. Most therapists did not teach sports skills. Active amputees did not want allowance made for their disability; they were usually informed about sports by prosthetists. Amputees requested better impact-absorbing legs, better foot and ankle mobility, limb rotators, lightweight limbs, ventilation, more comfortable sockets, better suspension, and better knee units.


A normal man set for one hour on each of 24 commercially available cushions, with its original cover. Skin temperature, heat flux, and relative humidity were measured under the ischia. Room environment was monitored.

Foam and viscoelastic foam cushions caused significant temperature rise, reduced heat flux, and little humidity increase. They tend to be hot because foam and entrapped air are poor heat absorbers and heat conductors. Humidity is stable if the cover is porous, because the open-cell structure provides a pathway through which moisture can diffuse. A vinyl cover increases humidity. Increased skin temperature is undesirable because the accompanying metabolic increase compels tissues, already suffering from poor circulation due to pressure, to use more oxygen. Temperature rise also aggravates risk of infection and sweating and decreases skin tensile strength. On gel cushions, temperature remained constant while heat flux and humidity increased markedly, probably due to the relatively high specific heat of gel and to its nonporous nature. Water floatation pads caused significant temperature drop, increased heat flux, and slight humidity rise due to the high specific heat of water combined with its good conduction and mechanical circulation; its nonporous nature accounts for the humidity elevation. The styrofoam bead-filled cushion produced temperature and humidity rise and low heat flux, as did the balloon cushion.

A layered combination cushion may improve optimum thermal and mechanical performance. The moisture control properties of gels could be improved by a separate top layer of porous foam, with the cushion encased by a porous cover.


A ballistic model of swing phase assumes that muscle action during double support establishes a set of initial conditions and velocities for both stance and swing legs, and assumes also that in the rest of swing limbs move under the influence of gravity, that total energy is constant during ballistic swing, and that zero muscular torques act during swing. The swing leg moves like a pure pendulum. Most muscles of the swing leg are inactive, except at the beginning and end. The mathematical model includes hip flexion and knee flexion of the swing leg, the most important determinants of normal walking. The model has one link representing the stance leg and two for the thigh and shank of the swing leg, the foot being rigidly attached. The moment of inertia and location of the center of mass of each link are taken from anthropometric data. In stiff-legged walking, the swing leg will hit the ground during swing, if one does not plantarflex the stance ankle or tilt the pelvis. If the knee locks before heel strike, the vertical force dips due to pulling down of the center of mass of the body produced by the centripetal acceleration of the swing leg at midswing. The impulsive moment at the
knee stops shank swing and locks it with the thigh, reducing backward thigh movement because if no moment were applied to the knee, the thigh would have continued to swing. Knee locking keeps the thigh flexed for heel strike. Equations are provided for stiff-legged gait, ballistic walking with knee flexion, and swing times for various angles as related to various velocities. Basic assumptions, such as constant step length and prohibition of toe drag, would not change if the model were more complex.

The assumption that muscles do not act during ballistic swing is not justified at very low or high speeds. Horizontal and vertical forces and joint angles of a simple inverted pendulum all execute trajectories close to the model, but swing time is prolonged. The model couples an inverted pendulum for the stance leg and a compound pendulum for the swing leg as the simplest representation of walking which has a natural period with accurate ground reaction forces.

For Accelerated Postamputation Rehabilitation—Zoroc Intermediate Prostheses: J. M. Leal and others (Veterans Administration Medical Center, Tucson, Arizona), Orthotics and Prosthetics 34:3-12, March 1980.

A new technique for construction of removable intermediate prostheses uses Zoroc resin-impregnated plaster. The lightweight, durable prosthesis can be fabricated in 2 hours and ready for patient use in 1 day. The technique uses predesigned shapes such as the quadrilateral rim, sometimes with a medial window for knee disarticulates.

Above-knee and knee disarticulation prostheses require a polyethylene brim, polypropylene pelvic joint with pelvic band, below-knee immediate postoperative prosthesis belt, and above-knee postsurgical pylon or OHC polycentric hydraulic knee. The below-knee prosthesis has postsurgical felt relief pads and below-knee wrist suspension belt and pylon. All prostheses also include SACH feet, Zoroc plaster, elastic plaster, and other supplies. The below-knee socket is constructed on the seated patient; the above-knee and knee disarticulation sockets are molded on the supine patient.

Normally a temporary plastic prosthesis is provided 2 or 3 days after removal of the final immediate postoperative prosthesis by staff prosthetists. Outside facilities delayed provision of the temporary prosthesis 2 to 4 weeks. Use of Zoroc prostheses in 19 patients (including below-knee, knee disarticulation, and above-knee cases) reduced hospitalization and enhanced maturity of the amputation limb. Zoroc does not replace a plastic temporary prosthesis, but serves as an inexpensive interim device. Patient acceptance has been excellent.

Bilateral Shoulder Disarticulation: Equipment Used to Facilitate Independence: Janet Poole and M. Martha Parkinson (Towers Unit, University of Virginia Hospital, Charlottesville, Virginia), American Journal of Occupational Therapy 34:397-399, June 1980.

Independent living skills were developed for a 24-year-old man who acquired bilateral traumatic shoulder disarticulation. He used his teeth and feet for simple tasks, but could not feed, dress, toilet, or bathe. Two battery-powered prostheses aided feeding, communication, and some hygiene activities. The prostheses were too limited in range of motion for dressing, bathing, and toileting. Their passive shoulder joints could not achieve full range of motion in any direction. Equipment was designed for tasks in which prostheses were not functional. Alternative methods in communication and hygiene were implemented during periods of skin breakdown and mechanical problems with the prostheses.

Dressing was accomplished with a frame chair used as the base for attaching devices. A double hook clamped to the back of the chair assisted the patient in donning trousers. Using feet, he maneuvered the pants up his thighs. He then stood and hooked a belt loop over the double hook to stabilize his pants. The hook also enabled him to engage the zipper with the aid of a zipper ring. An attachment mounted to the chair's front legs was for donning adapted socks. Two overhead bars bracketed to the chair aided shirt donning; a button hook was also clamped to the chair.

For bathing, two long-handled sponges were clamped to each end of a vertical grab bar. Wearing soap-on-a- rope around his neck, the patient lathered the sponges, then moved his body against them. He scrubbed with a hairbrush suctioned to the shower wall, and dried himself by wearing a bag-type robe and rubbing against the wall. Two goosenecks aided tooth brushing, shaving, and hair combing.

A commercially available BeOK deluxe toilet aid was attached to a conventional removable toilet side rail for perianal cleansing. Another aid for donning clothing for urination was suitable for use away from home. A mouthpiece with interchangeable end pieces aided typing, writing, page turning, and telephone dialing. Lower body agility may be a prerequisite for efficient use of some of the equipment.


Tibial torsion implies a fixed rotary deformation of the tibia along its longitudinal axis, with either excessive anterior or posterior displacement of the medial malleolus relative to the lateral malleolus. Internal tor-
sion is normal in utero; at birth no torsional deformity exists; a progressive external torsion occurs to an average 23 degrees in adulthood. Pathologic torsion usually causes out-toeing or in-toeing. Torsional deformities may be congenital, developmental or traumatic. Roentgenographic measurements require trained personnel and are not applicable to the incompletely developed osseous structures of the child; goniometric apparatuses are cumbersome for routine office use. Clinical assessment by estimation of the angle formed by the transmalleolar axis with the axis of the knee is possible, but grossly inaccurate.

The new apparatus has been applied to 500 adult tibias. It consists of a goniometer to the movable limb to which are attached two parallel hinged rods. Rubberized malleolar cups are placed equidistant from the hinged portion of the rods. The movable limb is placed parallel and in congruity with the axis of rotation of the knee with the knee flexed 90 degrees. The malleolar cups contact the malleoli, while maintaining parallel relationship of the rods and equidistance of the cups from the movable limb. The angle described by the goniometer is the same as that between the transmalleolar axis and the transcondylar axis.

Roentgenographic confirmation of measurements with the apparatus was obtained on one hundred tibias; all measurements were within three degrees.


Priority in a new prosthetic design was given to stability with minimum muscular effort, smooth passage from stability to knee flexion, and dorsiflexion in swing phase. Substantial muscular effort is always required at the beginning and end of stance or both. Strain on extensors during weightbearing, or on flexors at push-off, depends on the position of the instantaneous center of rotation of the shank with respect to the socket. Amputees rarely control the rate of knee flexion, which results in unaesthetic appearance and sudden weight transfer to the contralateral limb. The prosthesis has a simple adjustment device for changing the degree of voluntary control; swing-phase dynamics were not dealt with.

The rationale of the new design is based upon analysis of the prosthesis as a kinetic chain, the proximal end of which is the femoral head and the distal end the foot link subjected to forces and torques due to ground reactions. Single-axis and polycentric four-bar-linkage prostheses have their centers of rotation lying in a sector bounded by a straight line from the hip to the heel and another line from the hip to the ball of the foot. In this sector, the minimum control moment required at the beginning of stance decreases when the rotational center gets closer to the line from hip to heel, while the control moment required to flex the knee at the end of weightbearing decreases by moving the center toward the line from hip to forefoot. These moments are both reduced by raising the center. Polycentric mechanisms have higher controllability than single axis, but none permits reducing the control moment as much as one would wish. Prosthetic stability increases from heel strike to toe-off, in contradiction to the normal requirement of highest stability at beginning of stance and decrease going toward push-off to allow effortless knee flexion. For this requirement, the shank and foot were linked.

A prototype knee-ankle linkage prosthesis was manufactured. A computer program for calculating the relative controllability of the prosthesis was developed, and the prototype was fitted on two middle-aged patients. Qualitative results were encouraging, and quantitative gait analyses are in progress.


Prior to fabrication of an Orthoplast body jacket, the patient has a Risser or Cotrel cast with an average 27-kg longitudinal traction. A roentgenogram shows the amount of realignment. The cast is removed, and a positive mold is made and modified to relieve pressure points. Plastic is molded to the model. Trim lines are at the level of the pubic symphysis and greater trochanters and high in the axillae. The jacket opens in front. Fabrication time and cost are about half of that for the Milwaukee brace.

The jacket suits flexible immature curves less than 40 degrees with the apex below the seventh thoracic vertebra. A significant rib hump or respiratory insufficiency contraindicate it. The jacket is worn 23 hours daily until the spine is stable. Then the patient is out of it for 2 hours daily for 2 to 3 months. If the curve remains stable on X-ray, time out is 4 hours daily. After another 2 months with curve stability, time out is 8 hours, then 12 hours after another 2 months. Patients wear it nightly for 2 years. All correction is achieved with the original mold; no structural adjustments are made.

Exercise within the total-contact orthosis are impossible, but pelvic tilt and sit up exercises to avoid paraspinal and abdominal atrophy are done with it off. Tumbling, trampoline, and gymnastics are restricted; swimming without the jacket is encouraged. Five hundred children have been treated with the orthosis. The average age of application was 11 years, 10 months; weaning started at 14 years and 3 months and the program was completed at 16 years and 9 months. The av-
verage reduction was 62 percent at all curve levels.

Of patients older than 16 years who had been without the jacket for at least 6 months, half the curves were unchanged, a third improved, and only 6 progressed more than 5 degrees beyond the initial curve. Vital capacity with the jacket was reduced 18 percent, but was normal when the jacket was removed. Patients preferred it to a Milwaukee brace because of the absence of neck ring. More durable plastics, Vitathene or polypropylene, decreases frequency of replacement. Prefabricated versions are being tested.


Conventional elbow orthoses for ambulatory patients usually have an elbow lock and cable; they require strong shoulder muscles and are bulky, heavy, and difficult to operate. The experimental orthosis uses a pneumatic device to assist elbow flexion. It has a shoulder cap, wrist cuff, and five-bar elbow linkage; a pneumatic-spring cylinder flexes the elbow. Minimal force is needed to initiate flexion, and increase in flexion produces non-linear force increase. The user requires some extension activity because the force needed to extend the system exceeds that needed for flexion. Counterbalance is produced between forces used to extend the cylinder during flexion and compress it during extension, permitting the system to be stabilized against the weight of the forearm. After the elbow is flexed moderately, the wearer can hold objects weighing up to one pound. The unit continues to flex until the triceps retard flexion or stop it. Slight elbow extension is required to maintain full extension. Three different cylinders provide 200, 300, or 400 newtons of force. The system is lightweight, functional, and cosmetic, although patients need help in donning and doffing it.

Fabrication requires casting the shoulder and upper arm and the forearm, modifying the casts, and laminating (or vacuum-forming or drape-molding) low-density polyethylene. The shoulder and wrist sections are lined with Pelite. Cross-chest and upper-arm straps support the device. The pneumatic unit is screwed to the shoulder cap and wrist cuff. The orthosis has been fitted to a polio patient, one with brachial plexus avulsion who has used it successfully for nearly two years, and one with another neuropathy.


Testing of commercial environmental control units, self-contained telephone, and typewriter systems was done in the occupational therapy laboratory, bedside, and home with 52 patients. None were respiratory-dependent; most lesions were C4,5 (although levels ranged from C2 to C6, 7).

Of environmental controls, Fidelity Comfort and Communication was preferred initially, but was ultimately rejected because of unreliability. The bulk and error-prone dialing mode of Possum Selector were disliked. Nu-Life was too slow. Remote Operation by Oral Triggering (ROBOT) has an exhausting operation mode. Environmental Control Unit ECU-1 was preferred, although Prentke Romich ECU-2 was not, due to lack of a separate display. Genie was annoying with its constantly scanning display. Touch Operated Selector Control (TOSC-2) lacked visual numerical telephone dialing display. Prentke Romich Automatic Dialing Telephone (ADT-5A) was most popular due to its total digit dial capability and easy operation.

Typewriter systems were no better than mouth-stick and balanced forearm orthosis control of an electric typewriter. The PMV Printer had a demanding mode of operation. Possum Scanner was better, but only one patient preferred scanning over other typing methods. Possum Hi-Speed gained five advocates; others disliked its complicated random-access method. PMV Minimum was easy to operate.

Training for all patients for all units required a single explanation. All, except one with periodic cyanosis, could operate all pneumatic interfaces easily. None could operate the ROBOT by either audio or manual input.

ECU-2, Nu-Life, ROBOT, and TOSC-2 were maintenance-free. All typewriting systems required repair. Cost are compared. C2-4 patients use pneumatic interfaces best; C4-5 often used pneumatic and pressure controls; C5-6 used only pressure.

ECU-1 and ADT-5A demonstrated exceptional patient acceptance and reliability.

Skin Problems of the Leg Amputee: S. William Levy (Department of Dermatology and Biomechanics Laboratory, University of California, San Francisco), Prosthetics and Orthotics International 4:37–44, April 1980.

A snug socket prevents free air circulation and traps perspiration. Uneven loading stresses local areas. Intermittent stretching of skin and friction against the socket edge and interior also abuse skin. A thigh corset may obstruct venous and lymphatic drainage. Minute lesions may initiate extensive disorder with mental, social, and economic disaster. Poor hygiene produces infections, nonspecific eczematization, intertriginous dermatitis, and epidermoid cysts, as well as maceration and malodor. Cleansing with bland soap or detergent nightly, and daily wear of a clean sock, are necessary.

Initially a suction socket causes reactive hyperemia, reddish-brown pigmentation resulting from capillary
hemorrhage; elastic bandaging reduces this innocuous condition. An edematous end may strangulate, ulcerate, or become gangrenous. Socket choking, poor fit and alignment, and excessive negative pressure must be eliminated, and distal tissues supported. Varnishes, lacquers, plastics, cements, and resins (especially incompletely cured epoxy) may cause contact dermatitis; the irritant must be removed. Nonspecific eczematization may be secondary to faulty fit or alignment or to edema. Epidermoid cysts on the proximomedial thigh result after much prosthetic friction; surgery, topical medications, and socks such as an adductor rim sock, may be beneficial. Folliculitis and furuncles, especially among those with hairy, oily skin, may ensue from poor hygiene. Fungus usually appears only on skin enclosed by the socket and generally responds to fungicides. Intriginous dermatitis occurs in the inguinal and crural folds and at the invaginated scar; it requires cleansing and powdering apposing skin. Chronic ulcers from bacterial infection, poor cutaneous nutrition, or local pressure may progress to malignant ulcers. Benign and malignant tumors, verrucous hyperplasia which responds to distal contact, acne, seborrheic dermatitis, psoriasis, and lichen planus may also occur; treatment procedures are suggested.

**Toileting Self-Care Methods for Bilateral High Level Upper-Limb Amputees:** L. Friedman (Paediatric Occupational Therapy Department, Institute of Rehabilitation Medicine, New York, New York), Prosthetics and Orthotics International 4:29–36, April 1980.

Toileting is of greatest concern for the bilateral high level amputee. Inability to cleanse oneself eliminates school attendance, independent travel, or employment. It is destructive of self-confidence to have toileting care. The principles are the same with children with congenital or acquired amputation and with adults, although their range of lower-limb motion is generally restricted.

Individual assessment of limb length, motion, strength, and agility is crucial prior to a trial of methods and devices. Juvenile motivation reflects parental wishes.

Before toileting, clothing and underclothing must be removed; adaptations, especially for adolescents, should be inconspicuous. Few special devices should be used, so that travelling is not unduly hampered. Loose clothing without elastic eases doffing and donning. Procedures for disrobing for urination and defecation are detailed. A wrist flexion unit aids manipulating zippers and some can use the prosthetic hook for wiping. A clothing hook on the wall facilitates dressing. Various types of forked rod aid in pushing trousers down and pulling them up. An "S" shaped dressing hook benefits patients with upper phocomelia and normal legs.

The child with short upper limbs with adequate grasp may use one of the several custom or commercially available limb extenders (illustrated) for clothing doffing and holding toilet paper. Patients with upper extremities with inadequate grasp and limited lower-limb mobility do best by placing toilet paper on the seat or other stationery object and rocking against it. Patients with no hand function can manage with well-developed foot function.

Several modifications for menstrual cleanliness are described.

Patients with quadriamimal involvement need various dressing devices; a bidet is generally required for perineal cleansing.

**Controlled Environment Treatment (CET):** I. M. Troup (Limb Fitting Centre, Dundee, Scotland), Prosthetics and Orthotics International 4:15–28, April 1980.

Clinical impressions are the basis of the report of 100 cases. Wound healing depends on physical environment, including the degree of pressure on tissues and its variation in level and time. A conventionally dressed wound is warm, moist, and not sterile, allowing bacteria to thrive. The CET SteriShield® bag has an internal proximal apron which forms a partial seal, and is suspended by shoulder harness and hemipelvic band. Automatic cycling of pressure level and time imposes a vascular pump, promoting lymphatic and venous return. Pressure is uniform, avoiding a tourniquet effect. Air or gas humidity and temperature can be controlled. All cases treated preoperatively, from three to nine days, had edema eradicated or diminished. Most treated postoperatively had edema controlled, but infection (which may have been due to ischemia) was not always controlled; a third of these patients had pain. Most had about 2 weeks of treatment with CET. Compared with a rigid dressing, CET controls edema better, although plaster may control pain better. Many of those with nonhealing were aided by CET. CET also benefited varicose ulceration, diabetic foot lesions, and nondiabetic infection. The doctor is involved in critical assessment of case suitability, daily observation, and instruction of paramedical staff. Nurses must be familiar with patient management, including moving patient with machine. The physiotherapist can mobilize the patient within a limited area and can move the joint within the Sterishield; the patient may be frustrated, however, seeing others more mobile.

The apparatus is self-managing; air filters are changed monthly, and bacterial filters yearly. No skill of application is required, the extremity can be observed during CET treatment, and no bandaging is needed. Reducing peripheral vascular stasis with CET is especially important in varicose ulceration and in the diabetic foot; the latter also requires radical surgery.

The therapist usually deals with older dysvascular amputees who have diabetes, hypertension, or cerebrovascular accidents. Preoperative treatment is directed to muscle reinforcement and joint mobility; the patient balances on one foot and transfers. Postoperative care begins when the patient's condition permits, with strengthening and preventing of contractures. If there is no rigid dressing, the patient should press his amputation limb manually, preparing him for prosthetic tolerance and acceptance of it as a part of his body. Standing in parallel bars is started with or without a prosthesis. He learns to flex and extend his knee to work the amputation limb in the socket and bring weight over the prosthesis. He must bring full weight over the prosthesis before starting walking. A mirror helps correct posture. Once he needs only slight support from the bars, walking starts. He first raises each knee alternately. Then, with the prosthetic foot slightly ahead of the sound one, he flexes his knee with progressively more weight on it, until the prosthetic foot is flat on the floor. He does the reverse, extending the knee fully while bringing weight back to the sound leg. Then he brings the prosthetic foot forward and steps with the normal foot while extending the knee on the amputated side. These exercises prepare him for free walking in the parallel bars.

When he can walk confidently in the bars, he starts walking with crutches or canes, first with one aid and a bar, then with two aids inside the bars, using the four-point gait. He learns to rise from his wheelchair and from a straight chair. Walking exercises are progressed to outdoors, walking with one cane, clearing obstacles, and climbing inclines and stairs, usually with prosthesis and sound leg alternating. Young patients also run, jump, and practice equilibrium exercises on a beam.

The gait should have foot flatness at midstance, lateral knee stability, controlled knee use, smoothness, minimal lateral trunk bending—and even step length, timing, and arm swing. Causes of stance and swing deviations are noted.

Ideas on Sensory Feedback in Hand Prostheses:


Myoelectrically controlled systems have developed rapidly, with some clinical success in spite of the lack of feedback which mandates visual control. Patient performance is close to that with cable-operated prostheses. A hand prosthesis replaces prehension and some sensation. Sensory feedback enables comparison of output to input to increase control accuracy. Proprioceptive feedback, information about position, movement, and force in prosthetic joints, and somatosensory feedback, concerned with grip force and slippage, are needed; most systems convey the latter. Systems usually have vibratory or electrical stimulation. Rejection has been due to fragility, control interference, and bulk.

Systems using physiological mechanisms have greater acceptance than entire artificial ones. Position sense probably has its neural basis in muscle spindles and the central nervous system, not in joint and skin afferents. The below-elbow amputee retains some hand muscles. In the Boston arm, effort sensing accompanies muscle work at the myoelectric control site; a negative feedback signal proportional to the force resisting movement augments the myoelectric signal. Prosthetic control should be related to physiologic movements, rather than to single-muscle action—which is unphysiological. Pattern recognition for hand prostheses should permit proportional control of effort and force, through integration of signals from several muscles relevant to a movement.

Most acquired amputees easily move the perceived phantom and feel how it moved. The neural basis of perception of phantom movement probably is muscle afferents from the distal amputation limb. Pattern-recognition control requires that specified phantom movements result in corresponding prosthetic movements. Extended physiological proprioception refers to the ability to translate movements and positions of the amputation limb to the prosthesis proportionally; the brain adapts to prosthesis length just as a golfer adapts to the length of his club.

Patient acceptance depends on psychological and socioeconomic analysis and prosthesis reliability, easy use, and inconspicuousness; thus self-containment and self-suspension are vital.