ABSTRACTS OF RECENT LITERATURE

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Abstracts are drawn primarily from the orthotics and prosthetics literature. Selection of articles was made from the following journals:
American Journal of Physical Medicine
Archives of Physical Medicine and Rehabilitation
Clinical Prosthetics and Orthotics
Ergonomics
Journal of Biomechanics
Journal of Bone and Joint Surgery
Orthotics and Prosthetics
Prosthetics and Orthotics International
Scandinavian Journal of Rehabilitation Medicine
Spine

ALTNER PC, ROCKLY P, KIRBY K (Veterans Administration Medical Center, Northport, NY 11768).

Retrospective study of 52 consecutive patients treated during a 14-year period indicates mean age at onset of disability was 65.2 years. More than two-thirds had hemiplegia first. Mean interval between first and second disability was 62.5 months. Prosthetic fitting is influenced by side of hemiplegia, laterality of disability, amputation level, order of disability, neuromuscular status, mental status, sex, and age.

Thirty patients received prostheses; 8 walked independently and 16 had limited ambulation. More patients had left hemiplegia and more had ipsilateral disability, but neither factor was statistically significant with regard to function. More below-knee amputees were fitted. More patients with amputation prior to hemiplegia were fitted, but function was not affected significantly. Good-to-fair neuromuscular status is a prerequisite for ambulation. Sex and age were not significant in affecting function. Although the results are at variance from other reports, the only significant deciding factor for good ambulation is good-to-fair neuromuscular status.


Twenty patients undergoing below-knee amputation were allocated into either the group receiving 28 percent adjuvant oxygen for 48 hours postoperatively, or the group not receiving oxygen. Transcutaneous pO2 measurements were made independently. Patients had light gauze dressings, regular therapy, and early ambulation using the pneumatic prosthesis. In a related study, 39 patients with below-knee amputation were assigned randomly to a treated or untreated group. The former received adjuvant oxygen. Healing was assessed.

In the treated group, a significant fall in transcutaneous pO2 of the anterior flap occurred on day 2, following cessation of adjuvant oxygen. This fall occurred immediately in the untreated group. No significant difference existed with regard to healing among groups; however, low tissue oxygen is more likely to lead to failure. No difference occurred between length of hospital stay for the groups. Although significant differences in healing rates are not evident, adjuvant oxygen use is associated with healing at significantly lower levels of preoperative
transcutaneous $pO_2$. The overall healing rate was 83 percent. There is little expectation of healing below a transcutaneous $O_2$ level of 20 mmHg at the anterior 10 cm below knee level. Success in amputation surgery and rehabilitation depends on the interest shown in the individual patient, use of careful operative technique and enthusiastic post-operative care.


A quarter of patients who had paralytic poliomyelitis develop new complaints decades after stable function. The mean latency is 36 years. The risk increases with severity of the original poliomyelitis, both with regard to early appearance of post-polio syndrome and its severity. The cause of the syndrome is not established; it may be due to attrition of neurons with aging, or that motor units grossly enlarged by reinnervation in the original recovery may now have peripheral disintegration. Patients with or without new symptoms have evidence of ongoing neuromuscular disorder. Pain is the most common symptom, from insertional tendonitis and bursitis from overuse of weak muscles. Rest, non-steroidal anti-inflammatory agents, steroids, weight reduction, and orthotic changes are used. Degenerative arthritis and nerve compression syndromes are also painful. Muscle pain associated with cramps, fasciculations, or intense local fatigueability may be treated with rest, orthoses, or intermittent wheelchair use.

Generalized and local fatigue is common, especially in muscles previously severely affected; rest, ambulatory aids, activity planning, and agents that enhance neuromuscular transmission are used. New weakness with new atrophy indicates late denervation, a concomitant of massive monophasic antecedent denervation, rather than new disease. New weakness may produce overwork myopathy; patients should reduce activity, exercising only to prevent disuse atrophy but avoiding overuse. Ankle-foot and knee-ankle-foot orthoses support weak muscles, although adequate function of unbraced muscles is a prerequisite. Joint instability, such as knee hyperextension, may be associated with new pain; a knee-ankle-foot orthosis with posterior offset hinge is indicated.

Pulmonary complaints, increasing scoliosis, aspiration pneumonia, and gradual loss of motor units also occur. The patient rehabilitated from acute poliomyelitis must now be helped to accept activity aids and lifestyle modifications to ameliorate the second disability.


“Mold-A-Brace” is a liquid plastic having many characteristics of polyethylene, including strength, durability, and slight flexibility. The material can have straps riveted, sewn, or glued to it. Spot adjustments can be made with a heat gun and trim lines cut with scissors or a jigsaw. The plastic is supplied with a cotton pattern for a body jacket in five sizes. The two-part pattern is fitted to the patient. With the patient supine, the anterior section is removed. The plastic is heated to melt, at 190 to 200 degrees Fahrenheit. The plastic is poured into the anterior section of the jacket, then smoothed with a roller and applied to the patient. Shoulder straps are tied. Cold wet towels hasten plastic hardening which takes 5 to 8 minutes. Trim lines are cut with bandage scissors.

The posterior section is then molded in a similar manner. Velcro straps secure the jacket. Patients report that the plastic feels softer than plaster and there is no slippage when changing positions. The technique requires practice before practitioners become proficient in the method which eliminates plaster modifications, vacuum forming, and the use of central fabrication laboratories—and yields a body jacket rapidly.


Hand splints should maintain the hand in the position of comfort or function, allow finger mobility in accordance with the lesion, support the hand and forearm, and be firm but flexible, lightweight, durable, cost-effective, prefabricated, and easily modified. Fingers should be positioned so that ligaments are taut, thus metacarpophalangeal joint is flexed 35-40 degrees and interphalangeal joints are almost
extended. The wrist is slightly dorsiflexed and ulnar deviated, and the thumb is opposed.

High density "Plastazote" is suitable because it is light, firm but flexible, durable, reusable, and inexpensive. The pattern is cut from 1/4-inch-thick Plastazote sheet, heated at 200 degrees Centigrade for 3 minutes, then wrapped on a master cast and held with crepe bandage. Two sizes of splints for right and left are stocked, meeting the needs of most adults, with or without bulky dressings.

The splint has been used on 50 hands following operation for Dupuytren's contracture. None rejected the splint; all could move the fingers and thumb freely and agreed the splint was light. Six complained of splint odor as sweat and blood accumulated. No splint broke and all could be reused two or three times. The splint is also used for postoperative management of flexion contracture correction, extensor tendon repair, and rheumatoid surgery, infection, metacarpal fractures, and neuromyopathies. The splint positions the wrist in 30 degrees dorsiflexion, the position of maximum grip power, thus permitting the user to mobilize the finger with forceful grip to reduce swelling and pain. Plastazote can be trimmed with simple bandage scissors.


Thirteen healthy men, 16 to 48 years of age, were examined with shoes having heels ranging from 1.9 through 5.7 cm in height. All heels were of the same rubber. Shoe fit was determined to insure adequate toe room. Skin electrodes were placed over the right anterior tibial and medial gastrocnemius muscles, and connected to an overhead cable. Subjects walked on a level floor 13.5 m long at a rate of 88 steps per minute, first in stocking feet and then in the various shoes. Electromyographic data were also recorded while subjects walked on a treadmill.

Gastrocnemius demonstrated decreasing peak activity with increasing heel height, with significant difference between the 1.9-cm and 5.7-cm heels. Tibialis anterior had linear increase in peak activity from zero to the 3.8-cm heel, then a decrease from 3.8 to 5.7 cm. Swing-phase dorsiflexor activity did not change with heel height. On the treadmill, gastrocnemius activity did not change with heel change, but anterior tibialis increased for the first two heel increments, then decreased for the third increment. Mean gastrocnemius activity was significantly greater on the treadmill, while dorsiflexor activity was less there than when subjects walked on the floor.

Anterior tibialis increase when the foot was in equinus prevented foot slap at early stance, although it is not clear why dorsiflexor activity decreased with the highest heel. Perhaps it is related to marked reduction of heel strike with higher heels. Gastrocnemius responds to the heel lift by shortening muscle fiber length, thereby decreasing active tension generated in the muscle. At toe-off with the heel lift, the ankle is plantar flexed, reducing the need for plantar flexors to achieve plantar flexion. Differences noted on treadmill walking suggest different kinematics there. The heel lift is a reasonable therapeutic approach for conditions requiring heel cord relaxation.


A prosthesis was designed for an above-knee amputee who has a very short amputation limb. The sport is dangerous, because the alpinist may have to balance on an inch of rock with the feet while the hands explore a precarious hold. The sport requires physical endurance, powerful leg and arm muscles, and efficient footgrips and handholds to deal with steep surfaces. Above-knee climbers find the footgrip ineffective with the prosthesis, the forefoot catches in crevices; they cannot use knee grips—the knee is unstable sometimes, and movement is restricted because of outward rotation of the leg and foot. The bulk of the knee unit hampers movements and prosthetic weight imposes extra energy expenditure and excessive friction.

The new prosthesis has a conventional socket, modified pelvic band, thigh rotation system, foot close to the knee, modular polycentric knee, titanium shank, and a SACH lower foot. The socket was flexed 10 degrees and abducted 5 degrees and the anterior brim was lowered one inch. The stainless steel pelvic band has a four-way hip joint with
anterior and posterior elastic straps to prevent amputation-limb protrusion during climbing. A manually-controlled thigh rotation system fitted under the socket allows 110 degrees of external rotation and locks in neutral position, permitting the climber to bear weight on the medial border of the shoe, keeping the trunk close to the rocky wall.

Grip close to the amputation limb was assured by use of a SACH foot placed between the thigh rotation system and the knee unit; the heel cushion was removed and the keel was stripped of its rubber covering. Titanium foot adaptors were affixed to the top and bottom of the keel to eliminate torsion. A rubber anti-skid sole was glued under the forefoot. The knee unit allows up to 5 degrees hyperextension and may be maintained in full flexion to prevent accidental hooking of the lower foot in crevices. A titanium shank tube and adaptor reduces weight. A 25-year-old climber uses the prosthesis. Remaining problems concern the appearance of the upper foot and lack of protection of the knee unit, which can rub against rock.


Twenty consecutive patients with unstable cervical injuries were treated with the halo vest during a 3-year period. Age ranged from 13 to 81 years. None had previous pulmonary disease or thoracic injury. Injuries ranged from C1 to T1. Eight were neurologically intact. The halo vest has a metal ring fixed to the skull with pins in the external lamina. The ring is connected by vertical bars to a plastic thoracic vest.

Treatment for all patients was 3 months. Vital capacity measured with a spirometer was determined within 2 weeks of injury with the halo vest applied, 3 months later with the appliance, and 1 week after the halo vest was removed. All but one patient had reduction in predicted vital capacity at the first reading, especially those with neurologic impairment. Vital capacity improved significantly during halo vest treatment of intact patients, but not in the impaired ones.

After removal of the orthosis, intact patients improved to achieve normal values, except for the 81-year-old patient. In contrast, neurologically impaired patients did not demonstrate improved capacity upon removal of the halo vest. Reduction of vital capacity among intact patients may be due to the tight fitting of the vest. Age did not influence vital capacity change, although the possible respiratory disadvantages of the halo vest in the elderly may be offset by the advantage of early mobilization. During treatment, both groups improved equally, approximately 10 percent, attributed to loss of cautiousness and relief from neck pain. Upon removal of the vest, intact patients improved, perhaps because of removal of respiratory restriction attributed to the vest. For the neurologically impaired, the halo vest affects respiration less. The apparatus is not more harmful to patients with neurologic impairment; they benefit from early mobilization.

One patient with incomplete C5 lesion acquired pneumonia during the first week of vest use, but was successfully treated without removal of the apparatus. No skin complications occurred and all injuries healed.


Eleven individuals with thoracic paraplegia had percutaneously implanted electrodes intended to stimulate most of the major muscles used for walking. Ten subjects had complete cord transection. None had peripheral neuropathy or major medical problems. Prior to implantation, muscles were tested with a hypodermic needle inserted near the motor point and a stimulation pulse introduced. If the muscle contracted, it was included in the regimen. Individuals with lesions distal to T10 did not have many responsive muscles.

Study participants had intramuscular, Teflon-insulated, stainless steel wire electrodes implanted. The distal 3 cm was desinsulated and the wire was coiled to form a hook. Implantation required an average of 3.3 trials to place the electrode satisfactorily. Four body-entry points were used: mid-medial thigh and proximal medial calf on each leg. A principal electrode and, whenever possible, a backup one, were implanted in tensor fasciae latae, gracilis, sartorius, semimembranosus, adductor magnus, gluteus maximus, glutecess medius, gluteus minimus, quadriceps, tibialis anterior, peronei, gastrocnemius, and soleus.
A lightweight ankle-foot orthosis provided mediolateral support. Electrodes were monitored for function and impedance—increased impedance indicated breakage and the need for replacement. Stimulation was achieved with a 32-channel portable stimulator weighing 775 grams. The stimulation pattern was based on normal muscle activity in walking. Subjects, using a hand-operated switch, could choose either to stand, exercise, walk, manage stairs, or sit. Training consisted of 15 to 20 hours for several weeks, beginning with quadriceps exercise, then standing between parallel bars, reciprocal walker, rolling walker, and axillary crutches.

Five subjects discontinued participation. Nine could stand, seven could walk in parallel bars, six could walk with a walker, and three could climb stairs. Of 969 electrodes implanted, 30 percent functioned 1 year later. An average of 2.5 electrodes required replacement per month. Subjects were not allowed to use the system without staff supervision except for daily exercise. Infections were few. Muscle strength increased for all subjects.


Four new components are commercially available. The first, introduced in 1981, is the Seattle Foot, designed by Prosthetics Research Study and Boeing Aircraft. The commercial version, available October 1985, consists of a Delrin bolt block and keel and Kevlar toe pad, contained in an injection-molded polyurethane form. The foot has been field-tested by the Veterans Administration. To date, over 8,000 have been used. Early problems with keel and toe failures have prompted changes in design and material. Remaining problems include occasional keel slippage from the shell, bolt breakage, and relative heaviness.

The Flex-Foot was developed in the early 1980's by a plastics engineer and a research prosthetist-amputee. The graphite composite structure is handmade from computer-generated design specific to each wearer. Flex-Foot requires at least 5 inches from distal amputation limb to the floor. It stores energy through its entire length, significantly improving mass distribution of the prosthesis, and saving 10-15 percent of actual weight. One can adjust the anterior and posterior lever arms independently. Failures are few, usually at the attachment of heel pylon to anterior pylon. A new "Modular Flex-Foot" has premade pylons in standard configurations.

Carbon Copy II, introduced in May 1986 by Ohio Willow Wood Company, is a conventional solid ankle design with a choice of heel cushion durometer. The keel has a rigid posterior bolt Kevlar/nylon block with two flexible anterior deflection plates. Very-low-density Styrofoam fills cavities and prevents infiltration of the polyurethane elastomer outer shell. In normal walking, the lower anterior plate provides gentle energy return. At fast gait, the upper plate provides additional push-off. The plantar surface is broad and flat to fit the shoe. It is lighter than the Seattle Foot.

The STEN Foot, made by Kingsley, comes in the greatest selection of sizes, from child's through adult men, with three heel durometers. The keel articulates at the metatarsophalangeal and tarsometatarsal joints, joined by keel bumpers which may dissipate, rather than store, energy. It offers a soft roll-over and is very durable. No hard data demonstrate any energy savings by any foot. All feet have widespread application, including the geriatric amputee.


Four adult unilateral below-knee amputees ran 30 meters at self-selected speeds ranging from 2.5 to 5.7 meters per second. Kinematic and kinetic data were recorded with a motion picture camera and force platform, permitting calculation of flexion/extension joint forces and moments with a plantar link-segment analytical model that assumed the calculated moment was primarily attributed to the muscle group that provided the moment of force in the particular direction.

Estimates of the prosthesis inertia characteristics involved direct measurement and predictive equations; prostheses were weighed, measured, and balanced on a knife-edge to locate the center of gravity. The combined weight and center of gravity location of the amputation limb and prostheses were estimated. The combination was lighter than the
anatomic limb: 4.5-5.9 percent of body weight compared with 6.0 percent of the sound limb, with a higher center of gravity. All subjects were rearfoot strikers. A 55-year-old woman with Greissinger foot showed 8-18 degrees dorsiflexion at heel strike and more plantar flexion at toe-off than at foot-strike. Her average vertical force was 1.2 times body weight on the intact limb and 1.0 body weight on the prosthesis. A 46-year-old soccer player had reasonably symmetrical running, although plantar flexion limitation imposed by his SACH foot was evident. His ground force on the intact limb averaged 1.5-1.7 times body weight and 1.4-1.6 times on the prosthesis. A 30-year-old man maintained a straight knee on the amputated side during stance. His thrust peak of ground force was 3 times body weight on the sound side and 2.7-2.9 times on the prosthesis. All runners exhibited concentric hip extensor moment on the intact side prior to the end of swing; on the prosthetic side the moment was greater in magnitude and duration. Hip extensors appear to compensate by assisting quadriceps in controlling knee flexion.

On the intact limb, most amputees exhibited brief initial knee flexor moment; on the prosthetic side, all began stance with knee flexor moment that lasted longer than on the intact side. After brief dorsiflexor moment, both limbs showed plantar flexor moments throughout stance, especially on the intact side.

A knee orthosis for prevention of patellofemoral disorder and for postoperative use consists of a patellar band with a silicone rubber patellar part and popliteal strap. The silicone part has a longitudinal elliptical hole and a small pad lateral to the patella. As the knee flexes, the band tension increases, compressing toward the inside of the knee. Clinical evaluation includes determination of contracture of the lateral retinaculum—when the knee is flexed, the examiner moves the patella medially so it touches the medial condyle; if one feels as if pressing a sponge, the test is positive. The patellar instability test requires that the examiner grasp the medial and lateral margins of the patella when the knee is flexed 30 degrees—a positive test occurs when the patella deviates more than a finger width or the patient becomes apprehensive. The patellar band is indicated for individuals having plica syndrome, with local tenderness in the medial patellofemoral joint and snapping of the plica; also those with lateral retinacular contracture or a history of patellar dislocation, or degeneration of the patellar cartilage.

The orthosis has been fitted to 75 patients who complained of spontaneous pain, pain while moving, knee giving way, popliteal pain, snapping, swelling, pain when kneeling or stair-climbing. The orthosis was effective in relieving most symptoms, and is smaller than alternative devices.

A second survey was conducted with 61 patients 1 to 8 months following orthosis application; excellent results were seen most frequently in those with a history of patellar dislocation. The orthosis corrects malalignment of the patella, reducing or eliminating pain. The band is used for 3 months and then the plica is excised for those still complaining of pain. Subluxation is prevented at 45 and 60 degrees of knee flexion; even though subluxation is not prevented at 30 degrees, patients do not request surgery.

Many women developed dermatitis because the silicone rubber adheres to the skin. The band is worn 2 hours in the morning and 2 hours in the afternoon, or only when walking or playing sports.


Twenty traumatic amputees participated in the study: amputations included unilateral below-knee, unilateral above-knee, unilateral partial foot, and above-knee/below-knee. None had participated in regular physical training prior to the study. Heart rate, expired volume of air, oxygen consumption, and expired carbon dioxide were determined, as was blood pressure prior to exercise. Subjects walked on a treadmill at normal walking speed at zero, 2, 4, and 6 percent grades. They also used an exercise bicycle, the Schwinn Air-Dyne ergometer, both in the laboratory and at home. Of the 20 who began the study, 10 completed the protocol. Their re-
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Responses were compared with seven unilateral amputees who walked on the treadmill at the beginning and end of the study but did not alter their daily activities otherwise. After the 15-week training program, subjects showed significant decrease in heart rate and significant increase in maximum work capacity on the ergometer, heart rate at volitional exhaustion increased significantly. On the treadmill, heart rate decreased significantly as did oxygen consumption. Control subjects did not have significant heart rate or oxygen consumption change. Subjects had no body weight or prosthetic fitting changes.

The bicycle was chosen because it did not injure the amputation limb, and no interruption of training occurred even when the amputation limb was irritated from other causes. The ergometer allowed subjects to exercise a large percentage of muscle mass. Improved fitness was coupled with improvement in walking economy, as demonstrated by the reduction in oxygen uptake for a given submaximum work load on the treadmill, perhaps as a result of improved hip girdle strength. The 50 percent compliance rate with the exercise program was considered good. Exercise programs must address the behavioral, biological and social factors associated with compliance.


A triaxial load cell 8 x 19 x 19 mm consists of four loops of loadbearing elements and a total of 16 strain gauges to achieve triaxial force output. Two cells are attached to the shoe on the heel and three under the first and fifth metatarsals and great toe, or the corresponding locations under the prosthetic foot. Fifteen channels of force data were recorded through lightweight trailing cables from a 42-year-old below-knee amputee and a nondisabled subject. The center of pressure was determined by relating ratios of the load cell outputs to the outline of the shoe, creating a force-time history of the gait cycle. The system can be used to quantify adaptation to the prosthesis. Initially, the amputee spent a much longer time supporting body weight through the prosthesis and less peak force. Loading of various portions of the foot also changes over time. The amputee’s foot has excessive pronation at heel strike. The system detects subtle differences in gait and can speed training and can guide prosthetic alignment.


Over 5000 amputees participate in organized competitive sports in the United States, including some who compete in world class events alongside the able-bodied. Factors contributing to athleticism include the individual’s ability to handle the stress and trauma of amputation, as well as the environment. Most amputee athletes have a strong desire to overcompensate for their disability. Positive role models show the amputee that limitations are what they place upon themselves. Pain is initially the greatest barrier, but the successful athlete will develop ways of minimizing discomfort by increasing pain tolerance or seeking a lifestyle that reduces trauma. The amputee must learn how the prosthesis works and how to deal with skin breakdown due to overactivity. Skin protection material, "2nd Skin" is a 1/16 inch thick gel applied to the skin to prevent friction; it has plastic on both sides which should be removed to prevent migration. It can be used only once. It works well on below-knee amputees beneath a sheath. Above-knee suction-prosthesis wearers may experience migration from donning the prosthesis. Another means of friction-reduction is Spenco Skin Care Pad, which is reusable. It adheres to the skin without sticking and can be gas sterilized or washed in soap and water. Op-Site, Bioclusive, Tegaderm and Acuderm are transparent dressings with adhesive on one side applied to the skin, especially suitable for suction-socket users.

Organizations (such as National Handicapped Sports and Recreation Association, United States Amputee Athletic Association, National Amputee Golf Association, and National Wheelchair Athletic Association) bring amputees together for the exchange of ideas on the consumer level. Some provide competition based on ability and level of amputation. The organizations have compelled adaptation of technology to accommodate athletic amputees and have created a market for extra-ambulatory prostheses.

Twenty-four healthy young women, 18 to 29 years, walked barefoot and when wearing shoes with: a) soft soles without heel; b) rigid soles without heel; c) medium heels; and d) high heels. Subjects chose their own shoes. Subjects walked over a force platform that measured horizontal ground reaction forces including peak forces. Limb angular displacements were recorded with a polarized light goniometer. Speed was not controlled. Area of ground contact decreased significantly with increasing heel height. Peak ground reaction forces were significantly lower with the medium heel and high heel shoes. A significant difference also exists between medium-heeled and rigid-soled flat shoes, the latter being higher in peak ground reaction force. Shoe type influenced calf and foot displacement, but not thigh and pelvis. High-heeled shoes caused less range than did soft or rigid flat shoes. When walking barefoot, extension was lower than with soft flat shoes. Soft flat shoes produced greater range than rigid flat shoes or barefoot. Flexion was also higher with soft flat shoes than medium or high-heeled shoes.

Shoes change foot pressure patterns and the timing of foot contact. High heels cause plantar flexion, knee flexion, and increased lumbar lordosis, and raise the body's center of gravity with a possible increased tendency to rotate forward at the ankle. Most shoes increased anteroposterior force considerably above that of barefoot, due to differences in compliance of foot-floor interface and the size and angulation of the heel of the different shoes. Mediolateral forces are greater than barefoot with flat shoes, soft or rigid, than with heeled shoes. With heeled shoes, subjects modify gait by changing stride length and cadence. Calf and foot displacements decreased with increasing heel height and decreased ground-contact area. The greatest values were with flat soft-soled shoes, except for calf flexion with flat rigid shoes and foot flexion when barefoot. When assessing gait, account should be taken of the type of shoe worn. Floor surfaces should provide a high degree of friction if shoe soles are not corrugated.

Suction suspension may be achieved with: 1) tension, the socket being made volumetrically smaller than the amputation limb and a valve placed at the distal end; 2) atmospheric suspension, requiring a nonelastic flexible interface that collapses around the limb when the prosthesis is unweighted; or 3) active compression with an elastic or elastomeric interface stretched over the amputation limb. Suction appears to stimulate circulation and may help to stabilize limb volume. It suits dysvascular amputees and has been fitted to patients from 5 to 88 years of age. It minimizes skin friction and skeletal movement inside the socket, and can be fitted to limbs as short as 3 1/2 inches. Fitting causes an immediate fluid volume adjustment that persists for 6 weeks until volume stability is achieved. Unlike patellar-tendon-bearing, the new socket distributes weight over the entire surface, including pressure-sensitive areas, and eliminates relief buildups over bony areas. The diagonal four-stage casting technique uses sheer nylon as the barrier between skin and plaster, beveled anterior splint, distal elastic plater, posterior splint molded at the hamstrings, and optional fourth splint for supracondylar suspension. After the hardened cast is removed, dental alginate is poured inside the wrap and refitted for more intimate contouring. Modification follows the posterior tibial crest angulation, rather than the PTB bar. After reliefs have been achieved, the model is reduced from 1/2 inch to 1 inch circumferentially. A flexible Surlyn or a rigid check socket is used. The definitive socket may be of acrylic and polyester laminate padded with "PE-LITE" or "Aliplast." Frame-supported polyethylene sockets enhance atmospheric suction, but are not durable or adjustable. Auxiliary suspension should be worn with all suction fittings. PE-LITE with or without Surlyn is a suitable soft suction liner, durable, easily cleaned, and adjusted, although they change shape with wear and can collect malodorous debris. Silicone liners are difficult to fabricate, not durable, and not adjustable. Other new liners include the PM Liner and the Socket Liner Stump Sock. Several air expulsion valves are available, although problems with acces-
sibility and leakage remain. Latex and neoprene sleeves, with or without cloth lining, are suitable; cuff suspension does not seal the socket adequately.


Both feet of 441 normal persons, ranging from 1 to 88 years old, were recorded by means of a chalk footprint technique. None complained of past or present musculoskeletal abnormalities. An arch index was calculated by dividing the width of the foot in the area of the arch by the heel width. A significant linear relationship exists between right and left arch indices. The mean arch index for female subjects was 0.66 as compared with 0.71 for male subjects; only 2 percent of the variance, however, could be explained by differences in sex. The arch index varies considerably throughout life, with no evidence that flexible flat foot produces disability. If flexible flat foot falls within the normal range, then shoe modifications, orthoses, and surgery are inappropriate.

The mean value of the arch index in infancy is slightly more than 1.0. The mean decreases through childhood to adolescence to approximately 0.63 and rises very slightly through the adult years to a mean slightly less than 0.8 by 70 years of age.


Knee joints stabilize the anatomic knee during stance. Orthotic joints also provide mediolateral control and can provide stance stability only during gait. Aluminum, stainless steel and composite plastics form the joints. The joint is one component of a complex system whose success depends on accuracy of the prescription, fabrication, joint alignment, leverage, fit, and patient training and motivation.

Free knee joints provide mediolateral stability; the patient needs adequate voluntary muscle control to maintain knee extension, although the orthosis may permit slight hyperextension to enhance stability.

The offset knee joint stabilizes the knee during stance, while permitting free flexion during swing. The patient must be able to extend the joint fully and move the ground reaction force ahead of the knee by voluntary hip extension and crutches. Uneven walking surfaces and change of heel height pose problems with offset joints.

Locked joints are stable during stance and swing phases, and include gravity ring (drop), spring-assisted drop, cam, pawl, and Swiss locks. Unlocking mechanisms include drop lock extensions and bails. No failsafe system exists that will completely eliminate inadvertent knee flexion. Solid knee orthoses are very stable, but inconvenient when the patient sits. Medial and lateral knee joints increase orthotic weight and difficulty in fabrication. Joints incorporated in metal and leather orthoses are adjustable and have limited skin contact, as compared with joints in laminated and thermoformed orthoses which fit more intimately, control the leg better, are streamlined and lighter, but afford less adjustability.

The Lower Extremity Telescoping Orthosis does not have a knee joint, but has a telescoping posterior rod that can bridge the anatomic knee.

Functional electrical stimulation, still experimental, can also be used to control the knee.


Twenty hemiplegics had peroneal stimulators implanted 2 cm behind the fibular head. The implant is disc-shaped with no leads between the receiver and the electrode which measures 17 x 8 mm. Electrodes are platinum wire. The patient positions the antenna on the skin above the implant. The antenna is energized from a controlling device connected to a sole switch under the affected leg. Stimulation starts after heel-off and stops at heel-on. If heel-on does not occur, stimulation stops after 3 seconds. Stimulation intensity, usually 33 Hz, can be controlled by the patient. A single AA 1.5 volt battery is the power source.

Patients were selected on the basis of the following
criteria: a) no further improvement of motor function by conventional methods; b) stimulation significantly improves gait; c) surface stimulation causes skin irritation or the patient has problems positioning the electrode; and d) the patient is communicative and cooperative. Patients had used surface stimulators or an ankle-foot orthosis. Implantation under local anesthesia takes less than 30 minutes. Subjective evaluation revealed pronounced correction of equinovarus and gait improvement.

Objective evaluation of vertical ground reaction forces was aided by shoes equipped with eight pressure sensors. Before implant, the patient loaded the foot too laterally and needed substantial support by the crutch. After implantation, the patient used less crutch support and exhibited more symmetry of ground forces between left and right sides. The implant was reliable and had no noxious effects on the peripheral nerve. All patients were happy with the system. Their walking radius increased with the system. Peroneal nerve conduction velocities were lower on the affected side and did not change with the implant.


One hundred lower-limb amputees, ranging in age from 10 to 83 years, had foot loading measured by a double video forceplate that has separate plates for each foot. Subjects stood for 15 seconds without support, after which a time-averaged display of foot loading was produced showing individual centers of foot pressure and the overall center of foot pressure. Results were compared with records of 100 age- and sex-matched individuals who had no locomotor disability; their average foot loading was 51 percent of body weight on the right, with no difference between men and women or right- and left-handed persons. Above-knee amputees transmitted an average of 39.5 percent through the prosthesis, compared with 45 percent for patellar-tendon-bearing wearers, 40 percent for through-hip patients, and 51 percent for Symes amputees. Four bilateral below-knee amputees bore an average of 57 percent on the right leg.

Age, sex, or time since amputation did not influence the results. Most above-knee amputees had anterior centers of foot pressure, although 25 percent had posterior placement. Those with stabilized knees all had anterior loading. Quadrilateral socket wearers had more posterior placement than those with conventional and total-surface-bearing suction sockets. Those with anterior placement had the pressure center central within the foot, while those with posterior placement had the center of pressure laterally placed. Patellar-tendon-bearing socket wearers had the pressure center anterior and medial. Thigh corset wearers had more variable placement. Bilateral amputees tended to lean forward.

Most amputees, particularly above-knee, do not achieve ideal weight-bearing, based on calculation of the theoretical foot pressure, which should amount to 48 percent of body weight for above-knee, 49 percent of body weight for below-knee, and 45 percent for through-hip amputees. The values account for the lighter weight of the prosthetic side. Gritti-Stokes and through-knee amputees have significantly higher loading than above-knee amputees. Rapid analysis of weight distribution may help in analysis of alignment problems; lateral placement of pressure indicates malalignment.


A new multiaxial stored-energy foot has two chrome-vanadium-alloy spring steel springs to increase elasticity and tensile strength over regular steel spring, which is more brittle. The springs are helical coils that have greater energy storage capabilities than leaf springs, which do not offer mediolateral movement. The two flat die springs are attached proximally to an ankle plate and distally to a plantar plate, both made of aircraft aluminum. Helical nuts provide rigid attachment without changing spring temper properties. Springs of different compression may be substituted, depending on the needs of the amputee.

A posterior flexible Kevlar strap extends from the ankle to the plantar plate, serving as an “Achilles tendon”; it allows compression of both springs in any direction, but prevents much elongation of the posterior spring.

The foot has been fitted to individuals with below-knee, knee disarticulation, and above-knee amputations, and to both endo- and exoskeletal prostheses. The foot is compatible with some hydraulic knee
units. It was introduced in Spring 1986, has been fitted to 41 patients, and has been submitted to the Veterans Administration for approval.

Maximum energy absorption, storage, and return is achieved when used with a rigid carbon-fiber foot having a leaf spring at the toe break; smoothest heel-strike to toe-off is obtained with a soft foam foot. Controlled energy absorption and release in inversion-eversion and plantar-dorsiflexion negates the effects of jerks, abrupt bumps, and inclines, and allows the amputee to recover balance more easily without depending solely on the sound limb. During early stance the posterior spring compresses and the anterior spring bows and compresses at its posterior aspect, storing energy that is released at midstance when the Achilles band prevents further elongation of the posterior spring. From midstance to heel-off the anterior spring is compressed; it releases energy at heel-off.

Alignment begins with the standard SACH foot for mediolateral and ab-adduction placement. The dual-ankle foot is then substituted to determine plantar-dorsiflexion and anteroposterior foot placement. The new foot weighs 2.2 pounds for size 11, compared with 1.4 pounds for a SACH foot.


Based on energy expenditure measurements of 150 patients with traumatic paraplegia, the goal of orthotic prescription is to provide external support to compensate for motor and sensory deficits. Mobility, strength, proprioception, sensation, and spasticity influence prescription. The most common indication for knee-ankle-foot orthoses is quadriceps strength less than Fair plus; impaired knee proprioception or severe hyperextension thrust during stance also indicate KAFOs. Bracing requires hip range from full extension to 110 degrees flexion, full knee extension, at least 10 degrees dorsiflexion, and good trunk strength. Ankle-foot orthoses require quadriceps strength greater than Fair; the orthoses are useful if plantarflexion strength is less than Good, dorsiflexion strength less than Fair, ankle proprioception is impaired, or plantarflexors are spastic. Plastic, lighter than metal, is sometimes preferable, especially for the patient with weak hip flexors.

Maximal aerobic capacity is the single best indicator of physical work capacity; orthoses should not be prescribed until the patient has sufficient strength to meet the required energy demand. The minimal criterion is 20 ml/kg-min maximal aerobic capacity if a swing-through gait is required. The wheelchair is a highly efficient means of transportation with speed and energy requirements comparable to normal walking, although heart rate was higher in paraplegics using the wheelchair than in walking. Swing-through crutch walking by a T12 paraplegic was 64 percent slower with 560 percent greater oxygen cost and heart rate increased 46 percent as compared with normal walking. Three patients with Fair plus hip flexors, bilateral KAFO's, walked with a reciprocal gait pattern with the same effort and speed as for swing-through gait. The only spinal-cord-injured patients tested whose energy expenditure during walking does not exceed normal values are those with intact sacral function and hip abductor and extensor strength to maintain erect posture without crutches. The average cadence of low lumbar paraplegics with bilateral AFOs and crutches was 26 m/min; thus it would take more than 5 minutes to travel 150 meters. Thus a wheelchair should be prescribed for anyone who requires crutch assistance.


The manual wheelchair is designed to be propelled by the occupant or an attendant. The powered wheelchair is sometimes indicated for the paraplegic to make more effective use of his energy. The basic chair has two sideframes connected by a pivoted crossbar, flexible seat and back, two large rear driving wheels and two front casters, a pattern originated by Everest and Jennings in 1936, a compromise between maneuverability, stability, and portability. A cushion is generally used to distribute pressure better over the thighs and buttocks; the cushion affects the chair dimensions. Too narrow a seat is uncomfortable, difficult to enter, and increases risk of ulcers; too wide a seat encourages scoliosis and unilateral buttock pressure and hampers propulsion. A shallow seat increases tissue pressure and adversely affects foot support, while a long seat can restrict leg circulation. Seat height and type need consideration, as does the backrest.
Armrest choice depends on transfer method, generally indicating removable armrests. The desk model permits one to get closer to a desk, but does not support the distal forearm. Newer rear wheels have cast alloy or plastic to overcome maintenance inherent in the traditional wire spoke design. Pneumatic and semipneumatic tires absorb shock better than solid tires and are suitable for outdoor use. Vinyl coating or knobs make handrim control easier. Toggle, lever, and pin locks stabilize the chair.

Polyurethane or polyether foam cushions are more resilient than viscoelastic foam. Gel cushions are rather firm and have a plastic casing. Water, air, or water-and-foam particles encased in a plastic bag distribute forces. The “ROHO” is a collection of air-filled tufts; the Veterans Administration Spinal Injury Orthosis has foams of two densities contoured for the paraplegic’s needs.

Most sports wheelchairs use standard size rear wheels, although some use larger ones, but front wheels are generally smaller. Few offer arm rests. Many models have adjustable features.


Polyurethane-coated bandages overcome problems associated with plaster of Paris, which has a poor strength-to-weight ratio, rapid loss of strength when wet, tendency to scatter X-rays, is messy to apply, and takes 2 days for a leg cast to cure. Wrapping the plaster cast with a rapidly curing synthetic bandage, such as Crystona or Deltacast, does not improve durability. The newer bandages consist of knitted cotton, polyester, or fiberglass coated with a moisture-curing polyurethane prepolymer which, after being soaked, hardens in 30 minutes. The bandages derive much of their strength, typically 55 percent, from the fiberglass. The casts are much stronger and tougher than plaster, are lighter, and regain most of their strength after immersion in water, thus reducing incidence of cast breakage. Unlike plaster which is crystalline and thick, the new bandages are more radiolucent because of lower density and amorphous structure.

Uncured, unmoistened polyurethane may present inhalation toxicity; the applicator should use gloves or barrier creams to prevent the resin from sticking to the hands. The resins burn easily; however, the patient would be aware of the raised temperature before the cast ignited. There is minimal danger of toxic gas emission. Airborne dust generation during cast removal is less severe than is experienced with plaster dust.

Average weights and costs of a below-knee cast are compared; plaster is least expensive and heaviest; “Dynacast” (polyester impregnated with polyurethane) is the most expensive; “Hexcelite” (cotton impregnated with a thermoplastic polyester) is lightest. Other materials compared in the study include Dynacast XR, Scotchcast 2, Deltalite, Du-reset-lite, Zimmer, Scotchflex, Deltacast (Baycast), and Crystona.